Murlach Field Development
Environmental Statement

BEIS Reference: ES/2022/002

BPEOC Doc No: NS046-HS-REP-040-00001/B01

April 2022

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Project Name	Murlach Field Development
Development Location	Block 22/24h
Licence No	P2452
OPRED Reference No	ES/2022/002
Type of Project	Subsea tie-back development
Undertaker	BP Exploration Operating Company Limited (BPEOC) Chertsey Road, Sunbury On Thames, Middlesex, TW16 7BP
Licensees/Owners	See table below
Distance to Nearest Coastline and Median Line	The field is located approximately 203 km east of the Aberdeenshire (Scotland) coast and approximately 27 km from the UK/Norway median line.
Short Description	See below
Latitude and Longitude	See table below
Key Dates	See table below

Licensees/Owners

Co-venturers	% Holding
BPEOC	80
NEO Energy Central North Sea Limited	20

Short Description

BPEOC propose to develop the Murlach Field via a two production well subsea tie-back to the Eastern Trough Area Project (ETAP) platform by tying into infrastructure associated with the Seagull and Heron Fields. The proposed development concept can be summarised as follows:

- The drilling of two production wells tied back to a new manifold;
- The installation of:
  - A *c.* 7 km gas lift flowline from the ETAP platform to the new Murlach manifold;
  - A 100 m tie-in from the Murlach manifold to the repurposed Heron A production flowline;
  - A 150 m tie-in from the repurposed Heron to Seagull wash water flowline system to the Murlach manifold;
  - A 500 m umbilical connecting the existing Seagull umbilical to the Murlach manifold; and
- Processing of the Murlach hydrocarbons at the ETAP platform; and
- First production in June 2025.

Latitude and Longitude

Well	Co-ordinates (ED 1950 UTM Zone 31N)
Murlach Well 1	57º 14' 08.302" N 01º 37' 41.391" W
Murlach Well 2	57º 14' 07.947" N 01º 37' 41.464" W

Key Dates

Activities	Date
Drilling of wells	Q1 - Q4 2024
Subsea installation	Q3 - Q4 2024
Topside modifications	Q3 2023 - Q4 2024
Commissioning and start -up	Q1 2025
First production	Q2 2025

Significant Environmental Effects Identified	The Environmental Statement (ES) assesses the worst case impact of the project on the environment and is therefore very conservative. Even then applying the mitigation measures identified it is the conclusion of this ES that the current proposal for the Murlach Field Development can be completed without causing any significant long term environmental impacts or cumulative or transboundary effects.	
Statement Prepared by	BP Exploration Operating Company Limited and Genesis Energies	
Company	**Job Title**	**Relevant Qualifications/Experience**
BPEOC	Environmental and Social Advisor	10+ years' environment with 5+ in oil and gas
Genesis Energies	Senior Consultant Environmental Engineer x 2	Both with 20+ years' experience in environment /oil and gas
	Environmental Specialist	2+ years' experience in earth and environmental science

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NON-TECHNICAL SUMMARY

Background

The Murlach Field, formerly known as Skua, was discovered in 1986 and is located in Block 22/24h *c.* 203 km from the Aberdeenshire coastline and *c.* 27 km from the UK/Norway median line (Figure 1).

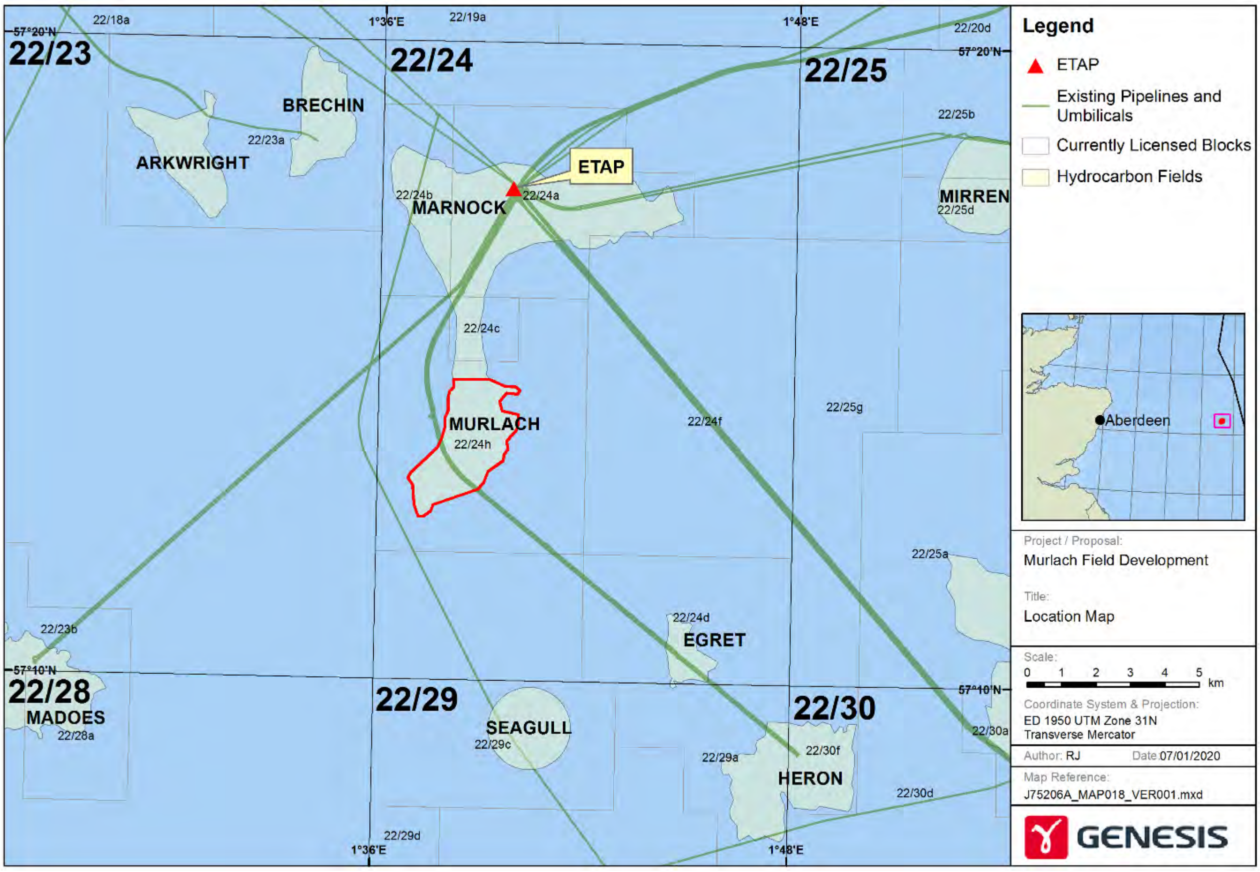


Figure 1: Location of the Murlach Field.

BPEOC, on behalf of itself and its Co-Venturer, NECNSL, propose to redevelop[1] the field as a two well subsea tie-back to the existing ETAP platform.

BPEOC have selected a tried and tested concept for the proposed Murlach Field Development which reflects current industry practices and technologies and makes use of existing infrastructure where possible. A synergy with the new Seagull development will be employed, with both projects sharing/ re-using existing re-purposed subsea infrastructure from Heron, Egret and Skua.

The Murlach Field Development supports the UK Government's statutory "principal objective" of maximising the economic recovery of UK petroleum and will support the increased longevity of its host. The development also aligns with the Oil and Gas Authority's expectations of the offshore industry to support the UK's transition to Net Zero by producing hydrocarbon products with significantly lower Greenhouse Gas intensity than the

[1] Though the project is a redevelopment of the Skua Field, the ES refers to the project as the Murlach Field Development.

average across the UK Continental Shelf. This, in turn, will help the sector to achieve the emissions reduction targets set out in the North Sea Transition Deal.

Environmental Statement Scope

Under the Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020, (here after referred to as the 2020 Offshore EIA Regulations) the proposed Murlach Field Development Project (hereafter referred to as the Murlach Field Development) requires an Environmental Impact Assessment (EIA) and Environmental Statement (ES) to be submitted to the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) for approval. This requirement is due to the anticipated volumes of hydrocarbons to be produced such that consent is being sought for the *'Extraction of oil and natural gas for commercial purposes where the amount extracted exceeds 500 tonnes per day in the case of oil and 500,000 cubic metres per day in the case of natural gas'.*

The scope of the EIA and resultant ES includes all activities associated with the proposed Murlach Field Development Project and comprises:

- Drilling and completion of two subsea wells;
- Installation of a new subsea manifold;
- Installation of a new gas lift flowline from the ETAP platform;
- Installation of subsea tiebacks to existing infrastructure (wash water, control umbilical, production flowline);
- Installation of subsea equipment (e.g. Xmas trees) on the seabed; and
- Increased production at the ETAP platform.

This document provides details of the EIA that has been undertaken to support BPEOC and their Co-Venturer's application for consent to undertake the proposed project. This process includes a public consultation followed by a comprehensive review by various bodies including OPRED. The EIA and ES Report has been completed in line with the 2020 Offshore EIA Regulations, which came into force in January 2021.

The ES presents the results of the EIA conducted to evaluate the environmental impacts of the proposed project. These include: the physical presence of vessels and infrastructure, atmospheric emissions, discharges to sea, impacts on the seabed, the effects of underwater noise, the production of waste and an evaluation of the potential impacts from unplanned events, as well as vulnerability of the proposed activities to natural disasters. In addition, potential impacts on designated protected sites, sensitive habitats, and cumulative and transboundary impacts are assessed.

Option Selection

The ETAP platform currently has the capacity for Murlach such that minimal additional infrastructure is required on the ETAP platform as part of this development. At the time of writing, three pipeline installation options are being considered for the laying of the new gas lift flowline (*c.* 7 km) between the ETAP platform and the Murlach Field:

Table 1: Gas lift flowline installation options.

Option	Description
Installation Option 1	Surface laid flexible flowline, left exposed on the seabed. ES assumes a worst case whereby 10% of the flowline will be covered with spot rock to mitigate upheaval buckling.
Installation Option 2	100% rock dump using a flexible or rigid flowline that follows a new route at least 50 m away from other rock berms to the ETAP platform.
Installation Option 3	100% rock dump using a flexible or rigid flowline which is laid alongside an existing rock berm hence allowing for an extension of the existing rock berm rather than the creation of a new one.
Installation Option 4	Trench and burial of a rigid pipe following the same routing as Option 1 with spot rock dump where required.

The option selection process for the Murlach Field Development is currently ongoing and the full option selection evaluation of each option is detailed in the ES. The ES also assesses the worst case impact of te options.

Murlach Field Development Project

The Murlach Field is part of the Heron Cluster Area and will tie back to the ETAP platform via shared infrastructure with Seagull. Murlach production fluids will be transported to the ETAP platform whilst wash water and lift gas will be provided to the Murlach wells from the ETAP platform.

The proposed Murlach Field Development is summarised in Table 2:

Table 2: Subsea infrastructure associated with the Murlach Field Development.

	Description
1	A *c.* 7 km (approx.) gas lift flowline from the ETAP platform to the new Murlach manifold
2*	A new manifold (20 m Length (L) x 10 m Width (W) x 5 m Height (H)) **
3*	A Xmas tree at each well
4*	Approx. 100 m tie-in from the Murlach manifold to the existing 10" Pipe in Pipe (PiP) ex-Heron production flowline
5*	Approx. 150 m tie-in from the existing subsea wash water flowline system to the Murlach manifold.
6*	Approx. 500 m umbilical connecting the existing Seagull umbilical to the Murlach manifold.
7*	Tie-ins between the new Murlach manifold and each of the two Murlach wells for: • Approx. 40 m production spool from each well to the manifold; • Approx. 40m gas lift spool from the manifold to each well; • Approx. 40 m wash water spool from the manifold to each well; and • Approx. 50 m control umbilical from the manifold to each well.
*Each of these structures/spools/umbilical jumpers will be located within the existing Skua Drill Centre 500 m zone at the Murlach Field. **The new manifold will either be piled or gravity based; this ES assesses the worst-case environmental impacts and so piled has been assumed to assess the impact of underwater sound.	

Schedule of Activities

An indicative schedule for the offshore activities is shown in Table 3.

Table 3: Indicative schedule of offshore activities.

Phase	2023				2024				2025			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Drilling of Murlach wells												
Subsea installation												
ETAP topside modifications												
Commissioning and start-up												
First Oil												

Baseline Environment

The Murlach Field is situated in Block 22/24 approximately 203 km east of the Aberdeenshire coastline and *c.* 27 km from the UK/Norway median line. The Field is situated in water depths ranging between *c.* 93 – 95 m, with a gentle slope downwards to the south-west.

The direction of residual water movement in the Central North Sea (CNS) is generally to the south-east (DTI, 2001; DECC, 2016b). The mean residual current in the Murlach area is approximately 0.01 m/s, running north-west to south-east in winter and south-west to north-east in summer (Wolf et al., 2016). The mean spring tidal range is between 0.9 m and 1 m.

BPEOC commissioned an environmental survey at the Murlach Field. The data that was available from this has been used to inform the impact assessment. In addition to using the available data from the Murlach Field environmental survey, the results from other surveys carried out at surrounding Fields have been referenced. Figure 2 shows the location of these survey points, taken from Fugro (2019a and 2019c).

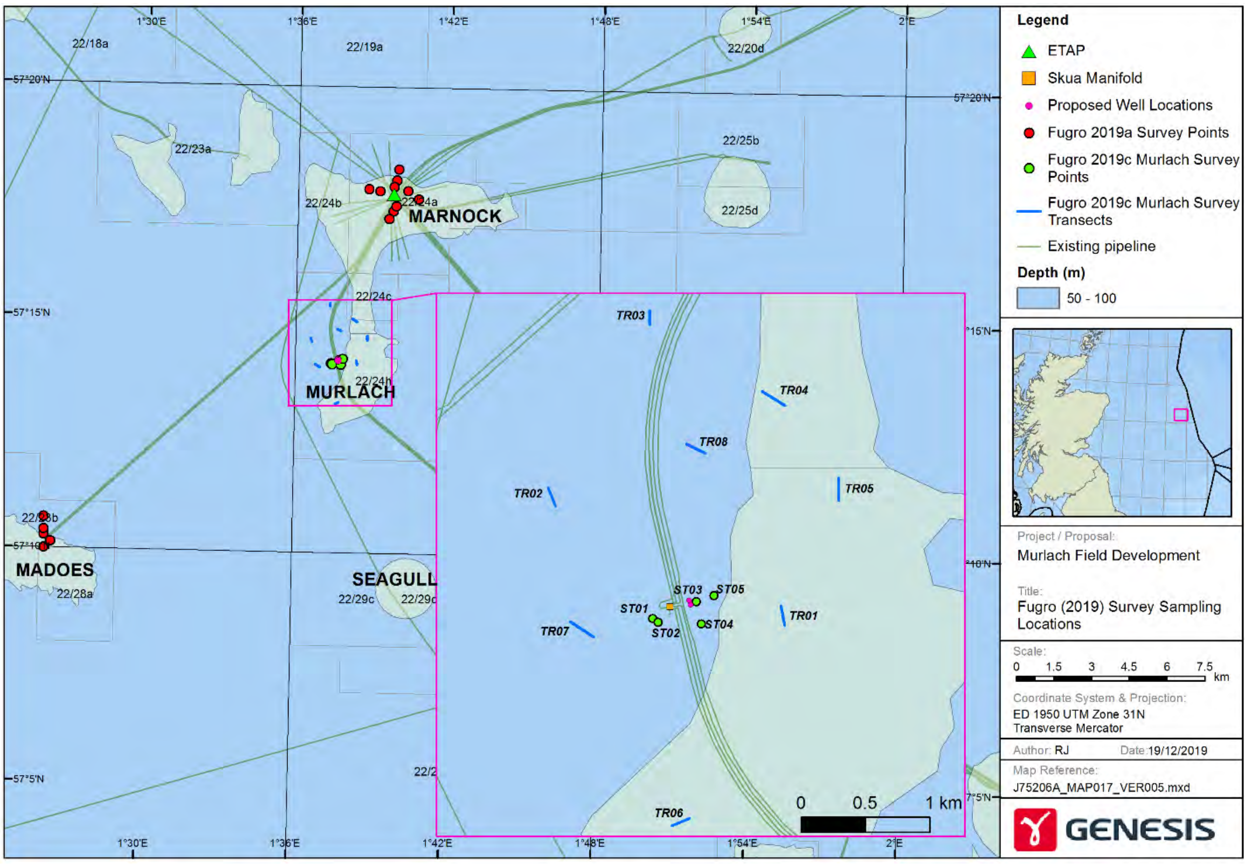


Figure 2: Extent of the environmental surveys used to support this ES.

The information available from these surveys was deemed sufficient to inform the impact assessment carried out in support of this ES. The reports from the Murlach site and pipeline route surveys will be made available to OPRED and their Statutory Consultees and will be used to support the relevant permit applications to be submitted at a later date.

The Murlach field survey results show two distinct European Nature Information System (EUNIS) biotopes in the area, 'Circalittoral muddy sand' and 'Circalittoral mixed sediments' (Fugro, 2019b). Species observed across the site in the Circalittoral Muddy Sand areas included hermit crabs (Paguridae including *P. bernhardus*), brittlestars (Ophiuridae), starfish (Asteroidea including *A. rubens* and *A. irregularis*) and spider crab (Majidae). Small faunal tubes and worm casts were also observed, suggesting the presence of polychaetes across the site. Analysis of the grab samples showed evidence of *Artica islandica* in the area (listed on the OSPAR list of threatened and/or declining species and habitats).

Features of the biotope 'Circalittoral fine mud' were also observed across the survey area. The sea pens *P. phosphorea* and *V. mirabilis* are characteristic species of this biotope complex and were observed across the site. Faunal burrows were also found to be present, however the faunal burrows were not considered to form a prominent feature of the sediment surface. Therefore the areas of sea pens and burrows observed were not thought to be representative of the OSPAR listed threatened and/or declining habitat 'Sea pens and burrowing megafauna communities'.

The biotope 'Circalittoral mixed sediments' was classified in certain transects due to the occurrence of shell and shell fragments with occasional pebbles, cobbles and boulders. The characterising species of mixed sediment habitats observed across the three transects included hydroids (Hydrozoa), hermit crabs (Paguridae), brittlestars (Ophiuridae), sea urchin (*Echinus esculentus*), starfish (Asteroidea including *A. rubens*), scallop (*Pecten maximum)*, encrusting polychaete tubes (Serpulidae), soft coral (Alyconacea) and faunal turf (Hydrozoa/Bryozoa). Overall faunal abundance and diversity increased in areas of mixed sediments due to the availability of substratum on which encrusting fauna can attach (Fugro, 2019b).

Spawning and nursery grounds for fish species including blue whiting, Norway pout, sandeels and mackerel have been identified in the area.

A number of seabirds are known to occur in the area including northern gannet, great skua, razorbill, northern fulmar, black legged kittiwake, guillemot etc. Based on the Seabird Oil Sensitivity Index (SOSI) the sensitivity of seabirds to surface oil pollution is generally low throughout the year within Block 22/24h.

The most abundant cetaceans in the Murlach Field area are the harbour porpoise and the Atlantic white-beaked dolphin. Other species known to occur there include the white-sided dolphin and the minke whale.

For management purposes the International Council for the Exploration of the Sea (ICES) collates fisheries information for area units termed ICES rectangles. The importance of an area to the fishing industry is assessed by measuring the fishing effort within each ICES rectangle. The proposed project area is located within ICES rectangle 43F1. UK commercial fishing effort within this rectangle varies throughout the year and is generally considered to be low when compared to other ICES rectangles.

Shipping in the area is considered very low and there are no military exercise areas in the vicinity of the field.

Environmental Impact Assessment

In order to determine the impact that the proposed Murlach Field Development may have on the environment an ENVironmental and socio-economic impact IDentification (ENVID) was undertaken following a structured methodology. The purpose of the ENVID was to identify the significance of the environmental and socio-economic risks associated with the planned activities and any possible unplanned events and to identify appropriate mitigation measures, controls and safeguards to minimise this risk.

For each of the planned activities an environmental and/or socio-economic impact significance is assigned for the relevant aspects (e.g. emissions to air, discharges to sea, underwater noise etc.) by taking into account the sensitivity of the receptors and the magnitude of the effect.

For unplanned events the environmental and/or socio-economic significance of risk ranking also takes into account the likelihood of the event occurring. A summary of the key findings of the ENVID and supporting impact assessment is presented here.

Physical Presence

The physical presence of the project vessels, the drilling rig and the subsea infrastructure has the potential to be a navigational hazard, to restrict fishing operations in the area and / or to cause disturbance to wildlife. However, taking account of the mitigation measures outlined in Table 4, which includes early consultation with the Scottish Fisheries Federation (SFF), and notification to other users of the sea regarding the project's activities, the socio-economic risk is considered low and is therefore acceptable when managed within the mitigation measures described.

Emissions to Air

The impact of installation, completions and start-up activities on air quality will be localised, short term and will mainly occur more than 200 km from the nearest shoreline. The significance of impact to the local ecological receptors is therefore considered to be low.

The introduction of Murlach could result in an increase in emissions of exhaust gases such as oxides of nitrogen from ETAP of up to 26% at its peak. The total emission levels from ETAP are projected to remain significantly lower than levels that have previously been modelled to show low environmental impact. The significance of impact on air quality over the life of field for Murlach is therefore considered to be low.

Murlach is predominantly an oil field, with relatively small proportion of gas anticipated. Production of Murlach is projected to result in a small increase in Green House Gas (GHG) emissions at ETAP, with an average increase of less than 3% per year except for 2026 during which the increase is projected to be approximately 23%. The increase in production at ETAP due to Murlach is projected to be approximately 40% over field life for the Base case and approximately 50% for the Upside case. Overall, production of oil from Murlach is projected to have a GHG Intensity of 46 – 58 $kgCO_2$ equivalents per tonne of oil, which compares favourably with the average intensity of 162 $kgCO_2$ equivalents per tonne of oil for production from all fields within the UK continental shelf.

A range of mitigation measures to minimise emissions to air is proposed, as outlined in Table 4. When compared against other emission sources on the UKCS and taking the mitigation measures into consideration, the overall impact of emissions to air resulting from the project is considered low and is therefore acceptable when managed within the mitigation measures described.

Discharges to Sea

There will be a number of planned discharges to sea associated with the project. Planned and permitted discharges to sea during drilling include drill cuttings and seawater with bentonite sweeps, cement and associated chemicals.

Planned and permitted discharges to sea during the installation and commissioning phase are primarily associated with testing the pipelines and infrastructure. All associated chemicals will be risk assessed and permitted in accordance with the Offshore Chemicals Regulations 2002 (as amended).

The ETAP platform operates 100% Produced Water (PW) reinjection such that there will be no PW discharges to sea. Increased inputs from Murlach will not result in exceedance of the existing ETAP platform PW re-injection system capacity.

The environmental impacts of all planned discharges associated with the proposed Murlach Field Development are considered to be low and are therefore considered acceptable when managed within the additional controls and mitigation measures identified.

Seabed Disturbance

A number of activities will be carried out which have the potential to impact on the seabed and its associated benthic communities. These include the laydown of the anchor system for the drilling rig or jackup drilling rig spud cans, the discharge of drill cuttings from the upper sections of the two wells, the discharge of cement from the top hole sections and the impacts associated with the subsea installation activities. Seabed impacts have been divided into permanent impacts and temporary impacts. The former are associated with the long term installation of new infrastructure and its associated stabilisation features e.g. the manifold, pipeline, tie-in spools, rock dump, and mattresses etc. Although some of these features will be removed upon final decommissioning, for the purposes of this EIA they have been classed as permanent. Temporary impacts include those associated with the drill rig anchor system, which will be recovered once the drilling campaign has been completed and the resettlement of suspended solids.

Depending on the installation option selected for the gas lift pipeline, the permanent area of impact is estimated to range from 0.009 km^2 (Option 3) to 0.053 km^2 (Option 1) whilst the temporary area of impact could range from 1.25 km^2 (Option 3) to 0.5 km^2 (Option 1).

Impacts on the receptors in the area as a result of the seabed disturbance was considered low when the receptor sensitivity, area of impact and level of impact were considered.

Underwater Sound

The main sources of underwater sound associated with the proposed Murlach Field Development will result from the piling of the manifold, vessel use and drilling operations.

Many marine organisms use sound for navigation, communication and prey detection. Therefore, the introduction of man-made sources of underwater noise has the potential to impact marine animals if it interferes with their ability to receive and use sound. Types of impact include temporary avoidance or behavioural changes, the masking of biological sounds, auditory and other injuries.

Although the sound from the proposed Murlach Field Development does have the potential to cause disturbance to marine animals it is not expected to have a significant impact on any cetacean or fish species. Taking this into account and considering the mitigation measures outlined in Table 4, the environmental impact of the underwater sound associated with the vessels and the piling is considered low and is therefore acceptable when managed within the mitigation measures described.

Waste

BPEOC is committed to applying the waste management hierarchy and managing all produced waste using approved methods. Waste will only be disposed of if it cannot be prevented, reclaimed or recovered. Waste produced will be correctly documented, transported, processed and disposed of in accordance with applicable legislation. The overall environmental risk of waste generation is therefore considered to be low and is therefore acceptable when managed within the mitigation measures described.

Unplanned Hydrocarbon Releases

Modelling of a worst-case unplanned hydrocarbon release was carried out using the Oil Spill Contingency and Response (OSCAR) model. There is a potential risk to several environmental receptors from such releases, including internationally protected areas, the magnitude of which is dependent on the size of the release. Worst-case releases are rare in the industry and the likelihood of an unplanned hydrocarbon release reaching its full effect potential is such that the overall risk is reduced to as low as reasonably practicable. However, should an uncontrolled release occur there will be robust measures in place to confirm a co-ordinated and co-operative response.

Overall Conclusion

The proposed Murlach Field Development project will be developed using proven technology incorporating the current industry practices. A robust design, strong operating practices and a highly trained workforce will help prevent any significant long-term environmental, cumulative or transboundary effects. Additional measures will be in place during operations to effectively respond to unplanned events.

Table 4: Murlach Field Development Project commitments.

Aspect	Commitments
Physical presence	• Notice to Mariners will be circulated prior to rig mobilisation; • The drilling rig will abide by CtL conditions; • A Collision Risk Management Plan will be produced if determined to be required; • All vessels will adhere to COLREGS and will be equipped with navigational aids, including radar, lighting and AIS (Automatic Identification System) etc.;

Aspect	Commitments
	• The drilling rig will be equipped with navigational aids and aviation obstruction lights system, as per the Standard Marking Schedule for Offshore Installations; • Vessel use will be optimised by minimising the number of vessels required and length of time vessels are on site; • A fisheries interaction assessment to aid selection of the optimal flowline installation method will be carried out. In the event that the study identifies an unacceptable risk to flowline integrity or fishing gear, the option to install the flowline exposed on the seabed will not be carried forward; and • Should the gaslift line be trenched and buried, post installation surveys will be carried out to determine if any clay berms remain on the seabed. Similarly should a semi-submersible drilling rig be used, post anchor recovery surveys will be carried out to determine if recovery of the anchors has resulted in any clay berms. In the event that they are detected, BPEOC will discuss appropriate mitigation with OPRED and SFF.
Emissions to air	• The drilling rig and other project vessels will be subject to audits to assess compliance with UK legislation and the BPEOC Marine Operations and Vessel Assurance Standard; • Vessel use will be optimised where possible by minimising the number of vessels required, and their length of time on site; • Vessels will be operated where possible in modes that allow for economical fuel use; and • Minimise flaring during well clean-up operations by sending fluids to ETAP for processing as the base case and preferred option. In accordance with the revised NSTA strategy, and associated Stewardship Expectation 11, as well as with the industry commitments within the NSTD, BPEOC will incorporate the impact of the Murlach production within ETAPs controls, including: • Asset GHG Emission Reduction Action Plans; • Flaring and venting reviews to identify/action zero routine flaring by 2030; • Active flare reduction strategy; • Active vent reduction strategy; • Emission key performance indicators and targets; and • Industry level benchmarking of flaring and venting.
Discharges to sea	• The drilling rig will be audited under BPEOC's Marine Operations and Vessel Assurance Standards and subject to rig recertification audits; • All vessels used will be MARPOL compliant; • Where technically feasible BPEOC will prioritise the selection of PLONOR, or chemicals with a lower RQ; and • The discharges of any water based hydraulic fluids, sand or chemicals are regulated by the OPPC and/or the OCR regulations and reported through the EEMS. As such, BPEOC will confirm that sampling, analysis and reporting in line with the applicable regulations and permit conditions.
Seabed disturbance	• Pre-deployment surveys will be undertaken to identify suitable locations for the drilling rig anchors or jack-up drilling rig spud cans;

Aspect	Commitments
	• Tie-ins to existing infrastructure where possible; and • The use of mattresses, rockdump and grout bags will be minimised through optimal project design.
Underwater noise	• Optimise duration of drilling and installation activities in order to minimise vessel use. • Recommendations of the JNCC protocol for minimising risk or injury to marine mammals from piling noise (JNCC, 2010) will be adopted; • Use of properly qualified, trained and equipped marine mammal observers (MMOs) to detect marine mammals within a "mitigation zone" and potentially recommend a delay to piling operations. The mitigation zone should be at least 500 m. MMOs should carry out a 30 minute pre-piling survey and if an animal is detected then work should be delayed until it has left the area; • Soft-start of piling, whereby there is an incremental increase in power and, therefore, sound level. This should be carried out over a minimum period of 20 minutes. This is believed to allow any marine mammals to move away from the piling location and reduce the likelihood of exposing the animal to sounds which can cause injury; • Repeat of the pre-piling survey and soft-start whenever there is a break in piling of more than 10 minutes; and • Avoiding commencing piling at night or in poor visibility when marine mammals cannot reliably be detected.
Waste	• BPEOC will apply the principles of the Waste Management Hierarchy during all activities i.e. Reduce, Reuse, Recycle; • Existing asset and vessel WMPs will be followed; • Only permitted disposal yards / landfill sites will be used.
Accidental events	• Activities will be carried out by trained and competent offshore crews and supervisory teams; • An approved OPEP will be in place prior to any activities being undertaken; • Process Safety Assurance Processes will be identified and adhered to; • Records will be kept of oil spill training and exercises as required by the OPEP; • A co-ordinated industry oil spill response capability will be available; • Enhanced sharing of industry best practices via the OSRF will continue for BPEOC personnel; Wells specific control measures: • A robust BOP pressure and functional testing regime will be in place; • Appropriate mud weights will be used to allow well control to be maintained; and • A contract will be in place with a well capping advice provider, in case of emergency. Operations-specific control measures: • Import and export facilities will be secured by a combination of topside Emergency Shut Down Valves (ESDV); • Pipelines will have pressure monitoring and low pressure alarms; and • Oil spill control measures will be followed as outlined in the OPEP.

The ES assesses the worst-case impact of the project on the environment and is therefore very conservative. Even then, applying the mitigations measures identified, it is the conclusion of this ES that the current proposal for the Murlach Field Development can be completed without causing any significant long-term environmental impacts or cumulative or transboundary effects.

ACRONYMS

>	More Than
%	Percentage
% wt	Percentage Weight
‰	Per thousand
(H)	Height
(L)	Length
(W)	Width
"	Inches
<	Less Than
≥	More than or equal to
°	Degrees
°C	Degrees Celsius
µg/g	Micrograms per Gram
µg/l	Micrograms per Litre
µm	Micrometres
µPa	Micropascal
AEL	Associated Emission Level
AHV	Anchor Handling Vessel
AIS	Automatic Identification System
ALARP	As Low As Reasonably Practicable
API	American Petroleum Institute
Ba	Barium
BAP	Biodiversity Action Plan
BAT	Best Available Techniques
BAT	Best Available Technology
bbls	Barrels of Oil
BEIS	(the Department of) Business, Energy and Industrial Strategy
BOD	Biological Oxygen Demand
BOP	Blowout Preventer
BPEOC	BP Exploration Operating Company Limited
c.	Approximately
CA	Comparative Assessment
CCS	Carbon Capture and Storage
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CH_4	Methane
CHARM	Chemical Hazard Assessment and Risk Management
cm	Centimetre
CNS	Central North Sea
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalents
COLREGS	Collision Regulations
CoP	Cessation of Production
COSHH	Control of Substances Hazardous to Health
cP	centiPoise
CSIP	Cetacean Stranding Investigation Programme
CtL	Consent to Locate
CIP	Communication & Interface Plan
dB	Decibels
dB re 1 µPa	Decibels relative to 1 mico Pascal
dB re 1 µPa^{2}s	Decibels relative to 1 squared mico Pascal second
DECC	Department of Energy and Climate Change
Defra	Department for Environment Food and Rural Affairs
DepCon	Deposit Consent
DHSV	Down Hole Safety Valve
DP	Dynamic Positioning
DSV	Dive Support Vessel
DTI	Department of Trade and Industry
EC	European Commission
ED	European Datum
EEMS	Environmental Emissions Monitoring System
e.g	For example
EIA	Environmental Impact Assessment
ELV	Emission Limit Values
EMODnet	European Marine Observation and Data Network
EMS	Environmental Management System

ENVID	Environmental and socio-economic Impact Identification
EPS	European Protected Species
ERL	Effects Range Low
ERRV	Emergency Response and Rescue Vessel
ES	Environmental Statement
ESAS	European Seabirds at Sea
ESD	Emergency Shutdown
ESDV	Emergency Shutdown Valve
ESIA	Environmental and Socio-Economic Impact Assessment
ESRA	Environmental and Socio-Economic Risk Assessment
ETAP	Eastern Trough Area Project
ETS	Emissions Trading Scheme
EU	European Union
EU ETS	European Union Emissions Trading Scheme
EUNIS	European Nature Information System
FARAM	Faunal Acoustic Risk Assessment Model
FeAST	Feature Activity Sensitivity Tool
FEPA	Food and Environmental Protection Act
FPSO	Floating Production Storage and Offloading
g/kg	Grams per Kilogram
g/m^2	Grams per Metre Squared
GEBCO	General Bathymetric Chart of the Oceans
GEN	National Marine Plan General Policies
GES	Good Environmental Status
GHG	Greenhouse Gases
GTG	Gas Turbine Generator
GWO	Global Wells Organisation
GWP	Global Warming Potential
h	hour
HF	High Frequency
HPHT	High Pressure High Temperature
HQ	Hazard Quotient
HSE	Health Safety and Environment
HSSE	Health, Safety, Security and Environment

Hz	Hertz
IAMMWG	Inter-Agency Marine Mammal Working Group
IAPP	International Air Pollution Prevention
ICES	International Council for the Exploration of the Sea
ILI	Inline Inspection
IMO	International Maritime Organisation
IOGP	International Association of Oil & Gas Producers
IPIECA	International Petroleum Industry Environmental Conservation Association
IPPC	Integrated Pollution Prevention and Control
IR	Infrared
ISO	International Standards Organisation
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
kg	Kilogram
kg/m^2	Kilogram per Metre Squared
kg/m^3	Kilogram per Metre Cubed
kHz	Kilohertz
kJ	Kilo Joules
km	Kilometre
km^2	Squared Kilometres
KW/m	Kilowatts per metre
LAT	Lowest Astronomical Tide
LCP	Large Combustion Plant
LF	Low Frequency
LNG	Liquefied Natural Gas
LSA	Low Specific Activity
LTOBM	Lox Toxicity Oil Based Mud
m	Metre
m/s	Metres per Second
m^2	Square Metres
m^3	Cubic Metres
MAH	Major Accidents and Hazards
MARPOL	Maritime Pollution
MAT	Master Application Template

MCAA	Marine and Coastal Access Act
MCZ	Marine Conservation Zone
MEG	Monoethylene Glycol
MEI	Major Environmental Incident
MF	Mid Frequency
mg/kg	Milligrams per Kilogram
mg/l	Milligrams per Litre
MJ	Megajoule
mm	Millimetre
Mm^3/day	Cubic millimetres per day
MMBBL	Million Barrels of Oil
MMO	Marine Mammal Observer
MMO	Marine Management Organisation
MPA	Marine Protected Area
ms	Milliseconds
MSFD	Marine Strategy Framework Directive
MSS	Marine Scotland Science
MTe	Million Tonnes
mTVDss	Metres True Vertical Depth Subsea
MU	Management Unit
MW(th)	Mega Watt (thermal)
N	North
N/A	Not Applicable
NAOI	North Atlantic Oscillation Index
N_2O	Nitrous Oxide
NCMPA	Nature Conservation Marine Protected Area
NECNSL	NEO Energy Central North Sea Limited
nm	Nautical Miles
NMFS	National Marne Fisheries Service
NMP	National Marine Plan
NMPi	National Marine Plan Interactive
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NOAA	National Oceanic and Atmospheric Administration
NOEC	No Observed Effect Concentration
NORM	Naturally Occurring Radioactive Material

NOx	Nitrogen Oxides
NPI	Non Production Installation
NSS	North Sea Standard
NSTD	North Sea Transition Deal
OBM	Oil Based Mud
OCR	Offshore Chemicals Regulations
OGA	Oil and Gas Authority
OMAR	Offshore Major Accident Regulator
OPEP	Oil Pollution Emergency Plan
OPOL	Offshore Pollution Liability Association Ltd
OPPC	Oil Pollution Prevention and Control
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
OSCAR	Oil Spill Contingency and Response
OSPAR	Oslo/Paris Convention
OSRF	Oil Spill Response Forum
OSRL	Oil Spill Response Limited
OVI	Offshore Vulnerability Index
PAH	Polycyclic Aromatic Hydrocarbons
PE	Parabolic Equation
PETS	Portal Environmental Tracking System
PiP	Pipe in Pipe
PLONOR	Posing Little or No Risk
PMF	Priority Marine Features
PNEC	Predicted No Effect Concentration
PPC	Pollution Prevention and Control
PTS	Permanent Threshold Shift
PVA	Particularly Vulnerable Area
PW	Produced Water
PWA	Pipeline Works Authorisation
PWRI	Produced Water Re-injection
Q1, Q2, Q3, Q4	Quarter 1, 2 3 or 4
QU	Quarters and Utilities (platform)
RAM	Range-dependent Acoustic Model
RBA	Risk Based Approach
rms	Root Mean Squared
ROV	Remotely Operated Vehicle

RQ	Risk Quotient
SAC	Special Areas of Conservation: cSAC, candidate; pSAC, possible; dSAC, draft
SACFOR	Super-abundant, Abundant, Common, Frequent, Occasional and Rare
SAT	Subsidiary Application Template
SCANS	Small Cetacean Abundance in the North Sea
SCR	Safety Case Regulations
SCSSV	Surface Controlled Sub-Surface Safety Valve
SDM	Species Distribution Modelling
SDS	Safety Data Sheet
SE	Stewardship Expectations
SEL	Sound Exposure Level
SFF	Scottish Fisheries Federation
SIMOPS	Simultaneous Operations
SNH	Scottish Natural Heritage
SO_2	Sulphur Dioxide
SOPEP	Shipboard Oil Pollution Emergency Plan
SOSI	Seabird Oil Sensitivity Index
SOx	Sulphur Oxides
SPA	Special Protection Area
Spp.	Species
SPL	Sound Pressure Level
te/m^3	Tonnes per Metre Cubed
te	Tonne
Te/hr	Tonnes per hour
TeOE	Tonnes of Oil Equivalent
THC	Total Hydrocarbon Concentration
UHB	Upheaval Buckling
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
UKOOA	UK Offshore Operators Association
UTM	Universal Transverse Mercator
UV	Ultraviolet
VOC	Volatile Organic Compounds
VU	Vulnerable
W	West
WBM	Water Based Mud
WMP	Waste Management Plan
WOA	World Ocean Atlas
WONS	Well Operation Notifications System
WWC	Wild Well Control

1. INTRODUCTION

BP Exploration Operating Company Limited (BPEOC) on behalf of itself and its Co-Venturer, Neo Energy Central North Sea Limited (NECNSL), is proposing to redevelop the Murlach Field (formerly known as Skua)[1] located on the United Kingdom Continental Shelf (UKCS), *c.* 203 km from the Aberdeenshire coastline and *c.* 27 km from the UK/Norway median line (Figure 1-1). The Murlach reservoir lies within Block 22/24h at a water depth of ~97 m. The field is high temperature field (150°C) with a relatively high pressure (*c.* 410 barg). Note, this pressure does not meet the technical definition of a High Pressure High Temperature (HPHT) well (see Section 2.1 for more details).

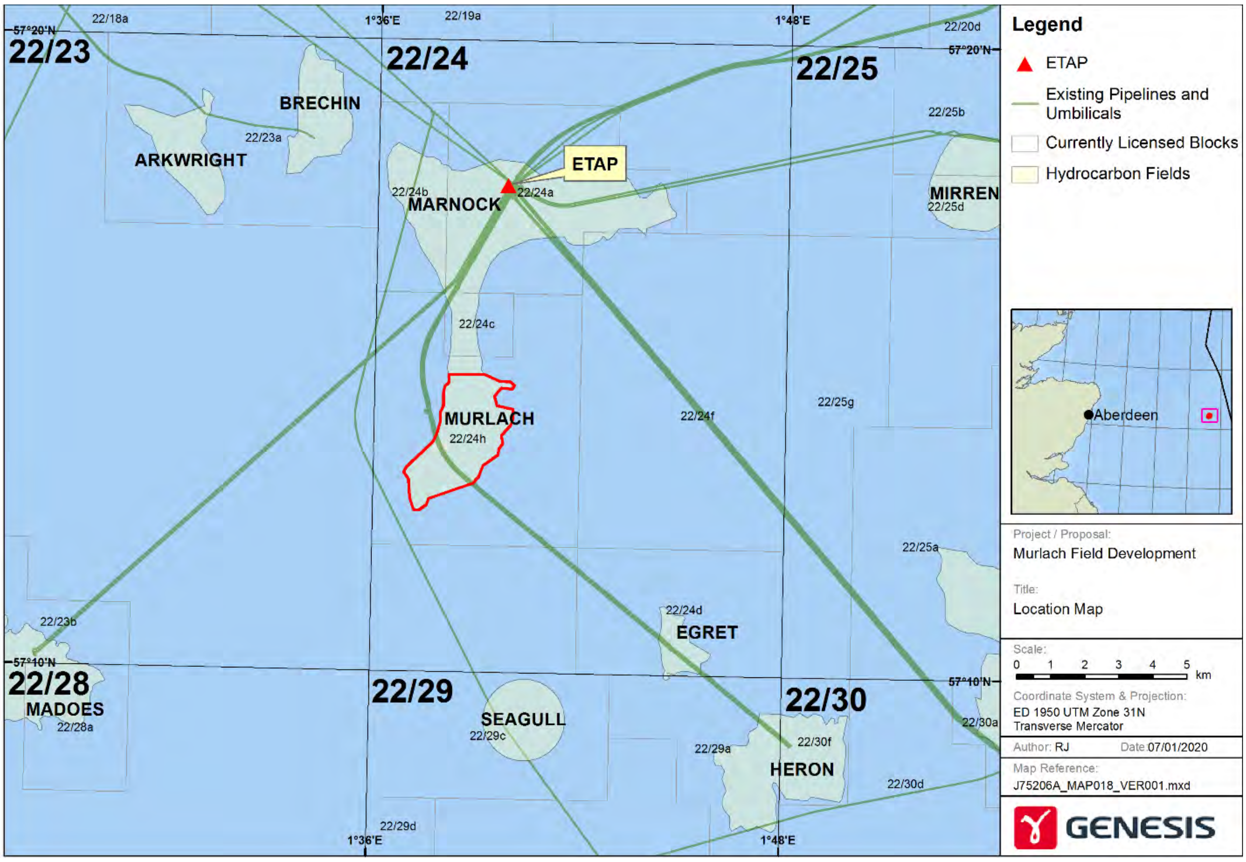


Figure 1-1: Location of the proposed Murlach Field Development.

The Field was discovered in 1986 and the licence interests are summarised in Table 1-1.

Table 1-1: Licence interests of the Murlach Field.

Equity holder	% holding
BPEOC	80
NECNSL	20

The Murlach Field will be developed as a subsea tie-back (two production wells) to the Eastern Trough Area Project (ETAP) platform. This tie-back will share existing infrastructure already present around the Murlach

[1] Though the project is a redevelopment of the Skua Field, the ES refers to the project as the Murlach Field Development.

Field, including the Heron A production pipeline and the Seagull control umbilical, and will involve the installation of a new manifold and a new gaslift pipeline from the ETAP platform.

Under the Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020, hereafter referred to as the 2020 Offshore EIA Regulations, the proposed Murlach Field Development Project (hereafter referred to as the Murlach Field Development) requires an Environmental Impact Assessment (EIA) and Environmental Statement (ES) to be submitted to the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) for approval. This requirement is due to the anticipated volumes of hydrocarbons to be produced such that consent is being sought for the *'Extraction of oil and natural gas for commercial purposes where the amount extracted exceeds 500 tonnes per day in the case of oil and 500,000 cubic metres per day in the case of natural gas'.*

1.1 Overview of the Murlach Field Development

The base case for the proposed Murlach Field Development comprises:

- The drilling of two production wells;
- The installation of:
    - A *c.* 7 km gaslift pipeline from the ETAP platform to the new Murlach manifold;
    - A new piled manifold;
    - A Xmas tree at each well;
    - A *c.* 100 m tie-in from the Murlach manifold to the existing Heron production pipeline;
    - A *c.* 300 m tie-in from the existing Heron wash water pipeline system to the Murlach manifold;
    - A *c.* 500 m umbilical connecting the existing Seagull umbilical to the Murlach manifold; and
    - Tie-ins between the new Murlach manifold and each of the two Murlach wells for production, gaslift, wash water and a control umbilical.

Further details are provided in Sections 2.3 and 2.6.

1.2 Purpose of the Murlach Field Development and Net Zero Context

The demand in the UK for oil and gas is predicted to decline significantly over the next 30 years to 2050, although the UK Government forecasts show that oil and gas will remain an important part of the UK energy mix for the foreseeable future, including under net zero (OGA, 2021). As production from existing fields naturally depletes, meeting the continued demand will require a combination of either the development of new fields within the UKCS and/or imports.

Current projections show that the UK is forecast to remain a net importer of oil and gas for the foreseeable future, even with the development of new fields within existing licensed blocks (BEIS, 2021b).

In this context, the development of fields within the UKCS that have low Green House Gas (GHG) emissions per unit of hydrocarbon production is consistent with supporting the UK Government's strategy for transitioning to net zero GHG emissions.

bp's ambition is to become a net zero company by 2050 or sooner and to help the world get to net zero. The Company's strategy will reshape the business as it decarbonises and diversifies into different forms of energy, such as renewables, biofuels and hydrogen.

Oil and gas will continue to perform a vital role for the world, but we expect demand will start to fall over the longer term. Therefore bp plans to reduce production by about 40% by 2030 and create a resilient, lower cost and lower carbon oil, gas and refining portfolio that is smaller but of the highest quality.

Over its field life, Murlach is estimated to produce between 3.2 MTe and 4.0 MTe oil equivalent with a GHG intensity of 58 $kgCO_2e$/TeOE (Base case) or 46 $kgCO_2e$/TeOE (Upside case). This GHG intensity is less than one third of the average intensity (162 $kgCO_2e$/TeOE) for oil and gas production across the UKCS (see

Section 6.5.4 for further details).

Through production of this relatively low GHG intensity field, BPEOC are supporting the UK in its transition to reduce emissions on the path to becoming Net Zero.

1.3 Purpose of the Environmental Statement

The purpose of this ES is to report on the EIA process undertaken to meet both statutory and BPEOC internal project requirements. The ES provides a public consultation document which supports consultees in the decision-making process and is therefore required to be a comprehensive report. The ES provides an opportunity to reassure the Regulator and consultees that BPEOC is informed and understands:

- the likely consequences of the activities, emissions, discharges and physical presence of the project;
- the local environment; and
- the nature of the environmental and commercial issues arising for other users of the sea.

The ES has been prepared in accordance with the 2020 Offshore EIA Regulations and guidance from OPRED.

1.4 Scope of the Environmental Statement

The scope of the EIA and resultant ES includes the following activities:

- The drilling of the Murlach wells;
- The installation and commissioning of the required subsea infrastructure; and
- Production of Murlach hydrocarbons.

In line with the 2020 Offshore EIA Regulations, the EIA sets out to describe and evaluate the impacts of any emissions to air, discharges to sea, seabed disturbance, underwater noise, waste production and resource use resulting from the proposed development on a range of receptors including flora, fauna, water, air, climate and material assets. In addition, the potential interactions with other users of the sea are considered. These aspects are considered for planned activities and unplanned (i.e. accidental) events.

1.5 Document Layout

To determine the environmental and socio-economic impacts of the proposed Murlach Field Development Project, an understanding of the regulatory context, stakeholder concerns, the proposed activities and the environmental and socio-economic baseline is required. Table 1-2 details the structure of the ES report.

Table 1-2: Structure of the ES.

Section No.	Title	Contents
	Non-Technical Summary	A summary of the ES Report.
1	Introduction	Introduction to the project and scope of the ES. This chapter also includes a summary of applicable legislation, BPEOC's Management System, areas of uncertainty and the consultation process to date.
2	Project Description	An overview of option selection, description of the drilling and subsea installation operations, an overview of the ETAP platform and the anticipated production profiles.
3	Environmental and Socio-Economic Baseline	A description of the environmental and socio-economic receptors in the area.
4	Risk Assessment Methodology	Description of the methodology used to determine the significance of the environmental and social risk of the proposed activities.
5 to 10	Assessment of Aspects	Detailed assessment of Physical Presence (Section 5); Emissions to Air (Section 6); Discharges to Sea (Section 7); Seabed Disturbance (Chapter 8); Underwater Noise (Section 9); and Waste (Section 10) aspects of the development.
11	Accidental Events	Details of accidental events identified during the ENVironmental and socio-economic Impact IDentification (ENVID).
12	Conclusions	Key findings including a register of commitments.
13	References	Lists sources of information drawn upon throughout the ES.
Appendix A	Scotland's National Marine Plan	Assessment of the project against Scotland's National Marine Plan.
Appendix B	ENVID Results	Results of the ENVID.
Appendix C	Oil Spill Modelling	Modelling of the impacts of a hydrocarbon release in the event of a well blowout during drilling.
Appendix D	Underwater Noise Modelling	Modelling of impacts of piling activities associated with the new manifold.
Appendix E	Base Case Production Profiles	Base Case Production Profiles

1.6 Legislative Overview

This section provides a summary of the current environmental legislation applicable to the project.

1.6.1 Environmental Impact Assessment

Offshore environmental control has developed significantly over the past thirty years and is continuing to evolve in response to increasing awareness of potential environmental impacts. Strands of both primary and secondary legislation, voluntary agreement, and conditions in consents granted under the petroleum licensing regime and international conventions have all contributed to the current legislative framework.

The main controls for new oil and gas projects are EIAs, which became a legal requirement of offshore developments in 1998. Current requirements are set out in the 2020 Offshore EIA Regulations and accompanying Guidance Notes for Industry (BEIS, 2021).

Schedule 1 of the 2020 Offshore EIA Regulations identifies those projects that require an ES to be prepared. As described previously, the proposed Murlach Field Development requires an ES due to the anticipated production profiles.

1.6.2 Protected Sites and Species

The EIA needs to consider the impact on the surrounding environment including any protected areas. Many protected areas have been designated in the UK under the European Union (EU) Nature Directives, in particular the Habitats Directive (92/43/EEC) and the Birds Directive (2009/147/EC). Since January 2021 these are now maintained and designated under the Habitats Regulations for England and Wales, Scotland and Northern Ireland. Amendments to the Habitats Regulations mean that the requirements of the EU Nature Directives continue to apply to how European sites (Special Areas of Conservation (SACs) and Special Protection Areas (SPAs)) are designated and protected. The Habitats Regulations also provide a legal framework for species requiring strict protection, e.g. European Protected Species (EPS). All offshore projects or developments must demonstrate that they are not “likely to have a significant impact on the integrity of the conservation objectives for the protected site” or “significantly disturb or injure European Protected Species (EPS)” either alone or in combination with other plans and projects.

1.6.3 Discharges to Sea

Oil Discharges

In accordance with the Oslo/Paris Convention (OSPAR) Recommendation (2001/1), the UK through OPRED has introduced regulatory requirements which reduce the permitted average monthly oil concentration in produced water discharged overboard from oil and gas installations to a maximum of 30 mg/l. OSPAR Recommendation 2001/1 also required contracting parties to reduce the total discharge of oil in produced water (PW) by 15% by 2006 measured against a 2000 baseline. The permits replaced the granting of exemptions under the Prevention of Oil Pollution Act 1971 and are issued under the Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended). The ETAP platform operates 100% PW reinjection such that there will be no PW discharges associated with the proposed Murlach Field Development. Note, at any time that the PW reinjection is not available, production is shut-in at ETAP, such that PW is never discharged at the platform.

Chemical Discharges

In June 2000, the OSPAR Convention for the Protection of the Marine Environment in the North East Atlantic made a decision requiring a mandatory system for the control of chemicals (OSPAR Decision 2000/2 on a Harmonised Mandatory Control System for the Use and Reduction of the Discharge of Offshore Chemicals). This decision operates in conjunction with two OSPAR Recommendations:

- OSPAR Recommendation 2000/4: The application of a Harmonised Pre-Screening Scheme for Offshore Chemicals to allow authorities to identify chemicals being used offshore; and
- OSPAR Recommendation 2000/5: The application of a Harmonised Offshore Chemical Notification Format for providing data and information about chemicals to be used and discharged offshore.

OPRED implemented OSPAR Decision 2000/2 on the control of chemical use offshore, through the Offshore Chemicals Regulations (OCR) 2002 (as amended). The regulations require offshore Operators to apply for permits for the use and / or discharge of chemicals in the course of all relevant offshore energy activities, including well operations, production operations, pipeline operations, and decommissioning operations. The 2011 Amendment Regulations extended the provisions to take enforcement action in the event of any unintentional offshore chemical release. The Murlach Field Development will have limited chemical discharges associated with production due to the ETAP platform operating 100% PW reinjection.

Risk Based Approach

OSPAR Recommendation 2012/5 for a Risk-Based Approach (RBA) to the Management of PW Discharges from Offshore Installations aims to produce a method for prioritising mitigation actions for those discharges and substances that pose the greatest risk to the environment. As the ETAP platform operates 100% PW reinjection, this is not relevant to the proposed Murlach Field Development.

1.6.4 Atmospheric Emissions

Combustion installations on oil and gas platforms with a rated thermal input, including flaring of 20 MW(th) or more require permitting under the UK's Emissions Trading Scheme (UK ETS). The UK ETS replaced the UK's participation in the European Union ETS system on 1 January 2021. The EU ETS is based on Directive 2003/87EC establishing a scheme for greenhouse gas emission allowance trading within the Community (the EU ETS Directive) and the UK ETS broadly aligns with the Directive. The UK ETS is implemented by the Greenhouse Gas Emissions Trading Scheme Order 2020 (as amended). The relevant provisions of the Order include the requirement to monitor and report carbon dioxide (CO_2) emissions, surrender allowances and to notify of any changes affecting the allocation of allowances.

Combustion installations on oil and gas platforms with a rated thermal input of 50 MW(th) or more require permitting under the Offshore Combustion Installations (Pollution Prevention and Control) Regulations 2013 (as amended). This includes conditions limiting releases notably for carbon monoxide (CO), oxides of nitrogen (NOx), oxides of sulphur (SOx), methane (CH_4) and volatile organic compounds (VOCs) and the demonstration of the use of Best Available Technique (BAT). Combustion installations with a rated thermal input of 1 MW(th) to 50 MW(th) also require permitting under Pollution Prevention and Control (PPC) regulations to comply with the Emission Limit Values (ELV's) as stipulated in the Medium Combustion Plant directive EU 2015/2193 of 25th November 2015 for sulphur dioxide (SO_2), NO_x and dust.

The revised OGA Strategy (February, 2021) retains a binding obligation to secure that the maximum value of economically recoverable petroleum is recovered from the strata beneath relevant UK waters. The Strategy also states that in doing so, appropriate steps must be taken to reducing greenhouse gas emissions and assist in meeting the UK net zero target. The Strategy is supported by Stewardship Expectations (SE). The OGA 'Stewardship Expectation 11 – Net Zero' (March 2021) (SE 11) sets out the OGAs expectations of the steps that should be taken across the exploration and production lifecycle, to reduce emissions and promote Carbon Capture and Storage (CCS) and Hydrogen.

1.6.5 Marine and Coastal Access Act

The Marine and Coastal Access Act (MCAA) came into force in November 2009. The Act covers all UK waters except Scottish internal and territorial waters which are covered by the Marine (Scotland) Act (2010), which mirrors the MCAA powers. The MCAA provides the legal mechanism to help ensure clean, healthy, safe, productive and biologically diverse oceans and sea by putting in place a new system for improved management and protection of the marine and coastal environment. It replaces and merges the requirements of the Food and Environmental Protection Act (FEPA) Part II (environment) and the Coastal Protection Act (navigation).

The MCAA has enabled:

- Establishment of the Marine Management Organisation (MMO) to operate as the competent marine planning authority in English territorial waters and UK offshore waters (for matters that are not devolved) such as marine licensing and enforcement of marine legislation;
- A strategic marine planning system to agree marine objectives and priorities and establish a series of marine plans to implement marine policy;
- A new marine licensing system for marine activities; and
- Powers enabling the designation of Marine Conservation Zones (MCZ) in the territorial waters adjacent to England and Wales and UK offshore waters.

However, the following are exempt from the MCAA as they are regulated under different legislation:

- Activities associated with exploration or production / storage operations that are authorised under the Petroleum Act; and
- Additional activities authorised solely under the OPRED environmental regime, e.g. chemical and oil discharges.

Some oil and gas activities, which are not regulated by the Petroleum Act or under the OPRED environmental regime, require an MCAA licence.

1.6.6 National Marine Plan

The Scottish National Marine Plan (NMP) comprises plans for Scotland's inshore (out to 12 nm) and offshore waters (12 to 200 miles) as set out under the Marine (Scotland) Act 2010 and the Marine and Coastal Access Act 2009. The NMP represents a framework of Scottish Government policies for the sustainable development of marine resources. The NMP is underpinned by the following strategic objectives:

- Achieving a sustainable marine economy;
- Ensuring a strong, healthy and just society;
- Living within environmental limits;
- Promoting good governance; and
- Using sound science responsibly.

These objectives are to be achieved through the application of 21 'General Planning Principles'. Development projects should take these principles into account in order to support the overall NMP objectives for sustainable development of Scotland's marine environment.

The NMP sets out specific key issues for oil and gas sector in supporting the objectives of the plan:

- Maximise extraction;
- Re-use infrastructure;
- Transfer of skills to renewables and CCS;
- Co-operation with the fishing industry;
- Noise impacts to sensitive species;
- Chemical and oil contamination of water, sediments and fauna;
- Habitat changes.

The NMP also sets out general policies and objectives as part of the UK's shared framework for sustainable development. The proposed operations as described in this ES have been assessed against all NMP objectives (Appendix A) and policies, but specifically GEN 1, 4, 5, 9, 12, 14 and 21:

GEN 1- General Planning and Principle

Development and use of the marine area should be consistent with the Marine Plan, ensuring activities are undertaken in a sustainable manner that protects and enhances Scotland's natural and historic marine environment.

GEN 4 - Co–existence

Where conflict over space or resource exists or arises, marine planning should encourage initiatives between sectors to resolve conflict and take account of agreements where this is applicable.

GEN 5 - Climate Change

Marine planners and decision makers should seek to facilitate a transition to a low carbon economy. They should consider ways to reduce emissions of carbon and other greenhouse gasses.

GEN 9 - Natural Heritage

Development and use of the marine environment must:

- Comply with legal requirements for protected areas and protected species.
- Not result in significant impact on the national status of Priority Marine Features (PMF) (see Section 3.5.2).
- Protect and, where appropriate, enhance the health of the marine area.

GEN 12 – Water Quality and Resource

Developments and activities should not result in a deterioration of the quality of waters to which the Water Framework Directive, Marine Strategy Framework Directive or other related Directives apply.

GEN 14 – Air Quality

Development and use of the marine environment should not result in the deterioration of air quality and should not breach any statutory air quality limits. Some development and use may result in increased emissions to air, including particulate matter and gases. Impacts on relevant statutory air quality limits must be taken into account and mitigation measures adopted, if necessary, to allow an activity to proceed within these limits.

GEN 21 – Cumulative Impacts

Cumulative impacts affecting the ecosystem of the marine plan area should be addressed in decision making and plan implementation.

These NMP policies and objectives have been considered during the development of the proposed project and when undertaking the EIA.

1.7 BPEOC Management System

BPEOC is committed to conducting activities in conformance with all applicable legislation and in a manner that minimises impacts on the environment. The proposed Murlach Field Development will be delivered in conformance with BPEOC's Environmental Management System (EMS) which has been developed in line with the principles of the International Standard for Environmental Management Systems (ISO14001:2015).

bp North Sea UK HSE Policy

bp's commitment to **health, safety** and **environmental** (HSE) performance

Our HSE goals are simply stated:

no accidents, no harm to people and **no damage to the environment.**

We strive to be a safety leader in our industry, a world-class operator, a good corporate citizen and a great employer. Nothing is more important to us than the health, safety and security of our workforce and the communities in which we operate, and behaving responsibly towards our shared environment. We must be vigilant, disciplined and always looking out for one another.

We are committed to:

- complying with applicable laws and company policies and procedures
- systematically managing our operating activities and risks
- reporting our HSE performance
- learning from internal and external HSE events

In the North Sea our mission is to achieve zero life changing injuries, zero serious process safety events and have the lowest possible environmental impact, emissions, and methane intensity. We therefore expect all staff and contractors to stop work when there is an unsafe act or condition, non-compliance with legislation or when unable to meet bp requirements.

Everyone who works for bp has a part to play in meeting our HSE commitment. Our Safety Leadership Principles are an important guide on how we can achieve this . Together we:

1. Genuinely care about each other
2. Will not compromise our focus on safety
3. Encourage and recognize speak up
4. Understand how work actually happens
5. Learn why mistakes occur and respond supportively

Emeka Emembolu
SVP North Sea

1st July 2021 (updated 3 yearly)

Figure 1-2: BPEOC's Health, Safety, Security and Environment (HSSE) Policy.

1.8 Areas of Uncertainty

This ES was prepared during the Optimise Phase of the project. As a result, some assumptions have been made in order to undertake the EIA. Where assumptions have been made, the option considered to have greater potential environmental impacts was assessed. Assumptions and uncertainties are outlined below.

1.8.1 Pipeline Installation Method

At the time of writing it had yet to be determined if the c. 7 km gaslift pipeline will be (1) surface laid and exposed (2) surface laid and rock covered or (3) trenched and buried. The different options are considered in detail in Section 2.3.2, whilst the ES assesses the worst case impact of the options.

1.8.2 Rock Cover, Mattresses and Grout Bags

Maximum anticipated quantities of rock cover, mattresses and grout bags are presented in the ES to assess the worst-case scenario in terms of impacts on the seabed. The requirements for stabilisation/protection material will be further assessed and confirmed in later PWA (Pipeline Work Authorisation) and associated environmental permit applications.

1.8.3 Manifold Installation

At the time of writing, it had yet to be determined if the new manifold will be gravity based or piled. The ES assumes a worst case of the structure being piled.

1.8.4 Production Profiles

Production profiles based on models have a certain degree of uncertainty associated with them. The production profiles presented in this ES are based on a high case and are an annualised average of the projected production from the Murlach Field.

1.9 Consultation Process

During the process to assess the environmental impact of the proposed project, BPEOC consulted a number of stakeholders. A summary of the issues raised at various stakeholder meetings held in October 2019, November 2019, January 2020, November 2021 and March 2022 are provided in Table 1-3. Stakeholders represented at the different meetings included OPRED, the Joint Nature Conservation Committee (JNCC), Marine Scotland Science (MSS) and the Scottish Fishermen's Federation (SFF). Issues, recommendations and queries raised in the meetings are detailed in Table 1-3. The process of consultation will continue throughout the project.

As required by the 2020 Offshore EIA Regulations, a copy of the ES and the public notice has been made publicly available on the Company's website at the time of submission.

Table 1-3: Summary of consultations.

	Consultee Comment	BPEOC response
Summary / feedback from Stakeholder Engagement meeting held on 30/10/19: attended by OPRED, JNCC and SFF.		
1	• It was discussed that the ES would have a section outlining project options. Recognised that the section would be relatively short given the option to use existing lines where possible.	Addressed in Section 2. 3.1.
2	• The type of drilling rig (semi-submersible or jack-up) has not yet been determined. Discussion was held with regards to which type of drilling rig should be considered in the ES. OPRED and JNCC agreed the seabed disturbance associated with the anchor system of a semi-submersible drilling rig would be greater than that associated with a jack-up drilling rig. In addition, in the event of a well blowout, the release of oil from a semi-	Impact assessment captures use of a semi-submersible drilling rig: Section 8 and Section 11.

	Consultee Comment	BPEOC response
	submersible drilling rig could occur subsea whilst it would be more likely to occur at the surface from a jack-up rig. Given the near proximity (3.7 km from the drill centre) to the East of Gannet and Montrose Nature Conservation Marine Protected Area (NCMPA), the environmental impact of a subsea release was considered to be the worst-case. Therefore it was agreed that as a base case the ES would assess the impacts of a semi-submersible drilling rig due to it having a potentially greater environmental impact.	
3	• Given that 2 x Skua wells have previously been drilled at the proposed location JNCC confirmed that they did not see a requirement to support the ES with drill cuttings modelling given the location of the wells in a brownfield site.	Impact of discharged cuttings are considered in Section 8.1.2.
4	• OPRED questioned if there are any compatibility issues with the PW that could impact produced water re-injection (PWRI). BPEOC advised that none were identified.	No compatibility issues have been identified: Section 2.8.
5	• SFF was aligned with the approach to trench and bury the gaslift line from the ETAP platform. Discussions were held with regards to whether or not there is rock dump on the existing pipelines. SFF advised that a distance of 50 m is required between rock berms on adjacent lines. This is the distance required for fishing gear to "right" itself when it passes over the rock dump. Note: subsequent discussion was held with stakeholders in relation to surface laying and rock dumping the gaslift line. See line items 13-15 below.	Addressed in Section 2.3.2.
6	• SFF asked about any post-lay verification that there are no clay berms as a result of the trench and backfill activities. BPEOC committed to mitigation measures to confirm a safe seabed. JNCC requested that the impacts of any potential over-trawl surveys are considered in the ES.	Addressed in Section 2.3.2. Impact of over trawl trials are addressed in Section 8.2.
Summary / feedback from Stakeholder Engagement meeting held on 07/11/19: attended by MSS.		
7	• MSS discussed the possibility of any disturbance to the cuttings piles at the ETAP platform with the installation of the new gaslift pipeline. BPEOC advised there would not be a new riser required, and that the cuttings were present to the north of the ETAP platform whilst the gaslift pipeline would be connecting from the south and therefore minimal disturbance is anticipated.	Addressed in Section 3.3.3.1.
8	• MSS advised that it is important to document clearly the decision-making process throughout the ES for the reasoning behind the drill rig selection/ pipeline installation method etc. BPEOC/Genesis confirmed this would be part of option selection within the ES.	See line item 2 with regards to selection of drilling rig for assessment in the ES. Section 2.3.1 discusses development options considered and Section 2.3.2 discusses pipeline installation methods considered.
9	• MSS questioned the life expectancy of the Murlach Field vs. the life expectancy of the existing infrastructure being tied into and advised that this information would need to be specified in the ES.	Addressed in Section 2.3.1.
10	• MSS suggested the use of historical geotechnical survey data for establishing the type of sediment likely to be found at the depth of the trenches for the gaslift pipeline, as this will enable a better understanding of whether clay berms are likely to occur.	Post installation surveys are discussed in Section 8.2.
11	• MSS confirmed that drill cuttings modelling was not needed to support the ES given the location of the wells in a brownfield site, however, suggested the use of literature to establish the potential extent of the cuttings when compared with other drilling in the same area.	Addressed in Section 3.3.3.
12	• MSS advised to check whether the sediment type within the area is favourable to sandeels which are found in the greater region around the Field.	Addressed in Section 3.4.3.
Summary / feedback from Stakeholder Engagement meeting held on 31/01/20: attended by OPRED, JNCC, SFF and MSS.		

	Consultee Comment	BPEOC response
13	• This additional engagement was held because since the initial meeting, more detailed engineering suggested that surface lay and rock dumping the gaslift line could be a viable option. • Discussions were held on potential to recover a rock dumped pipeline at the time of decommissioning.	Addressed in Section 8.4
14	• OPRED asked, should surface lay and rock dump be selected, if the option exists to lay the new gaslift pipeline adjacent to a pre-existing rock berm thereby minimising the amount of additional rock required and the need for an additional pipeline corridor. SFF welcomed this suggestion as it would minimise the number of rock berms to be crossed when trawling.	As the project progresses BPEOC is committed to investigating the feasibility of laying the line next to the existing rock berms. Addressed in Section 2.3.2.
15	• OPRED and the other Statutory Consultees requested that appropriate technical and engineering information be provided so the advantages and disadvantages of the different pipeline installation options are clearly described in the ES.	Addressed in Section 2.3.2.
Summary / feedback from Stakeholder Engagement meeting held on 10/11/21: attended by OPRED, JNCC and SFF		
16	• OPRED queried why the well at the field had previously been shut in?	As a consequence of produced water, drop in reservoir pressure and no availability of gas lift there was insufficient energy to continue producing from the original Skua well. The early water breakthrough and decline in reservoir pressure meant the well was shut in earlier than expected.
17	• OPRED asked for confirmation on the number of wells to be drilled.	BPEOC confirmed that two wells will be drilled.
18	• OPRED queried what topside modifications would be required at ETAP.	BPEOC confirmed that modifications would be minimal.
19	• JNCCC requested that a map is included in the ES which shows which grab samples had evidence of *Arctica islandica* associated with them.	Map has been added to section 3.4.2.1
20	• OPRED/SFF queried the proposed pipeline installation method.	BPEOC confirmed that it had not yet been finalised. The ES discusses all options being considered at the time of submission.
21	• SFF raised discussion in relation to potential of clay berms being formed on the seabed when drill rig anchors are recovered.	BPEOC is committed to mitigating any potential clay berms. See Section 5.2.1 and 5.4.
Summary / feedback from Stakeholder Engagement meeting held on 12/11/21: attended by MSS.		
22	• MSS advised that minimal quantities of rock should be used e.g. by laying line along side existing rock berm and using mattresses inside safety zones rather than rock berm. In addition, MSS requested that the cumulative impact of rock is considered in line with other projects in the area.	Use of rock is discussed in Section 2.6.4. Impacts of the addition of rock are addressed in Sections 8.5 and 8.6.
23	• MSS advised various data sources to be used for the Baseline chapter.	Where applicable the data sources have been used in Section 3.
24	• MSS requested that in the absence of drill cuttings modelling, that the qualitative assessment takes account of what is known of cuttings being discharged at other wells.	The impact of the discharge of drill cuttings is addressed in Section 8.5.
25	• MSS advised that that the baseline section should provide high level details of the survey carried out (data collected, sample locations etc.)	Details of the surveys are presented in Section 3.

	Consultee Comment	BPEOC response
26	• MSS support SFF views that, if required, measures should be taken to mitigate any snagging risk associated with clay berms that may form as a result of anchors associated with the drilling rig.	BPEOC is committed to mitigating any potential clay berms. See Section 5.2.1 and 5.4.
Summary / feedback from Stakeholder Engagement meeting held on 9/3/22: attended by OPRED, JNCC, SFF and MSS. This meeting was held to inform the stakeholders that BPEOC were considering an additional option (surface laid and exposed) for the installation of the c. 7 km gaslift flowline. Previously BPEOC had only considered surface laid and rock covered or trenched and buried options.		
27	• JNCC requested that the volume of rock covered associated with the exposed surface flowline option is included in the ES.	Details of rock cover volumes are included in Section 2.6.4 and
28	• MSS queried the size of the flowline and whether it would be a rigid or flexible flowline.	BPEOC confirmed it will be a 6" flowline, and that it was yet to be determined if it will be a flexible or rigid.
29	• MSS queried location of the flowline relative to the existing flowlines and whether or not existing rock could be used to provide spot rock cover where required.	BPEOC advised that a fisheries interaction assessment would be carried out to determine the optimal location of the flowline. It is not expected that existing rock could be used to provide the spot rock cover requirements on the flowline.
30	• MSS queried if the impact of a release due to damage of the exposed surface laid gaslift flowline would be assessed in the ES.	This has been considered in Section 11.1.3.
31	• SFF raised the need to consider risk of flowline upheaval and buckling, and subsequent occurrence of free spans. In addition, they requested that the fisheries interaction assessment took account of the weight of trawl doors and other fishing gear.	BPEOC advised that a fisheries interaction assessment would be carried out to aid selection of the optimal flowline installation method. It was confirmed that the assessment would take account of the weight of the trawl doors and other fishing gear. The ES assumes that the surface laid option would require a maximum of 10% of the flowline to be covered with rock in order to mitigate upheaval buckling.
32	• MSS requested that any fisheries interaction assessment should consider future fishing efforts in the area, rather than utilising only historic data. Particularly to allow for consideration of possible future changes in fishing activity due to displacement caused by changes in MPA fisheries management.	Fishing interactions are considered in Section 5.2.1. BPEOC agreed that the fisheries interaction assessment will take account of possible future changes in activity.
33	• JNCC queried if decommissioning would be assessed as part of the flowline installation options.	BPEOC confirmed that decommissioning would be considered in the evaluation for option selection.

2. PROJECT DESCRIPTION

2.1 Introduction

BPEOC propose to develop the Murlach Field via a two production well subsea tie-back to the ETAP platform by tying into infrastructure associated with the Seagull and Heron Fields (Figure 2-1). The Murlach Field, formerly known as Skua, was produced by Shell via ETAP from 2001 until shut-in in late 2004. The Murlach Field Development is therefore considered a redevelopment as it will seek to access both potentially partially depleted and new areas of the previously licensed Skua area.

The Murlach field is a relatively high temperature (150˚C) and high pressure (closed in tubing head pressure[1] of *c*. 410 barg) field. A High Pressure High Temperature (HPHT) well is defined as a well that has a bottom hole temperature > 150˚C and one that requires pressure control equipment with a rated working pressure of 689 barg, such that the Murlach field technically is not a HPHT well. The existing topsides infrastructure at ETAP has a design pressure of 614 barg and an overpressure protection system to protect the downstream systems which means it is suitable for receiving the Murlach fluids. Note also that the Skua field had been produced to the same facilities.

The subsea infrastructure for the project includes short tie-ins to existing production and wash water flowlines, and to a controls umbilical being laid for the Seagull project. In addition, a gas lift pipeline will be laid between an existing riser to the ETAP platform and the Murlach Field (Figure 2-1). A new manifold will also be installed. Between the new manifold and each of the production wells, production and gas lift spools and a control umbilical will also be installed.

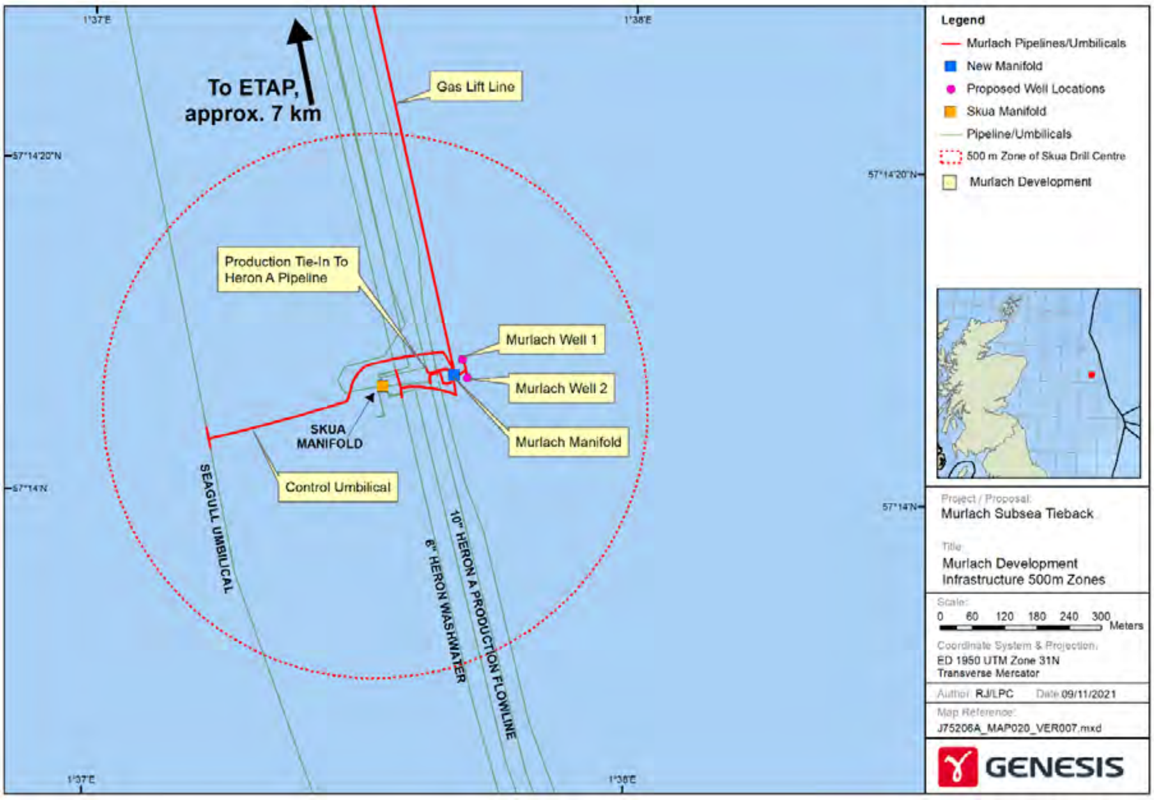


Figure 2-1: Proposed Murlach Field infrastructure in relation to the Skua Drill Centre 500 m zone.

[1] The closed in tubing head pressure is defined as the pressure at the top of an oil or gas well when it is shut in (not flowing).

2.2 Nature of the Reservoir

The Murlach reservoir is part of the Heron cluster of fields (Murlach, Heron and Egret) and lies adjacent to the Marnock Field (See Figure 3-17). It was discovered in 1986 and is a Triassic Skagerrak reservoir made of fluvial sediments. The Field has an anticipated life of around 11 years. The composition of the Murlach reservoir is shown in Figure 2-2:

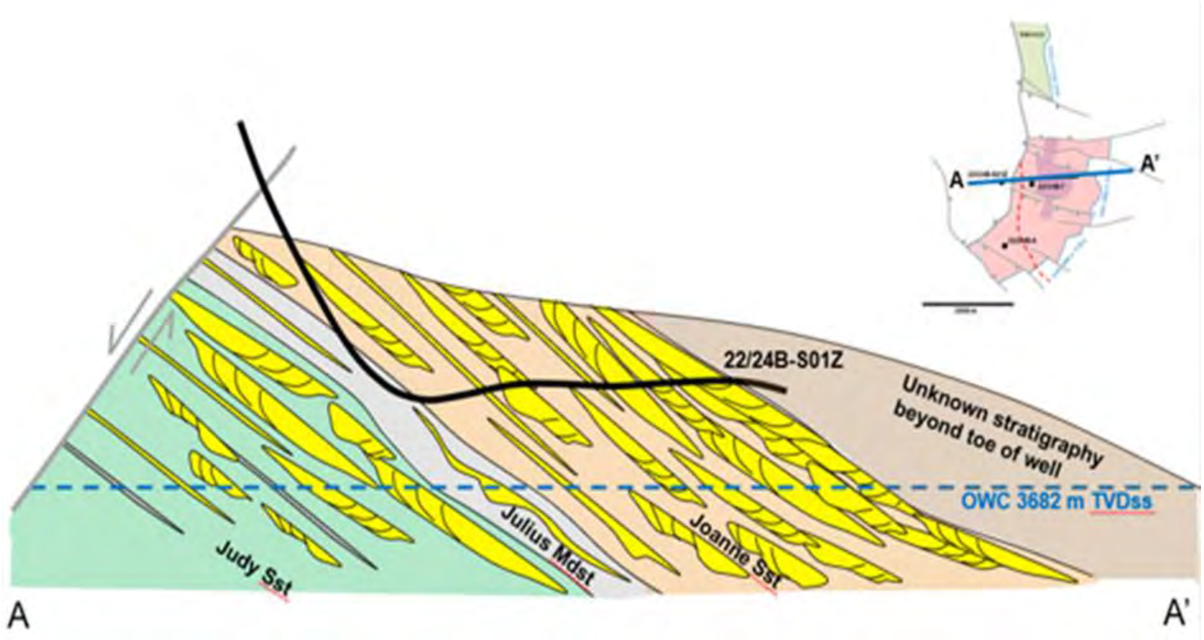


Figure 2-2: Schematic of the composition of the Murlach reservoir.

Characteristics of the Murlach reservoir are summarised in Table 2-1.

Table 2-1: Reservoir Properties.

Property	Value
Reservoir type	Oil
Reservoir depth	3,559 mTVDss*
Reserves of Oil	*c.* 25.9 MMBBL**
Reserves of Gas	*c.* 602 million m^3
Density at standard conditions (kg/m^3)	830 kg/m^3
Wax appearance temperature	29°C
Dissolution temperature	34°C
Maximum pour point	-3°C
*mTVDss – metres True Vertical Depth subsea **MMBBL – Million Barrels of Oil	

2.2.1 Anticipated Recoverable Volumes

The estimated total recoverable volumes of oil from the Murlach Field are anticipated to be *c.* 25.9 MMBBL, approximately 3.4 million tonnes. Total recoverable volumes of gas are anticipated to be *c.* 602 million cubic meters (approximately 0.6 million tonnes).

2.3 Option Selection

2.3.1 Development Option

Consideration was given to different development options with the aim of optimising the value of the Murlach Field and the surrounding infrastructure, through a safe and environmentally responsible development, taking advantage of opportunities and accounting for risks and capital expenditure.

Both standalone (for example a platform and a Floating Production Storage and Offloading (FPSO) vessel) and subsea tie-back options were initially considered for the development of the Field. Due to the volumes of hydrocarbons associated with the Murlach Field, it was determined that a standalone development was not economically practicable. In addition, given the proximity of the Murlach Field to existing infrastructure, and the potential to re-use existing pipelines, a subsea tie-back option was considered to have a smaller environmental footprint overall compared to a standalone development.

Figure 3-19 and Table 3-12 show the location of the Murlach Field in relation to existing oil and gas installations. These include the ETAP, Culzean, Arbroath and Mungo installations located *c.* 7 km, 17.5 km, 21.5 km and 22 km respectively from the proposed development. As shown in Figure 2-1, a tie-back to the ETAP platform would include a minimal addition of subsea infrastructure. Only one pipeline (gas lift) would be required to be installed between the ETAP platform and the Murlach Field, whilst short ties-in ranging in length from 100 m to 500 m would connect the Murlach Field to existing production, wash water and control lines (Figure 2-1). Tie-backs to other installations in the area would require a greater quantity of subsea infrastructure to be installed, including longer pipeline lengths. Therefore, given the close proximity of the ETAP platform and the potential to tie in to existing subsea infrastructure, a tie-back to the ETAP platform was selected[2].

The ETAP platform came on stream in July 1998 and is expected to be producing well into the 2030's. The Murlach umbilical will tie into the Seagull umbilical which will be installed in advance of the Murlach Field Development (it is currently further ahead in its development stage). Hydrocarbons from Murlach will flow to the ETAP platform via the existing Heron pipeline system and wash water will flow to the Murlach field via the existing Heron wash water system.

The Heron production pipeline has been subjected to in-line inspection (ILI, also known as pigging) in 2018 and the results showed that the pipeline is suitable for use to transport the Murlach fluids. BPEOC have therefore concluded that all infrastructure planned to be utilised by the Murlach Development is predicted to last for equal to or greater than the predicted eleven-year Murlach Field life.

2.3.2 Flowline Installation Method

At the time of writing, surface lay and trench and bury options were considered for the installation of the gas lift flowline (see Table 2-2). Assessment of the environmental, safety and practicality considerations for each option has not resulted in any option being ruled out, such that at the time of submitting the ES, all options are still being considered. The ES therefore assesses the worst-case impact for physical presence and permanent habitat change based on a new rock berm, whilst the area of temporary disturbance is assessed based on the trench and bury option given the area over which suspended seabed sediments will settle. A A fisheries interaction assessment, taking account of the weight of the trawl doors and other fishing gear will be carried out to aid selection of the optimal flowline installation method.

[2] Note the ETAP platform has the capacity for the Murlach fluids such that any topside changes would be minimal.

Table 2-2: Murlach flowline installation options.

Option	Environmental	Safety	Practicality
Option 1: Surface laid 6" flexible flowline, left exposed on the seabed.	Results in minimal seabed impact as no trenching activities. In addition, it is estimated that a maximum of 10% of the line would require to be rock covered to mitigate upheaval buckling, such that the volume of rock to be added would be less that the volume associated with Options 2 and 3.	BPEOC have discussed the potential risks of a surface laid flowline with the SFF (see Table 1.3). SFF have confirmed that given the small diameter of the flowline they do not consider any potential snagging even to result in a significant impact on the fishing gear or vessel.	Inspection regime will be determined by risk assessment. It is likely there may be an increase of inspection frequencies when compared to the rock cover or trench and bury options. Given current trends in the UKCS it is expected that at time of decommissioning a Comparative Assessment (CA) will be carried out to determine the fate of the flowline whilst any spot rock would not be recovered.
Option 2: Surface laid 6" flexible or rigid flowline, rock dumped for full length. For this option the flowline follows a new route at least 50 m from other existing rock berms.	Results in a *c.* 7 m wide corridor of rockdump along the full length of the flowline. The rock will be laid on a predominantly sandy mud/muddy sand seabed and could therefore be considered to have the potential to create a new habitat. The environmental baseline survey also identified the presence of gravel and pebbles in the area (Fugro, 2019c). As there are other rock covered pipelines in the vicinity following the same route and gravel and pebbles across the seabed the additional rocky habitat is unlikely to result in colonisation by species not already found in the area. In addition, the survey did not identify any environmentally sensitive habitats or species. Will result in a permanent seabed feature as the rock will not be recovered at the end of field life. Shorter vessel installation campaign and less ongoing pipeline maintenance to rectify free-spans therefore less atmospheric emissions relative to trenching and burying, however, periodic rock berm maintenance may be required. Minimises sediment suspension.	No potential for clay berms to be left on seabed. In line with SFF preferences, the pipeline and associated rock berm will be laid a minimum of 50 m from existing rock berms. Rock berm profile will align with industry standards and SFF preferences such that it will be overtrawlable.	Less ongoing pipeline maintenance for rectifying free-spans, as long as, the rock berm sufficient to restrain the UHB. Easier to expose pipeline for inspection relative to a trenched and buried line if necessary. Given current trends in the UKCS it is expected that at time of decommissioning a Comparative Assessment (CA) will be carried out to determine the fate of the pipeline whilst the rock associated with the rock berm will remain in situ. Should the CA determine that the pipeline should be decommissioned *in situ*, BPEOC will agree an ongoing monitoring plan with the relevant authority (currently this is OPRED).
Option 3: Surface laid 6" flexible or rigid flowline, laid alongside an existing rock berm, and rockdumped for its full length. This option differs to Option 1 as the flowline is laid alongside an existing rock berm which is extended to cover the new line.	Results in extension of existing rockdump corridor. Estimated that existing rock berm will be extended by *c.* 3 m. As for Option 1, rockdump will be introduced into a sandy mud/muddy sand seabed area, however, this will be laid immediately adjacent to pre-existing rock dump. As for Option 1, is not expected to result in colonisation by species not already found in the area.	No potential for clay berms to be left on seabed. No new rock berm introduced, rather existing rock berm will be widened. Rock berm profile will align with industry standards and SFF preferences such that it will be overtrawlable.	As for Option 2.

Option	Environmental	Safety	Practicality
Option 4: Trench and bury 6” rigid pipeline following the same routing as Installation Option 1 and allowing for spot rock dumping on 10% of the line to counter possible upheaval buckling.	This option minimises permanent change to existing habitat. Increased sediment suspension during trenching process. Expected that spoils would impact on *c.* 3 m either side of the trench prior to being backfilled, whilst sediment in the water column is expected to settle out over an area of up to 20 m either side of the trench. However, ecosystem recovery is expected to commence as soon as trenching and burying activities are completed.	For majority of the pipeline there would be a clear seabed following burying activities. Possible that there will be some areas of spot rockdump to mitigate upheaval buckling or where trench depths could not be reached. Potential for clay berms to be created that would require mitigation resulting in additional seabed disturbance. All mitigation would be in coordination with the SFF.	Offshore campaign will include mobilisation of pipelay, trench and bury, and rock dump vessels such that length of installation campaign will be longer than for rockdump options and have potential for simultaneous operations. Given current trends in the UKCS it is expected that at time of decommissioning a CA will be carried out to determine the fate of the pipeline. Should the CA determine that the pipeline should be decommissioned *in situ*, BPEOC will confirm a safe seabed remains and will agree an ongoing monitoring plan with the relevant authority (currently this is OPRED).

2.4 Schedule of Activities

The offshore activities associated with the Murlach Field Development are scheduled to commence in Q1 2024 as shown in Table 2-3.

Phase	2023				2024				2025			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Drilling of Murlach wells					■	■	■	■				
Subsea installation							■	■				
ETAP topside modifications			■	■	■	■	■	■				
Commissioning and Start-up									■			
First Oil										■		

Table 2-3: Indicative schedule of activities for the proposed Murlach Field Development.

2.5 Drilling

At the time of writing, it is expected that a jack-up drilling rig would be the preferred rig choice for Murlach. However, the ES has been written assuming the use of a semi-submersible rig as a base case as this is considered to have greater potential environmental impacts compared to the use of a jack-up rig (see Table 1-3).

2.5.1 Drilling Location

The proposed Murlach well locations are provided in Table 2-4, and shown in Figure 2-1. Each wellhead will be located within 30 m of the new manifold and within the existing Skua drilling centre 500 m safety zone.

Table 2-4: Proposed Murlach well locations.

Well	Co-ordinates (ED 1950 UTM Zone 31N)
Murlach Well 1	57º 14' 08.302" N 01º 37' 41.391" W
Murlach Well 2	57º 14' 07.947" N 01º 37' 41.464" W

2.5.2 Positioning and Anchoring of the MODU

Anchor Handling Vessels (AHVs) will be required to help position the drilling rig which will be held on site using between 8 and 12 anchors each with an anchor line length of *c.* 1,500 m.[3] The precise anchor mooring spread for the semi-submersible rig will be defined by mooring analysis which will be undertaken prior to bringing the drilling rig onto location and will take into account the water depth, currents, tides, prevailing wind conditions and any seabed features at the drilling locations.

Details of the placement of the anchors will be provided in the Consent to Locate (CtL) permit application which will be submitted under the Drilling Operations Master Application Template (MAT) before the drilling rig is on location at the Field.

[3] Note: The ES will assess the impacts associated with 12 anchors.

2.5.3 Blowout Preventer and Well Control Equipment

The drilling rig will be equipped with a Blowout Preventer (BOP) which is rated for pressures beyond the maximum pressure anticipated for the wells being drilled.

The function of the BOP will be to prevent uncontrolled flow from the well to the surface during drilling by positively closing in the well in the event of an uncontrolled release from the reservoir into the well bore. The BOP is made up of a series of hydraulically operated rams that can be closed in an emergency from the drill floor, or from a safe location elsewhere on the rig. In the event that a semi-submersible drilling rig is selected the subsurface BOP could also be operated subsea from a Remotely Operated Vehicle (ROV).

The integrity of the BOP will be tested prior to usage and periodically during the drilling. Inspection and testing of the BOP will be undertaken in line with the duty holder, BPEOC procedures and UK legislation.

2.5.4 Well Design

The Murlach wells will be drilled and completed in accordance with BPEOC's Common Wells Process. The basic well design is summarised in Table 2-5 and Table 2-6. It is also illustrated in Figure 2-3. Detailed well design specifics are still under analysis but will be provided in future drilling permit applications.

Table 2-5: Murlach 'Central' well details.

Hole Section	Total vertical depth below seabed (m)	Total length along hole (measured depth) (m)
26" x 36" x 42"	240	240
26"	850	850
16"	2,825	2,840
12.25"	3,525	3,636
8.5"	3,650	4,866

Table 2-6: Murlach 'South' well details.

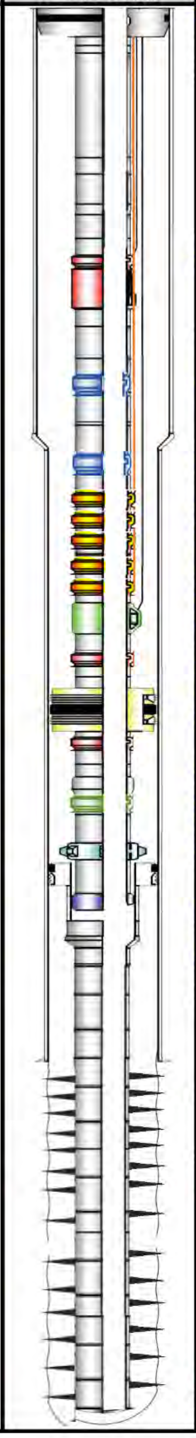
Hole Section	Total vertical depth below seabed (m)	Total length along hole (measured depth) (m)
26" x 36" x 42"	240	240
26"	850	850
16"	2,825	2,837
12.25"	3,525	3,618
8.5"	3,677	5,157

Completion Schematic: FIELD: Murlach PLATFORM: TBD WELL: South SLOT: TBD

WELL DATA

WELL TYPE :	Gas Producer	RTE :	32m	MAXIMUM DOG LEG :	
COMPLETED :	Optimise Stage	SWAB :		MAXIMUM DEVIATION :	
WORKOVER DATE :	N/A	KOP :		MINIMUM I.D. :	
WORKOVER # :	N/A	HUD :		AV. ANG. THRU. PAY :	
ANNULUS FLUID :	1.02SG Inhibited Brine	TBG HANGER :	-	UNITS :	Depths (m)
FLUID WEIGHT :	1.02 SG	REF. LOG :			Dimensions (in)

WELL SCHEMATIC



MD (m)	DESCRIPTION	MAKER	MIN ID	MAX OD	DRIFT	LENGTH	MATERIAL	OTHER INFO
95.0	5 -1/2in Tubing Hanger		4.791	-	4.767	1.38	718-20ksi	
96.4	5.1/2" 26.8ppf Pup Joint 7m		4.438	5.978	4.375	6.790	SM2535	Vam Top HT
103.2	5.1/2" 26.8ppf Pup Joint 1m		4.438	5.978	4.375	0.899	SM2535	Vam Top HT
104.1	5.1/2" 26.8ppf tubing		4.438	5.978	4.375	635.00	SM2535	Vam Top HC
739.1	5.1/2" 26.8ppf pup joint		4.438	6.071	4.375	3.000	SM2535	Vam Top HC
742.1	5.1/2" TR-SCSSSV c/w 4.437in Nipple		4.437	7.986	4.437	7.000	A955	Vam Top HC
749.1	5.1/2" 26.8ppf pup joint		4.438	6.071	4.375	2.000	SM2535	Vam Top HC
751.1	5.1/2" 26.8ppf tubing		4.438	6.071	4.375	400.000	SM2535	Vam Top HC
1151.1	Gas Lift Mandrel			8.110	4.375	2.00	SM2535	Vam Top HC
1300.0	10-3/4" x 9.5/8" SHOE							
1153.1	5.1/2" 26.8ppf tubing		4.438	6.071	4.375	2000.0	SM2535	Vam Top HC
3153.1	Gas Lift Mandrel			8.110	4.375	2.00	SM2535	Vam Top HC
3155.1	5.1/2" 26.8ppf tubing		4.438	6.071	4.375	100.0	SM2535	Vam Top HC
3255.1	Chemical Injection Mandrel			8.150	4.375	2.00	SM2535	Vam Top HC
3257.1	5.1/2" 26.8ppf tubing		4.438	6.071	4.375	16.7	SM2535	Vam Top HC
3273.8	Chemical Injection Mandrel			8.150	4.375	2.00	SM2535	Vam Top HC
3275.8	5.1/2" 26.8ppf tubing		4.438	6.071	4.375	16.7	SM2535	Vam Top HC
3292.5	Chemical Injection Mandrel			8.150	4.375	2.00	SM2535	Vam Top HC
3294.5	5.1/2" 26.8ppf tubing		4.438	6.071	4.375	16.7	SM2535	Vam Top HC
3311.2	Chemical Injection Mandrel			8.150	4.375	2.00	SM2535	Vam Top HC
3313.2	5.1/2" 26.8ppf tubing		4.438	6.071	4.375	16.7	SM2535	Vam Top HC
3329.9	Chemical Injection Mandrel			8.150	4.375	2.00	SM2535	Vam Top HC
3331.9	5.1/2" 26.8ppf tubing		4.438	6.071	4.375	5.00	SM2535	Vam Top HC
3336.9	5.1/2" Gauge Mandrel		4.438	6.650	4.375	2.00	A955	Port Depth
3338.9	5.1/2" 26.8ppf pup		4.438	6.071	4.375	5.00	SM2535	Vam Top HC
3343.9	4.312" Nipple Profile		4.438	6.071		11.41	SM2535	Vam Top HC
3355.3	5.1/2" 26.8ppf pup		4.438	6.071	4.375	3.00	SM2535	Vam Top HC
3358.3	9.5/8" x 5.1/2" Production Packer		4.695	8.310	4.375	4.45	A955	Mid-Element Depth mMD
3362.7	5.1/2" 26.8ppf pup		4.438	6.071	4.375	2.00	SM2535	Vam Top HC
3364.7	4.125" Nipple Profile		4.438	6.071		23.40	SM2535	Vam Top HC
3388.1	5.1/2" 26.8ppf pup		4.438	6.071	4.375	3.00	SM2535	Vam Top HC
3391.1	Contraction Joint		8.110	4.450	4.375	1.35	SM2535	Vam Top HC
3392.5	5-1/2" x 5-1/2" crossover		4.438	6.071	4.652	1.00	SM2535	VTHC x Vam FJL
3393.5	5.1/2" 26.8ppf pup		4.438	5.500	4.375	2.00	SM2535	Vam FJL
3395.5	Fluted No-Go		8.110	4.450		1.35	SM2535	
3396.8	5.1/2" 26.8ppf tubing		4.709	5.500	4.375	23.40	SM2535	2jts Vam FJL
3400.8	9 5/8 x 7" Liner Hanger		6.000	8.310	6.056	8.70	A718-120ksi	
3409.5	7" 29ppf tubing		5.500	8.120	4.375	35.10	25%Cr -125ksi	Vam Top HT
3420.8	BOTTOM of WEG					0.60		
3444.6	7" 29ppf tubing pup		4.816	7.648	4.375	3.00	25%Cr -125ksi	Vam Top HT
3447.6	7" x 5-1/2" Crossover		4.438	7.644	4.375	0.80	25%Cr -125ksi	VTHT X VTHC
3448.4	5.1/2" 26.8ppf pup		4.438	6.071	4.375	2.00	25%Cr -125ksi	Vam Top HC
3593.3	9 7/8" SHOE							
3450.4	5.1/2" 26ppf tubing/liner		4.438	6.071	4.375	1677.00	25%Cr -125ksi	Vam Top HT
3713.3	Top Perforation (top of Skagerrak)							
4106.4								
5082.4	Bottom Perforation							
5127.4	BOTTOM of Liner							
5132.4	8 1/2in Hole - Well TD							
	Perforation Interval	1369.2	m					

Prepared by Ilkin Guliyev

Figure 2-3: Example schematic of the production well.

2.5.5 Drilling Mud and Cuttings

Drilling fluids are required for a number of reasons including:

- Managing hydrostatic pressure and primary well control;
- Transportation of drill cuttings to the surface;
- Preservation of the wellbore to facilitate casing / completion installation; and
- Cooling and lubrication of the drill bit.

Drilling fluid is continuously pumped down the drill string to the drill bit and returns to the surface through the annular space between the drill string and the sides of the well. Different mud formulations are required at different stages in the drilling operation because of variations in pressure, temperature and the physical characteristics of the rock being drilled.

Table 2-7 summarises the anticipated mud volumes and mass of cuttings associated with each well section. The fate of the drill cuttings from each section is also shown. Full details of the mud volumes to be used will be provided in subsequent drilling Subsidiary Application Template (SAT) permit applications.

Table 2-7: Anticipated mud requirements and cuttings mass associated with each well.

Hole Size (")	Drilling fluid	Volume of mud (m^3)	Volume of cuttings (m^3)	Cuttings disposal route
42"	Seawater and bentonite sweeps	39,300	400	Discharged at the seabed
26” x 36” x 42”		52,400	700	
16"	High Temp OBM	2,900	900	Collected on the rig and shipped to shore
12.25"	High Temp OBM	2,400	200	
8.5"	High Temp OBM	3,800	200	

2.5.6 Cementing Chemicals

Cement is used to secure the steel conductor and casings in the well bore, whilst cementing chemicals are used to modify the technical properties of the cement slurry. During cementing operations the majority of these chemicals are left downhole but a small quantity of cement may be discharged onto the seabed around the top of the 30" conductor and 20” casing while filling the annulus between them and the host rock formation with cement. This excess over the annulus volume is required to give confidence that the cement has completely filled the conductor annulus and displaced all the mud present to provide a strong bond, on which the entire well is secured. It is estimated that approximately 20 te of cement could be discharged on the seabed immediately adjacent to each well location. Subsequent use of cement is contained downhole as further casings do not require the cement to be pumped into the annulus all the way up to the surface.

Discharges of other cementing chemicals such as cement mix water and spacers may occur when cleaning out the cement mixing and pumping equipment. Cement mix water is the term used to describe the fluids used to mix the cement, whilst spacers are the fluids used to aid the removal of drilling fluids before cementing.

At the time of writing the detailed cement design has yet to be finalised, however, estimates of the type and volume of cement are provided in Table 2-8.

Table 2-8: Estimated cement requirements per well.

Cement job	Volumes	Cement type
42" x 30" conductor	300 bbls spacer + 3,300 bbls cement	Class G
26" x 20" surface casing	300 bbls spacer + 6,000 bbls cement	Class G + Silica
13 3/8" intermediate casing	300 bbls spacer + 4,000 bbls cement	Class G + Silica
10 3/4" x 9 5/8" production casing	300 bbls spacer + 1,500 bbls cement	Class G + Silica
7" x 5 1/2" Liner	300 bbls spacer + 900 bbls cement	Class G + Silica
Kick-off plugs	500 bbls spacer + 1,000 bbls cement	Class G + Silica
Abandonment plugs	500 bbls spacer + 1,000 bbls cement	Class G + Silica

All cementing chemicals to be used will be selected based on their technical specifications and environmental performance. Class G cements have no additions other than calcium sulphate and/or water and are intended for use as a basic well cement. Chemicals with substitution warnings (i.e. chemicals that are considered to be harmful to the environment) will be avoided where technically possible. The cementing chemicals to be used have not yet been determined but will be detailed in subsequent drilling SAT permit applications.

Similar to the drilling and cementing chemicals, the chemicals associated with the completions operations will be captured in the subsequent drilling SAT permit applications.

2.5.7 Relief Well Location

A plan will be put in place for the drilling of a relief well to intersect the Murlach wells in the event of a well blowout and will include a proposed drilling rig location from which a relief well could be drilled.

2.5.8 Drill Rig Support Activity

Various support vessels will be associated with the drilling operations such as Anchor Handling Vessels (AHVs), supply vessels etc. Table 2-9 summarises the estimated duration that each vessel will be on site and their estimated fuel use. Estimates provided are based on an indicative maximum drilling duration of 150 days per well. Due to the proximity of the wells, if a semi-submersible rig is utilised the rig will be skidded between the wells without having to relocate its anchors so as to minimise seabed disturbance.

Table 2-9: Fuel consumption of vessels associated with the drilling of the Murlach wells.

Vessel type	Days on site[1]	Fuel consumption (te/d)[2]	Total fuel use (te)
Drilling rig	300 (assumes 150 days per well)	10	3,000
AHV (in transit) x 3 [3]	12 (assumes four days for rig mobilisation (therefore 3 x 4)	25	300
AHV (rig positioning) x 3 [3]	12 (assumes four days for rig positioning (therefore 3 x 4)	25	300
Emergency Response and Rescue Vessel (ERRV)	300	1.5	450
Supply vessel (in transit)	150	10	1,500
Supply vessel (working)	150	1.5	225
Helicopter (te/hr)	Twice a week (86 trips – 3 hours each) = 258 hours or *c.* 11 days	12 te per day (0.5 per hour)	132
Total fuel use			**5,907**

[1] Drilling schedule still being developed, duration presented is the maximum anticipated.
[2] Source: The Institute of Petroleum, 2000.
[3] Assumes the semi-sub rig will be skidded between wells rather than changing anchor positions to be relocated.
Note if jack-up is used, anticipated AHV vessel days could be less.

2.6 Subsea Infrastructure

Table 2-10 and Figure 2-4 summarise the infrastructure to be installed as part of the proposed Development

Table 2-10: Subsea infrastructure associated with the Murlach Field Development.

Item No.	Description
1	A *c.* 7 km 6" gas lift flowline from the ETAP platform to the new Murlach manifold.
2*	A new manifold (20 m Length (L) x 10 m Width (W) x 5 m Height (H))**.
3*	A Xmas tree at each well.
4*	A *c.* 100 m tie-in production flowline from the Murlach manifold to the existing 10" Pipe in Pipe (PiP) Heron Production A flowline.
5*	A *c.* 300 m tie-in wash water flowline from the existing subsea 6" Heron wash water flowline system to the Murlach manifold.
6*	A *c.* 500 m umbilical connecting the existing Seagull umbilical to the Murlach manifold.
8*	Tie-ins between the new Murlach manifold and each of the two Murlach wells for: • A *c.* 40 m production spool from each well to the manifold; • A *c.* 40 m gas lift spool from the manifold to each well; • A *c.* 40 m wash water spool from the manifold to each well; and • A *c.* 50 m control umbilical from the manifold to each well.

*Each of these structures/spools/umbilical jumpers will be located within the existing Skua Drill Centre 500 m zone at the Murlach Field.
**The new manifold will either be piled or gravity based; this ES assesses the worst-case environmental impacts associated with piling.

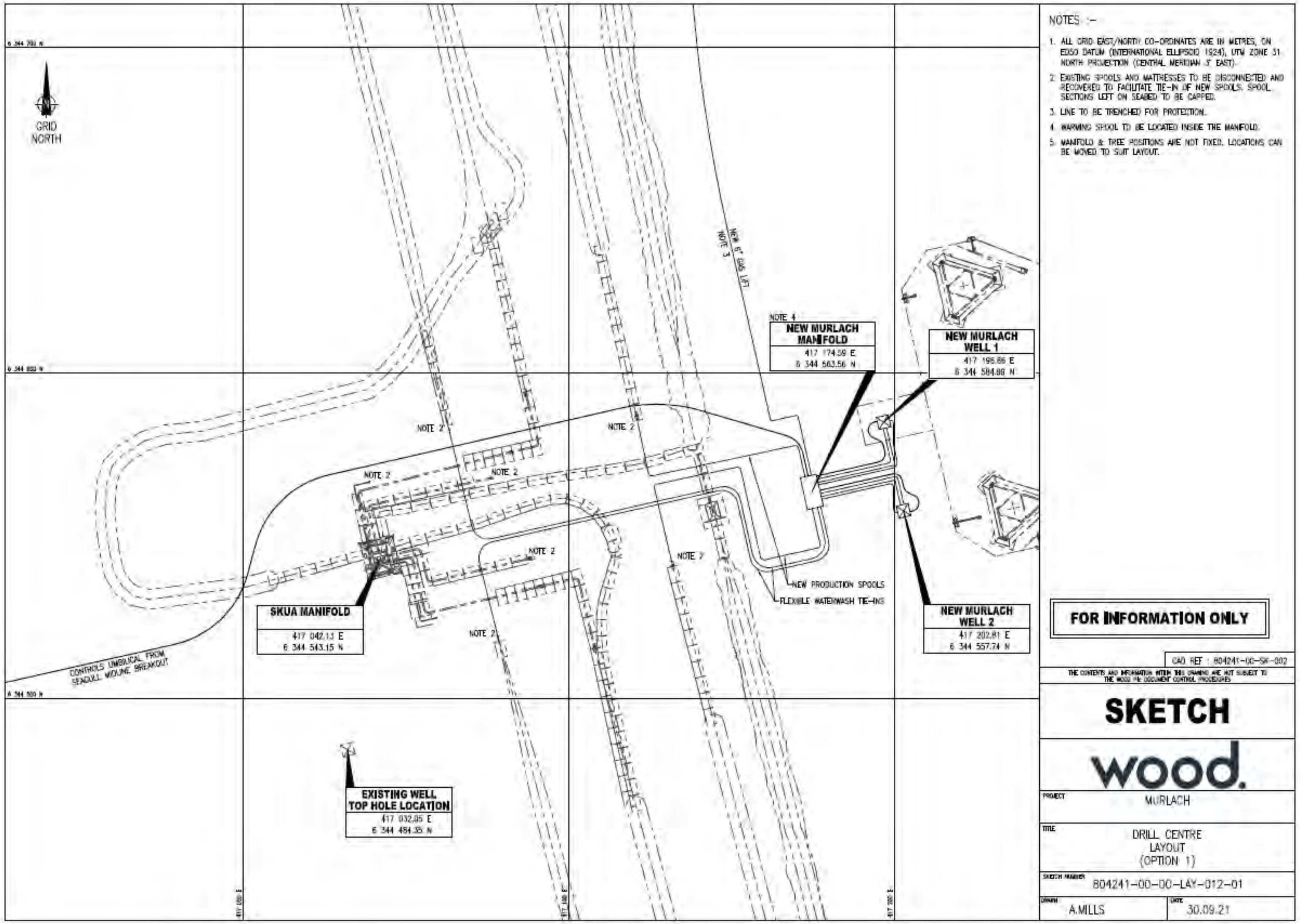


Figure 2-4: Infrastructure involved within the proposed Murlach development area.

2.6.1 Wellheads and Xmas Trees

The Xmas trees will have an arrangement of hydraulically operated valves, with manual back-up valves, to provide integrity barriers from the reservoir. The wells will also feature a Downhole Safety Valve (DHSV) which is a hydraulically operated isolation device. It will be possible to fully close the master valves and the Surface Controlled Subsurface Safety Valves (SCSSVs) within thirty minutes from start of initiation of Emergency Shutdown (ESD).

Calcite scale across the sand face and into the tubing is expected with Murlach fluids as well as asphaltene deposition under the proposed production conditions. To manage these threats scale inhibitor and asphaltene inhibitor will be injected downhole at the production wells which will require the provision of injection metering and a control valve. Two to three scale squeeze jobs may be performed over the course of the well life as the scale inhibitor injection point is above the sandface.

Methanol will be injected at the production trees on an intermittent basis primarily for the inhibition of hydrates during transient operations. Methanol use will be metered at the ETAP platform.

Meters for wash water volumes and lift gas will be located on the ETAP platform and the production wells respectively.

At the time of writing BPEOC is undergoing a detailed sand management study in order to assess the volumes of produced sand likely to occur and any strategy required to reduce the likelihood of sand production. Depending on the expected sand production, strategies may include continual sand monitoring, management of sanding by controlling drawdown and evaluating equipment to be used to clean-up the sand. The aim will be to minimise sand production from the Murlach wells, however, if this does occur it will be managed using mobile sand cleaning technology as has been undertaken in the past on the ETAP platform. Any discharges of cleaned sand to sea will be the subject of a Production Operation SAT permit application.

The wash water is used to dilute the salinity of the Murlach PW. This prevents scale (halite) forming, allows corrosion inhibitor to work better, and brings the salt content of the export oil down to FPS specifications. It comprises seawater treated with oxygen scavenger, a sulphate reducing package and biocide. Wash water is returned to the ETAP platform along with the production fluids where it is separated out along with PW and injected.

2.6.2 Manifold Installation

The original Skua manifold was installed approximately 20 years ago. The proposed project requires additional metering/monitoring, chemical injection and controls that cannot be supplied via the existing manifold. Therefore, given potential operational issues associated with its age and as it would not meet all the functional requirements for the Murlach Field, a new manifold will be installed.

The ES assumes that the base case for the Murlach manifold is that it will be a piled structure and will be installed within the existing Skua Drilling Centre 500 m safety zone. The exact details of the piling (e.g. size of piles, hammer energy, rate of blows etc.) is not known at the time of writing, such that a worst-case scenario has been assumed for the purposes of this ES. It is assumed that four 24" (diameter) x 30 m (length) piles will be used to provide a foundation for the manifold. It is expected the piling will take a maximum of two days to complete, with each pile taking approximately 503 minutes using a hammer maximum blow energy of 150 kJ.

2.6.3 Pipelines, Spools and Jumpers

As described in Section 2.3, surface laid production and wash water spools and umbilical jumpers will connect the Murlach manifold to existing infrastructure (associated with the Heron field: see Figure 2-1), the gas lift pipeline will connect directly to the ETAP platform and the controls and chemicals will be provided via the shared Seagull umbilical. Where possible the spools and flowline will follow the most direct route between locations.

Where required, and as summarised in Table 2-10 surface laid spools will be installed to connect the new wells and existing infrastructure to the new Murlach infrastructure.

Once the pipelines and umbilical have been installed, post lay surveys will be undertaken to determine the presence of any excessive free-spans (areas where the pipeline bridges depressions or hollows in the seabed) that may need to be mitigated.

The *c.* 7 km gas lift flowline from the ETAP platform the new Murlach manifold will cross a number of pipelines, as summarised in Table 2-11. For each crossing a maximum of 2 mattresses will be used, which are factored into the total mattress quantity in Section 2.6.3. As can be seen all of the crossings occur within existing 500 m zones.

Table 2-11: Pipelines which will crossed by the gas lift pipeline from ETAP to the Murlach Field.

Pipeline No.	In/out 500 m zone	Diameter	From	To	Physical Status	Status	Owner
PL1532	Inside	10"	East Heron	ETAP	Carbon steel pipeline (no mention of mattressing)	Suspended	BPEOC (formerly Shell)
PL1533	Inside	10"	West Heron	ETAP	Carbon steel pipeline (no mention of mattressing)	Suspended	BPEOC (formerly Shell)
PL1466	Inside	6"	ETAP	Heron	Concrete mattress	Suspended	BPEOC (formerly Shell)
PL1947	Inside	10"	Madoes	ETAP	Concrete mattress	Operational flexible oil jumper	BPEOC
PL1948	Inside	4"	ETAP	Madoes	Concrete mattress	Operational flexible gas jumper	BPEOC
PLU1949	Inside	5"	ETAP	Madoes	Concrete Mattress	Operational control jumper	BPEOC

2.6.4 Subsea Infrastructure Protection

In order to determine the worst-case subsea infrastructure protection required, Installation Option 2 was assessed (see Table 2-2). For this option, the *c.* 7 km gas lift pipeline will be surface laid away from any other existing lines and protected with rockdump along its full length. As a worst case this ES assesses the impact of 150,000 te of rock being laid. Installations Options 1, 3 and 4 would require less rockdump.

Mattresses and 25 kg grout bags will be used to protect the tie-in spools. In addition, they will be used at crossings over existing infrastructure (as detailed in Table 2-11) at the ETAP platform and Murlach drill centre over which the Murlach infrastructure will be laid. The estimated maximum quantities of protective features are shown in Table 2-12.

Table 2-12: Anticipated quantities of protection features.

Item	Quantity
Rock cover (Option 2)*	150,000 te
Mattresses 6 m (L) x 3 m (W) x 0.15 m (H)	280 (total number)
25 kg Grout bags	75 te (3,000 bags)
*For Options 1 and 4 a maximum of 15,000 te of rock would be used (i.e. 10% of volume associated with rock cover of the full length).	

Prior to laying any rock cover, mattresses or grout bags, BPEOC will submit a Deposit Consent application to the North Sea Transition Authority (NSTA) (formerly the Oil and Gas Authority (OGA)) and the supporting environmental permit applications to OPRED.

All mattresses and grout bags will be laid within the existing 500 m safety zones of the ETAP platform and the Skua Drilling Centre.

2.6.5 Pipeline Testing and Commissioning

Following installation, flooding and pressure-testing operations will be performed to verify system integrity, to test for any leaks, to dewater the production and gas lift pipelines and to prepare the system for the introduction of hydrocarbons. The testing and commissioning operations will be performed on all infrastructure that the Murlach development ties into. This will include the gas lift pipeline, any tie-ins to the wash-water system and the entire length of the Heron A pipeline up to the Wye at Egret. All testing and commissioning operations will be performed using a combination of equipment on the ETAP platform or by vessel at the Murlach Field.

After completion of the flooding operations, a hydrostatic pressure test (strength test) will be performed to verify integrity of the welded joints within the 'as-installed' pipelines. Subsequently, once the complete pipeline system has been connected, a further hydrostatic pressure test (leak test) will be carried out to prove the integrity of the tie-in connection points. The pipelines will be pressurised in accordance with design codes to pressures above the maximum operating pressure. On completion of the testing programme the pressurisation fluid is expected to be discharged to the sea or flowed back to the ETAP platform and injected into the reservoir.

The permitted discharge of chemicals to the marine environment is a routine part of subsea installation operations. The quantities of chemicals to be used and whether or not they are to be discharged to sea will be determined during the project detailed design stage and will be subject to a Chemical Permit application under the OCR. A risk assessment will be carried out as per the OCR for the relevant chemicals, profiles and associated application. Based on current methodologies, there are no chemicals planned for use/discharge during pipeline testing and commissioning that significantly differ from those currently on associated ETAP permits, that would imply a specific chemical risk assessment is required to be carried out as part of this ES.

2.6.6 Subsea Installation Support Vessels

Various support vessels will be associated with the subsea installation activities. Typical vessel use, duration and fuel usage by vessels during installation are provided in Table 2-13.

Table 2-13: Vessel type and anticipated fuel usage during the installation of subsea infrastrucutre at Murlach.

Vessel type	Days on site	Fuel consumption (te/d)[1]	Total fuel use (te)
Survey vessel (mob/demob/transit)	6	10	60
Survey vessel (working)	5	10	50
Dive Support Vessels (DSVs)(mob/demob/transit)	18	18	324
DSVs (working)	28	18	504
Rockdump vessel (mob/demob/transit)	8	18	144
Rockdump vessel (working)	4	18	72
Total fuel use			**1,154**

[1] Source: The Institute of Petroleum (2000).

2.7 ETAP Overview and Modifications

The proposed concept for the Murlach Field Development means that the gas and liquids can be processed within the existing capacity of the ETAP platform without major modifications to processing facilities.

Details of the ETAP platform, including storage capacity, are provided in Table 2-14.

Table 2-14: Details of the ETAP platform.

Description	Value
Length	40 m
Breadth	24 m
Depth	112 m
Accommodation (max)	157

Existing facilities on the ETAP platform include: oil separation and processing, gas compression and dehydration, water processing and injection. The Murlach design premise is to utilise spare capacity within the ETAP system where practical. Some modifications will be required at the ETAP topsides (existing Heron system) to accommodate the Murlach fluids. These include but are not limited to modifications to the topsides arrival facilities and separation for overpressure and temperature protection together with metering/ instrumentation requirements. As the reception and separation facilities being re-used for Murlach has been out of service, a fit for service assessment will determine the requirements to replace or refurbish existing equipment and instrumentation. Post separation, gas, oil and PW from Murlach will commingle with the existing ETAP fluids. Gas and oil are exported to CATS and FPS respectively with some of the gas production used for gas lift, fuel and flare. All PW is re-injected via the existing ETAP PW re-injection system.

To support Murlach reservoir management, new gas lift pipework will connect the existing ETAP compression to the new gas lift pipeline via an existing riser (referred to as the R16 rise)r and will include means to manage overpressure and blowdown through the existing ETAP flare. Murlach will require topsides and subsea chemicals. Supply for subsea chemicals will largely utilise the existing ETAP infrastructure's spare capacity. New chemical pumps are required for injecting scale and demulsifier into the Murlach separator.

It may be necessary to mobilise a flotel to provide temporary accommodation for personnel carrying out the modifications to the ETAP topsides. If a flotel is required, it is expected to be on site for a maximum of six months and will maintain its position using dynamic positioning (DP). Table 2-15 summarises the anticipated fuel use associated with having the flotel on location for six months.

Table 2-15: Total fuel use associated with the flotel.

Vessel type	Days on site	Fuel consumption (te/d)	Total fuel use (te)
Flotel	183	30	5,490

PW systems are designed to treat the PW to minimise oil and sand content to within permitted limits for re-injection into the reservoir (produced water reinjection (PWRI)). The ETAP platform operates 100% reinjection such that there will be no PW discharges to sea. Increased inputs of PW from Murlach will not result in exceedance of the existing ETAP platform PWRI system capacity. In addition, there are no compatibility issues with the PW that could impact PWRI.

2.8 Production

Chemicals are used during the production of hydrocarbons to maintain process efficiency, for example: demulsifiers improve the separation of oil and water; scale inhibitors slow down the build-up of scale in pipework and valves and biocides reduce microbial growth.

Chemical usage and discharge will be captured in an update to the ETAP platform production Chemical Permit prior to production commencing. It is anticipated that chemical types and brands required for the production of hydrocarbons from the Murlach Field will be the same as those being used at ETAP at the time of First Oil, although quantities used are likely to increase. Those chemicals which partition to the oil phase will be exported along with the oil, whereas aqueous phase chemicals will partition into the PW. As the ETAP platform operates 100% reinjection there will be no PW discharges to sea as a consequence of the Murlach Field Development, and there will be no discharge of chemicals to sea.

Production profiles have been developed for the purpose of the Murlach Field Development Project. These forecast the likely volumes of oil, gas and PW that will be produced. Anticipated high (‘Upside’) case volumes of oil, gas and resultant PW profiles are presented here as the environmental impacts associated with the production of these volumes are likely to be greatest with respect to, for example, atmospheric emissions. Base case production profiles are presented in Appendix E.

2.8.1 Upside Case Oil Production Profiles

Table 2-16 and Figure 2-5 show the anticipated Upside case oil production rates from the Murlach Field, assuming start-up in 2025. Maximised annual oil production for the field is anticipated in 2026 at a rate of *c*. 1,856 te/day.

Table 2-16: Murlach Upside case and ETAP oil production rates.

Year	Oil Production Rate (te/day)		
	ETAP without Murlach	Murlach	ETAP with Murlach
2025	3,895	1,117	5,012
2026	3,496	1,856	5,352
2027	2,818	1,304	4,122
2028	2,230	1,030	3,260
2029	1,543	800	2,343
2030	1,251	724	1,975
2031	1,009	621	1,630
2032	839	549	1,388
2033	673	495	1,168
2034	562	451	1,013
2035	477	413	890

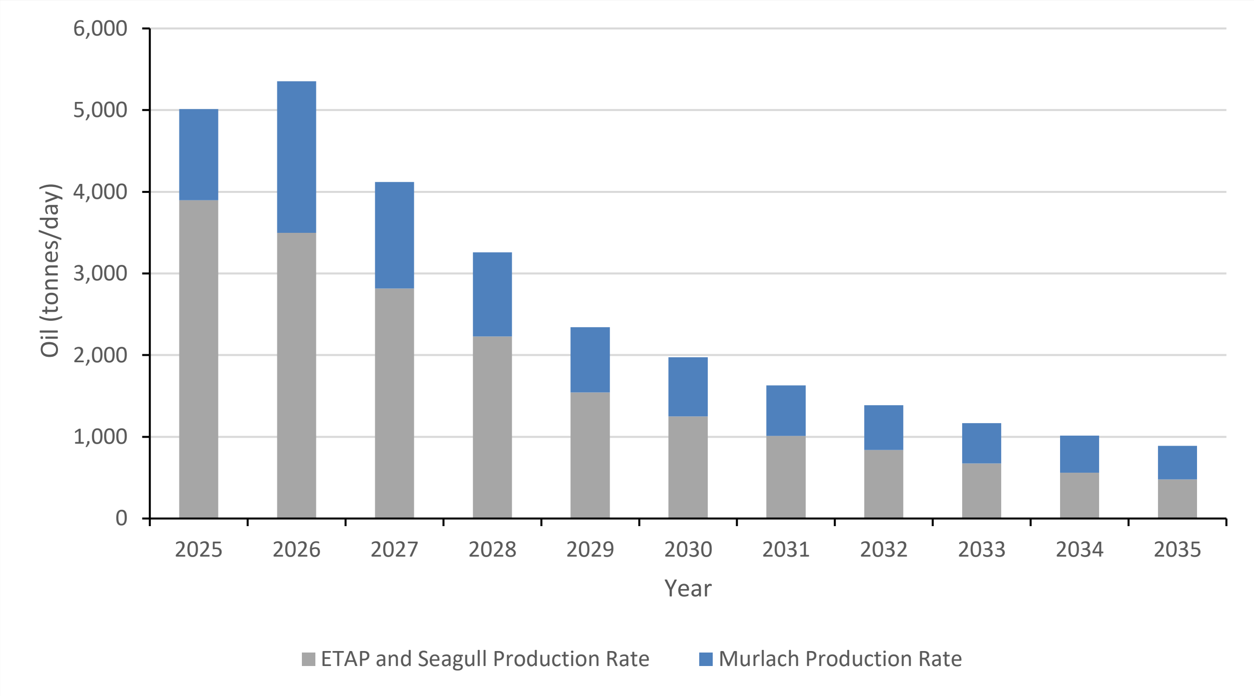


Figure 2-5: ETAP upside oil production rate alone and with Murlach upside production rate.

2.8.2 Upside Case Gas Production Profiles

Table 2-17 and Figure 2-6 show the anticipated upside case gas production rates from the Murlach Field, assuming start-up in 2025. Maximised annual gas production for the field is anticipated in 2025 at a rate of *c*. 0.34 million cubic meters per day (Mm^3/day).

Table 2-17: Murlach Upside Case and ETAP gas production rate.

Year	Gas Production Rate (Mm^3/day)		
	ETAP without Murlach	Murlach	ETAP with Murlach
2025	2.69	0.20	2.89
2026	2.56	0.34	2.89
2027	2.25	0.23	2.48
2028	1.86	0.18	2.04
2029	1.53	0.14	1.67
2030	1.57	0.13	1.69
2031	1.53	0.11	1.64
2032	1.51	0.10	1.60
2033	1.52	0.09	1.61
2034	1.39	0.08	1.47
2035	1.28	0.07	1.35

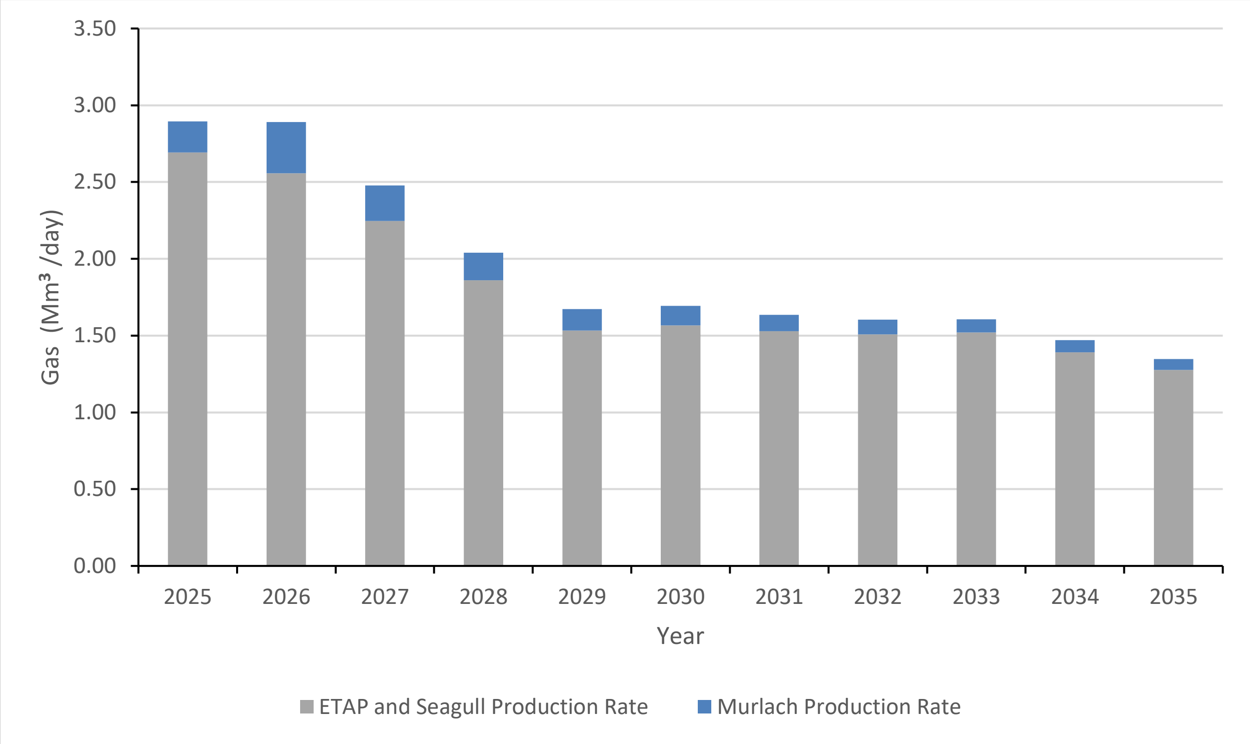


Figure 2-6: Murlach Upside Case and ETAP gas production rate.

2.8.3 Water Production Profiles Associated with Upside Hydrocarbon Profiles

Table 2-18 and Figure 2-7 show the anticipated water production rates associated with the Upside oil and gas profiles from the Murlach Field, assuming start-up in 2025. Peak water production at the Murlach Field is anticipated in 2035, at a rate of *c.* 232 te/day.

Table 2-18: Water Production Profiles Associated with the Upside Production Profiles.

Year	Water Production Rate (te/day)		
	ETAP without Murlach	Murlach	ETAP with Murlach
2025	5,275	20	5,295
2026	4,920	68	4,988
2027	4,848	100	4,948
2028	4,780	131	4,911
2029	4,625	146	4,771
2030	4,587	180	4,768
2031	1,629	196	1,824
2032	1,528	208	1,736
2033	1,452	218	1,670
2034	1,426	225	1,651
2035	1,532	232	1,764
Based on a density of 1.1 kg/m^3			

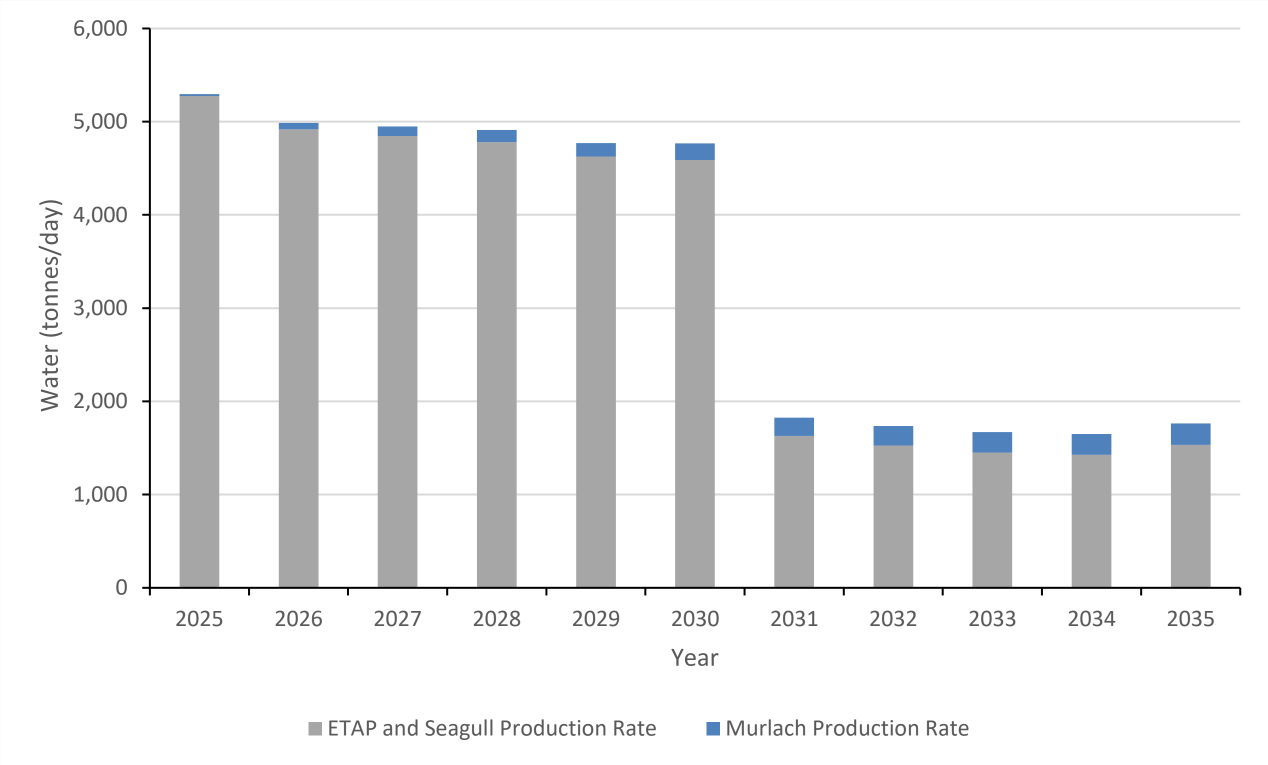


Figure 2-7: Water Production Profiles Associated with the Upside Oil and Gas Profiles.

2.8.4 Key Permits and Consents

The Portal Environmental Tracking System ('PETS') is OPREDs environmental permitting system accessed via the UK Energy Portal. PETS integrates permits and consents under one centralised MAT. There are six types of MAT available on the PETs system:

- Drilling Operations;
- Pipeline Operations;
- Production Operations;
- Decommissioning Operations;
- Well Intervention Operations; and
- A Standalone application.

Once a MAT has been created it can support various types of permit applications (referred to as SATs).

Note that Oil Pollution Emergency Plans (OPEPs) and UK ETS Permits are not available on the PETS system.

2.8.5 Pollution Prevention and Control (PPC) Permit

It should be noted that the Murlach Development will require a slight increase in power demand on the ETAP platform. The existing PPC Permit will therefore be reviewed and any changes to fuel use as a result of the Murlach tie-back will be captured in a Variation.

2.8.6 UK Emissions Trading Scheme (UK ETS)

No new Greenhouse Gas (GHG) Permit under the UK ETS Trading Scheme will be required; however, the description of the installation in the existing ETAP permit application will be updated to reflect Murlach coming online.

2.8.7 Oil Pollution, Prevention and Control (OPPC)

Discharges of oil to sea are controlled under The Petroleum Activities (Oil Pollution, Prevention and Control) Regulations 2005. The existing ETAP Oil Discharge Life Permit will be updated to capture Murlach coming online. In addition, Oil Discharge Term Permits will be required for the drilling activities.

2.8.8 Chemical Use and Discharges to Sea

The relevant permits to use and discharge chemicals offshore will be applied for in accordance with the OCR. All offshore activities are covered by the Regulations including oil and gas production, drilling of wells, discharges from pipelines and discharges made during decommissioning.

2.8.9 Oil Pollution Emergency Plan (OPEP)

BPEOC on behalf of its Co-Venturers will submit a Communication and Interface Plan (CIP) to interface the existing approved Production Installation OPEP for the ETAP Platform and the Non-Production Installation (NPI) OPEP for the drilling rig contracted for the drilling of the proposed Murlach wells. The ETAP OPEP will subsequently be updated to incorporate production from Murlach.

2.8.10 Consent to Drill

BPEOC on behalf of its Co-Venturers will submit a Consent to Drill in the Well Operations Notifications (WONS) system to apply for consent to carry out drilling at the proposed project.

2.8.11 Consent to Locate (CtL)

Where applicable, BPEOC will apply for the following CtLs:

- Mobile Installation, e.g. drilling rig;
- Permanent / fixed Structure, e.g. Xmas trees; and
- Pipeline or Cable System, e.g. gas and liquid flowlines, and control umbilicals.

2.8.12 Pipeline Works Authorisation (PWA) and Deposit Consent (DepCon)

BPEOC will submit an application for a PWA detailing the pipelines, structures and umbilical to be installed whilst an application for a DepCon will be submitted providing the location of any rockdump, grout-bags and mattresses required on the pipeline route.

2.9 Decommissioning

At Cessation of Production (CoP) the Murlach infrastructure will be decommissioned in line with legislation and guidance in force at that time. In 2022 this would constitute the following:

- The Petroleum Act 1998 (as amended) and other relevant UK legislation at the time of decommissioning;
- OPRED Decommissioning Guidance (November 2018);
- The UK Guidelines for Well Decommissioning;
- The Pipeline Safety Regulations 1996 requiring the safe decommissioning of pipelines;

- Any additional applicable legislation in place at the time of decommissioning; and
- Any other agreements with the OPRED and relevant regulatory bodies.

Nearer the time of CoP, a full decommissioning plan will be developed in consultation with the relevant statutory authorities. The plan will be designed to confirm that potential effects on the environment resulting from the decommissioning of the facilities are considered and minimised.

2.9.1 Pipeline and Subsea Infrastructure

In line with current guidelines and legislation the decommissioning of the subsea pipelines would be subject to a CA and Decommissioning Programme. It is expected that the subsea structures will be removed from the seabed and returned to shore for reuse / recycling / disposal and a seabed clearance campaign conducted, however, this would be subject to future legislative requirements and guidance.

2.9.2 Wells

All well programmes will be subject to a Well Notification assessed by the Offshore Major Accident Regulator (OMAR) under the Offshore Installations (Offshore Safety Directive) (Safety Case etc). Wells will be plugged and permanently abandoned in accordance with Offshore Energies UK (formerly Oil & Gas UK -OGUK) well decommissioning guidelines (OGUK, June 2018) (or applicable guidance at that time). All well programmes will have been reviewed by the OMAR as required under the Design and Construction Regulations.

On completion of the well abandonment programme each conductor and internal tubing will thereafter be cut below the seabed. The subsea wellheads will then be recovered at location which could be conducted utilising either a DSV or semi-submersible rig.

3. ENVIRONMENTAL BASELINE

3.1 Introduction

This section describes the current nature and status of the environment in the vicinity of the proposed Murlach Field Development. An understanding of the baseline environment is required in order to identify the potential environmental impacts of the development and to provide a basis for assessing the potential interactions of the proposed project with the environment.

3.2 Environmental Baseline Surveys

The Murlach Field is located in Block 22/24h *c*. 203 km east of the Aberdeenshire coastline and *c.* 27 km from the UK/Norway median line. The proposed development will include works at the Murlach field and the laying of a pipeline between Murlach and the ETAP host platform within the Marnock field.

Table 3-1 summarises the most recent environmental surveys that have been carried out in the vicinity of the proposed development. A combination of seabed samples and seabed imagery were acquired during these survey campaigns to determine the physio-chemical status of the seabed, as well as the typical biological communities in the region. The presence of potentially sensitive species and habitats was also ascertained.

The seabed around ETAP was surveyed in 2012 and 2017. Results reported from these surveys (Gardline, 2013 and Fugro, 2019) have informed understanding of the environmental baseline between ETAP and Murlach presented in this section.

BPEOC commissioned an environmental survey at the Murlach Field in Q3 2019. The results of this survey are captured in three reports; an environmental habitat assessment report (Fugro, 2019b), a site survey field report (Fugro, 2019c) and a site survey report for Skua and Andrew (Fugro, 2020). These surveys will be referenced throughout the baseline, and supplemented with details on the surrounding area from past survey reports (Gardline, 2013; Fugro, 2019).

Table 3-1: Environmental surveys undertaken in the development area.

Survey	Report	Report Reference
August 2012 ETAP Environmental Survey	ETAP Environmental Survey, Environmental Monitoring Report	Gardline, 2013
August 2017 Environmental Survey at the Madoes, Marnock, Monan & Mungo Fields	Environmental Monitoring Survey Report ETAP (Madoes, Marnock, Monan & Mungo)	Fugro, 2019a
September & October 2019 Skua and Andrew Site Survey	Skua Environmental Habitat Assessment Report	Fugro, 2019b
	Skua Field Report	Fugro, 2019c
	Site Surveys Skua and Andrew	Fugro, 2020

Figure 3-1 shows the sampling locations for the 2017 (Fugro, 2019a) and 2019 (Fugro, 2019c) survey campaigns.

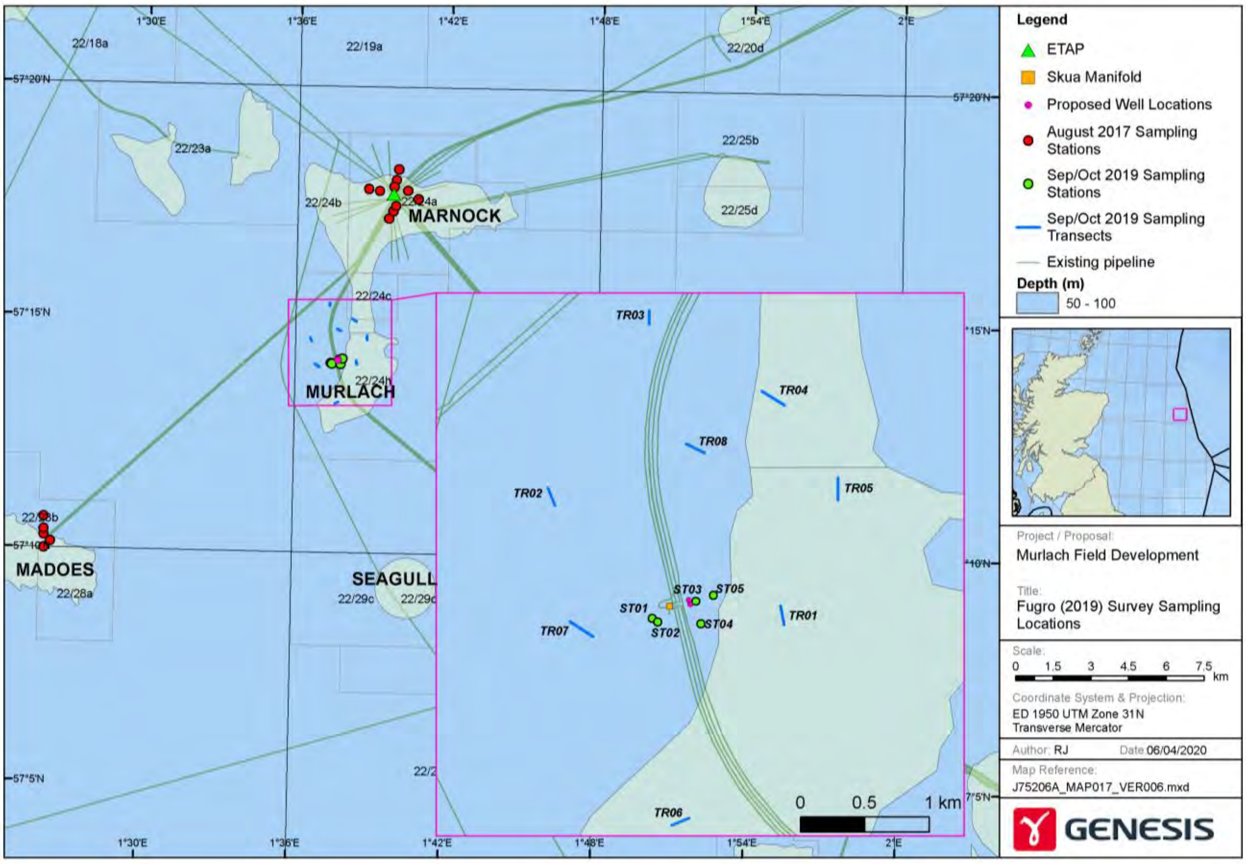


Figure 3-1: Location of the environmental surveys carried out in in the vicinity of the proposed Murlach Field Development (Fugro, 2019a, Fugro 2019c).

3.3 Physical Environment

The type and distribution of marine life is influenced by the physical conditions of the surrounding environment, biological interactions and anthropogenic activities. These physical factors, which include currents and tides, waves, temperature, salinity and the wind also help set the design parameters for offshore facilities and influence the fate and behaviour of any emissions and discharges from an installation and the risks associated with them.

3.3.1 Hydrology

3.3.1.1 *Bathymetry*

The water depth across the survey area ranged from 95 m Lowest Astronomical Tide (LAT) to 97.8 m LAT in the base of a depression in the south-west (Fugro, 2019b).

3.3.1.2 *Water masses, currents and tides*

The anti-clockwise movement of water through the North Sea and around the Central North Sea (CNS) region originates from the influx of Atlantic water, via the Fair Isle Channel and around the north of Shetland, and the main outflow northwards along the Norwegian coast (DECC, 2016b). Against this background of tidal flow, the direction of residual water movement in the CNS is generally to the south-east (DTI, 2001; DECC, 2016b) (Figure 3-2). The mean residual current in the Murlach area is approximately 0.01 m/s, running north-west to south-east in winter and south-west to north-east in summer (Wolf *et al.*, 2016). The mean spring tidal range is between 0.9 m and 1 m.

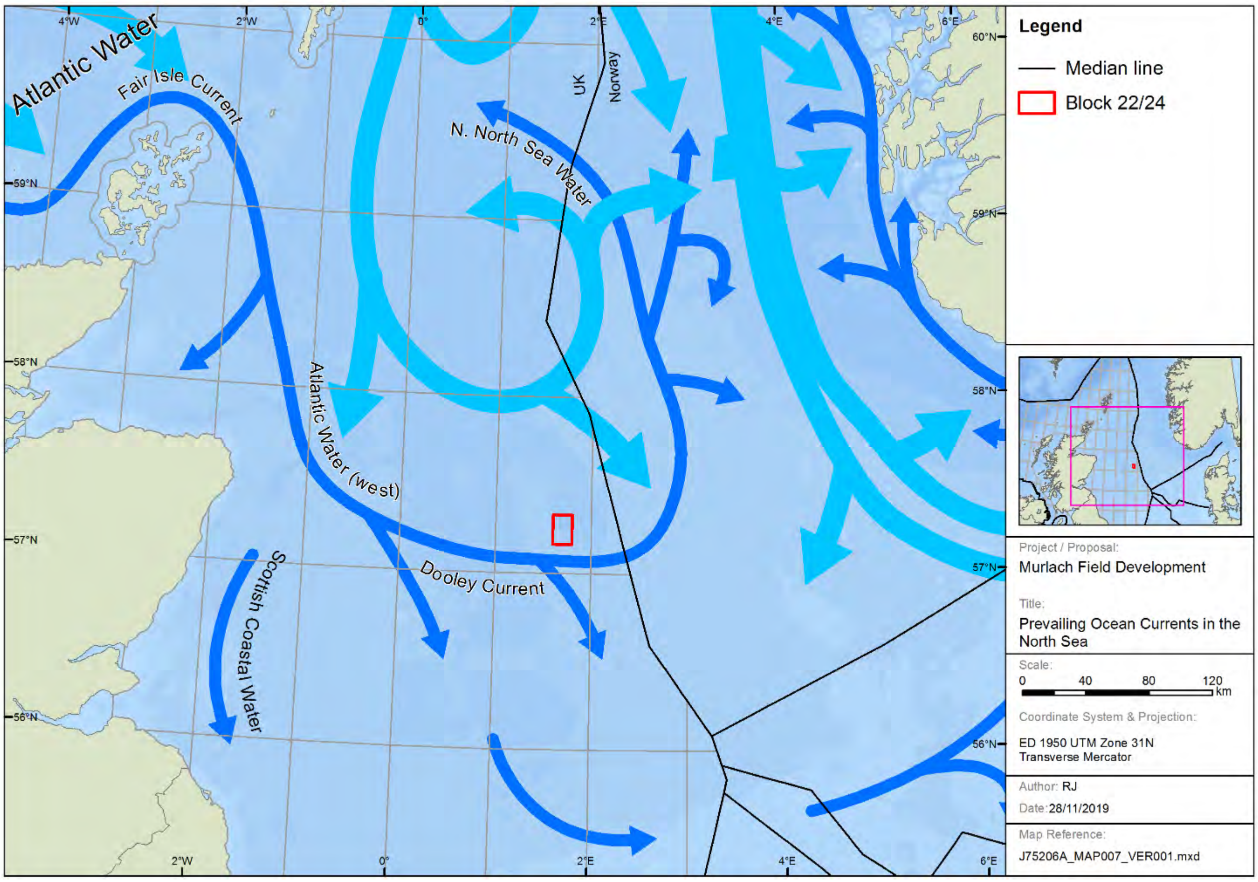


Figure 3-2: Schematic of ocean circulation in the North Sea (Turrell, 1992).

3.3.1.3 *Waves*

The mean wave height ranges from 1.51 – 2.4 m, and averages 2.19 m at the Murlach development site (Scottish Government NMPi). The mean significant wave height in the area ranges from 2.41 – 2.70 m primarily from the north (Figure 3-3), whilst the annual mean wave power ranges from 18.1 – 24.0 kW/m (Scottish Government NMPi).

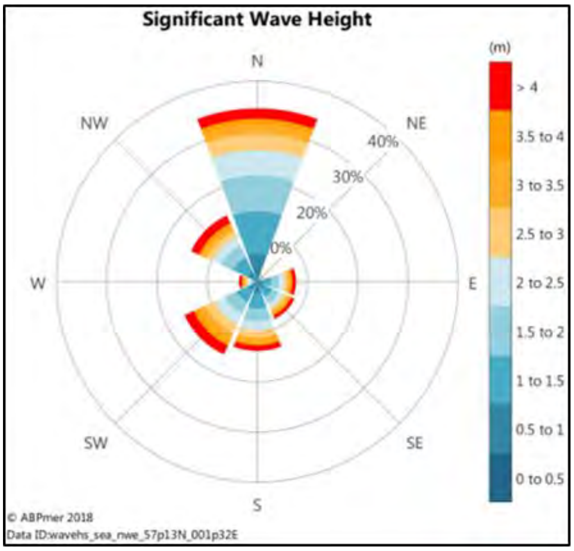


Figure 3-3: Wave rose for the Murlach area (Data Explorer, 2018).

3.3.1.4 *Temperature and salinity*

The temperature of the sea affects both the properties of the sea water and the fates of discharges and spills to the environment. Seawater temperatures vary with season, depth and proximity to land. The annual mean water temperature at the near-bed is 7.16 °C, and the annual mean surface temperature is 9.59 °C. Temperatures at the surface peak in August at 14.4 °C (Scottish Government NMPi).

Fluctuations in salinity are largely caused by the addition or removal of freshwater to or from seawater through natural processes such as rainfall and evaporation. Salinity increases with water depth and distance from shore. The salinity of seawater around an installation has a direct influence on the initial dilution of aqueous effluents such that the solubility of effluents increases as the salinity decreases. Salinity in the area of the Blocks show little variation with season and water depth. The annual mean near-bed salinity is 35 ‰ and the surface salinity is 34.9 ‰ (Scottish Government NMPi).

3.3.1.5 *Water quality*

Regional inputs from coastal discharges and localised inputs from existing oil and gas developments may affect water quality in different areas in the CNS. Water samples with the highest levels of contaminants are found at inshore sites prone to high levels of industrial usage. High hydrocarbon concentrations in offshore locations are normally in the immediate vicinity of installations, originating primarily from the discharge of produced water and contaminated drill cuttings.

Water quality around the Murlach Development is predicted to be good, with contaminants being close to background levels due to the distance from anthropogenic inputs and prevailing ocean current systems which disperse and dilute pollutants (NSTF, 1993).

3.3.2 Meteorology

3.3.2.1 *Winds*

Wind direction and speed directly influence the transport and dispersion of atmospheric emissions from an installation. These factors are also important for the dispersion of marine discharges, including oil releases, influencing the movement, direction and break up of substances on the sea surface. The wind strength in winter for the Murlach area generally ranges from between 6 – 11 m/s, which is considered a moderate to strong breeze, and is higher than 8 m/s for 60 – 65 % of the time in this season (Figure 3-4). Although less frequent, high wind speeds of 17 – 32 m/s can occur (DECC, 2016b).

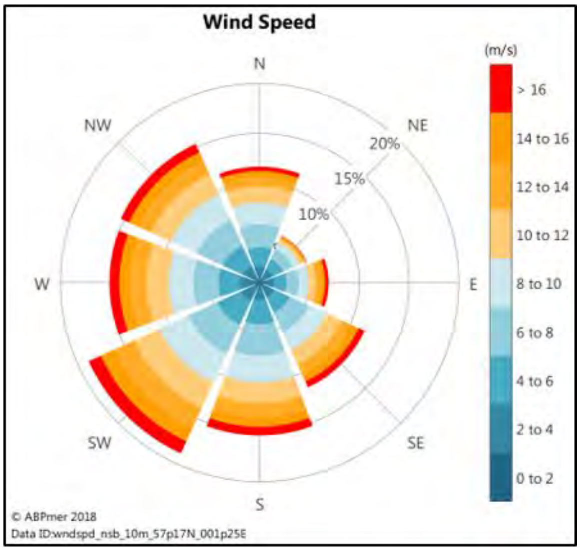


Figure 3-4: Wind rose for the Murlach area (Data Explorer, 2018).

3.3.3 Seabed Sediments

Seabed sediments comprising mineral and organic particles occur commonly in the form of mud, sand or gravel and are dispersed by processes driven by wind, tides and density driven currents. The distribution of seabed sediments within the North Sea results from a combination of hydrographic conditions, bathymetry and sediment supply. The characteristics of the local sediments and the amount of sediment transport within a project area are important factors in determining the potential effects of possible developments (drill cuttings, installation of pipelines, anchor scouring) on the local seabed environment.

The main sediment type observed over the Murlach survey area was sandy mud/muddy sand (Fugro, 2019c). Varying proportions of shell and shell fragments were present as well as gravel and pebbles and occasional patches of clay and cobbles. The general seabed type within the area is circalittoral muddy sand (as defined by the MSFD (Marine Strategy Framework Directive) habitat classification A5.26) (Fugro, 2019c) (Figure 3-5). Sediments across the survey area had a mean particle size ranging from 63 µm at station ST01 (shown in Figure 3-1) to 99 µm at station ST04, with a mean of 81 µm. Figure 3-6 shows example seabed sediment photographs taken at the survey sites around the Murlach area, and highlights the mostly muddy sand nature of the area with patches of gravelly mud.

Sediments found at the Marnock Field are composed of fine to very fine, poorly sorted sand (Fugro, 2019a). The mean diameter of sediment reported 300 m from the platform at Marnock was broadly equivalent to that reported 200 m from the platform in 2012. The description of the Marnock sediments as being fine sand to very fine sand is similar to the survey undertaken in 2000 (ERT, 2000), showing little change in composition over this time. At the Madoes Field, sediments were described as very fine sand at all but one survey location, which contained coarse silt.

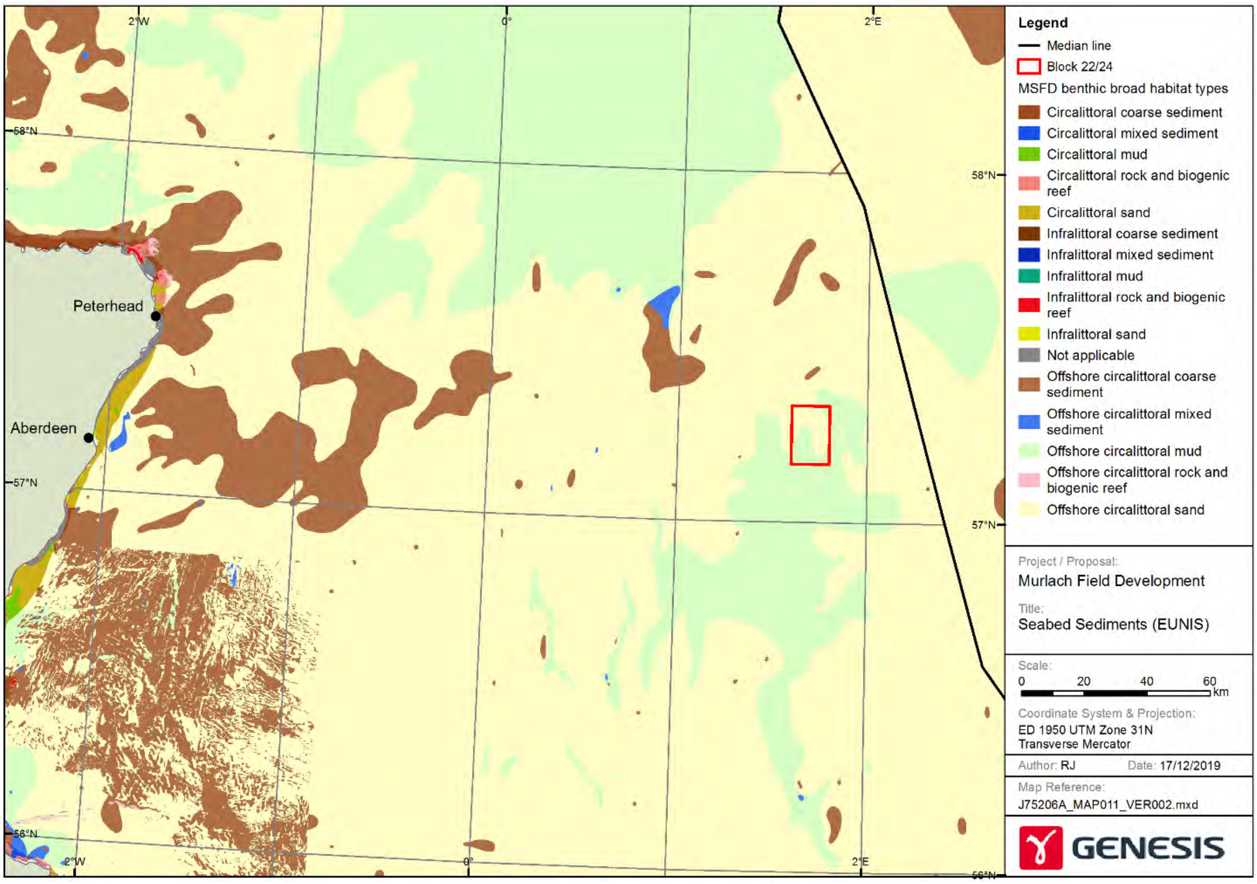


Figure 3-5: North Sea sediment distribution (MSFD predominant habitat classification) (EMODnet, 2019).

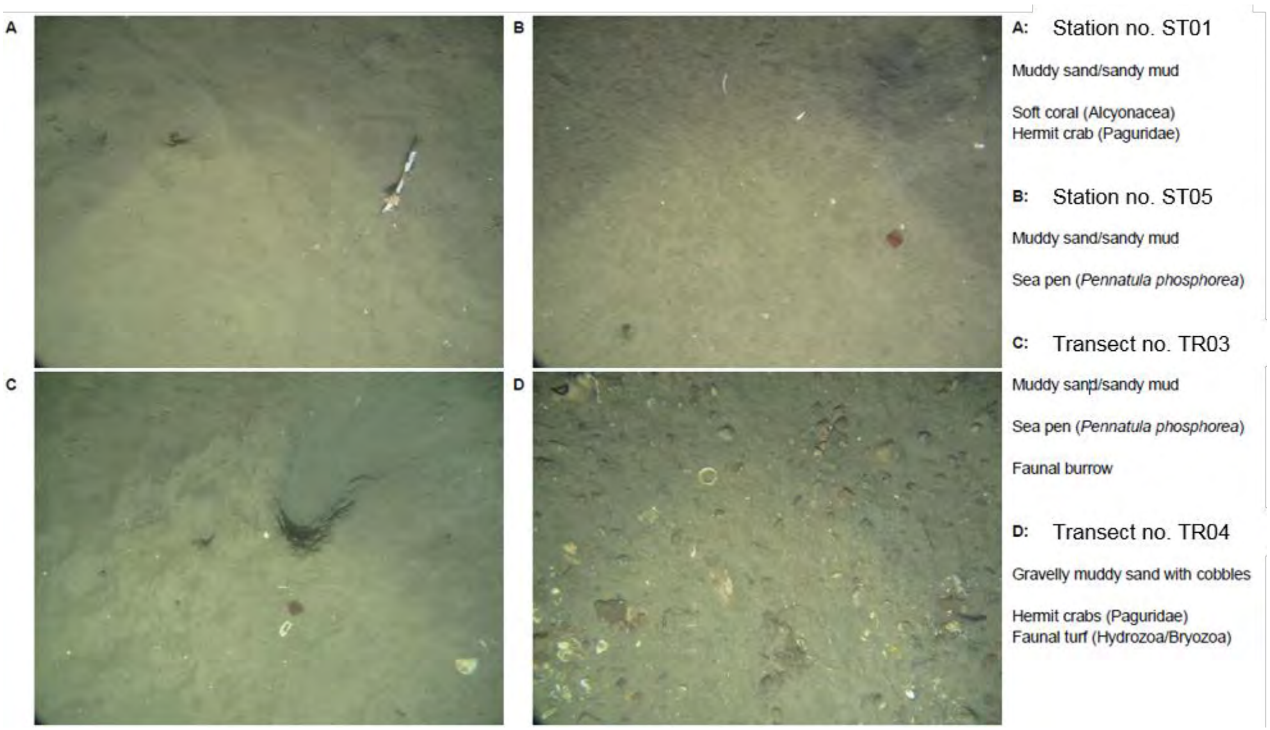


Figure 3-6: Example seabed sediment photographs around Murlach (Fugro, 2019c) Locations of sampling stations and transects referenced are shown in Figure 3-1.

3.3.3.1 *Sediment Chemistry*

Deep-water marine environments generally show relatively low levels of contamination compared to coastal waters and industrial estuaries.

Exposure of marine organisms to contaminants can occur either through uptake of dissolved fractions across the gills or skin, or direct ingestion of the pollutant. Organisms spending the majority of their lifecycle in the water column are likely to receive the highest exposure to contaminants that remain in solution, though some will also accumulate sediment bound contaminants indirectly through their diet (i.e. digestion of animals that have accumulated the contaminants in their tissues). Organisms associated with the seabed (benthic organisms) are more exposed to particle bound contaminants with the main exposure route being either directly through ingestion of contaminated sediments or through their diet. Benthic organisms can also absorb contaminants through the surface membranes as a result of contact with interstitial water.

Heavy/Trace Metals

Elevated levels of contaminants can affect organisms (flora and fauna) in a variety of ways, ranging from cellular effects in individuals to ecosystem effects resulting from changes in population sizes or even the loss of an entire species (UK Marine SACs Project, 2001).

Metal concentrations above their respective OSPAR Effects Range Low (ERL) thresholds were not recorded in any of the samples collected in the area in 2019 (Fugro, 2020). Note: the ERL value is defined as the lower tenth percentile of the data set of concentrations in sediments which were associated with biological effects. Adverse effects on organisms are rarely observed when concentrations fall below the ERL value (OSPAR, 2009). Total barium concentrations at the Murlach site ranged from 389 µg/g at ST05 to 1100 µg/g at station ST02, with a mean of 757 µg/g. For other metals, sample analyses showed that metal concentrations were typical for the area given the historical and ongoing drilling activity.

At the Madoes Field concentrations of barium (Ba) ranged from 156 µg/g to 320 µg/g. This was lower than barium levels at Marnock which ranged from 187 µg/g to 3020 µg/g, with a mean of 744 µg/g. For both field sites no reported metals concentrations exceeded their respective OSPAR ERL thresholds (Fugro, 2019a).

Hydrocarbons

The incorporation of minimal quantities of hydrocarbons in the tissue of a marine organism can affect its predators. At every link in the food chain, organisms consume *c.* 10 kg of matter from the level below to produce 1 kg of their own living matter. If a contaminant passes from one level to another without being broken down, its concentration in the living matter multiples nearly ten times at each link in the chain. Organisms at the top of the food chain can therefore be exposed to detrimentally high concentrations of a product which will not affect the organisms further down the chain. This is known as the bioaccumulation of chemicals through the food chain. Many of the components of oil and petroleum products are biodegradable at some level of the food chain and only the rarer, higher molecular weight PAHs tend to have significant bioaccumulation potential. The primary risk from these PAHs is that some are carcinogenic with the impacts including acute toxicity, liver neoplasm and other abnormalities.

Particles of various types and sizes, notably the silt/clay fraction, can absorb petroleum hydrocarbons from seawater and, through this pathway, hydrocarbons become incorporated into the sediment system. Organic matter within the sediment matrix is also likely to absorb hydrocarbons and heavy metals, providing a means of transport and incorporation into sediments. The bioavailability of contaminants that are adsorbed to sediment or organic matter is poorly understood. However, in general terms, prolonged contact between hydrocarbons and sediment may result in stronger bond formation and a subsequent reduction in bioavailability (Van Brummelen *et al.,* 1998). This phenomenon is referred to as 'ageing' and is especially important for sediments with historic contamination such as prolonged discharge of drill cuttings or produced water.

The Total Hydrocarbon Concentrations (THC) found within the Murlach field ranged from 2.2 µg/g at station ST05 to 3.6 µg/g at stations ST01 and ST02, with a mean of 3.0 µg/g (Fugro, 2020). The mean THC value reported was broadly comparable to the nearby Marnock Field, which ranged from 2.6 µg/g to 7.8 µg/g, with a mean of 4.1 µg/g. These values are all below the United Kingdom Offshore Operators Association (UKOOA) CNS mean background concentration of 9.5 µg/g. Mean THC at Marnock were observed to be below those recorded during previous studies, with mean values of 9.1 µg/g in 2000 (ERT, 2000) and 8.8 µg/g in 2012 (Gardline, 2013). At the Madoes field (Fugro, 2019a), THC levels ranged from 7.3 µg/g to 10.8 µg/g with a mean of 8.7 µg/g. Madoes showed low variability across the survey area and was generally below the UKOOA mean background concentration of 9.5 µg/g (UKOOA, 2001).

All three fields have values well below the recognised threshold of 50 µg/g above which concentrations are expected to have a Significant Environmental Impact on macrofauna communities (Kjeilen-Eilertsen *et al*., 2004; UKOOA, 2002; UKOOA, 2005).

Figure 3-7 shows evidence of previously discharged drill cuttings in the vicinity of the ETAP platform. Three piles are located to the north west of the platform (Figure 3-7). None of these cuttings piles are expected to be disturbed by the activities associated with the Murlach Field Development, as any infrastructure changes will occur to the south east of the ETAP platform, where the risers are located for all lines connected to the platform.

The nearest well to the proposed Murlach wells is *c.* 90 m to the south-west at Skua. No cuttings are visible for this well in a survey chart produced in January 2020 (Figure 3-8).

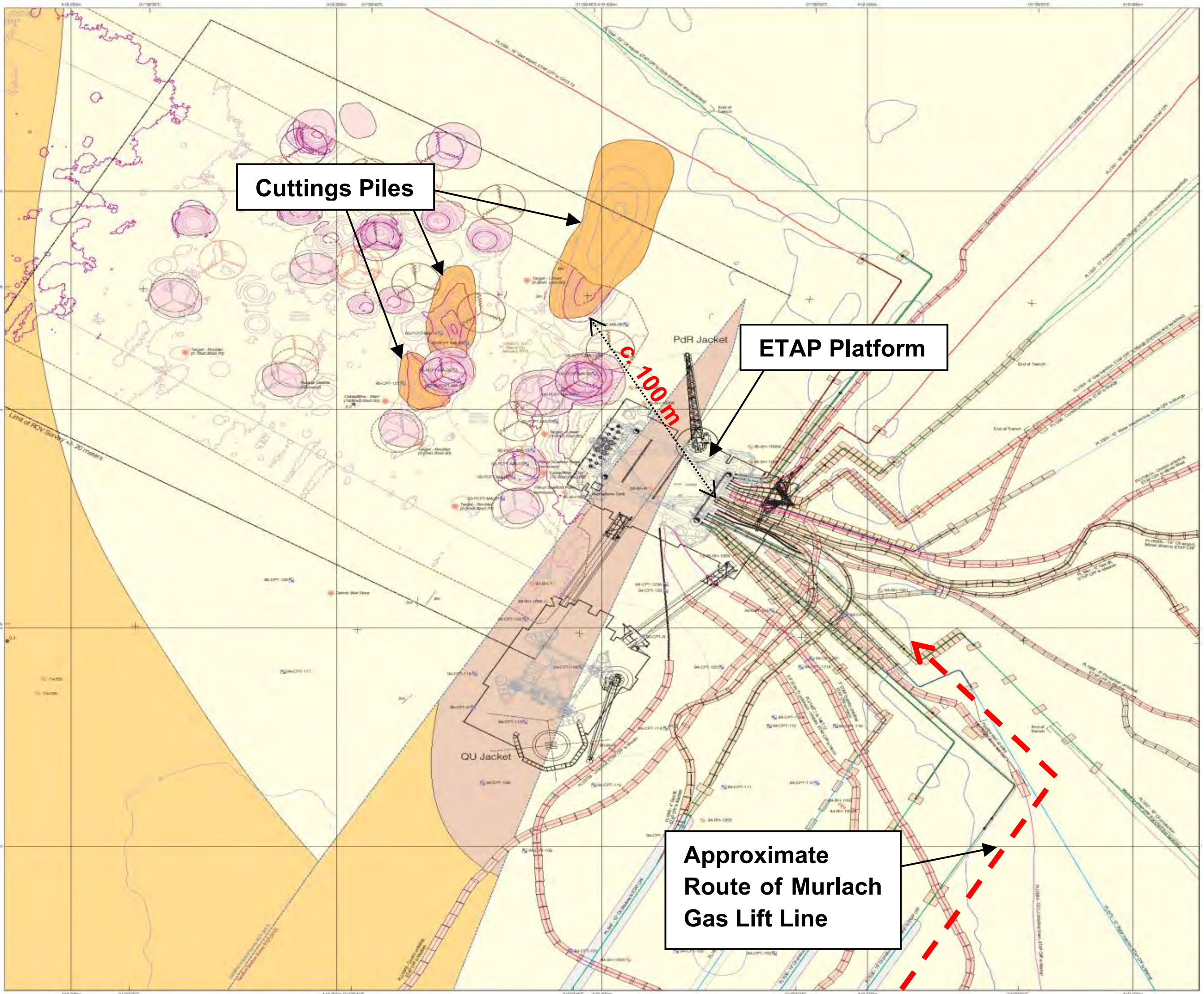


Figure 3-7: Cuttings piles in proximity to the ETAP platform.

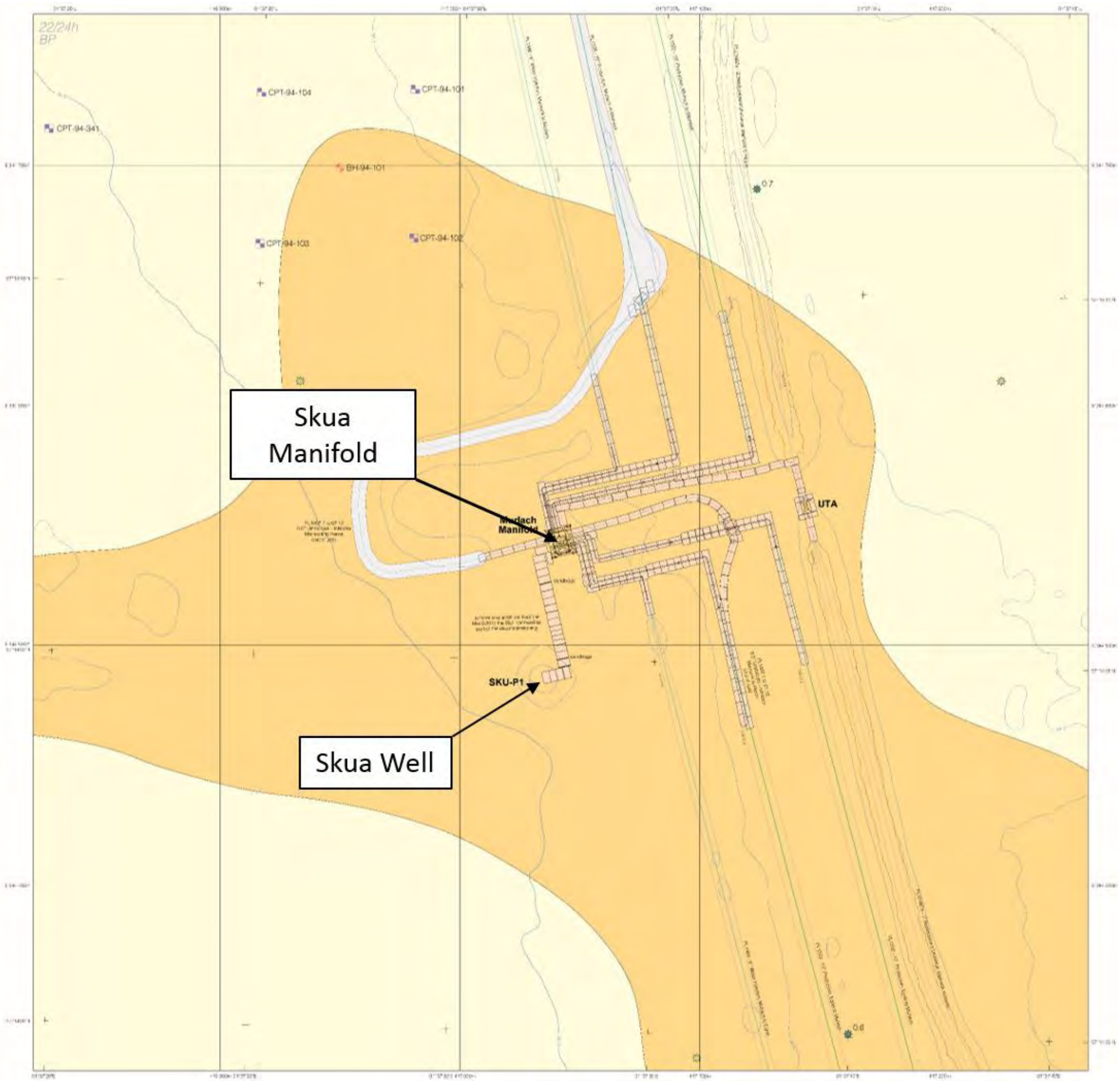


Figure 3-8: Location of Skua well showing no nearby cuttings piles in the area.

3.3.3.2 *Seabed Habitats*

Two distinct European Nature Information System (EUNIS) biotopes were observed at Murlach, ‘Circalittoral muddy sand’ (A5.26) and ‘Circalittoral mixed sediments’ (A5.44) (Fugro, 2019b). Species observed across the site in the Circalittoral Muddy Sand areas included hermit crabs (Paguridae including *P. bernhardus*), brittlestars (Ophiuridae), starfish (Asteroidea including *A. rubens* and *A. irregularis*) and spider crab (Majidae). Small faunal tubes and worm casts were also observed, suggesting the presence of polychaetes across the site.

Features of the biotope ‘Circalittoral fine mud’ (A5.36) were also observed across the survey area. The sea pens *P. phosphorea* and *V. mirabilis* are characteristic species of this biotope complex and were observed across the site. Additionally, the relatively stable conditions of this biotope can often lead to the establishment of communities of burrowing megafaunal species, such as *N. norvegicus*.

The biotope ‘Circalittoral mixed sediments’ was classified in certain transects due to the occurrence of shell and shell fragments with occasional pebbles, cobbles and boulders. The characterising species of mixed sediment habitats observed across the three transects included hydroids (Hydrozoa), hermit crabs (Paguridae), brittlestars (Ophiuridae), sea urchin (*Echinus esculentus*), starfish (Asteroidea including *A. rubens*), scallop (*Pecten maximum)*, encrusting polychaete tubes (Serpulidae), soft coral (Alyconacea) and faunal turf (Hydrozoa/Bryozoa). Overall faunal abundance and diversity increased in areas of mixed sediments due to the availability of substratum on which encrusting fauna can attach (Fugro, 2019b).

The Marnock and Madoes fields are within the EUNIS biotope ‘Circalittoral muddy sand’ (Fugro, 2019a). This habitat falls within the broad habitat Priority Marine Feature (PMF) ‘offshore subtidal sands and gravels’ (PMFs are discussed further in Section 3.5.2).

3.4 Biological Environment

3.4.1 Plankton

Plankton are drifting organisms that inhabit the pelagic zone of a body of water and include single celled organisms such as bacteria as well as plants (phytoplankton) and animals (zooplankton). Phytoplankton are primary producers of organic matter in the marine environment and form the basis of marine ecosystem food chains. They are grazed upon by zooplankton and larger species such as fish, birds and cetaceans. Therefore, the distribution of plankton directly influences the movement and distribution of other marine species. In addition to phytoplankton and zooplankton; meroplankton which includes the eggs, larvae and spores of non-planktonic species (fish, benthic invertebrates and algae) can be found in the water column.

The composition and abundance of plankton communities vary throughout the year and are influenced by several factors including depth, tidal mixing, temperature stratification, nutrient availability and the location of oceanographic fronts. Species distribution is directly influenced by temperature, salinity, water inflow and the presence of local benthic communities (Robinson, 1970; Colebrook, 1982).

Over the past 30 years, rising sea temperatures have been accompanied by a rise in the North Atlantic Oscillation Index (NAOI) (OSPAR, 2010). The NAOI is a measure of the pressure gradient between the relatively high subtropical surface pressure of the ‘Azores High’ and the relatively low surface pressure further north, the ‘Icelandic Low’. An increase in the NAOI tends to result in higher temperatures in northern Europe including the North Sea (Met Office, 2019). The seasonal timing of phytoplankton and zooplankton production has altered in recent decades with some species present up to four to six weeks earlier than 20 years before. This directly affects their availability to predators such as fish (OSPAR, 2010).

Seasonal stratification also occurs as the water column is heated by solar radiation and wind and convection induced heat exchange. Stratification affects the vertical distribution of nutrients and has a major impact on the production and succession of phytoplankton. Phytoplankton blooms in spring are followed by depletion of nutrients and waning of phytoplankton in summer and autumn. Remixing of the water column and regeneration of nutrients occurs during the winter. This cycle affects the structure of the food web throughout the year (Ruardij *et al*., 1998; Vidal *et al*., 2017).

A peak in phytoplankton abundance usually occurs every spring with phytoplankton communities dominated by relatively large diatoms, for example *Thalassiosiria* spp. and *Chaetoceros* spp. There may be an additional, but smaller, peak in phytoplankton numbers during the autumn with smaller dinoflagellate species, for example *Tripos*, dominating (SAHFOS, 2001).

Zooplankton communities in the North Sea are dominated by copepods, such as *Calanus* spp. *Acartia* spp. and *Metridia lucens*, occurring during the summer peak period (Nielsen and Richardson, 1989).

3.4.2 Benthos

Bacteria, plants and animals living on or within the seabed sediments are collectively referred to as benthos. Species living on top of the sea floor may be sessile (e.g. seaweeds) or freely moving (e.g. starfish) and collectively are referred to as epibenthic or epifaunal organisms. Animals living within the sediment (e.g. clams, tubeworms and burrowing crabs) are termed infaunal species. Semi-infaunal animals, including sea pens and some bivalves, lie partially buried in the seabed. The majority of marine benthic invertebrates exhibit a life cycle that includes a planktonic larval phase from which the bottom dwelling juvenile and adult phases recruit.

Benthic animals display a variety of feeding methods. Suspension and filter feeders capture particles which are suspended in the water column (e.g. sea pens) or transported by the current (e.g. mussels). Deposit feeders (e.g. sea cucumbers) ingest sediment and digest the organic material contained within it. Other benthic species can be herbivorous (e.g. sea urchins), carnivorous (e.g. crabs) or omnivorous (e.g. nematodes). Benthic communities show a strong correlation with habitat type, with depth mainly influencing epifauna, and sediment characteristics typically influencing the infauna (Basford *et al.,* 1990). Benthic communities in deeper soft sediment habitats tend to be spatially distributed over large scales, with distinctive species assemblages associated with particular substrate types. However, depending on the intensity and spatial extent of sampling, localised community types or subtler variations may be distinguished, often associated with topographic features (DECC, 2016).

Activities that result in the disruption of the seabed such as the deposition of discharged drill cuttings can affect the benthic fauna (Clark, 1996). The recognition that aquatic contaminants may alter benthic fauna, together with the relative ease of obtaining quantitative samples from specific locations, has led to the widespread use of infaunal communities in monitoring the long-term impact of disturbance to the marine environment. The species composition and relative abundance in a particular location provides a reflection of the immediate environment, both current and historic (Clark, 1996). Sessile infaunal species are particularly vulnerable to external influences that may alter the physical, chemical or biological community of the sediment as they are unable to avoid unfavourable conditions. Each species has its own response and degree of adaptability to changes in the physical and chemical environment.

Benthic Fauna

Benthic fauna found to be present in the area includes sea pens (*Pennatula phosphorea, Virgularia mirabilis*), hermit crabs (Paguridae including *Pagurus bernhardus*), brittlestars (*Ophiuridae*), starfish (Asteroidea: including *Asterias rubens* and *Astropecten irregularis*), anemones (Actiniaria including *Hormathia* sp.), colonial anemones (*Epizoanthus papillosus*), soft coral (Alcyonacea), squat lobsters (*Munida* sp.), sea spiders (Pycnogonida), Norway lobsters (*Nephrops norvegicus*), crabs (Brachyura including Majidae and *Liocarcinus depurator*), hydroids (Hydrozoa) and Hydrozoa/Bryozoan turf (Fugro 2019b).

3.4.2.1 *Arctica Islandica*

A. islandica is listed as a Scottish PMF and is also listed on the OSPAR list of threatened and/or declining species and habitats. Though a review of photographic data showed no evidence of visible *A. islandica* siphons, juveniles or adults on the seabed surface (Fugro, 2019b), analysis of the grab samples showed evidence of *A. islandica* in the area (Fugro, 2020). Figure 3-9 shows the location of grab samples that had evidence of *A. islandica* associated with them.

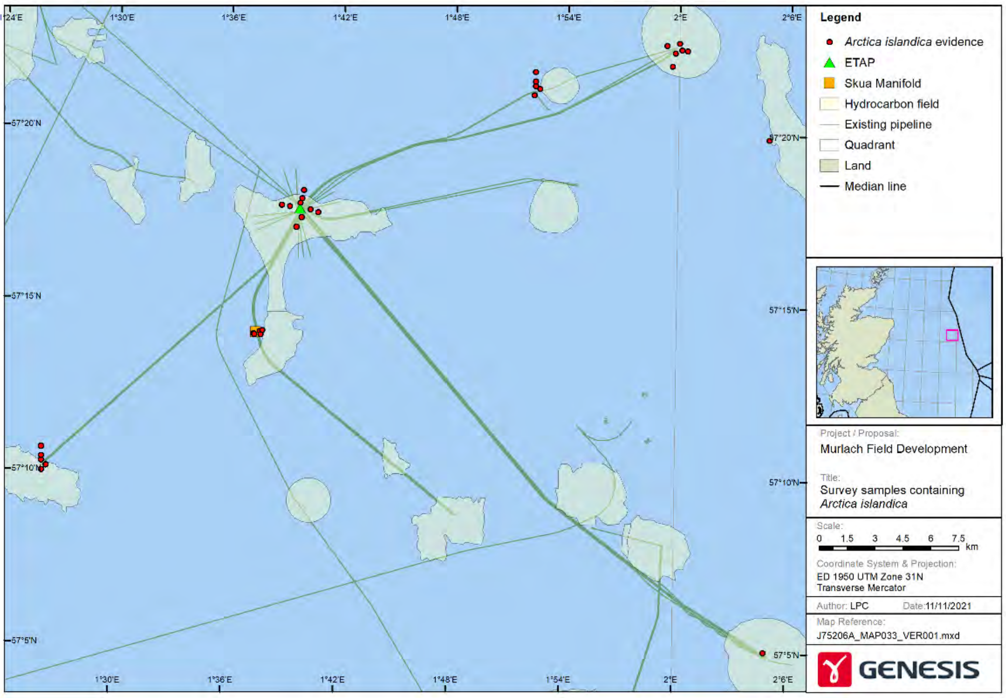


Figure 3-9: Location of grab samples with evidence of *A. islandica*.

3.4.2.2 *Sea Pens and Burrowing Megafauna Communities*

Within the circalittoral fine mud habitat, the sea pens *P. phosphorea* and *V. mirabilis* were observed across the site. Using the SACFOR (Super-abundant, Abundant, Common, Frequent, Occasional and Rare) abundance of *P. phosphorea* was considered to be rare to frequent whilst abundance of *V. mirabilis was* considered occasional and frequent (Fugro, 2019b).

Faunal burrows were present at all stations (ST01 to ST05) and along all the transects (TR01 to TR08) (Figure 3-1) and on the SACFOR scale they were considered to occur frequently. However, the faunal burrows were not considered to form a prominent feature of the sediment surface. Therefore the areas of sea pens and burrows observed were not thought to be representative of the OSPAR listed threatened and/or declining habitat 'Sea pens and burrowing megafauna communities' (Fugro, 2019b).

3.4.3 Finfish and Shellfish

More than 330 fish species are thought to inhabit the shelf seas of the UKCS (DECC, 2016). Pelagic species (e.g. herring, mackerel, blue whiting, and sprat (*Sprattus sprattus*)) are found in mid-water and typically make extensive seasonal movements or migrations. Demersal species (e.g. cod, haddock (*Melanogrammus aeglefinus*), sandeels (*Ammodytes tobianus*), sole (*Solea solea*) and whiting) live on or near the seabed and similar to pelagic species, many are known to passively move (e.g. drifting eggs and larvae) and / or actively migrate (e.g. juveniles and adults) between areas during their lifecycle.

Fish occupying areas in close proximity to offshore oil and gas installations will be exposed to aqueous discharges and may accumulate hydrocarbons and other contaminating chemicals in their body tissues. The most vulnerable stages of the life cycle of fish, to general disturbances such as disruption to sediments and oil pollution, are the egg and larval stages. Hence, recognition of spawning and nursery times and areas within a development area is important when considering potential disturbance caused by drilling and installation activities and when responding to accidental releases during operations.

The Murlach Field lies within ICES rectangle 43F1. Table 3-2 shows the approximate spawning times and nursery grounds of some commercial fish species occurring in 43F1. Maps of the spawning and nursery areas for all species identified in Coull *et al.* (1998) and high density species identified in Ellis *et al.* (2012) are shown in Figure 3-10. It should be noted that spawning and nursery areas tend to be transient and therefore cannot be defined with absolute accuracy (Coull *et al.,* 1998; Ellis *et al.,* 2012).

Data generated by Marine Scotland (Aires *et al.*, 2014) uses Species Distribution Modelling (SDM) to predict where aggregations of 0-group fish (fish in the first year of their life) may be found based on environmental information and catch records. The data indicates that low levels of juveniles are present in the area for the Norway pout, haddock and whiting (Table 3-2).

Table 3-2: Summary of spawning, nursery and juvenile activity for fish species in ICES rectangle 43F1 (Coull *et al.*, 1998[1]; Ellis *et al.*, 2012[2], Aires et al., 2014[3]).

Species	J	F	M	A	M	J	J	A	S	O	N	D	Nursery	Juveniles
Mackerel[1, 2]					*	*	*						Yes	
Lemon Sole[1]														
Norway Pout[1,3]		*	*										Yes	Yes
Nephrops[1]				*	*	*							Yes	
Haddock[1,3]													Yes	Yes
Blue Whiting[1,2]													Yes	
Spurdog[2]													Yes	
Herring[2]													Yes	
Cod[2]		*	*										Yes	
Whiting[2,3]													Yes	Yes
Ling[2]													Yes	
Hake[2]													Yes	
Anglerfish[2]													Yes	
Sandeels[2]													Yes	
Plaice[2]													Yes	
Key	Species Present (*Peak Spawning)						High Levels Observed				Species Not Recorded			

Sandeel habitat is considered further as this species is known to have a particularly important ecological function as a prey item for other fish, seabirds and marine mammals. There is evidence that the presence of fines in the sediment reduces its suitability to sandeels. Lancaster *et al.* (2014) indicated that sandeels avoid areas with greater than 10% of silt/clay or very fine sand. Moreover, Holland *et al.* (2005) recorded extremely low densities of sandeels in sediments with a silt content >4 % and found that increased fractions of silt from

0 to 10 % correlated with a reduction in sandeel density. The sediments in the Murlach area are described as silty sands (4 µm to 2 mm particle size) with occasional patches of shell and gravels with cobbles (2 mm to 64 mm particle size) (see Section 3.3.3). As such, high densities of sandeels are not expected to occur in the Murlach area.

The presence of cod (*Gadus morhua*) was also noted in the Murlach area. This species is a PMF which is listed as vulnerable (VU) on the International Union for the Conservation of Nature (IUCN) Red List as well as the Scottish Biodiversity List (IUCN, 2017; Scottish Biodiversity List, 2013). Peak spawning for cod in the area is shown to be in February and March and high levels of nursery cod are present year-round (Table 3-2). It should be noted that a 2016 publication (González-Irusta & Wright, 2016) identified the Murlach/ETAP area as being 'unfavourable' for cod spawning.

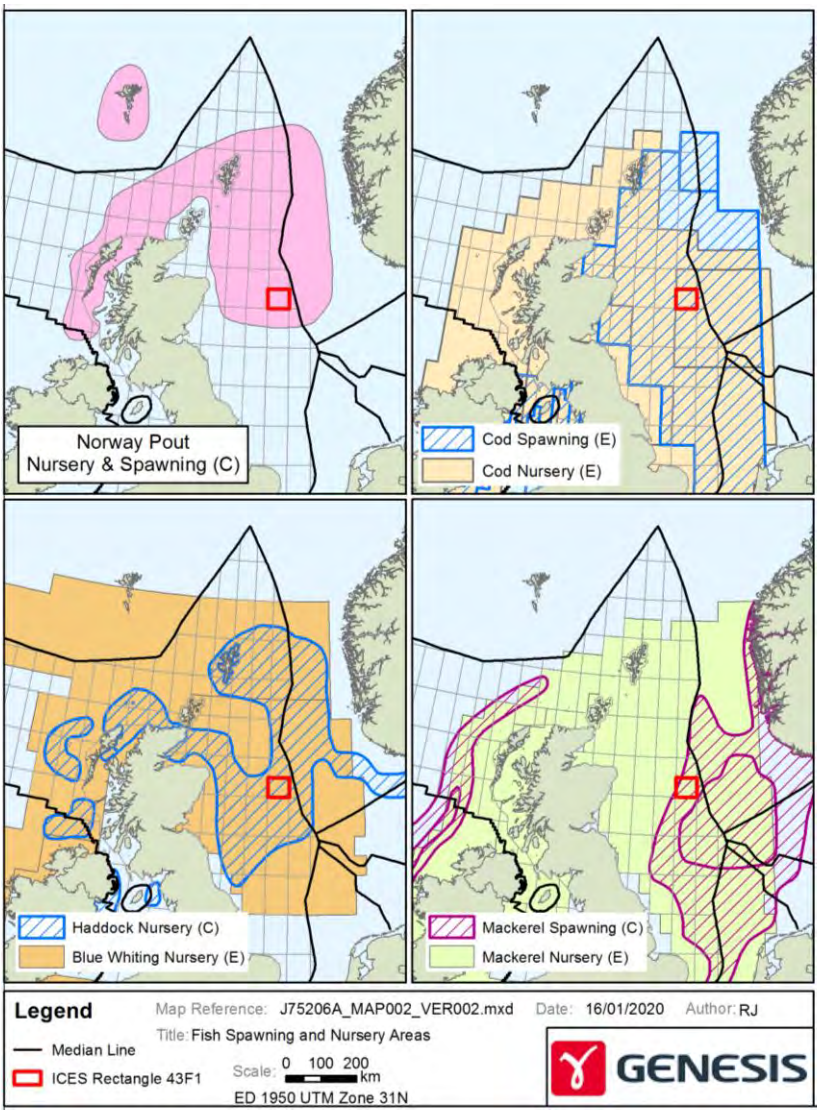


Figure 3-10: Fish spawning and nursery grounds in proximity to the proposed development (C = Coull *et al.,* 1998; E = Ellis *et al.,* 2012).

A number of the species known to occur in the area are represented on the PMF list (see Section 3.5.5) and are subject to appropriate protection and conservation measures (Tyler-Walters *et al.,* 2016). Marine Scotland have identified May to August as a 'period of concern' for seismic surveys within Blocks 22/24h due to fish spawning (OGA, 2017a).

3.4.4 Seabirds

The UK and its surrounding seas are very important for seabirds. The extensive network of cliffs, sheltered bays, coastal wetlands, and estuarine areas, provide breeding and wintering grounds for nationally and internationally important bird species and assemblages (DECC, 2016). Approximately 26 species of seabird regularly breed in the UK and Ireland as do a number of other waterbird and wader species (DECC, 2016).

Predicted maximum monthly abundance of seabirds in the Murlach area is based on an analysis of the European Seabirds at Sea (ESAS) data collected over 30 years (Kober *et al.,* 2010). Continuous seabird density surface maps were generated using the spatial interpolation technique ‘Poisson kriging’ and fifty-seven seabird density surface maps were created to show particular species distribution in specific areas. Data from the relevant maps has been summarised for the Murlach area in Table 3-3.

Distribution and abundance of these bird species vary seasonally and annually. Seabird densities such as Atlantic puffin are generally higher in the breeding season (April – July), whereas other species such as the Northern fulmar have higher densities in the winter season (August - February) (Table 3-3). Of the species expected to occur in the area, manx shearwater (*Puffinus puffinus mauretanicus*), European storm petrel (*Hydrobates pelagicus)* and common guillemot (*Uria aalge*) are afforded protection by the European Commission (EC) Birds Directive (Annex I).

Recent seabird distribution maps produced by Waggit *et al*. (2019) indicate the presence of black-legged kittiwake and northern fulmar at a moderate density of *c.* 0.93 – 1.24 animals/km^2, common guillemot and northern gannet at a low-moderate density of *c*. 0.62 – 0.93 animals/km^2, and great skua, herring gull and razorbill all at relatively low densities (*c.* 0.31 – 0.62 animals/km^2) in the Murlach area (Waggit *et al.* 2019).

Table 3-3: Predicted seabird surface density (maximum number of individuals/km^2) (Kober *et al.*, 2010).

Species	Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northern Fulmar	Breeding			10.0 - 20.0	10.0 - 20.0	10.0 - 20.0	10.0 - 20.0	10.0 - 20.0					
	Winter	10.0 - 20.0	10.0 - 20.0						10.0 - 20.0	10.0 - 20.0	10.0 - 20.0	10.0 - 20.0	10.0 - 20.0
Sooty Shearwater	Summer							≤1.0	≤1.0	≤1.0	≤1.0	≤1.0	
Manx Shearwater	Breeding					1.0 – 5.0	1.0 – 5.0	1.0 – 5.0	1.0 – 5.0	1.0 – 5.0			
European Storm Petrel	Breeding						≤1.0	≤1.0	≤1.0	≤1.0	≤1.0		
Northern Gannet	Breeding					1.0 – 5.0	1.0 – 5.0	1.0 – 5.0	1.0 – 5.0	1.0 – 5.0			
	Winter	≤1.0	≤1.0	≤1.0	≤1.0						≤1.0	≤1.0	≤1.0
Great Skua	Breeding					≤1.0	≤1.0	≤1.0	≤1.0				
	Winter	≤1.0	≤1.0	≤1.0	≤1.0					≤1.0	≤1.0	≤1.0	≤1.0
Black Legged Kittiwake	Breeding					5.0 – 10.0	5.0 – 10.0	5.0 – 10.0	5.0 – 10.0	5.0 – 10.0			
	Winter	5.0 – 10.0	5.0 – 10.0	5.0 – 10.0	5.0 – 10.0						5.0 – 10.0	5.0 – 10.0	5.0 – 10.0
Great black-backed gull	Winter	≤1.0	≤1.0	≤1.0						≤1.0	≤1.0	≤1.0	≤1.0
Black-headed gull	Breeding				≤1.0	≤1.0	≤1.0	≤1.0	≤1.0				
Common Gull	Breeding					≤1.0	≤1.0	≤1.0	≤1.0				
Herring Gull	Winter	1.0 – 5.0	1.0 – 5.0	1.0 – 5.0						1.0 – 5.0	1.0 – 5.0	1.0 – 5.0	1.0 – 5.0
	Breeding				≤1.0	≤1.0	≤1.0	≤1.0	≤1.0				
Glaucous gull	Winter	≤1.0	≤1.0	≤1.0							≤1.0	≤1.0	≤1.0
Common Guillemot	Breeding					10.0 - 20.0	10.0 - 20.0						
	Additional								10.0 - 20.0	10.0 - 20.0			
	Winter	1.0 – 5.0	1.0 – 5.0	1.0 – 5.0	1.0 – 5.0						1.0 – 5.0	1.0 – 5.0	1.0 – 5.0
Razorbill	Breeding					≤1.0	≤1.0						
Little Auk	Winter	≤1.0	≤1.0	≤1.0								≤1.0	≤1.0
Atlantic Puffin	Breeding				5.0 – 10.0	5.0 – 10.0	5.0 – 10.0	5.0 – 10.0					
	Winter	≤1.0	≤1.0	≤1.0					≤1.0	≤1.0	≤1.0	≤1.0	≤1.0
ALL species combined	**Breeding**			10.0 - 20.0	10.0 - 20.0	10.0 - 20.0	10.0 - 20.0	10.0 - 20.0	10.0 - 20.0	10.0 - 20.0	10.0 - 20.0		
	Summer							10.0 - 20.0	10.0 - 20.0				
	Winter	10.0 - 20.0	10.0 - 20.0	10.0 - 20.0								10.0 - 20.0	10.0 - 20.0

Key	Not recorded	≤1.0	1.0 – 5.0	5.0 – 10.0	10.0 - 20.0	20.0 ->30.0

Seabirds are generally not at risk from routine offshore oil and gas production operations. However, they may be vulnerable to pollution from less regular offshore activities such as well testing and flaring, when hydrocarbon dropout to the sea surface can occasionally occur, or from unplanned events such as accidental oil or diesel releases. Marine Scotland have not identified any 'period of concern' for drilling activities within Block 22/24h (OGA, 2017a).

The vulnerability of seabirds in the Blocks and surrounding areas has been assessed according to JNCC's Seabird Oil Sensitivity Index (SOSI). Oil and Gas UK commissioned HiDef (a digital aerial video and image specialist consultancy) to develop the SOSI tool and the results are available on the JNCC website (JNCC, 2017a). This model index supersedes JNCC's Oil Vulnerability Index (OVI) (JNCC, 1999). The purpose of this index is to identify areas where seabirds are likely to be most sensitive to oil pollution by considering factors that make a species more or less sensitive to oil-related impacts.

The SOSI combines the seabird survey data with individual seabird species sensitivity index values. These values are based on a number of factors which are considered to contribute towards the sensitivity of seabirds to oil pollution, and include:

- Habitat flexibility (the ability of a species to locate to alternative feeding grounds);
- Adult survival rate;
- Potential annual productivity; and
- The proportion of the biogeographical population in the UK (classified following the methods developed by Certain *et al.,* (2015)).

The combined seabird data and species sensitivity index values were then subsequently summed at each location to create a single measure of seabird sensitivity to oil pollution. The mean sensitivity SOSI data for the area is shown in Figure 3-11 and Table 3-4. For Blocks with 'no data', an indirect assessment has been made (where possible) using JNCC guidance (JNCC, 2017a). The sensitivity of birds to surface oil pollution is low throughout the year for 22/24 and its surrounding Blocks (JNCC, 2017a).

Figure 3-11: SOSI and indirect assessment for Block 22/24 and adjacent Blocks (JNCC, 2017a).

Table 3-4: SOSI and indirect assessment for Block 22/24 (inc. adjacent Blocks) (JNCC, 2017a).

Block	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22/18	5	5	5	5*	5*	5	5	5	5	5*	ND	5*
22/19	5	5	5	5*	5*	5	5	5	5	5*	ND	5*
22/20	5	5	5*	ND	5*	5	5	5	5	5*	ND	5*
22/23	5	5	5	5*	5*	5	5	5	5	5*	ND	5*
22/24	**5**	**5**	**5**	**5***	**5***	**5**	**5**	**5**	**5**	**5***	**ND**	**5***
22/25	5	5	5	5*	5*	5	5	5	5	5*	ND	5*
22/28	5	5	5	5*	5*	5	5	5	5	5*	ND	5*
22/29	5	5	5	5*	5*	5	5	5	5	5*	ND	5*
22/30	5	5	5	5*	5*	5	5	5	5	5*	ND	5*

Key					
	1 Extremely High	2 Very High	3 High	4 Medium	5 Low
	Indirect Assessment – data gaps have been populated following guidance provided by the JNCC (JNCC, 2017a). ** Data gap filled using data from the same Block in adjacent months.*				

3.4.5 Marine Mammals

Marine mammals include pinnipeds (seals) and cetaceans (whales, dolphins and porpoises). Marine mammals are vulnerable to the direct effects of oil and gas activities such as noise, contaminants and oil spills. They may also be affected indirectly by activities that affect prey availability.

3.4.5.1 *Pinnipeds*

Five species of seal have been identified in the North Sea and surrounding locations; these include the grey seal *Halichoerus grypus*, harbour seal *Phoca vitulina*, harp seal *Phoca groenlandica*, hooded seal *Cystophora cristata* and ringed seal *Pusa hispida*. Of these, grey and harbour seals are most likely to be found in the CNS, and both are protected under Annex II of the EU Directive.

Distribution maps based on telemetry data (1991 - 2012) and count data (1988 – 2012) indicate that grey seals and harbour seals are unlikely to occur in the vicinity of the proposed project (Figure 3-12).

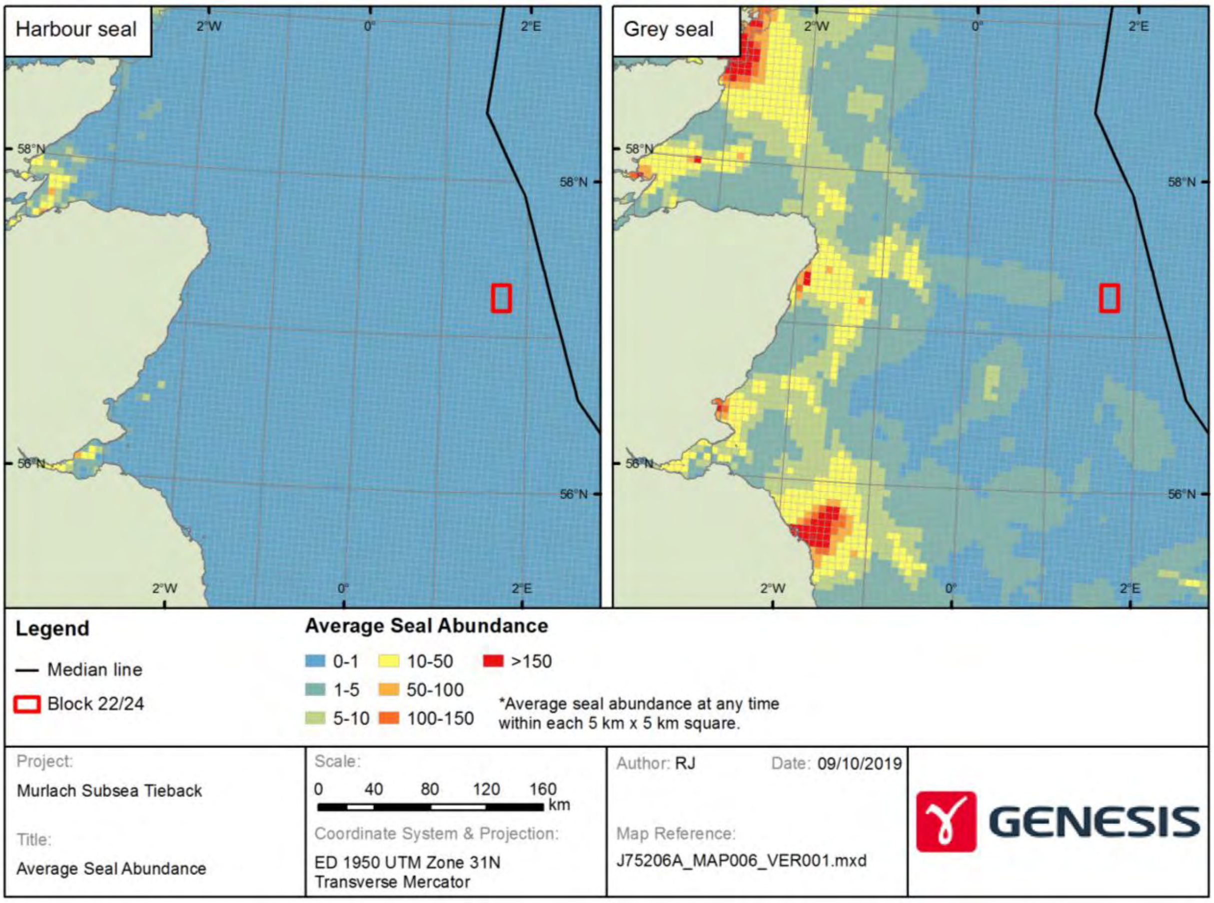


Figure 3-12: Harbour and grey seal distribution in relation to the Murlach development area (SMRU and Marine Scotland, 2017

3.4.5.2 *Cetaceans*

Many activities associated with the offshore oil and gas industry have the potential to impact on cetaceans by causing physical injury, disturbance or changes in behaviour. Activities with the potential to cause disturbance or behavioural effects include: drilling, seismic surveys, vessel movements, construction work including piling and decommissioning.

The JNCC has compiled an Atlas of Cetacean Distribution in Northwest European Waters (Reid *et al.,* 2003) which gives an indication of the annual distribution and abundance of cetacean species in the North Sea. Table 3-5 provides the monthly occurrence of cetacean species in the Murlach area. Some of the species listed here can also be observed in the Small Cetacean Abundance in the North Sea (SCANS-III) data provided in Table 3-6**.**

Table 3-5: Seasonal occurrence of cetaceans in the water around the Murlach Field (Reid *et al*., 2003; Scottish Government NMPi).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
White-sided dolphin					3	3	3	3				
White-beaked dolphin					2		3	3		3	1	
Harbour porpoise				3	3	3	3					
Minke whale						3	2	3				
Key Blank : No sightings	1: High Density				2: Moderate Density				3: Low Density			

Figure 3-13 shows the annual abundance and distribution of cetacean species most likely to occur in the area.

Data suggests that white-sided dolphin, white-beaked dolphin, harbour porpoise and minke whale have been recorded within ICES rectangle 43F1 (Reid *et al.,* 2003). These species of cetacean are all listed as mobile species on the PMF list; and are subject to appropriate protection and conservation measures (Tyler-Walters *et al*., 2016).

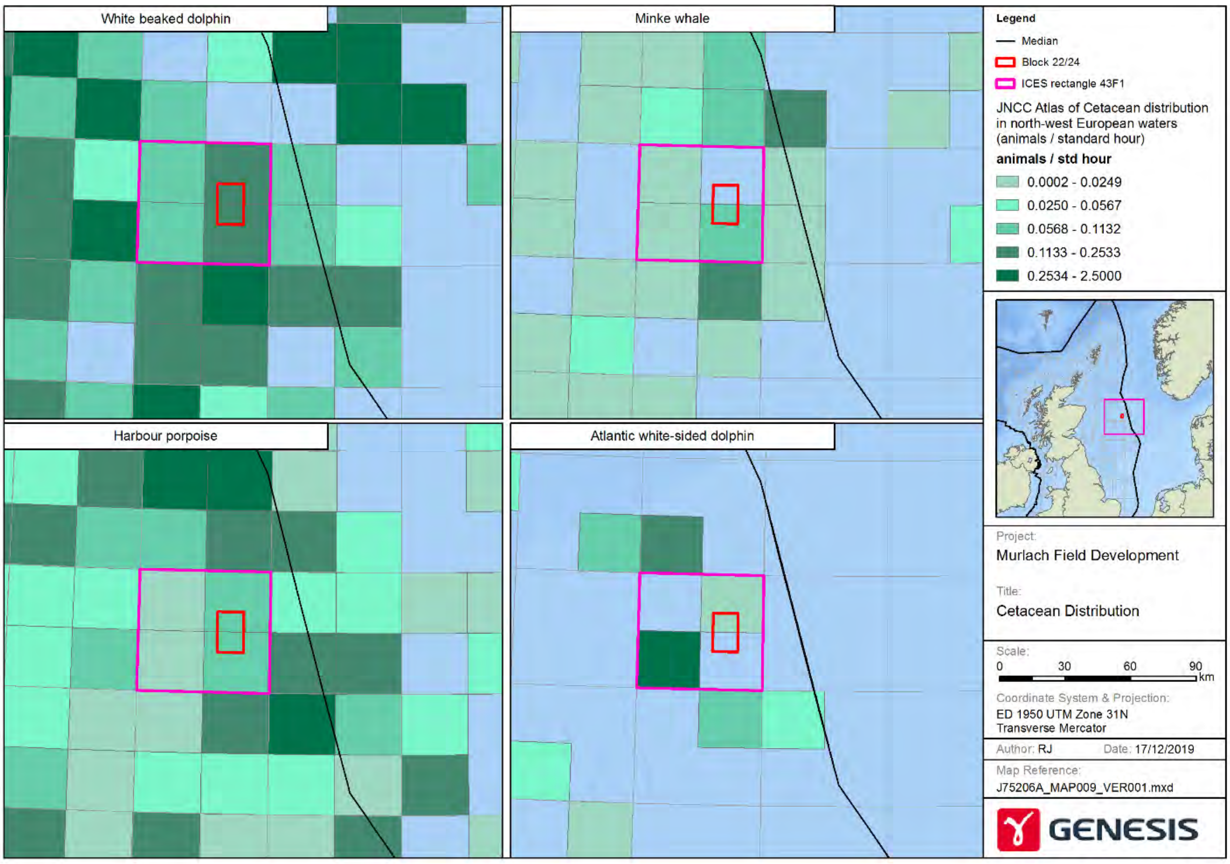


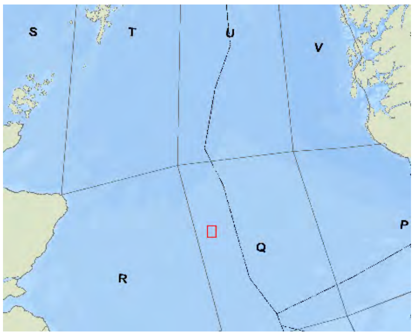
Figure 3-13: Distribution of cetacean species around Block 22/24 and ICES rectangle 43F1 (Reid *et al.,* 2003).

A series of SCANS surveys have been conducted to obtain an estimate of cetacean abundance in North Sea and adjacent waters. The results from the most recent survey (SCANS-III) are presented in Hammond *et al.,* (2017). Aerial and shipboard surveys were carried out during the summer of 2016 to collect data on the abundance of harbour porpoise, bottlenose dolphin, Risso's dolphin, white-beaked dolphin, white-sided dolphin, common dolphin, striped dolphin, pilot whale, all beaked whale species combined, sperm whale, minke whale and fin whale.

The Murlach area is located within SCANS-III survey block "Q". Aerial survey estimates of animal abundance and densities (animals per km^2) within this area are provided in Table 3-6.

Table 3-6: Cetacean abundance in SCANS-III Survey Block "Q" (Hammond *et al.*, 2017).

Survey Block	Species	Animal Abundance (MU)[2]	Density (animals/km^2)[1]
Q	Harbour porpoise	16,569	0.333
	Minke whales	348	0.007



The JNCC have published 'regional' population estimates for the seven most common species of cetacean occurring in UK waters (Inter-Agency Marine Mammal Working Group (IAMMWG, 2021) within ecologically defined spatial Management Units (MUs). The estimated abundance of animals in these MUs are currently considered the reference populations for cetacean species in the North and Celtic Seas (Table 3-7).

Table 3-7: MU cetacean abundance (IAMMWG, 2021).

Species	MU Name	MU Population
Harbour porpoise	North Sea	346,601
White-beaked dolphin	Celtic and Greater North Seas	43,951
White-sided dolphin	Celtic and Greater North Seas	18,128
Minke whale	Celtic and Greater North Seas	20,118

3.5 Conservation of Habitats and Species

A network of Marine Protected Areas (MPAs) is in place to aid the protection of vulnerable and endangered species and habitats through structured legislation and policies. These sites include Special Areas of Conservation (SAC) and Special Protection Areas (SPA), which were designated in the UK under the EU Nature Directives (prior to January 2021) and are now maintained and designated under the Habitats Regulations for England and Wales, Scotland, and Northern Ireland.

Amendments to the Habitats Regulations mean that the requirements of the EU Nature Directives continue to apply to how European sites (SACs and SPAs) are designated and protected. The Habitats Regulations also provide a legal framework for species requiring strict protection, e.g., EPS.

The protected sites in closest proximity to the Murlach Field are shown in

Figure **3-14** and those within 100 km of the field are summarised in Table 3-8. Details of other protected sites that are further from the Murlach field, including some international sites, are presented in Section 11.3.

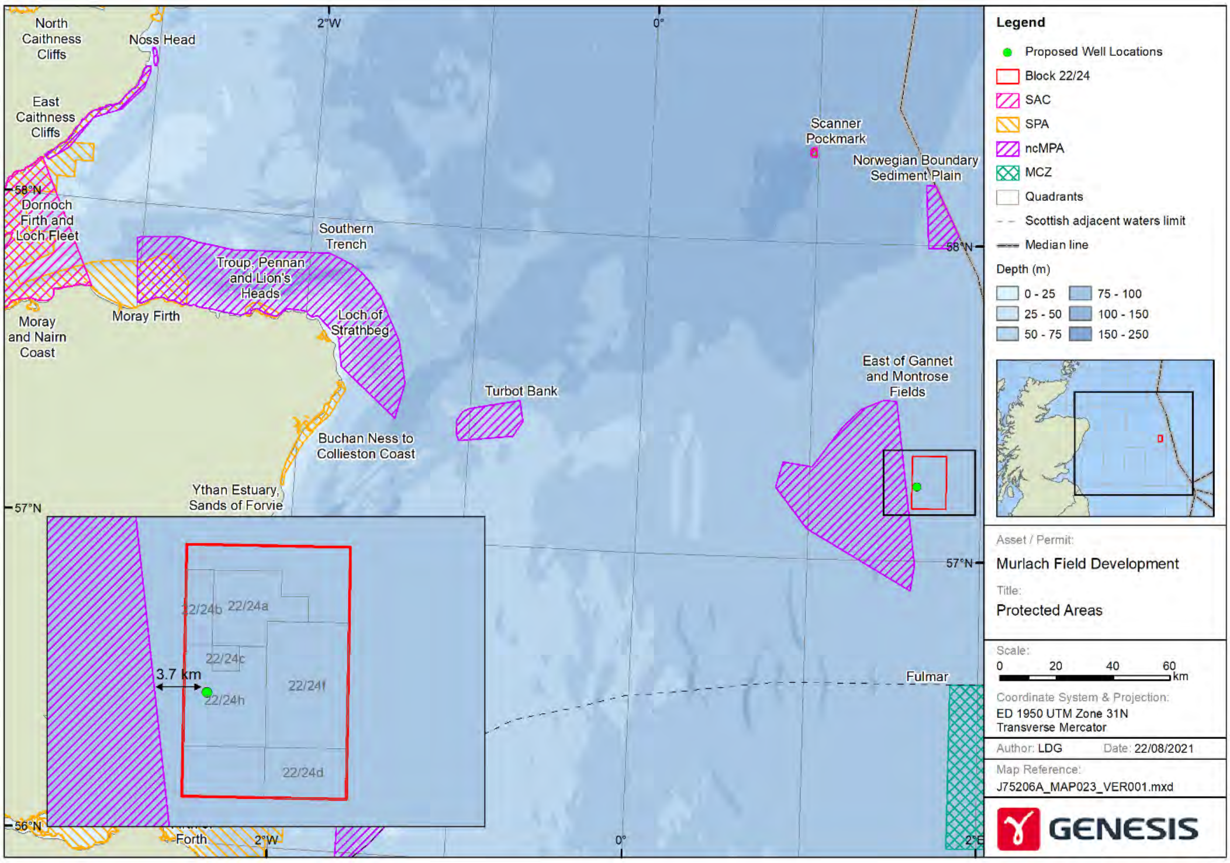


Figure 3-14: Protected areas in the region.

Table 3-8: Protected areas and distances from the proposed project (JNCC, 2017b; JNCC, 2017c, JNCC, 2017d).

Area	Qualifying Features	Approximate distance from Murlach drill centre (km)
East of Gannet and Montrose Field NCMPA	Habitat made up of offshore deep sea muds. The ocean quahog (*Arctica islandica*), a low or limited mobility species, is present in this area.	3.7
Fulmar MCZ	Designated for subtidal sand, mud and mixed sediment habitats and the presence of *Arctica islandica*.	70.5
Norwegian Boundary Sediment Plain NCMPA	Ocean quahog habitat and community present.	84

3.5.1 Species

The designation of fish species requiring special protection in UK waters is receiving increasing attention with particular consideration being paid to large slow growing species such as sharks and rays. A number of international laws, conventions and regulations as well as national legislation have been implemented which provide for the protection of these species. They include:

- **The UK Biodiversity Action Plan (BAP)** priority fish species (JNCC, 2007);
- **The OSPAR List of Threatened and/or Declining Species & Habitats** (OSPAR, accessed 2021);

- **The IUCN (International Union for Conservation of Nature) Red List of Threatened Species** (IUCN, 2021).
- **The Wildlife and Countryside Act 1981** (which consolidates and amends existing national legislation to implement the Convention on the Conservation of European Wildlife and Natural Habitats **(Bern Convention)** and the Birds Directive in Great Britain) (JNCC, 2020). The Wildlife and Countryside Act makes it an offence to intentionally kill, injure, possess or trade any animal listed in Schedule 5 and to interfere with places used by such animals for shelter or protection.
- **The EC Habitats Directive** (transposed into UK law through the Conservation of Habitats and Species Regulations 2010 in England and Wales and also the 1994 Regulations in Scotland).

Four marine mammal species listed under Annex II of the Habitats Directive occur in relatively large numbers in UK offshore waters:

- Grey seal (*Halichoerus grypus*);
- Harbour seal (*Phoca vitulina*);
- Bottlenose dolphin (*Tursiops truncatus*); and
- Harbour porpoise (*Phocoena phocoena*).

Of these four species only the harbour porpoise is expected to occur in any significant numbers the vicinity of the Murlach Field. The bottlenose dolphin and harbour porpoise, like all the cetacean species found in UK waters, also have EPS status, along with several other marine mammals found in UK waters. Developers must therefore consider the requirement to apply for the necessary licences if there is a risk of causing any potential disturbance / injury to EPS.

Under the Habitats Regulations, it is an offence to deliberately disturb any EPS, e.g. cetaceans, or to capture, injure or kill an EPS at any time. New projects / developments must demonstrate that they will not significantly disturb an EPS in a way that will affect:

- the ability of the species to survive, breed, rear or nurture its young or affect its hibernating or migration patterns (termed the injury offence); or
- the local distribution or abundance of any protected species (termed the disturbance offence).

3.5.2 Priority Marine Features (PMFs)

In addition to the list of features of nature conservation importance for which it is deemed appropriate to use area-based mechanisms (MPAs) as a means of affording protection, as part of the Scottish MPA Project, SNH and JNCC have compiled a separate list of 80 habitats and species, termed PMFs which are considered to be of particular importance in Scotland's seas. The purpose of this list is to guide policy decisions regarding conservation in Scottish waters. The following PMFs species are potentially of highest relevance to the proposed Murlach Field Development (Tyler-Walters, 2016):

Mobile Species (fish)

- Norway pout
- Sandeel
- Mackerel
- Blue Whiting
- Cod
- Whiting
- Ling
- Anglerfish

Low or limited mobility species (benthos)

- *A. islandica*

Mobile Species (cetaceans)

- Atlantic white-sided dolphin
- Harbour porpoise
- White-beaked dolphin
- Minke whale

3.6 Socio-Economic Environment

The following paragraphs consider both positive and negative socio-economic impacts in terms of benefits to the local communities and the country, along with the potential interface with existing industries and communities.

3.6.1 Social Impacts

There are both short term and long term positive social benefits resulting from the project in relation to the continuation and creation of skilled jobs in the construction yards, on the offshore installation vessels and within associated industries (road haulage, materials etc.). There will also be a need for project staff onshore to support the project. The project will help maintain employment in local services and supply industries and provide valuable monies into the economy.

3.6.2 Economic Impacts

The field is anticipated to produce significant hydrocarbon reserves with the option to expand the development in the future through drilling additional production wells. The positive impacts of this will be: the reduction in the UK's need to import hydrocarbons (making the UK less reliant on foreign oil and gas); the provision of increased revenue to the Exchequer; the provision of employment opportunities; and positive supply chain impacts. Projects like Murlach help to keep the skills and expertise needed for the energy transition within the UK.

3.6.3 Commercial Fisheries

Offshore structures have the potential to interfere with fishing activities as their physical presence may obstruct access to fishing grounds. Knowledge of fishing activities and the location of the major fishing grounds is therefore an important consideration when evaluating any potential impacts from offshore developments.

The ICES divides the north-east Atlantic into a number of rectangles measuring 30 nm by 30 nm. Each ICES rectangle covers approximately one half of one quadrant i.e. 15 license Blocks. The importance of an area to the fishing industry is assessed by measuring the fishing effort which may be defined as the number of days (time) x fleet capacity (tonnage and engine power). It should be noted that fishing activity may not be uniformly distributed over the area of the ICES rectangle.

The proposed project area is located within ICES rectangle 43F1. Based on UK annual fishing effort for vessels > 10 m the UK annual fishing effort in these ICES rectangles can be considered low. The total fishing effort in 43F1 was around 103 days in 2020 which constitutes 0.1% of the overall UK fishing effort in days[1]

[1] Note this value is based on landing values reported for ICES rectangles within which more than five UK vessels measuring 10 m were active. In those ICES rectangles where < 5 vessels were active the information is considered disclosive and is therefore not available.

(Marine Scotland, 2021). Between 2016 and 2020, the highest fishing effort in 43F1 was in 2016 with 272 days. This represents 0.2% of the UK total. Figure 3-15 shows the average fishing intensity between 2016 and 2020. A more detailed breakdown of effort in days within ICES rectangle 43F1 and, more broadly, the UK total is given in Table 3-9.

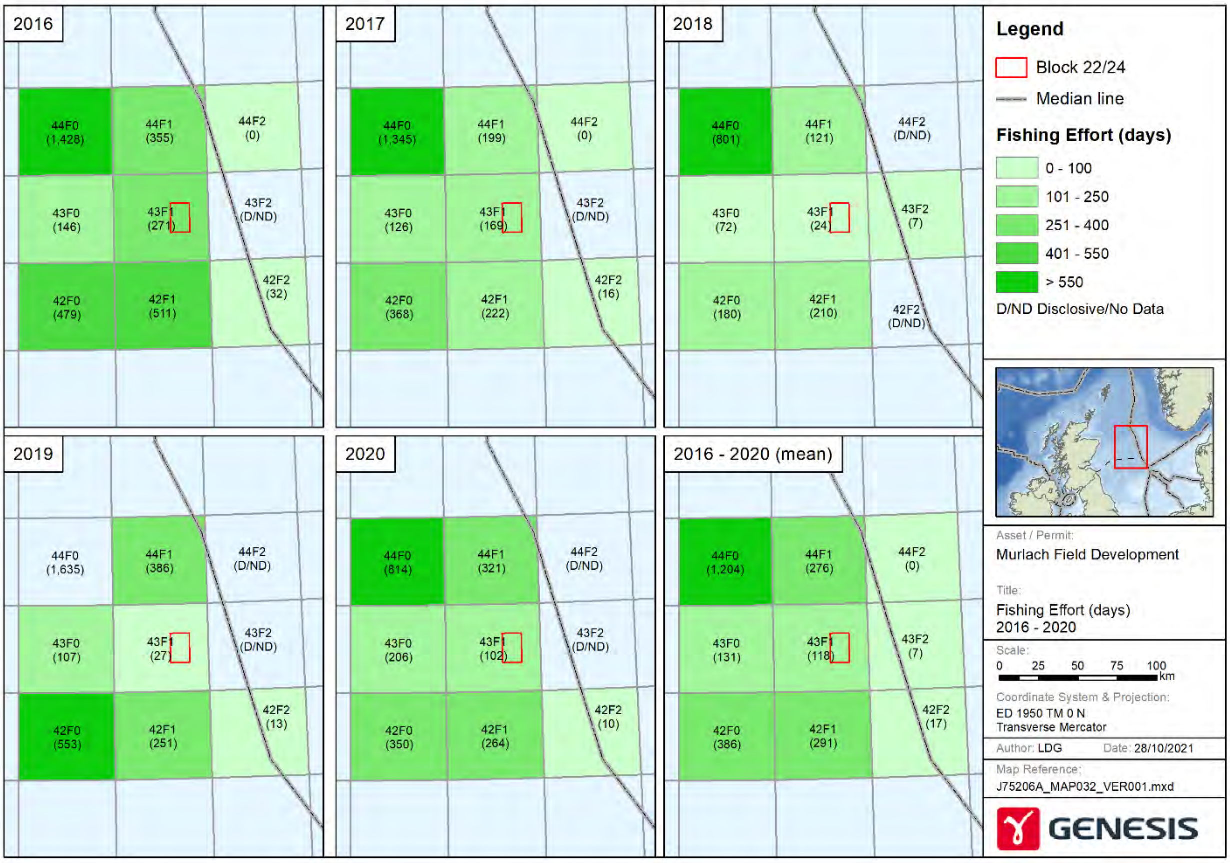


Figure 3-15: Fishing effort in the vicinity of the Murlach Field over five years (2016-2020) (Marine Scotland, 2021).

Table 3-9: Annual fishing effort in ICES rectangle 43F1 (Marine Scotland, 2021).

Year	UK Total Effort (days)	Effort (days) in 43F1	% of UK total
2016	131,589.7	271.7	0.2%
2017	125,831.0	169.7	0.1%
2018	124,843.6	24.2	0.0%
2019	126,353.3	27.8	0.0%
2020	103,917.6	102.8	0.1%
Average	122, 507.1	119.2	0.1%

'Within year' fishing effort is detailed in Table 3-10. Generally, the majority of fishing effort takes place in the summer months between May and September. Data from 2016 – 2020 shows seine nets and trawls were the only gear types used in 43F1. Trawls were the main gear type used, with the highest value of 266 days in 2016. Seine nets were also used; however, the data is classified as disclosive and are not available (i.e. less than five vessels (>10 m) undertook fishing activity) (Marine Scotland, 2021).

Table 3-10: 'Within year' fishing effort (2016 – 2020) (Marine Scotland, 2021).

Year	J	F	M	A	M	J	J	A	S	O	N	D
2016	D	D	20	D	59	0	D	D	148	14	0	13
2017	29	D	0	D	D	9	D	115	D	D	D	D
2018	8	D	0	0	D	D	0	D	0	D	0	D
2019	6	D	D	0	D	D	D	D	0	D	D	0
2020	5	D	D	D	D	14	D	36	D	D	D	D
KEY:	**Disclosive data***		**≤ 20 days**		**21 – 30 days**		**31 – 40 days**		**41 – 50 days**		**>51 days**	
If less than five vessels over 10 metres undertook fishing activity in the ICES rectangle the data is considered to be disclosive (D) and therefore not shown.* **Note: *In Table 3-9 the total number of effort days for ICES rectangle 43F1 includes the months with disclosive data and the total therefore may not equal the number of days shown here.*												

Figure 3-16 shows the annual landings between 2016 – 2020 of demersal, pelagic and shellfish species in ICES rectangle 43F1. Landings within this area are varied, with demersal fish species dominating weight and value in 2017, 2018, 2019, and 2020 and shellfish dominating in 2016 (Table 3-11)[2].

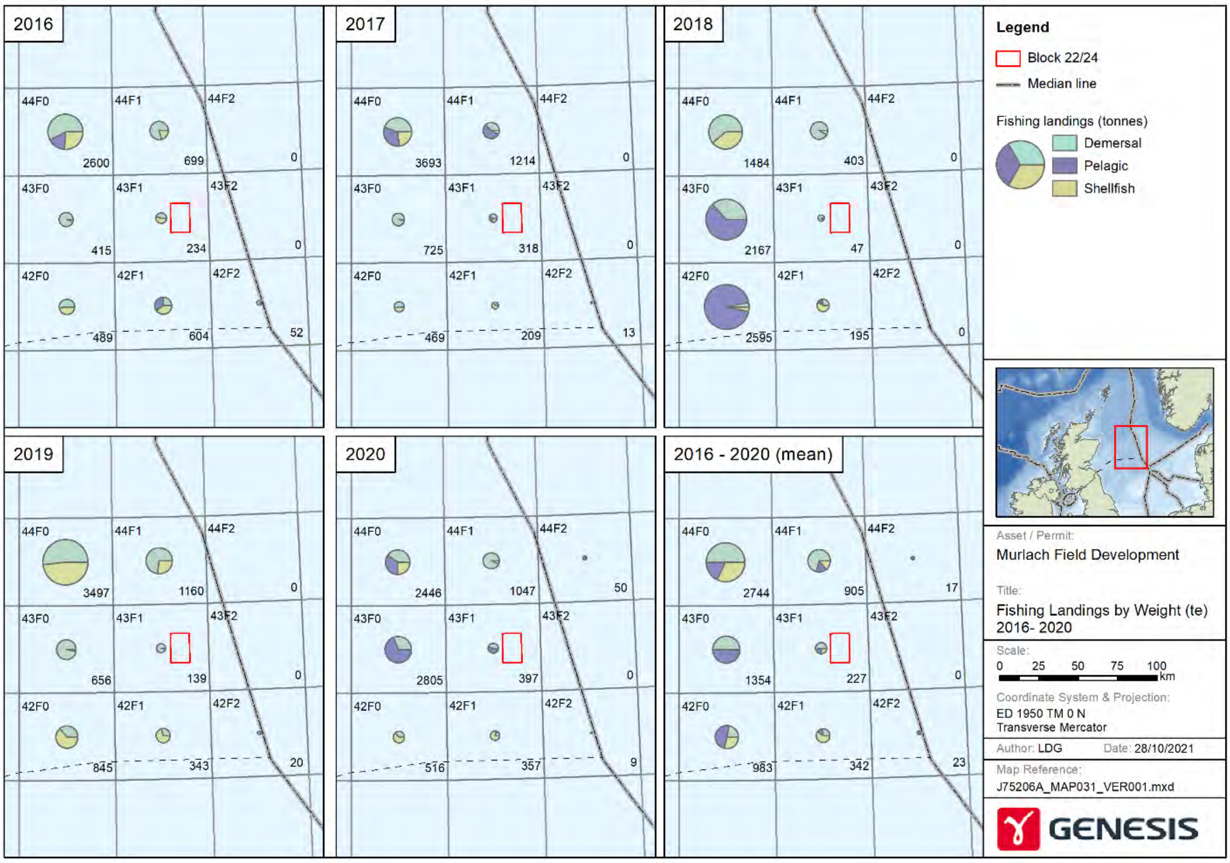


Figure 3-16: UK reported landings by quantity (te) within the Murlach region (2016 – 2020) (Marine Scotland, 2021).

[2] As for fishing effort data, reporting landing data provided refers to landings data by UK vessels over 10 m into UK ports where > 5 m vessels have been active.

Table 3-11: Landings data by species type between 2016 and 2020 in the Murlach area.

Year/ data		Demersal	Pelagic	Shellfish	Total
2016	Value (£)	136,761	967	528,622	666,349
	Live Weight (Te)	106	1	127	234
2017	Value (£)	183,682	33,760	409,909	627,351
	Live Weight (Te)	142	80	95	318
2018	Value (£)	56,045	90	21,766	77,901
	Live Weight (Te)	43	0	4	47
2019	Value (£)	149,129	0	18,736	167, 865
	Live Weight (Te)	136	0	4	139
2020	Value (£)	243,507	126,798	107,078	477,382
	Live Weight (Te)	182	173	42	397

3.6.4 Aquaculture

The worldwide decline of ocean fisheries stocks has provided impetus for the rapid growth of aquaculture. For example, between 1987 and 1997 global production of farmed fish and shellfish more than doubled in weight and value (Naylor et al. 2000). The aquaculture industry is important to Scotland's economic growth and is supported by the Aquaculture and Fisheries (Scotland) Act 2013 which aims to ensure that the interactions between farmed and wild fisheries are managed effectively to maximise their contribution to supporting sustainable economic growth.

The nearest finfish and shellfish farms to the proposed development are *c.* 215 km away (Figure 3-17). They are not expected to be impacted by the routine operations; however the sites may be at risk in the event of a well blowout.

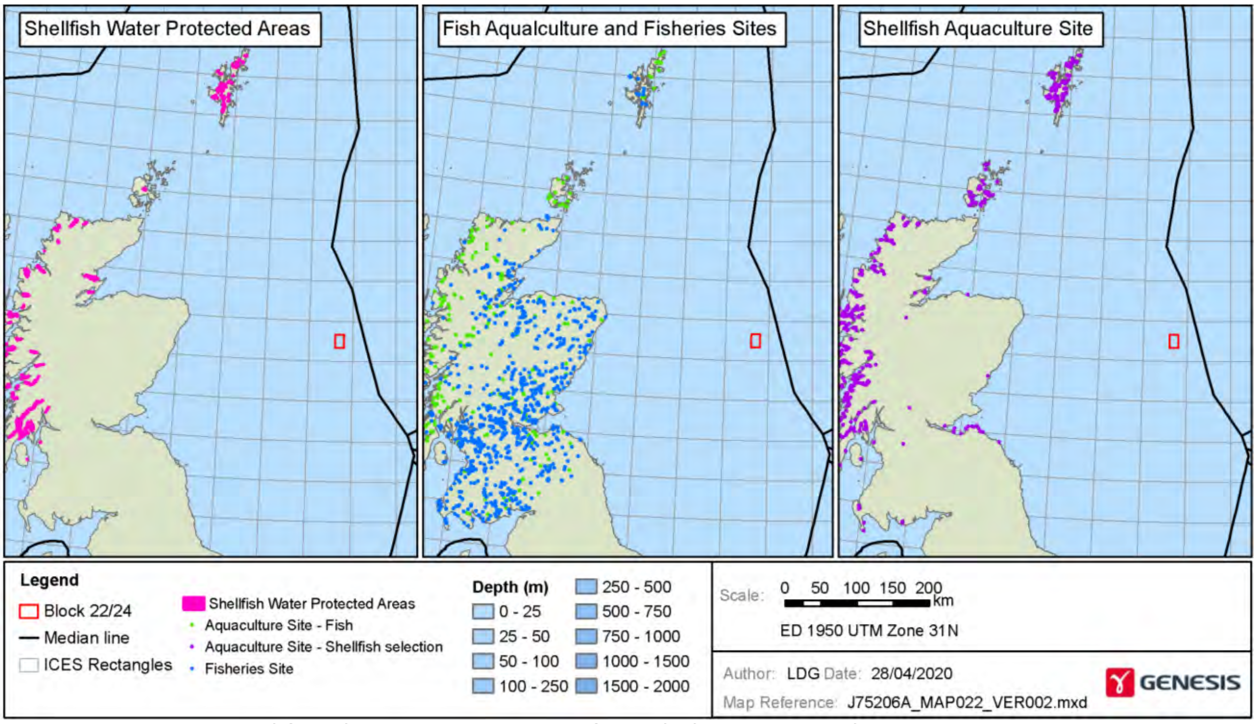


Figure 3-17: Location of Shellfish Water Protection Sites, finfish, and shellfish aquaculture sites in relation to the Murlach area (Scottish Government NMPi).

3.6.5 Shellfish Water Protection Sites

The Water Environment (Shellfish Water Protected Areas: Designation) (Scotland) Order 2013 provides for the protection of water bodies in Scotland for a number of special purposes, including shellfish harvesting. This recognises the need for clean water in shellfish production areas to ensure a good quality product which is safe for human consumption. A number of sites have been designated on the Shetland and Orkney Islands (Figure 3-17). Water bodies can be impacted by pollution from various sources, such as run-off from agricultural land or discharges from sewage treatment works. These sites are not expected to be impacted by the routine operations, however they may be at risk in the event of an accidental spill.

3.6.6 Shipping

The North Sea contains some of the busiest shipping routes in the world, with significant traffic generated by vessels trading between ports at either side of the North Sea and the Baltic and through servicing the offshore oil, gas and renewables industries. Shipping activities in the North Sea are categorised by OGA (2017b) to have either: very low; low; moderate; high; or very high shipping density. The shipping activity within Block 22/24 is considered to be very low as shown in Figure 3-18 (OGA, 2017b).

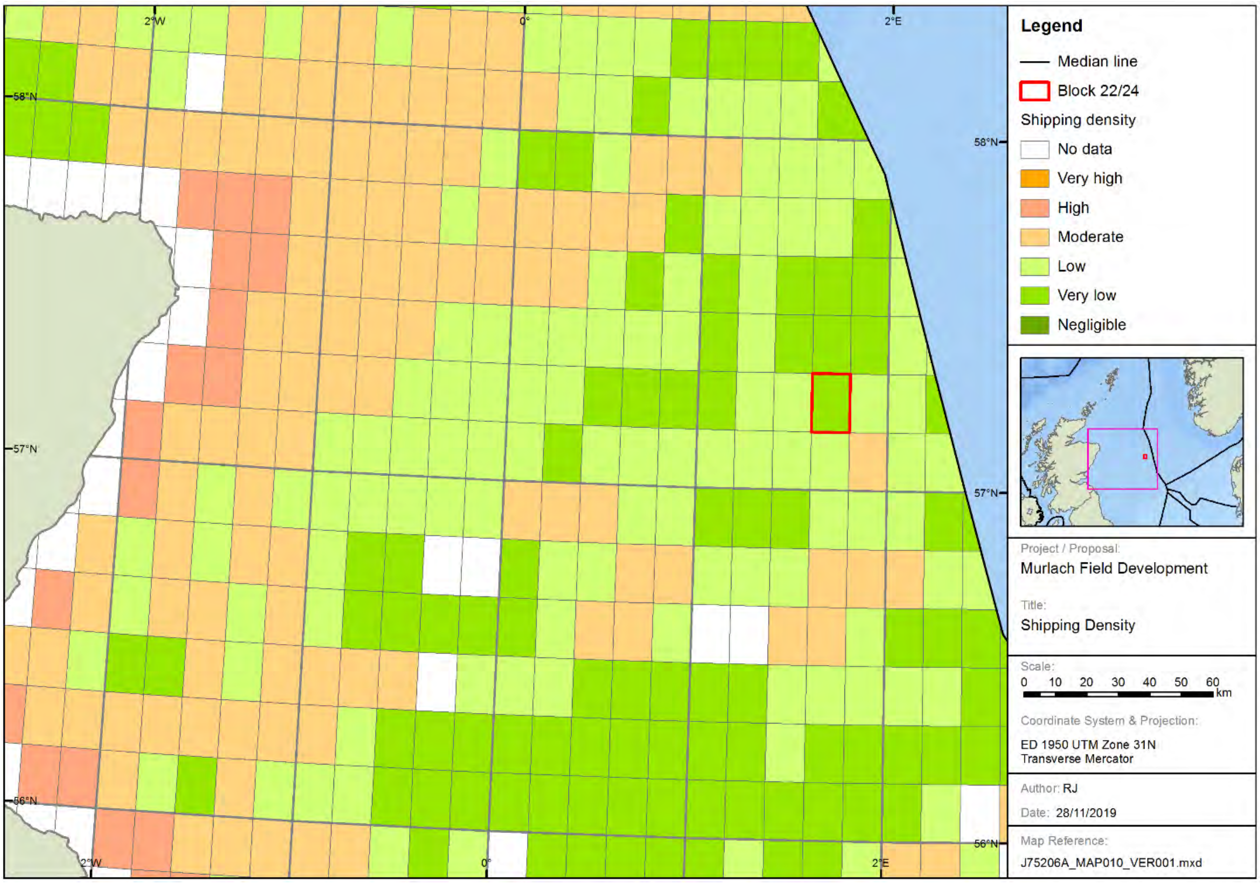


Figure 3-18: Shipping density as categorised by OGA (OGA, 2017b).

3.6.7 Oil and Gas Exploration

As shown in Figure 3-19 and Table 3-12, the Murlach Field lies within a well-developed area of existing oil and gas infrastructure and activity.

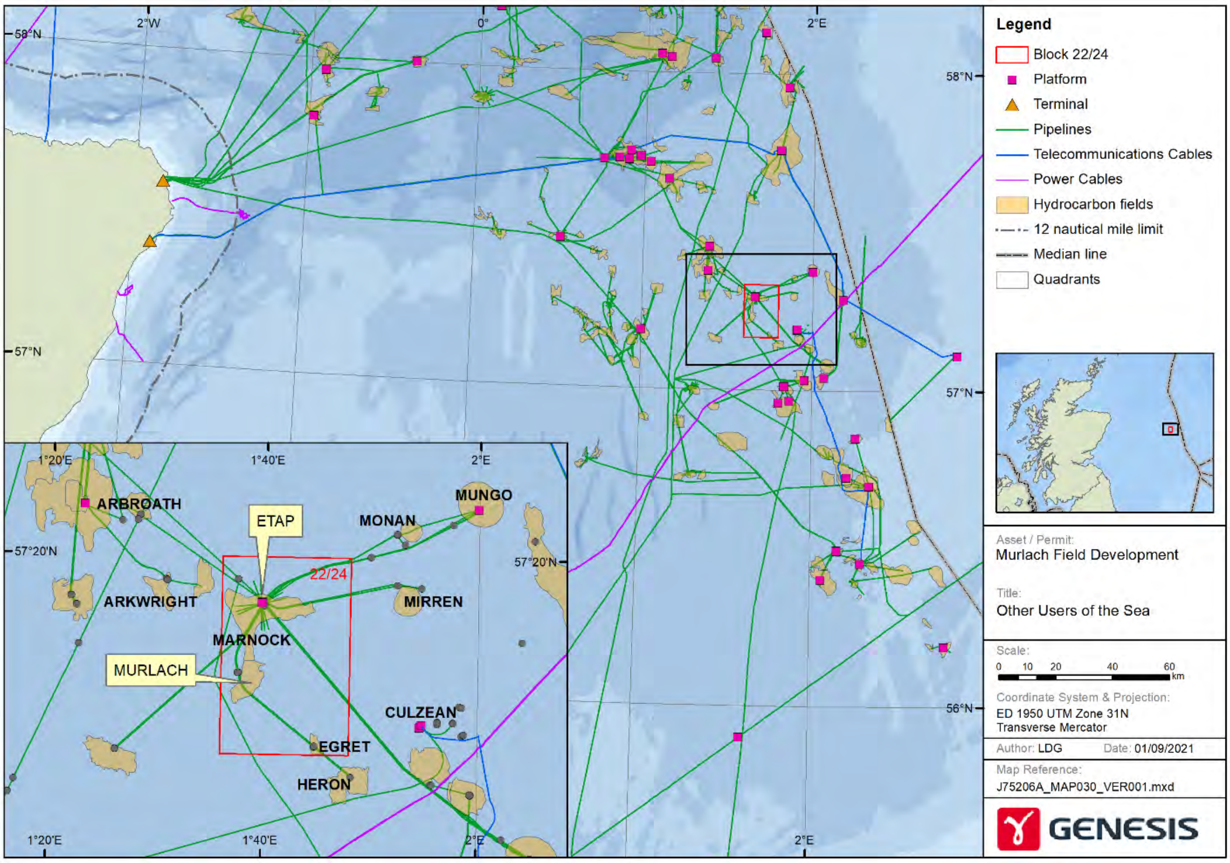


Figure 3-19: Other users of the sea within the vicinity of Murlach.

Table 3-12: Approximate distance of neighbouring installations to the Murlach development.

Installation	Approximate Distance (km)
ETAP	7
Culzean Platform	17.5
Arbroath Platform	21.5
Mungo	22

3.6.8 Submarine Cables

There are no telecommunications cables within the Murlach Field. The closest active submarine telecommunications cable is the CNS fibre optic cable, located *c.* 33.5 km east of the wells location shown in Figure 3-20 (Scottish Government NMPi).

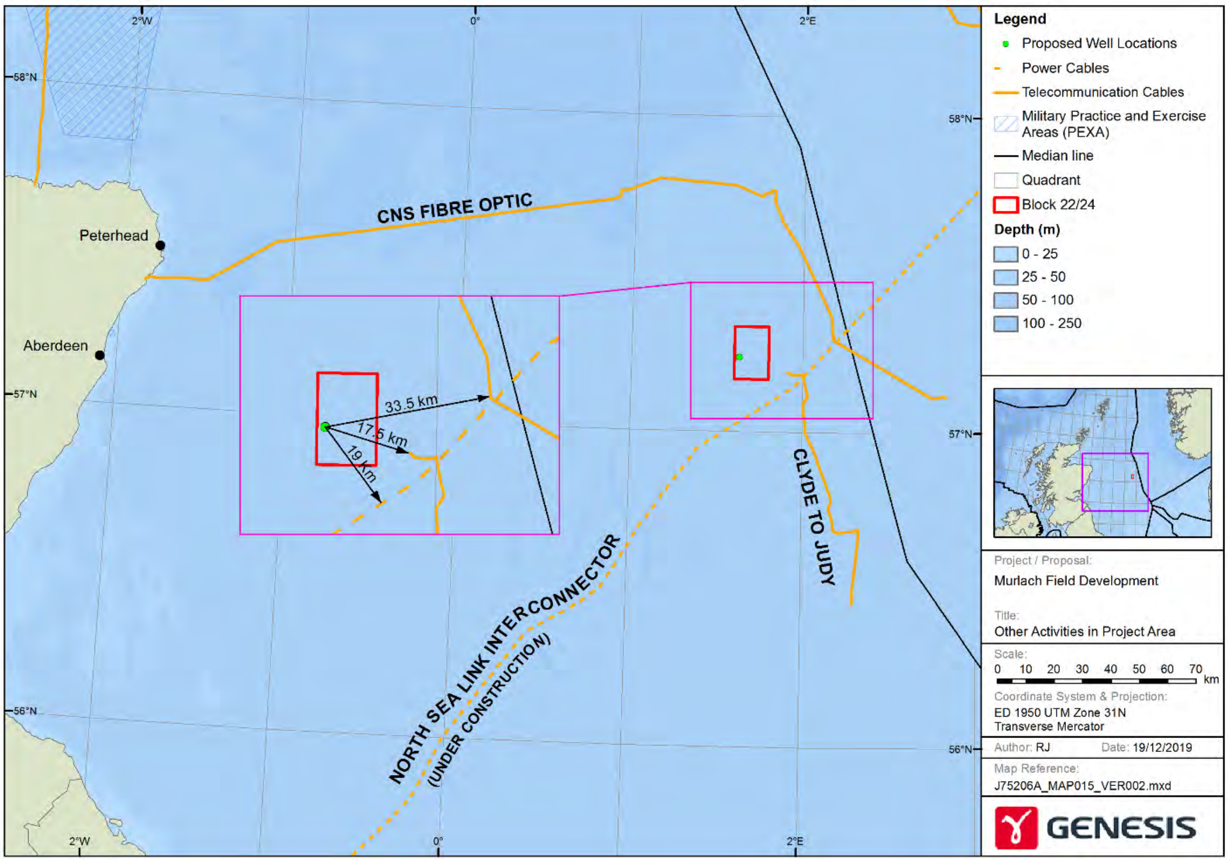


Figure 3-20: Telecommunication cables in the vicinity of Block 22/24 (Scottish Government NMPi).

3.6.9 Military Activities

There are no military exercise areas within or near to Block 22/24 (Figure 3-20) (OGA, 2017a; Scottish Government NMPi).

3.6.10 Cultural Heritage

There are a number of wrecks located around the Murlach development area, as shown in Figure 3-21. The closest wreck (unnamed) is *c.* 4 km from the manifold location. At this distance no known wrecks are expected to be impacted by the proposed activities.

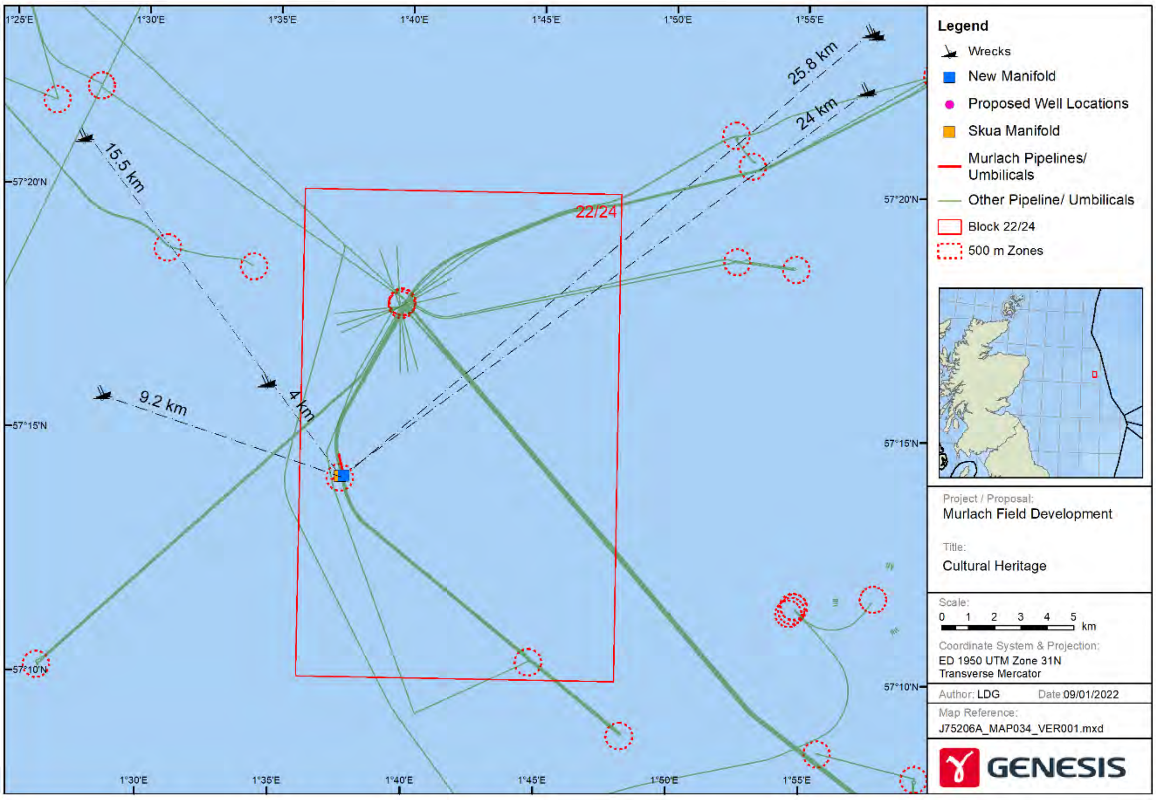


Figure 3-21: Wrecks in the vicinity of Block 22/24.

4. ENVIRONMENTAL IMPACT ASSESSMENT METHODOLOGY

4.1 Introduction

This section presents the Environmental and Socio-Economic Impact Assessment (ESIA) and the Environmental and Socio-Economic Risk Assessment (ESRA) matrices used to determine the impact of the planned and unplanned activities (respectively) associated with the Murlach Field Development.

4.2 Receptors and Aspects

Prior to carrying out the ESIA / ESRA the potential receptors likely to be impacted were identified (Section 3.

4.2.1 Environmental and Socio-Economic Receptors

Receptors to be considered in the ESIA and ESRA include:

Environmental receptors:

- Resource availability;
- Air quality;
- Water quality;
- Sediment quality;
- Plankton;
- Benthic communities (including flora and fauna);
- Fish;
- Marine mammals;
- Seabirds;
- Coastal marine communities;
- Designated areas.

Socio-economic receptors:

- Landfill resources;
- Fisheries;
- Shipping.

4.2.2 Identification of Aspects

Aspects to be considered include:

- Energy use and emissions to air;
- Physical presence of vessels and drilling rig;
- Physical presence of infrastructure installed;
- Discharges to sea;
- Disturbance to the seabed;
- Underwater noise;
- Waste generation;
- Resource use; and
- Unplanned events.

The aspects associated with each activity were assessed in terms of their impact on the receptors in the area. For example, the use of vessels will result in emissions to air, discharges to sea, underwater noise, physical use of space and, if anchored, disturbance to the seabed. Receptors potentially impacted by these aspects include air quality, marine mammals, seabirds, other users of the sea, seabed sediments and benthic communities (if anchored).

4.3 ESIA for Planned Activities

The significance of the environmental/socio-economic impact of planned activities on each of the susceptible receptors is derived by considering the 'Receptor Sensitivity' in relation to the 'Magnitude of Effect' of the aspect.

4.3.1 Receptor Sensitivity

Four categories of Receptor Sensitivity are applied ranging from 'Low' to 'Very High' as shown in Table 4-1.

Table 4-1 Receptor Sensitivity to a planned activity and an unplanned event.

Category	Environmental / Societal Definition
(a) Low	**Flora/Fauna/Habitats - within the impacted area:** • Population sizes are considered to be of little to no geographical importance. • Species do not have designated conservation status and are of IUCN 'Least Concern'. • No designated habitat/sites. • Impacted species are widespread in the North East Atlantic region. **Air quality:** Emissions may impact on other nearby installations. **Water quality:** Open offshore water body. **Cultural heritage sites:** Site integrity is already compromised. **Resource availability:** (e.g. landfill sites, diesel use) Renewable and/or abundant. **Third party users:** have capacity to absorb change without impact.
(b) Medium	**Flora/Fauna/Habitats – within the impacted area:** • Significant numbers of at least one receptor of national importance (e.g. PMFs). • Significant numbers of a species which is listed as IUCN 'Near Threatened'. • Nationally designated habitat/sites (e.g. PMFs). • Species may be of regional value. **Air quality**: Populated areas nearby. **Water quality**: Semi-enclosed water body with good flushing. **Cultural heritage sites:** Site is of local heritage importance. **Resource availability**: (e.g. landfill sites, diesel use) Renewable and/or available. **Third party users:** have capacity to absorb change without significant impact.
(c) High	**Flora/Fauna/Habitats – within the impacted area:** • Significant numbers of at least one receptor of regional (European) importance (e.g. Annex II / IV species and OSPAR designations). • Significant numbers of a species which are listed as IUCN 'Vulnerable'. • Regionally designated habitats/sites (e.g. OSPAR designations and Annex I habitats: SACs and SPAs). • Locally distinct sub-populations of some species may occur. **Air quality:** Densely populated areas nearby. **Water quality:** Semi-enclosed water body with limited flushing. **Cultural heritage sites:** Site is of regional heritage importance. **Resource availability:** (e.g. landfill sites, diesel use) Not renewable and/or limited availability. **Third party users:** have low capacity to absorb change and significant impact is likely to occur.

Category	Environmental / Societal Definition
(d) Very High	**Flora/Fauna/Habitat – within the impacted area:** • Significant numbers of at least one receptor of international importance. • Significant numbers of a species which are listed as IUCN 'Endangered' or 'Critically Endangered'. • Internationally designated habitats/sites (e.g. Ramsar sites). • At least one receptor is endemic (unique) to the area. **Air quality:** Very densely populated area with sensitive receptors such as schools and hospitals. **Water quality:** Enclosed water body with no flushing. **Cultural heritage sites:** Site is of international heritage importance. **Resource availability:** (e.g. landfill sites, diesel use) Not renewable and/or scarce availability. **Third party users:** have no capacity to absorb change e.g. unemployment due to long term closure of fisheries.

4.3.2 Climate Change

With respect to the emission of greenhouse gases, climate is considered a global receptor rather than a local receptor. The categories identified in Table 4-1 do not capture definitions for climate change. This is because the sensitivity status of climate is considered to be 'Very High' in line with the 2021 Climate Change Report produced by the Intergovernmental Panel on Climate Change (IPCC, 2021).

4.3.3 Magnitude of Effect

Definitions for the Magnitude of Effect on the receptors are presented in Table 4-2. Prior to determining the Magnitude of Effect, industry recognised 'base case' mitigation measures were assumed to be applied. For example, on mobilisation of vessels to carry out the work BPEOC will notify other sea users (e.g. SFF). These additional mitigations are considered prior to identifying the residual impact.

Table 4-2 Magnitude of Effect.

Magnitude Level		Description	
		Environmental Impact	Socio-economic Impact
0	**Positive/No effect** *Regulatory compliance or Company goals are not a concern.*	**No environmental concerns** • Positive environmental impact e.g. retaining a 500 m safety zone resulting in a 'protected area'. • No significantly negative environmental effects.	**No public concerns** • Possible enhancement in the availability of a resource benefitting the persons utilising the area e.g. removal of 500 m safety zones results in return of access to fishing grounds. • No impacts on sites or features of cultural heritage. • No impact on resource or landfill availability.
1	**Negligible** *Regulatory compliance or Company goals are not breached.*	**Negligible environmental effects** • Any effects are unlikely to be discernible or measurable and will reverse naturally. • No beaching or transboundary impacts.	**Limited local public awareness and no concerns** • An intermittent short-term decrease in the availability of a resource which is unlikely to be noticed e.g. vessels working out-with existing 500 m safety zones could temporarily impact on a shipping route or fishing area. • Undiscernible changes to a site or feature of cultural heritage that do not affect key characteristics and are not above background changes. • Undiscernible use of a resource (e.g. diesel, rock cover or landfill).
2	**Minor** *Regulatory compliance is not breached.*	**Minor, localised, short term, reversible effect** • Any change to the receptor is considered low, would be barely detectable and at same scale as existing variability. • Recover naturally with no Company intervention required. • No beaching or transboundary impacts.	**Some local public awareness and concern** • A temporary (<1 year) decrease in the availability or quality of a resource e.g. access to fishing grounds may temporarily be inhibited due to presence of vessels. • Minor changes to a site or feature of cultural heritage that do not affect key characteristics. • Minor use of a resource (e.g. diesel, rockcover or landfill).
3	**Serious** *Possible minor breach of regulatory compliance.*	**Detectable environmental effect within the project area** • Medium localised changes to the receptor are possible. • Localised Company response may be required. • No beaching or transboundary impacts.	**Regional / local concerns at the community or stakeholder level which could lead to complaints** • Medium decrease in the short-term (1-2 years) availability or quality of a resource affecting usage e.g. bring a rig on site for 1-2 years. • Nuisance impacts e.g. marine growth odour coming from yards. • Partial loss of a site or feature of cultural heritage. • Moderate use of a resource (e.g. diesel, rockcover or landfill).

4	**Major effect** *Possible major breach of regulatory compliance.*	**Severe environmental damage extending beyond the project area** • High, widespread mid-term (2-5 years) degradation of the receptor. • Company response (with Corporate support) required to restore the environment. • Possible beaching and / or transboundary impacts.	**National stakeholder concerns leading to campaigns affecting the Company's reputation** • High mid-term (2-5 year) decrease in the availability or quality of a resource affecting usage e.g. closure of fishing grounds. • Substantial loss or damage to a site or feature of cultural heritage. • High use of a resource (e.g. diesel, rockcover or landfill).
5	**Critical effect** *Major breach of regulatory compliance resulting in project delays and prosecution.*	**Persistent severe environmental damage** • Very high, widespread long-term (>5 years) degradation to the receptor that cannot be readily rectified. • Major impact on the conservation objectives of internationally/nationally protected sites. • Full Corporate response required. • Major beaching and/or transboundary impacts.	**International public concern and media interest affecting the Company's reputation** • Very high decrease in availability of a resource and potentially livelihood of users for > 5 years e.g. *hydrocarbons on beaches affecting tourism or tainting of fish resulting in the long-term closure of fishing grounds.* • Total loss of a site or feature of cultural heritage. • Significant use of a resource (e.g. diesel, rock cover or landfill).

4.3.4 Cumulative Impacts

The EIA sets the activities and potential impacts in the context of all other activities taking place in the Murlach Field area to determine the additional cumulative effects of the new activities. The potential cumulative effects are discussed in the impact assessment chapters.

4.3.5 Environmental / Socio-Economic Impact Significance

The 'Receptor Sensitivity' and the 'Magnitude of Effect' were combined using the matrix presented in Table 4-3 to determine the level of impact for planned activities.

Table 4-3: Impact significance matrix.

		Receptor Sensitivity			
		(a) Low	(b) Medium	(c) High	(d) Very High
Magnitude of Effect	(0) Positive/No Effect	[blue]	[blue]	[blue]	[blue]
	(1) Negligible	[green]	[green]	[green]	[green]
	(2) Minor	[green]	[green]	[yellow]	[yellow]
	(3) Serious	[yellow]	[yellow]	[yellow]	[red]
	(4) Major	[yellow]	[yellow]	[red]	[red]
	(5) Critical	[red]	[red]	[red]	[red]

Definition of categories of risk significance	
(i) Positive / No Effect significance	• Positive or no environmental or socio-economic impact • No public interest or positive public support
(ii) Low significance	• No/negligible environmental and socio-economic impact • No concerns from consultees
(iii) Moderate significance	• Discernible environmental and socio-economic impacts • Requirements to identify project specific mitigation measures • Concerns by consultees which can be adequately addressed by the Company
(iv) High significance	• Substantial environmental and socio-economic impacts • Serious concerns by consultees requiring Corporate support • Alternative approaches should be identified

4.3.6 Transboundary Impacts

Where relevant, transboundary impacts of each aspect on the receptors is discussed in the impact assessment chapters e.g. the impact of emissions on climate change.

4.4 ESRA for Unplanned Events

To determine the environmental and socio-economic risk of an unplanned event (e.g. dropped object or well blowout), the following approach considers firstly the significance of the environmental or socio-economic impacts of an event should it occur and secondly the likelihood of the event occurring.

4.4.1 Environmental and Socio-economic Significance of an Unplanned Event

The ESIA approach described in Section 4.3 for determining the environmental and socio-economic impacts of planned activities was also used to determine the significance of impacts that may result from unplanned events.

4.4.2 Likelihood of an Unplanned Event

Five categories of ‘likelihood’ have been identified as presented in Table 4-4.

Table 4-4: Likelihood of an unplanned event.

Likelihood Category	Definition
Extremely Remote	Has never occurred within industry or similar industry but theoretically possible.
Remote	Similar event has occurred elsewhere but unlikely to occur with current practices.
Unlikely	Event has occurred in the industry during similar activities
Possible	Event could occur during project activities.
Likely	Event is likely to occur more than once during the project.

4.4.3 Environmental Risk of an Unplanned Event

Combining the significance of the environmental/socio-economic impact with the 'likelihood of the unplanned event occurring' allows the level of environmental risk to be determined using the matrix presented in Table 4-5. Note the potential for a beneficial impact significance has been removed as it is not expected that an unplanned event would lead to a beneficial environmental or socio-economic impact.

Table 4-5: ESRA matrix for unplanned activities.

		Environmental Significance of Unplanned Event*		
		(ii) Low	(iii) Moderate	(iv) High
Likelihood of Event	Extremely Remote	Low	Low	Low
	Remote	Low	Low	Medium
	Unlikely	Low	Medium	Medium
	Possible	Low	Medium	High
	Likely	Low	High	High

*Note the numbers associated with each significance level range from (ii) to (iv) in keeping with assignment in Table 4-3.

Low risk	• Negligible environmental and socio-economic risks. • Mitigation measures are industry standard and no project specific mitigation required. • No consultee concerns.
Medium risk	• Discernible environmental and socio-economic risks. • Consultee concerns can be adequately resolved. • Local public interest.
High risk	• Significant environmental and socio-economic risks. • Serious consultee concerns. • Media interest and reputational impacts.

4.5 Assessment of Significance of Environmental and Socio-economic Risks

Using the information provided in Sections 2 and 3 and the criteria set out above, Appendix B (ENVID table) identifies all activities associated with the proposed project and their potential environmental risk.

The ENVID table is split into five nodes:

- Vessel use;
- Drilling Operations;
- Subsea installation and commissioning;
- Topside modifications; and
- Production.

The assessment showed that with the application of industry standard mitigation measures all of the planned activities are anticipated to have a low environmental/socio-economic significance risk.

As with the planned activities the significance of risk associated with the majority of the unplanned events identified were found to be low significance following the application of mitigation measures/safeguards which reduced the likelihood of the events occurring. Three were found to be of potential medium significance following mitigation and likelihood assessment (Table 4-6).

Table 4-6: Activities identified to have a medium or high significance of risk.

Aspect	Activity	Significance of risk following mitigation
Unplanned events	Release of hydrocarbons / chemicals to sea (e.g. from drains, bunkering operations etc.).	Medium
	Well blowout (uncontrolled hydrocarbon release in the event of loss of well control).	Medium
	Flowline rupture and subsequent release of hydrocarbons to sea.	Medium

Sections 5 – 10 further assess the impacts of the aspects/activities that:

- Are subject to regulatory control;
- Were found to pose a medium or high risk significance to the environment;
- Were raised during the consultation phase; or
- Were identified as areas of public concern.

Section 11 presents the results of modelling carried out to determine the impact of a major hydrocarbon loss.

5. PHYSICAL PRESENCE

This section discusses the potential impacts associated with the physical presence of:

- the vessels and drilling rig associated with the proposed Murlach Field Development; and
- all subsea infrastructure.

on other sea users and animals (other than the benthic species) using the risk assessment methodology presented in Section 4. The impacts on the seabed and the local benthic communities are discussed in Section 8 'Seabed Disturbance'.

Should it be necessary to mobilise a flotel to provide accommodation during the ETAP topside modifications (see Section 2.7), the flotel will be located within the ETAP 500 m zone, alongside the Quarters and Utilities (QU) platform. Given the location of the flotel next to the QU platform, the impacts associated with the physical presence of the flotel on site are considered minimal and are not considered further in this chapter.

5.1 Presence of Vessels and the Drilling Rig

The vessels required for the drilling, installation and commissioning activities associated with the proposed subsea tie-back development are expected to include: AHVs, survey vessels, construction support vessels, a rock dump vessel and supply vessels (see Tables 2-9 and 2-13). A drilling rig will be on location for *c.* 300 days and an ERRV will patrol the area while the drilling rig is on location. The physical presence of the installation vessels, support vessels and drilling rig could potentially result in navigational hazards, a restriction of fishing operations, and disturbance to marine mammals and seabirds.

During routine production operations (after drilling, installation and commissioning activities) the number of vessels present in the area will not significantly increase as a result of the development of the Murlach Field.

5.1.1 Impact of Vessels and Drilling Rig on Other Sea Users

When compared to shipping levels throughout the North Sea, shipping levels in the area are considered to be low or very low (see Section 3.6.6).

As the proposed project is located in close proximity to a well-developed oil and gas area, the increase in vessel traffic required for the drilling and installation activities is not anticipated to result in a significant change to existing levels.

To minimise navigation hazards, all vessels engaged in the project operations will have markings and lightings as per the International Regulations for the Prevention of Collisions at Sea (COLREGS) (International Maritime Organisation (IMO), 1972) and vessel use will be optimised where possible.

The selected drilling rig will be equipped with marine navigational aids and an aviation obstruction lights system, as per the Standard Marking Schedule for Offshore Installations (HSE, 2009), to warn ships and aircraft of their position. The systems comprise:

- Marine navigation lights;
- Fog-lights;
- Aviation obstruction lights;
- Helideck beacons (helideck status light system);
- Fog-horns;
- Fog detector;
- Helideck lighting;
- Radar beacons.

As required by HSE Operations Notice 6 (HSE, 2014), a rig warning communication will be issued at least 48 hours before any rig movement. The drilling rig routes will be selected with the aim of minimising interference to other vessels and the risk of collision. All drilling activities will occur within the existing 500 m safety zone of the Skua Drilling Centre. In addition, a CtL permit application will be submitted to OPRED and an ERRV will patrol the area during operations.

The proposed Murlach Field Development will be located within ICES rectangle 43F1. The information presented in Section 3.6.3 suggests that fishing effort within this rectangle is relatively low.

Note the potential production of clay berms as a result of the use of anchors and the proposed mitigation measures are discussed in Section 5.2.1.

As both shipping and fishing activities in the area are considered relatively low, receptor (other users) sensitivity is considered Low (a). In addition, given the use of navigational aids; the pre-existing 500 m safety zone at the drilling location; the submission of a CtL and BPEOC's commitment to submitting statutory notifications of any drilling rig moves and potential schedule changes and only using vessels adhering to the COLREGS, the magnitude of effect of the physical presence of the drilling rig and vessels on other sea users is considered Negligible (1). Given the Low sensitivity and the Negligible magnitude of effect, the impact significance is considered Low such that any social impacts are considered to be Negligible.

5.1.2 Impact of Vessels and Drilling Rig on Marine Mammals

Note the impact of underwater noise associated with vessels and drilling activities are discussed in Section 9. This section discusses the physical presence of the vessel and drilling rig. From Section 3.4.5 it can be seen that a number of marine mammals occur in the area which could be disturbed by the increase in vessel traffic. In addition, there could be an increased risk of injury to marine mammals through vessel strikes. Given that all cetaceans are EPS and harbour porpoise, an Annex I species, occur in the area, receptor sensitivity is considered Medium (b).

As the proposed project is within a well-developed oil and gas area, it is likely that marine mammals have been habituated to vessel activity in the area. In addition, the evidence for lethal injury from boat collisions with marine mammals suggests that collisions with vessels are very rare (Cetacean Stranding Investigation Programme (CSIP), 2011). Out of 478 post-mortem examinations of harbour porpoise in the UK carried out between 2005 and 2010, only four (0.8 %) were attributed to boat collisions.

Marine mammals may be attracted to installations due to increased prey abundance (Todd *et al*. 2009); however, no evidence of impacts of installations on marine mammals on the UKCS have been reported. Cetaceans are therefore anticipated to quickly adapt to the presence of the drilling rig and vessels, which will occupy a very small proportion of their overall available habitat such that the magnitude of effect of the presence of the drilling rig and vessels is considered to be Negligible (1). Given the Medium sensitivity and the Negligible magnitude of effect, the impact significance is considered Low such that any impacts of the vessels and drilling rig on marine mammals is considered to be Negligible.

5.1.3 Impact of Vessels and Drilling Rig on Birds

As described in Section 3.4.4 a number of bird species are found in the Murlach Field area, however applying the assessment methodology presented in Section 4, the sensitivity of birds likely to be impacted by the physical presence of the vessels and drilling rig is considered Low (a).

The vessels and drilling rig have the potential to cause displacement of seabirds from foraging habitat and may cause flying birds to detour from their flight routes. For example, auk species (e.g. guillemot, little auk) are believed to avoid vessels by up to 200 to 300 m but gull species (e.g. kittiwake, herring gull and great black-backed gull) are attracted to the presence of them (Furness and Wade, 2012). Seabird densities in the

North Sea are reported to be seven times greater within 500 m of a platform. Lights are known to attract seabirds, however, increased food availability at the installation and the availability of roost sites may also be a factor (Weise *et al*. 2001).

Though evidence suggests that the presence of vessels and the drilling rig could cause some bird species to be displaced from their foraging area, the very small proportion of their overall available habitat that will be occupied by the vessels and drilling rig means the impact is not considered to be noticeable. In addition, given the existing oil and gas vessel activity in the area, and the relatively close proximity to the ETAP and Culzean platforms it is expected that the impact of the vessels and drilling rig on bird migration routes is not expected to be significant. Therefore, the magnitude of impact of the physical presence of the vessels and drilling rig on birds is considered Negligible (1). Given the Low sensitivity and the Negligible magnitude of effect, the impact significance is considered Low such that any impacts of the vessels and drilling rig on seabirds is considered to be Negligible.

5.2 Presence of Subsea Infrastructure

All subsea infrastructure including the wellheads, Xmas trees, manifold, pipeline, spools, umbilical jumpers and pipeline protection materials (concrete mattresses, grout and/or sandbags and rockdump) have the potential to impact fishing operations and wildlife as a result of their physical presence.

5.2.1 Impact of Subsea Infrastructure on Other Sea Users

The majority of the fish caught in ICES rectangle 43F1 by UK vessels are demersal species (see Section 3.6.3). Many of the fishing gears used to catch these species are towed along the seabed such that they may impact on any subsea structures that they come into contact with. As discussed previously fishing activity in the area is considered relatively low such that receptor sensitivity is considered Low (a).

During the stakeholder meeting in March 2022 (see Table 1-3) MSS advised that fishing effort in the area may change in the future due to displacement of fishing activity in other areas caused by changes in fisheries management within marine protected areas. It is not possible at this time to determine if this will result in increased fishing in the area of the Murlach field, however measures will be taken to help ensure a safe seabed whether or not fishing effort was to increase in the future.

Other than the gaslift pipeline and its associated rockdump, all infrastructure will be laid within an existing 500 m safety zone (around the Skua Drilling Centre).

As discussed in Section 2.3.2, four installation options are currently being considered for the gas lift pipeline; Option 1, surface lay with spot rock cover to mitigate upheaval buckling; Option 2, 100 % surface lay and rock dump the line at least 50 m away from other rock berms; Option 3, 100 % surface lay and rockdump the line closely alongside an existing rock berm to ETAP; and Option 4, to trench and bury the line with spot rockdump to prevent upheaval buckling. All rockdump required will be laid in accordance with industry practice which is also the preferred SFF best practice such that it will be over trawlable. As described in Section 2.6.4 mattresses and 25 kg grout bags will be used to protect the spools and jumpers. No mattresses or grout bags will be laid outside the 500 m exclusion zones. Use of stabilisation features will be minimised.

BPEOC discussed the installation of a surface laid 6” flexible or rigid flowline with SFF (see Table 1-3). Given the small pipeline diameter, SFF do not predict a significant risk of damage to fishing gear in the event of snagging. BPEOC will carry out a fisheries interaction assessment to aid selection of the optimal flowline installation method. This assessment will take account of the weight of the trawl doors and other fishing gear. In the event that the study identifies an unacceptable risk to flowline integrity or fishing gear, the option to install the flowline exposed on the seabed will not be carried forward.

Options 2 and 3 will minimise risk to fishermen in the area by either establishing a minimum distance of 50 m between any existing rock berms and the new berm (Option 2) or by extending an existing rock berm so as to reduce the number of berms the trawl gear will pass over (Option 3). Note 50 m between rock berms allows any fishing gear which passes over the rockdump berms to "right" itself before it reaches the next rock berm.

In the event that the gaslift pipeline is trenched and buried, surveys will be carried out to determine if any clay berms have been left on the seabed. As clay berms are known to damage fishing nets and destroy fish hauls, should any clay berms be detected, BPEOC will discuss appropriate mitigation with OPRED and SFF e.g. use of chain gate to break up the berms. Similarly should the project select to drill the wells using a semi-submersible drilling rig, following recovery of the anchors, surveys will be carried out to determine if clay berms have been created and appropriate mitigation will be identified if required.

Prior to installing the subsea infrastructure, the project will apply for a Pipeline Works Authorisation (PWA), including a Deposit Consent to deposit materials; and the development will comply with any notification requirements associated with the PWA approval. This will include the positions of any pipelines and control tie-backs. The project will submit a CtL application to OPRED. The location of all infrastructure to be installed will be submitted for inclusion on the admiralty charts. BPEOCs adherence to these mitigation measures means the magnitude of impact of the installation of the subsea infrastructure on fishing activity is not considered significant and is therefore considered Minor (2).

Given the Low sensitivity and the Minor magnitude of effect, the impact significance is considered Low such that the impact significance of the subsea infrastructure on fishing activity is considered negligible.

5.2.2 Impact of Subsea Infrastructure on Marine Mammals and Fish

With respect to the impact of subsea infrastructure on fish and cetaceans receptor sensitivity is considered Medium (b) due to the presence of designated species e.g. PMFs (such as cod, mackerel and sandeel) and EPS (cetaceans). Marine mammals and fish in the area are anticipated to adapt to the presence of the subsea infrastructure, which will occupy a very small proportion of their overall available habitat such that the magnitude of effect is considered Negligible (1). Given the Low sensitivity and the Negligible magnitude of effect, the impact significance is considered Low such that the impact significant of the subsea infrastructure on marine mammals and fish is considered negligible.

Note, the impact on the benthic communities is discussed separately in Section 8 'Seabed Disturbance'.

5.3 Decommissioning Phase

At CoP the Murlach infrastructure will be decommissioned as part of a Decommissioning Programme. At the commencement of the decommissioning activities, vessel activity in the area will increase relative to the number of vessels typically present in the area of the development during the production phase.

It is expected that at end of field life it will be technically feasible to recover the Xmas trees, spools, umbilical jumpers, manifold, mattresses and grout bags. In line with current OPRED guidance (BEIS, 2018), a CA will be carried out to determine the fate of the gaslift pipeline, whether it is surface laid and rockdumped or trenched and buried.

Should the CA determine that the pipeline should be decommissioned *in situ*, BPEOC will agree an ongoing monitoring plan with the relevant authority (currently this is OPRED).

5.4 Cumulative and Transboundary Effects

The proposed activities will occur in proximity to a well-developed oil and gas area and will result in a modest increase in activity as a result of additional vessel movements. Given that these activities will occur within a well-established area for oil and gas activity and will be short term in nature, significant cumulative impacts are not expected.

The proposed Murlach Field Development will be located *c.* 27 km from the UK/Norway median line and therefore no transboundary impacts associated with the physical presence of the drilling rig or vessels are expected.

5.5 Mitigation Measures

The following industry standard mitigation measures will be undertaken to minimise the impacts associated with the physical presence of the vessels, drilling rig, and subsea infrastructure associated with the proposed Murlach Field Development. These are in addition to the presence of the pre-existing Skua 500 m zone around the drilling operation and the deposit of all concrete mattresses, grout and/or sandbags within the existing Skua or ETAP 500m zones.

Proposed Mitigation Measures

- Notice to Mariners will be circulated prior to rig mobilisation;
- The drilling rig will abide by CtL conditions;
- A Collision Risk Management Plan will be produced if determined to be required;
- All vessels will adhere to COLREGS and will be equipped with navigational aids, including radar, lighting and AIS (Automatic Identification System) etc.;
- The drilling rig will be equipped with navigational aids and aviation obstruction lights system, as per the Standard Marking Schedule for Offshore Installations;
- Vessel use will be optimised by minimising the number of vessels required and length of time vessels are on site;
- A fisheries interaction assessment to aid selection of the optimal flowline installation method will be carried out. In the event that the study identifies an unacceptable risk to flowline integrity or fishing gear, the option to install the flowline exposed on the seabed will not be carried forward; and
- Should the gaslift line be trenched and buried, post installation surveys will be carried out to determine if any clay berms remain on the seabed. Similarly should a semi-submersible drilling rig be used, post anchor recovery surveys will be carried out to determine if recovery of the anchors has resulted in any clay berms. In the event that they are detected, BPEOC will discuss appropriate mitigation with OPRED and SFF.

Applying the risk assessment methodology described in Section 4 and taking account of the mitigation measures listed above, the physical presence of the vessels, drilling rig and subsea infrastructure associated with the proposed development is considered to be of a low socio-economic impact significance. In addition, the environmental impact significance in relation to marine mammals, birds and fish is considered low (the environmental impact significance in relation to benthic species in considered separately in Section 8). The environmental and socio-economic impacts are therefore considered acceptable when managed within the additional controls and mitigation measures described.

The proposed project will be conducted in compliance with all NMP policies; an assessment against the relevant NMP objectives is given in Appendix A.

6. ATMOSPHERIC EMISSIONS

This section identifies the various sources of atmospheric emissions associated with project activities and subsequent hydrocarbon production operations. The quantity of atmospheric emissions is estimated, and their impact assessed.

Following the adoption of appropriate control and mitigation measures, residual effects and impacts are assessed in the context of the sensitivity of, and the dispersive capacity of, the receiving environment.

Emissions during production are related to the production profiles of both Murlach and other fields being produced at the host facility, ETAP. A degree of uncertainty will remain over Murlach production profiles until the reservoir behaviour can be monitored following commencement of production. The uncertainty is expressed by profiles showing the most likely (Base) case together with high (Upside) case presented in Section 2.

Emissions during production have been calculated for both the Base case and the Upside case.

Detailed calculations indicate that the projected emissions for both profile cases are similar, both for peak year emissions and for the aggregate over the full field life. Differences are well within the bounds of uncertainty in the estimation methods and assumptions with, for example, 2% difference in life of field aggregated CO_2 emissions.

In keeping with normal practice, the emissions estimates presented in this ES are based on the Upside case.

Projected estimates for the GHG intensity (emissions per tonne of oil equivalent) for the field are presented for both Upside and Base case profiles. Whereas GHG emissions are very similar for both cases, production figures for the Base case are lower than the Upside case, leading to higher GHG intensity estimations for the Base case.

First oil is currently planned to be achieved in June 2025. The production profiles presented in Section 2, and the emissions estimates presented in this section for 2025 are based on achieving this date.

6.1 Sources

The principal planned activities, including their location and estimated duration, are described in Section 2. Of these, the general use of vessels (including the drilling rig), well completion, commissioning and the production of hydrocarbons have been identified as warranting further assessment in terms of the impact of their atmospheric emissions.

Emissions from the end use of any oil and/or gas produced from the Murlach field are not in scope of this ES. The potential climate change impacts of these end use emissions are not considered to be direct or indirect significant effects of the proposed development (as described in Section 1.4) as any hydrocarbons produced will be subject to transportation, downstream processing, sale and, in the case of crude oil, refining, before their eventual end use, remote from the development itself. Moreover, the Climate Change Act 2008, the goals of the Paris Agreement and atmospheric emissions from fossil fuel sources, raise considerations which have to be and are addressed for the UK at strategic level rather than project level. This is reflected in the fact that end use emissions were addressed in the most recent Offshore Energy Strategic Environmental Assessment (DECC, 2016), which acknowledges that reliance on fossil fuel sources will continue during decarbonisation.

6.1.1 Drilling, Installation and Topside Modification Vessels

Energy in the form of liquid fuel (e.g. marine diesel, combustion of which will result in atmospheric emissions) is required by vessels to provide propulsion, dynamic positioning and ancillary services (e.g. electrical power).

While contracts securing the services of named vessels have not yet been established, the performance characteristics (including the fuel consumption) of the required generic vessel types are well understood. This has allowed, in conjunction with a consideration of the planned vessels' work programme, estimates of atmospheric emissions to be made and are presented in Table 6-1.

Production of Murlach is not anticipated to require an increase in the frequency of supply vessels or helicopters servicing ETAP during operational life of field.

Table 6-1 Fuel use and emissions associated with vessel use.

Source	Fuel Use (Te)[1]	Emissions From Fuel Use (Te)						
		CO_2	NOx	N_2O	SO_2	CO	CH_4	VOC
Drilling (see Table 2-9)	5,907	18,902	351	1.3	12	92	1.1	12
Subsea infrastructure installation (see Table 2-13)	1,154	3,693	69	0.3	2.3	18	0.2	2.3
Flotel (see Table 2-15)	5,490	17,568	326	1.2	11	86	1.0	11
Total vessels	**12,551**	**40,163**	**746**	**2.8**	**25**	**197**	**2.3**	**25**
UK shipping emissions 2019 (CCC, 2020)		13,680,000						
Total vessel emissions as % of 2019 UK shipping emissions		0.3						

[1] Institute of Petroleum (2000)

6.1.2 Well Completion

Well clean-up is an activity necessary to ensure that a well no longer contains any drilling and completion-related debris (mud, brine, cuttings) which could damage the topside process when commissioning and production begins. The process requires flaring of fluids if undertaken from the drill rig. However, if completion fluids are flowed to an operating host facility then it may be feasible to avoid or reduce flaring by accommodating the fluids within the process stream, making use of test separators and storage vessels to prevent damage.

The base case, and preferred option, is for clean-up fluids from the Murlach wells to be routed to ETAP where the extent of flaring can be minimised. However, at the time of writing assessments were still to be carried out to determine if ETAP can accept the clean -up fluids and what activities would be required.

To reflect the realistic worst case, atmospheric emissions resulting from clean-up and testing have been calculated assuming rig-based clean-up. An oxidation factor of 0.95 has been assumed and emissions factors based either on predicted compositions of the flared fluids or from the EEMS Atmospheric Calculations (Austin, 2008) have been applied. These are presented in Table 6-2.

Following completion activities, the well and production pipeline will be filled with brine.

Table 6-2 Summary of emissions from well clean-up operations.

Source	Mass Flared (Te)	Emissions from Flare (Te)						
		CO_2	NOx	N_2O	SO_2	CO	CH_4	VOC
Gas flared	480	1,230	0.5	0.04	0.006	3	10	12
Oil flared	2,607	8,344	10	0.21	0.033	47	65	65
Total	**3,087**	**9,573**	**10**	**0.25**	**0.039**	**50**	**75**	**77**

6.1.3 Start-Up

As part of the well completions, compressed nitrogen will be used to displace residual brines in the Murlach production pipeline. When the first Murlach well starts, the nitrogen stream will be sent to flare and hydrocarbon gas will be added to it to avoid extinguishing the flare. In addition, some fluids will be flared until the pipeline and Murlach topsides reception equipment is brought up to temperature and pressure conditions that are compatible with fluids being introduced into the ETAP separation process. This is estimated to result in 245 Te of hydrocarbon being flared. The resultant emissions from well start up are presented in Table 6-3. For the start-up of the second Murlach well, the process conditions in all systems will already be balanced and there will be no requirement for flaring.

Table 6-3 Emissions during well first start-up.

Source	Mass Flared (Te)	Emissions From Flare (Te)						
		CO_2	NOx	N_2O	SO_2	CO	CH_4	VOC
Gas flared	245	648	0.29	0.019	0.003	1.61	2.1	2.42

6.1.4 Production of Hydrocarbons

The principal atmospheric emissions that will arise during production are associated with power generation, compression, flaring and fugitive emissions at the ETAP host.

No physical modifications to the current power generation, compression and flaring systems at ETAP will be required to process Murlach fluids. These existing systems have been assessed as being sufficient to meet the operational requirements for the processing of Murlach production over field life.

Emissions increases due to the production of Murlach are discussed and estimated in Section 6.2.

6.2 Emissions Increases Due to Murlach Production

6.2.1 Power Generation and Compression

Power on ETAP is provided by two dual fuel gas turbine generators (GTG) operating one on one off. Production of Murlach will increase the load on the existing oil booster pumps, MOL pumps and PW injection pumps, all of which are electrically powered.

The increased loads are not directly proportional to throughput of the respective fluids and have been calculated from efficiency curves for each pump, plant availability targets and the number of pumps, etc, required. The increased fuel demand for the GTGs to support the increase in power demand has been calculated and the emissions resulting from combustion of the fuel is presented in Table 6-4.

Table 6-4 Emissions from fuel gas combustion at ETAP attributable to Murlach production.

Year	Fuel Use (Te)	Emissions from Fuel Use (Te)						
		CO_2	NOx	N_2O	SO_2	CO	CH_4	VOC
2025	444	1,212	2.7	0.10	0.006	2.7	0.4	0.02
2026	21,027	57,408	128.3	4.63	0.269	126.2	19.3	0.76
2027	266	727	1.6	0.06	0.003	1.6	0.2	0.01
2028	289	788	1.8	0.1	0.004	1.7	0.3	0.01
2029	910	2,485	6	0.2	0.012	5	0.8	0.03
2030	200	546	1.2	0.04	0.003	1.2	0.2	0.01
2031	333	909	2.0	0.07	0.004	2.0	0.3	0.01
2032	0	0	0	0	0	0	0	0
2033	0	0	0	0	0	0	0	0
2034	0	0	0	0	0	0	0	0
2035	0	0	0	0	0	0	0	0

ETAP currently operates with two compressor trains in service and is projected to do so until 2025, in the absence of Murlach, thereafter gas production rates would require a single compression train. The power demand for running a single compressor is dependent on gas throughput, though not in a linear relationship.

As such an increase in gas throughput may not result in a major increase in compressor power demand. However, when the gas throughput exceeds the capacity of a single compressor, a second compressor needs to be operated, and this results in a significant step change in power demand. With the introduction of Murlach at ETAP, operation with two compression trains will be extended through 2026. The additional fuel gas required to run a second compressor in this additional year has been attributed to Murlach and the resultant emissions are included here for impact assessment. Compression is one of the major power users and this results in a spike in Murlach emissions in 2026.

Between 2027 and 2031, there is projected to be an average incremental additional fuel gas demand of approximately 400 Te/yr (under the Upside case). Fuel gas demand in 2026 is substantially higher than this, reflecting the additional compression demand attributed to Murlach production in this year. Beyond 2031 production of Murlach will not place any additional power demand on ETAP.

6.2.2 Flaring

Flaring for safety reasons will occur for planned blowdown and start-up of ETAP, for planned turn arounds and potentially from unplanned controlled shutdowns, for example following compressor trips. Introduction of Murlach increases the hydrocarbon inventory tied into ETAP which needs to be flared for these events. The operating philosophy at ETAP is to keep the frequency of these events to an absolute minimum, both for environmental reasons and to optimise production. For the purpose of the impact assessment, a conservative assumption has been taken that there could be six events per year, three of these requiring depressurisation of the Murlach production pipeline. The quantity of hydrocarbons to be flared depends on the volumes of pipeline, riser and topsides equipment and also the pressures and densities of gases in each. The annual quantities to be flared have been projected for Murlach infrastructure and used to determine the consequential emissions.

Emergency flaring also occurs following process upsets. The quantities concerned are difficult to apportion to any particular field being processed at ETAP. For the determination of emissions attributed to Murlach, a projection has been made based on the proportion of Murlach gas to the total ETAP gas production.

Emissions have been calculated from the mass flared, applying an oxidation factor of 0.98 and using emissions factors based either on predicted composition of the flare stream or based on BEIS guidance for flaring of gas (Austin, 2008). These are presented in Table 6-5.

Table 6-5 Emissions from flaring at ETAP attributable to Murlach production

Year	Mass Flared (Te)	Emissions From Flare (Te)						
		CO_2	NOx	N_2O	SO_2	CO	CH_4	VOC
2025	1,060	2,833	1.3	0.09	0.014	7.1	12.3	8.7
2026	2,048	5,478	2.5	0.17	0.026	13.7	23	17
2027	2,020	5,405	2.4	0.16	0.026	13.5	22	17
2028	2,012	5,383	2.4	0.16	0.026	13.5	22	17
2029	2,012	5,383	2.4	0.16	0.026	13.5	22	16.6
2030	2,016	5,394	2.4	0.16	0.026	13.5	21.6	16.6
2031	2,011	5,379	2.4	0.16	0.026	13.5	21.6	16.6
2032	2,006	5,367	2.4	0.16	0.026	13.4	21.4	16.5
2033	2,006	5,367	2.4	0.16	0.026	13.4	21.4	16.5
2034	2,013	5,384	2.4	0.16	0.026	13.5	21.5	16.6
2035	2,007	5,370	2.4	0.16	0.026	13.4	21.5	16.5

6.2.3 Fugitive Emissions

Estimates for total fugitive emissions of gas on ETAP are based on UK norms for numbers and types of components such as flanged connections, valves etc., and the nature, pressures and flows of fluids passing through them, in accordance with EEMS Guidelines (Austin, 2008).

For the purposes of the impact assessment, a proportion of the estimated total fugitive losses at ETAP has been assigned to Murlach in proportion to the relative number of producing fields.

The estimate for Murlach is 1.43 te methane per year.

6.3 Aggregated Emissions

Of interest to the impact assessment are:

- The maximum emission levels for substances that reduce air quality; and
- The aggregated emissions of GHGs over the field life.

6.3.1 Emission Gases Impacting Air Quality

To consider the impacts from a realistic worst case, emissions are presented for the Upside production profile case during production field life along with estimates for emissions during the installation and start- up stages.

Production is scheduled to begin in June 2025. Installation is scheduled to be completed during Q3/Q4 2024, whilst drilling is due to take place between Q1 and Q4 2024, culminating in well clean up. Allowing for schedule slippage and therefore to consider a realistic worst case impact, it has been assumed that all installation, drilling, completions, commissioning and start-up activities will occur in 2025.

Total emissions relating to Murlach in 2025 are presented in Table 6-6, based on data throughout Section 6.1. This includes all emissions from supply boats, drilling, installation, well completions, start-up and for Murlach production between June and December of 2025.

Table 6-6 Total emissions relating to Murlach in 2025

Total Emissions 2025	Hydrocarbon Use (Te)	Emissions from Fuel, Flare & Fugitives (Te)						
		CO_2	NOx	N_2O	SO_2	CO	CH_4	VOC
Assuming Well Completion at Drill Rig	17,388	54,430	760	3.2	25	258	93	113

The peak year for emissions attributed to Murlach has been identified as 2026 and Table 6-7 presents the quantities aggregated from Section 6.2.1, Section 6.2.2 and Section 6.2.3 for that year. As explained in Section 6.2.1, 2026 is an exceptional year for Murlach, as its production requires the operation of an additional compression trains at ETAP. The next highest year (2029) is also included in Table 6-7 for comparison.

Table 6-7 Total annual production emissions attributed to Murlach for 2026 and 2029

Total Annual Production Emissions	Hydrocarbon Use (Te)	Emissions from Fuel, Flare & Fugitives (Te)						
		CO_2	NOx	N_2O	SO_2	CO	CH_4	VOC
Maximum emissions year with two compression trains (2026)	23,077	62,887	131	4.8	0.30	140	43	18
Maximum emissions year without extra compression train (2029)	2,924	7,869	8.0	0.36	0.04	19	24	17

6.3.2 GHG Emissions

GHG emissions are presented in Table 6-8 for pre-production stages and annually over the Murlach field life as CO_2 equivalents (CO_2e). The values for CO_2e are derived using GWP values for CO_2, methane and nitrous oxide from the IPCC 4th Assessment Report (IPCC, 2007). These emissions are used in conjunction with production profiles to generate estimates for the GHG intensity of the product as kg CO_2e per Te of oil equivalent (TeOE).

The GHG intensities are shown both annually and over field life (including pre-production emissions) for the Upside production case and for the Base case.

Table 6-8 Total installation and operation GHG emissions by year.

Year	Emissions (Te CO_2e)		GHG Intensity (Kg CO_2e/TeOE)	
	Upside Case	Base Case	Upside Case	Base Case
2025	4,436	4,561	9	10
2026	65,397	66,211	85	84
2027	6,786	7,287	12	14
2028	6,822	7,323	16	20
2029	8,574	8,637	25	42
2030	6,582	6,958	21	33
2031	6,942	6,629	26	39
2032	5,988	5,988	26	41
2033	5,988	5,988	29	47
2034	6,007	6,007	32	54
2035	5,991	5,991	34	61
Total Production Phase	**129,513**	**131,580**		
Drilling, Installation, Completions & Start-up (2025)	**53,281**	**53,281**		
Total Development	**182,794**	**184,861**	**46**	**58**

A breakdown of the emissions by source type for each year are shown in Figure 6-1 for the Upside case.

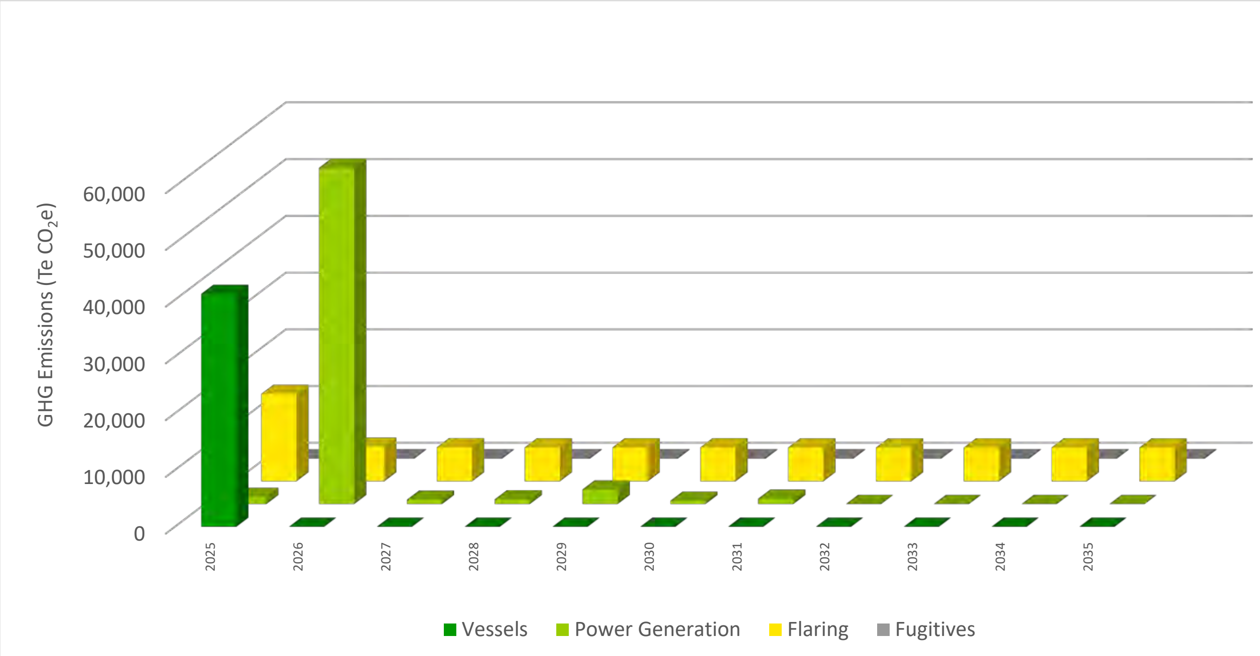


Figure 6-1 Murlach GHG emissions by source type.

The main source of GHG emissions in 2025, shown in Figure 6-1, relate to drilling, installation and commissioning works discussed in Sections 6.1.1, 6.1.2 and 6.1.3. The other principle contributions to GHG emissions relate to the extended operation of two compression trains through 2026.

6.4 Air Quality Impacts and Receptors

Increased concentrations of NO_x, SO_2 and VOCs in the atmosphere can result in the formation of photochemical pollution in the presence of sunlight, comprising mainly low level ozone, but by-products may include nitric acid, sulphuric acid and nitrate-based particulate. The formation of acid and particulates contributes to acid rainfall and the dry deposition of particulates. If such deposition occurs at sea, it is possible that the substances will dissolve in seawater. The ultimate fate of emitted pollutants can often be difficult to predict owing to the dependence on metocean conditions (especially wind), which may be highly variable and lead to wide variations in pollutant fate over short timescales.

6.4.1 Installation and Commissioning Phase

Vessel emissions, summarised in Table 6-1, and well clean-up flaring emissions summarised in Table 6-2, will be of localised extent, of relatively short duration, and take place a substantial distance (more than 200 km) from the nearest coastline. They are expected to disperse rapidly and dilute to background concentrations, resulting in localised and short term impacts only to air quality.

Given the above, the significance of the impact of energy use and atmospheric emissions from vessels and from well clean-up has been assessed as **low**.

6.4.2 Production Phase

The impact of emissions from ETAP on air quality were assessed in 2006 as a supporting study for the IPPC permit application. The study (CERC, 2006) was based on the conservative assumption of emissions of NO_x totalling 4,755 Te/yr and of CO totalling 3,819 Te/yr. The report concluded that the maximum predicted concentrations of NO_x and NO_2 were well below the long- and short-term national air quality objectives and that all predicted concentrations of CO were insignificant with regard short-term air quality objectives and with long-term environmental assessment levels. The risk of impact from the modelled scenario is consequently considered to be low.

Annual emissions at ETAP in recent years are well below the quantities used in the dispersion modelling study, as is evident from emissions reported for 2017 - 2020 presented in Table 6-9.

Table 6-9 Annual emissions from ETAP between 2017 and 2020

Year	Emissions from Fuel, Flare & Fugitives (Te)						
	CO_2	NOx	N_2O	SO_2	CO	CH_4	VOC
2020	246,512	675	0	21	474	174	142
2019	278,313	1,191	0	7	564	246	83
2018	264,553	1,085	0	14	504	265	104
2017	314,456	1,222	0	19	596	305	122

Production from the Murlach field would increase NO_x and CO emissions from ETAP by approximately 13% and 26% respectively in the year of highest Murlach emissions (2026). Annual emissions from ETAP during Murlach field life are projected to remain approximately one quarter of those considered in the dispersion modelling study and, as with that study, it can be concluded that the impact significance will remain **low**.

The two gas turbine compressors on ETAP qualify as Large Combustion Plant (LCP). They are not able to consistently meet the BAT Associated Emission Levels (AEL) for NO_x concentrations in the exhaust stream stipulated in the LCP BAT Reference document, and as is required by the Offshore Combustion Installations (Prevention and Control of Pollution) Regulations 2013 (as amended). As is provided for in the 2013 regulations, BEIS has set a higher AEL for the ETAP compressors in the facility PPC permit by way of a time-limited derogation. The alternative AEL was set following due consideration of a cost benefit analysis which evaluated the cost of alternative options against the environmental benefit these would achieve. As discussed above, the total annual mass of NO_x emitted from ETAP annually has low impact, including during production of Murlach.

The alternative AEL was set at the emission level that is achievable when operating at maximum compression load and production of Murlach will not cause emission levels from the compressors to exceed the permitted AEL.

6.4.3 Decommissioning Phase

A range of specialist and support vessel types will be required at various times, and for various durations, to undertake the decommissioning activities at the end of field life. This will lead to an increase in vessel activity relative to that associated with production.

A drilling rig will be brought to Murlach to plug and permanently abandon the wells. In addition, vessels will be required to remove and recover seabed infrastructure, and to complete pre-decommissioning, execute phase and post-decommissioning legacy surveys.

Vessel emissions associated with decommissioning activities are likely to be similar to those associated with subsea infrastructure installation. The extent, magnitude and duration of impact on air quality from offshore decommissioning activities are consequently anticipated to be less than those for the installation and commissioning phase and has therefore been assessed as **low**.

It is possible that decommissioning of the Murlach Development could coincide with decommissioning of other fields produced at ETAP, and of ETAP itself. The in-combination impacts on air quality from decommissioning multiple fields and large host facilities may be higher. This would need to be assessed as part of the preparation work of decommissioning and included in the Environmental Appraisal report submitted with the Decommissioning Programme. To date, environmental appraisals for even very large offshore decommissioning projects have not identified significant impacts to air quality from emissions.

6.4.4 Transboundary and Cumulative Impacts to Air Quality

ETAP is located approximately 25 km from the UK/Norway jurisdictional median line. Given this distance and the localised nature and low level of air quality impacts expected, no transboundary impacts are anticipated.

As discussed in Section 6.4.2, emissions associated with production of Murlach will make a small contribution to the cumulative emissions from ETAP, and that the cumulative emissions will have low environmental impact.

The emissions reported for the UK as a whole, and for the UKCS offshore oil and gas industry, in 2019 are presented in Table 6-10 in units of thousand tonnes per year.

The contribution that development of the Murlach field will make to the cumulative emissions across the UKCS, and to UK emissions as a whole can be seen from comparison of the data in Table 6-10 with that in Table 6-7.

By way of example the NO_x emissions from production of Murlach in 2027 (the year of highest emissions) would be approximately 0.25% of the annual emissions from the UKCS offshore industry in 2019, and approximately 0.015% of the annual UK emissions in 2019.

Table 6-10 Emissions from the UK, and from the UKCS, in 2018.

Year	Emissions (Thousand Te/Yr)						
	CO_2	NOx	N_2O	SO_2	CO	CH_4	VOC
UK Emissions (2019)[1]	369,700	852	68	167	1,653	1,980	814
UKCS Emissions (2019)[2]	13,683	51	1	2	31	40	47

[1] UK Greenhouse Gas Inventory, 1990 to 2019 from the Annual Report for submission under the Framework Convention on Climate Change (UK NIR, 2021).
[2] UKCS EEMS emissions data (EEMS, 2021).

6.5 Impact on Climate Change

In isolation the GHG emissions from the Murlach development would not cause a change to the global climate, however it is their contribution to the cumulative impact of total global emissions that is of relevance in assessing the impact of the development. As such, the Murlach GHG emissions are considered in the context of the UK emissions and the UK commitments to emissions reductions.

6.5.1 Murlach GHG Emissions in the Present National and Sector-Wide Context

The total GHG emissions for 2019 across the UK were reported in the UK National Inventory Report (UKNIR, 2021) as 453 MTeCO_2e. The UK offshore oil and gas sector accounted for 14.9 MTeCO_2e (EEMS, 2021), approximately 3% of the UK total.

For context, the incremental additional GHG emissions resulting from production of Murlach over ETAP peak in 2026 at 0.065 MTeCO_2e, which is 0.014 % of the UK total in 2019 and 0.44 % of the UKCS oil and gas total in 2019.

For the Upside case presented here, 2026 is an exceptional year for Murlach GHG emissions due to the extended requirement for operation with two compression trains at ETAP. For all other years of operation, Murlach production does not necessitate operation of more compression trains than would otherwise be required for ETAP production, and the incremental GHG emissions due to Murlach are expected to be substantially lower than those in 2026. Equivalent projected figures are also shown in Table 6-11 for 2029, which represents the next highest year for GHG emissions.

Table 6-11 Murlach incremental GHG emissions in the context of total UK and UKCS.

GHG Source	Emissions (MTe CO_2e)	% UK Total	% UKCS Total
UK Total (2019)[1]	453		
UKCS Total (2019)[2]	14.9		
Murlach maximum year (2026)	0.065	0.014	0.44
Murlach 2029	0.007	0.0015	0.05

[1] UK Greenhouse Gas Inventory, 1990 to 2019 from the Annual Report for submission under the Framework Convention on Climate Change (UK NIR, 2021).
[2] UKCS EEMS emissions data (EEMS, 2021).
Note these values are include all GHGs and so differ from those presented in Table 6-10 which are for CO_2 only.

6.5.2 Murlach GHG Emissions in the Future National Context

The Climate Change Act 2008, which committed the UK government by law to reducing greenhouse gas emissions by at least 80% of 1990 levels by 2050, was amended in 2019 to commit to achieving 100% reduction (net zero) by 2050. The Climate Change (Scotland) Act (2019) establishes an accelerated target for achieving net zero emissions by 2045 in Scotland.

The Climate Change Act requires the government to set legally-binding ‘carbon budgets’ to act as stepping stones towards the 2050 target. A carbon budget is a cap on the amount of greenhouse gases emitted in the UK over a five-year period.

Table 6-12 shows the UK Carbon Budgets allocation set under the UK Climate Change Act alongside the projected additional emissions from the development of Murlach.

Under the Upside case, the Murlach development spans the 4th, 5th and 6th Carbon Budget periods, with installation, start-up and the first three years of operation occurring in the 4th budget period, the subsequent 5 years of operation occurring in the 5th budget period, and the final three years production occurring in the 6th budget period. The total future GHG emissions from the Murlach development within each budget period are presented within Table 6-12 as million tonnes of CO_2 equivalent and as a percentage of the UK budget allocations.

Table 6-12 Murlach GHG emissions in the context of UK Carbon Budgets

Carbon Budget	Budget Period	UK Budget Allocation[1]	Murlach Incremental	
		(MTeCO_2e)	(MTeCO_2e)	% of Budget Allocation
1	2008 - 2012	3,018	-	-
2	2013 - 2017	2,782	-	-
3	2018 - 2022	2,544	-	-
4	2023 - 2027	1,950	0.130	0.0067
5	2028 - 2032	1,725	0.035	0.0020
6	2033 - 2037	965	0.018	0.0019

[1] UK Committee for Climate Change Sixth Carbon Budget Report (UKCCC, 2020)

6.5.3 Murlach GHG Emissions in the Future Oil & Gas Sector Context

In October 2017 the UK Government published its Clean Growth Strategy (UK Government, 2017) setting out policies and proposals for meeting future carbon budgets, together with pathways to the 2050 target (then of 80% reduction). In keeping with the Net Zero pathway the UK Government and offshore oil and gas industry established a North Sea Transition Deal (NSTD) in 2021 which, among other actions, agreed targets for staged reductions in GHG emissions from the UKCS as presented in the first two columns of Table 6-13. Based on the recorded UKCS GHG emissions for 2018, the third column of the table shows the target emissions for subsequent years stipulated in the NSTD. The final two columns of the table present the proportion of the NSTD budget that incremental GHG emissions from Murlach are projected to account for under Upside case and Base case production profiles.

Table 6-13 Murlach GHG emissions in the context of the North Sea Transition Deal

Year	North Sea Transition Deal[1]		Murlach Incremental	
	% of 2018	MTeCO_2e	Upside Case (%)	Base Case (%)
2018	100	14.5	-	-
2025	100	13.1	0.03	0.03
2027	90	10.9	0.06	0.07
2030	75	7.3	0.09	0.10
2050	0	0	-	-

[1] North Sea Transition Deal (BEIS, 2021)

The GHG emissions from Murlach represent a small proportion of the UKCS and UK annual totals and make up a small proportion of the 4th, 5th and 6th Carbon Budget allocations and of the total UKCS emissions targets established for 2025, 2027 and 2030 under the NSTD.

6.5.4 Murlach GHG Emissions Relative to Production

Whereas the figures presented in 6.5.3 indicate that GHG emissions from Murlach are projected to account for a small proportion of the agreed future emissions from the UKCS, this is most meaningful when put in the context of how much of the UK oil and gas demand Murlach will meet.

The demand in the UK for oil and gas is predicted to decline significantly over the next 30 years to 2050, although the UK Government forecasts show that oil and gas will remain an important part of the UK energy mix for the foreseeable future, including under net zero (OGA, 2021). As production from existing fields naturally depletes, meeting the continued demand will require a combination of either the development of new fields within the UKCS and/or imports.

Current projections show that the UK is forecast to remain a net importer of oil and gas for the foreseeable future, even with the development of new fields within existing licensed blocks (BEIS, 2021b).

In this context, the development of fields within the UKCS that have low GHG emissions per unit of hydrocarbon production is most consistent with supporting the UK Government's strategy for transitioning to net zero GHG emissions.

In 2018, oil and gas production in the UKCS is quoted by BEIS as 90 million tonnes oil equivalent (BEIS, 2019a). The sector resulted in emissions totalling 14.54 MTe CO_2e, giving an average GHG intensity of 162 $kgCO_2e$ per Te of oil equivalent (TeOE) across the basin. This figure covers both oil and gas.

According to the NSTA (OGA, 2020), the GHG intensity of imported Liquefied Natural Gas (LNG) is on average 59 $kgCO_2e$ per barrel of oil equivalent, which is approximately 385 $kgCO_2e$/TeOE. The GHG intensity for natural gas imported by pipeline from Norway is given as approximately 117 $kgCO_2e$/TeOE.

The corresponding GHG intensity of imported oil is more difficult to ascertain. A study to estimate GHG intensities of global oil production has been published by Masnadi *et al*. (2018) involving a comprehensive analysis of available datasets pertaining to multiple aspects of oil production and their differences between regions, onshore and offshore, around the world. The study concluded a global average GHG intensity of crude oils up to the point of delivery to refinery as being 10.3 gCO_{2e}/MJ (Masnadi *et al*, 2018), which approximately translates to 63 $kgCO_{2e}$/barrel, or to 462 $kgCO_{2e}$/Te. The estimation method derived by the Masnadi *et al*. study is relatively complex and direct comparison with the NSTA figures for the UKCS should be made with a degree of caution. Of relevance to such a comparison is the GHG intensity estimated by the Masnadi *et al* study for oil production in the UK of 7.9 gCO_{2e}/MJ for UK oil production, or 354 $kgCO_{2e}$/Te, roughly twice the estimate derived directly from BEIS data.

Murlach is predominantly an oil field, with relatively small proportion of gas anticipated. Production of Murlach is projected to result in a small increase in GHG emissions at ETAP, with an average increase of less than 3% per year except for 2026 during which the increase is projected to be approximately 23%. The increase in production at ETAP due to Murlach is projected to be approximately 40% over field life for the Base case and approximately 50% for the Upside case.

Over its field life, Murlach is estimated to produce between 3.2 MTe and 4.0 MTe oil equivalent with a GHG intensity of 58 $kgCO_2e$/TeOE (Base case) or 46 $kgCO_2e$/TeOE (Upside case). Production of this low GHG intensity field will thereby contribute to an overall reduction in the GHG intensity of the basin.

The GHG Intensity estimates for Murlach and other sources of oil and gas relevant to meeting future UK demand are presented in Table 6-14.

Table 6-14 GHG Intensity estimates for Murlach and other sources

Oil and/or Gas Source	GHG Intensity $kgCO_2e$/TeOE
UKCS Combined Oil and Gas Production (2018)[1]	162
UKCS Gas Production (2019)[2]	143
UK Imported LNG (2019)[2]	385
UK Imported Norwegian Gas (2019)[2]	117
Murlach Base Case (Life of Field)[3]	58
Murlach Upside Case (Life of Field)[3]	46

[1] Based on data in BEIS, 2019a
[2] Unit conversions from data in OGA, 2020
[3] Emissions calculations undertaken for this Environmental Statement

6.5.5 Climate Change Impact Conclusion

Impacts from GHG emissions are difficult to assess in isolation because they derive from all cumulative emissions, rather than from any one activity. Nevertheless, GHG emissions from Murlach are low in the context of current UK and UKCS emissions and in the context of projected targets for future emissions reductions. Furthermore, Murlach production represents significantly lower than average emissions per tonne of oil equivalent produced for the UKCS or imported. Development of Murlach would therefore contribute to achieving the goals for emissions reduction in the UKCS established by the NSTD.

6.6 Mitigation Measures

The following measures will be adopted to confirm that the impacts associated with energy use and atmospheric emissions during the drilling, installation and commissioning stage are minimised to 'as low as reasonably practicable'.

Proposed Mitigation Measures

- The drilling rig and other project vessels will be subject to audits to assess compliance with UK legislation and the BPEOC Marine Operations and Vessel Assurance Standard;
- Vessel use will be optimised where possible by minimising the number of vessels required, and their length of time on site;
- Vessels will be operated where possible in modes that allow for economical fuel use; and
- Minimise flaring during well clean-up operations by sending fluids to ETAP for processing as the base case and preferred option.

In accordance with the revised NSTA strategy, and associated Stewardship Expectation 11, as well as with the industry commitments within the NSTD, BPEOC will incorporate the impact of the Murlach production within ETAPs controls, including:

- Asset GHG Emission Reduction Action Plans;
- Flaring and venting reviews to identify/action zero routine flaring by 2030;
- Active flare reduction strategy;
- Active vent reduction strategy;
- Emission key performance indicators and targets; and
- Industry level benchmarking of flaring and venting.

These measures will help to ensure that opportunities for efficiency and reduction of atmospheric emissions, where not in conflict with safe operations, are identified, actioned as appropriate and reviewed.

The impact of installation, completions and start-up activities on air quality will be localised, short term and will mainly occur more than 200 km from the nearest shoreline. The significance of impact to the local ecological receptors is therefore considered to be low.

The introduction of Murlach could result in an increase in emissions of exhaust gases such as NO_x and CO from ETAP of up to 26% at its peak. The total emission levels from ETAP are projected to remain significantly lower than levels that have previously been modelled to show environmental impact to be low. The significance of impact on air quality over the life of field for Murlach is therefore considered to be low.

The development of Murlach is expected to result in a small increase in GHG emissions at ETAP of less than 3% per year on average, except for 2026 when the increase is projected to be approximately 23%. The increase in production through ETAP due to Murlach is projected to be more than 40%. The overall GHG intensity of the development, estimated as 56 $kgCO_{2e}$/TeOE for the Base case production profile, is very favourable compared to that of average UKCS oil and gas production, of average global oil production and of imported gas to the UK.

In summary, the overall significance of the impact of energy use and atmospheric emissions is considered to be low.

7. DISCHARGES TO SEA

This section assesses the planned and permitted marine discharges from the proposed Murlach Field Development using the risk assessment methodology presented in Section 4 and discusses the management and mitigation measures employed in order to adhere to legislation and to minimise environmental impact. All phases will involve the discharge of sewage and food waste from vessels; however, these discharges will be in line with MARPOL requirements such that the significance of the environmental impact of these discharges is considered low. They are therefore not assessed further.

7.1 Drilling Phase

Planned and permitted discharges to sea during drilling operations include drill cuttings, associated fluids (seawater and viscous bentonite sweeps), cement and associated chemicals. As discussed in Section 2.5.5, the LTOBM contaminated cuttings will be skipped and shipped to shore for treatment and subsequent disposal.

7.1.1 Discharge of Drilling Fluids and Drill Cuttings

The proposed development involves the drilling of two production wells. Section 2.5.5 estimates the maximum quantities of drill cuttings that will be produced as a result of the drilling programme (Table 2-5).

As described in Section 2.5.5 the lower well sections will be drilled using LTOBM and the cuttings will be returned to the drilling rig where they will be skipped and shipped to shore for treatment prior to disposal. The cuttings from the top sections (those drilled with seawater and bentonite sweeps) will be discharged around 1 m above the seabed. The total volume of discharges (cuttings and drilling muds) associated with the top hole sections has been estimated at *c.*92,800 m^3, some of which will disperse within the water column. The majority of these cuttings will settle out in the immediate vicinity of the well, with some expected to disperse further afield having been carried in the water column. The impacts associated with the deposition of drill cuttings on the seabed are discussed in Section 8, Seabed Disturbance whilst this section focuses on the impacts to fish.

Where avoidance by fish is not possible the sensitivity to suspended sediments varies greatly between species and their life history stages and depends on sediment composition (particle size and angularity), concentration and the duration of exposure (Newcombe and Jensen, 1996). Being the major organ for respiration and osmoregulation, gills are directly exposed to, and affected by, suspended solids in the water. If sediment particles are caught in or on the gills, gas exchange with the water may be reduced leading to oxygen deprivation (Essink 1999; Clarke and Wilber 2000). This effect is greatest for juvenile fish as they have a higher oxygen demand and small gills at higher risk of clogging (FeBEC 2010). As some fish species in the area are considered to be PMFs (Section 3.5.2) including sandeel, mackerel and cod, receptor sensitivity is considered Medium (b). However, given the relatively small volume of water expected to be impacted by sediments, and the relatively short time period that the sediments will be in the water column, the magnitude of impact is considered Negligible. The overall impact significance is therefore considered Low such that any impacts of the suspended drill cuttings is considered negligible.

7.1.2 Cement and Cementing Chemicals

As described in Section 2.5.6, when drilling a well, cement is used to secure the steel conductor and casings in the well bore, whilst cementing chemicals are used to modify the technical properties of the cement slurry. The discharges associated with these cementing operations are described briefly here and will be detailed in the drilling permit applications submitted to OPRED prior to commencement of drilling. These include:

- Discharge of residual mixed cement from the rig following a cementing operation;
- Discharge of cement as a result of an aborted cementing job;

- Discharge onto the seabed of excess cement pumped down the well; and
- Discharge of cement spacers, mix-waters and cement unit washings.

7.1.2.1 Residual mixed cement and aborted cement jobs

Prior to carrying out the cementing job, dry cement is mixed in a cement unit on board the drilling rig prior to being pumped into the wellbore. Cement mixwater (water with soluble and suspended additives required to confirm that the cement has the correct properties) is pre-mixed in pits onboard the drilling rig before being mixed with cement solids to form a slurry which is pumped into the well. Prior to cementing the tophole section cement spacer will be pumped directly into the annulus to confirm that any cement placed there gels up to maintain the structural integrity. The top hole cement spacer is discharged at the seabed. Following a cement job the cement unit is washed to remove any residual chemical additives and / or cement slurry from the lines as any cement slurry left in the lines will set and block the line rendering the cement unit incapable of performing the next job until this blockage is removed. The water and residual cement are discharged overboard.

The need to abort a cement job could arise for a number of reasons including a total failure of the pumping equipment, a blockage (either on surface or down the wellbore) in the pipes through which the cement is pumped, or due to changing downhole well conditions (i.e., wellbore collapse, losses, or well control scenarios). In these instances, the consequences of not discharging mixed cement would be severe with the potential for cement to settle in the pumps, pits and lines on the rig, rendering the equipment unusable until the hardened cement is removed from surface equipment. This could in turn result in major workscopes associated with disconnecting, removing and cleaning the lines before reconnecting them in order to return the equipment to operational status.

The cement discharges associated with the planned flushing operations of the cement unit or those associated with an aborted cement job are expected to disperse rapidly in the upper water column. Using data from Stark and Mueller (2003) it is concluded that at North Sea temperatures, cement particles that have been diluted will not increase significantly in particle size due to their hydration reaction, and will remain in the range 10-30 microns or smaller which is controlled by their manufacture and specification. Such particles will take many days to settle through the water column and will be in an inert reacted state once at the seabed, with negligible impact. The initial discharge may affect plankton in the localised area of the plume, with rapid recovery expected similar to a discharge of drilling solids.

Over a period of hours, it is expected that the cement discharged following the washing of the cement unit or as a result of an aborted cement job will be indistinguishable from background suspended solids concentrations. The sensitivity of the fauna in the water column that could be impacted by these discharges ranges from Low (e.g. plankton) to Medium (e.g. fish species), however given the relatively small volume of water impacted the magnitude of effect is considered Negligible. The overall impact significance is therefore considered Low such that any impacts of the suspended cement discharges is considered negligible

7.1.2.2 Excess cement pumped down the well

Once injected, the majority of the cementing material remains down hole, although with top hole sections some discharge to the environment is anticipated when the annulus is filled with cement and casings are cemented back to the seabed. Any cement returns (estimated at a maximum of 20 te per well) will be discharged in the immediate vicinity of the wellhead and will likely impact on an area already impacted by the drill cuttings.

The cement mixture is designed to set rapidly and the majority of the slurry will set into masses of inert solid cement, smothering a small area of seabed near to the casing, and ultimately will behave similar to inert hard substrate. Discharges to the seabed are at a density of around 1.9 te/m^3 in a semi-cohesive state and as mentioned are expected to flow onto the area already disturbed by cuttings from drilling the tophole sections, with some dispersion into the water column. The majority of the slurry will set into a thin diluted crust of weakened, inert solid cement and smother a small area of seabed near to the casing, and ultimately will behave as an inert hard substrate.

Large cement deposits on the seabed are not expected. Should they occur, they will be addressed in the mandatory debris survey at the decommissioning stage at the end of field life. It is not expected any deposits would be capable of posing a hazard to towed fishing gear in the area, however, if any large deposits are identified during the decommissioning stage, relevant measures will be taken to mitigate any potential dangers in the area. Any increase in turbidity of the water column as a result of cement returns would be localised and short-lived. The impacts of these cementing discharges on the seabed are discussed in Section 8, Seabed Disturbance.

7.2 Subsea Installation and Commissioning Phase

Depending on detailed design it is possible that the pipeline testing and commissioning operations would require a discharge to sea of the pipeline preservation fluids (Section 2.6.5).

These discharges could contain chemicals including oxygen scavengers and biocides to mitigate the risks of corrosion or bacterial growth whilst an ultraviolet-fluorescent dye may be added to assist in leak detection.

BPEOC aims to minimise the effect of the chemicals used/discharged during its operations and as such, wherever possible, chemicals will be chosen which are PLONOR (Pose Little Or No Risk) or are of a Hazard Quotient (HQ) <1. All CHARMable (Chemical Hazard Assessment and Risk Management) chemicals discharged will be further assessed by calculating a Risk Quotient (RQ). Where chemical use and discharge results in a RQ value >1, thus indicating a possible risk of the discharge causing harm to the marine environment, further investigation of the product will be carried out to determine if there is an alternative product that can be used which produces a lower RQ.

There is also the possibility of some hydraulic fluids being released during subsea valve operation and maintenance. However given the use of water based hydraulic fluids, any environmental impacts will be limited.

All chemicals used during pipeline testing and commissioning will be risk assessed within the relevant Chemical Permit applications. The testing will be carried out over a short timescale and the amount of chemicals discharged to the marine environment will be minimised.

Marine flora and fauna may be affected on a localised level but given BPEOC's commitment to prioritise the use of chemicals which are PLONOR, or are of a HQ <1, the rapid dilution that will occur on discharge means that the magnitude of effect is considered Negligible (1). Combined with a receptor sensitivity of Medium (b) the impact of significance is considered Low such that any impacts of the chemicals discharged during commissioning are considered negligible.

7.3 Production Phase

7.3.1 Water Discharges

Formation water is naturally trapped in oil and gas reservoirs and despite efforts to produce the hydrocarbons selectively, a fraction of this water is brought to the surface mixed with oil and gas. This produced water may comprise dispersed oil, metals and organic compounds such as dissolved hydrocarbons, organic acids and phenols.

The PWRI system in place on the ETAP platform is designed such that 100 % of the PW is reinjected. Therefore, there will be no PW discharges to sea and as such, PW is not discussed further within this section.

Discharges of cooling water and drainage water at the ETAP platform are not anticipated to change as a result of the proposed Murlach Field Development and are therefore not discussed further.

7.3.2 Produced Sand Discharges

A sand management study is underway to evaluate whether sand production can reasonably be expected from the Murlach wells and if so evaluate measures in the well completion design and well operating practices to minimise sand production.

At the time of writing it is too early to predict volumes of sand production from the wells, or even whether any sand can reasonably be anticipated. However, any sand that does build up in topsides plant will be managed similarly to the other ETAP fields i.e. utilising an offline sand removal system with discharge of cleaned sand to sea under the ETAP asset Oil Discharge Permit.

7.4 Decommissioning Phase

Some planned discharges to sea are likely to occur during the decommissioning of the Murlach infrastructure at the end of field life. These may include the following:

- Routine MARPOL compliant discharges from vessels associated with the decommissioning activities;
- Discharges associated with well abandonment; and
- Discharges resulting from the disconnection / cutting and recovery (where applicable) of the pipe spools, umbilical jumpers, pipeline, etc.

Discharges to sea resulting from the decommissioning activities will be described in the EIA submitted in support of the Decommissioning Programme.

All discharges that may be contaminated with hydrocarbons will be treated to below minimum levels required at the time of decommissioning or shipped to shore for treatment and disposal.

7.5 Cumulative and Transboundary Effects

The cumulative impact of drill cuttings and cement on the seabed are discussed in Section 8. In relation to all other discharges, given the proposed mitigation measures no significant cumulative impacts are anticipated.

The proposed Murlach Field Development will be located *c*. 27 km from the UK/Norway median line such that no transboundary impacts are anticipated from the discharges associated with the proposed drilling, installation, commissioning, production or decommissioning activities.

7.6 Mitigation Measures

The following mitigation measures are proposed to minimise the impacts associated with the discharges to sea associated with the proposed Murlach Field Development.

Proposed Mitigation Measures

- The drilling rig used will be audited under BPEOC's Marine Operations and Vessel Assurance Standards and subject to rig recertification audits;
- All vessels used will be MARPOL compliant;
- Where technically feasible BPEOC will prioritise the selection of PLONOR, or chemicals with a lower RQ; and
- The discharges of any water based hydraulic fluids, sand or chemicals are regulated by the OPPC and/or OCR regulations and reported through the EEMS. As such, BPEOC will confirm that sampling, analysis and reporting are undertaken in line with the regulations and permit conditions.

Applying the risk assessment methodology described in Section 4 and taking account of the mitigation measures listed above, the impact significance associated with the discharges to sea (other than those associated with the accumulation of drill cuttings or cement on the seabed, which are discussed in Section 8: Seabed Disturbance) is considered low. The impacts are therefore considered acceptable when managed within the additional controls and mitigation measures described.

The proposed development will be conducted in compliance with all NMP policies; an assessment against the relevant NMP objectives is given in Appendix A.

8. SEABED DISTURBANCE

A number of activities will be carried out during the proposed Murlach Field Development which have the potential to impact seabed habitats populated by the benthic communities in the area. This section considers the impact of the different sources of seabed disturbance identified, quantifies the area of potential seabed disturbance and assesses the impact of the disturbance using the risk assessment methodology presented in Section 4.

The extent to which the benthic habitats will be impacted depends on the size of the area that will be affected and the temporal extent of the impact e.g. positioning of the mooring anchors associated with the semi-submersible rig can have a temporary impact in the vicinity of the anchors whilst the area of seabed beneath the infrastructure to be installed can be considered a permanent impact. In addition, species sensitivity and the habitat type in the area, and whether they are unique to the area or of significant conservation importance, are important in determining the overall impact of the proposed project.

8.1 Drilling Phase

8.1.1 Drilling Rig

Having been towed to the site, in the highest impact scenario a semi-submersible rig will be held on location using 12 x *c.* 1,500 m chain anchors. Anchor dimensions of 2 m x 2 m are assumed. During positioning it is assumed each anchor will impact an area of 10 m x 10 m, whilst a maximum length of 1,000 m of each anchor line is anticipated to come into contact with the seabed. If a semi-submersible drilling rig is utilised this will be skidded between wells such that it will not be required to be repositioned when moving from one well to the other. The maximum anticipated area of seabed disturbance associated with the installation of the anchor system is provided in Table 8-1 whilst the impacts on the seabed and associated ecosystem are discussed in Section 8.5.

8.1.2 Drill Cuttings

As discussed in Section 2.5.5 the drill cuttings and associated seawater and bentonite sweeps from the 36" and 26" sections (92,800 $m^{3)}$ will be discharged *c.* 1 m above the seabed whilst the drill cuttings and associated LTOBMs associated with the lower sections will be skipped and shipped to shore. The impact of the discharged cuttings is discussed in Section 8.5.

8.1.3 Cement Deposits at the Well

As discussed in Section 2.5.6 it is possible that solid cement deposits could occur on the seabed in the immediate vicinity of the top of each well. If they do occur these deposits are expected to impact on an area of less than 0.0002 km^2: based on approximately 20 te impacting on an area extending 7.5 m around each well radius. The impact of these deposits on the seabed and its associated ecosystem are discussed in Section 8.5.

8.2 Installation Phase

Table 2-10 and Table 2-12 summarise the subsea infrastructure and stabilisation features to be installed as part of the proposed project. Table 8-1 summarises the seabed areas anticipated to be temporarily and permanently impacted by the proposed installation activities. It should be noted, the area of disturbance presented represents a worst case, for example the area impacted by the mattresses and the tie-in spools will overlap. Similarly, much of the area impacted by the grout bags will likely also be impacted by the mattresses and infrastructure. Rock cover was assessed based on the worst case estimate associated with Option 2 (100% rock cover of the line at least 50 m away from any nearby berms). Should Option 1 (surface laid with spot rock cover) or Option 3 (laying the gaslift flowline adjacent to an existing rock berm), be selected the anticipated volume of rock and associated footprint will be less.

If the gas lift flowline is trenched and buried (Option 4), the plough will create an area of deposited spoil at either side of the excavated trench. This material will subsequently be backfilled into the trench after the flowline has been laid. For this option, the ES assumes a worst case whereby 10% of the flowline will require rock cover to mitigate areas where the targeted trench depth cannot be achieved (for example due to the presence of rocks) or to mitigate upheaval buckling. Should clay berms be created as a result of the trench and bury activities BPEOC will work with SFF to identify suitable mitigation measures e.g. carrying out trawl sweeps using a chain mat in order to break up large clay lumps that could damage fishing vessels should their equipment become entangled with the berm.

The impacts of the anticipated disturbance on the seabed and its associated ecosystem are discussed in Section 8.5.

8.3 Production Phase

No planned seabed disturbance is anticipated to occur during routine production operations.

8.4 Decommissioning Phase

The decommissioning activities will result in some temporary disturbance to the seabed. Sources of disturbance could include:

- Seabed sampling for pre-decommissioning survey work;
- Localised dredging or jetting to allow access for cutting;
- Recovery of subsea infrastructure;
- Potential temporary wet storage of items following disconnection and prior to recovery;
- Temporary positioning of baskets for recovery of tie-in spools etc.; and
- Anchoring of drilling rig during well abandonment.

Following discussion with OPRED and its consultees, BPEOC, as operator, will meet survey requirements prior to the commencement of decommissioning activities. Should the gaslift flowline be rock covered and not be able to be recovered, a post-decommissioning survey strategy will be agreed with the Regulator.

The Environmental Appraisal submitted in support of the Decommissioning Programme will capture the impacts associated with the disturbance of the seabed. The activities will be further detailed on the relevant MAT and associated SAT applications including a Marine Licence in line with advice received from OPRED at the time. It is anticipated that the area disturbed by the decommissioning activities will mostly be within the area disturbed by the installation activities.

8.5 Seabed Disturbance Impact Assessment

Table 8-1 summarises the total area of disturbance associated with the drilling and installation activities. A number of worst case assumptions have been made to determine the maximum impact, for example a worst case volume of rock cover has been assumed, whilst the footprint of the grout bags will likely overlap with that of the mattresses.

Excluding the footprint associated with the discharged cuttings it is anticipated that the maximum area of permanent seabed disturbance is *c.* 0.055 km^2 (associated with Option 2) whilst the minimum area of permanent seabed disturbance is *c.* 0.0106 km^2 (associated with Option 4). However, the largest potential area of temporary disturbance (*c.* 1.256 km^2) is associated with Option 4 and is associated with mitigation that could be required to break up any clay berms that may result from the trenching activities. In the absence of any clay berms being formed and there not being a requirement for trawl sweeps and over trawl trials (e.g. should side scan sonar be used to show a safe seabed), the total area of temporary disturbance for Option 4 reduces to *c.* 0.556 km^2. The temporary area of disturbance associated with Option 2 is estimated at c. 0.514 km^2. Note, Option 3 (laying the gas lift flowline adjacent to an existing rock berm) will have less of an area of impact than Option 2 as it is estimated the width of the existing rock berm would be extended by around 3 m (whilst the rock berm associated with Option 2 is estimated to be c. 7 m wide. Option 1, surface laying of the flowline with spot rock cover has the smallest area of temporary disturbance associated with it (0.461 km^2).

Table 8-1: Anticipated area of seabed disturbance associated with the proposed drilling and installation activities.

Item number	Infrastructure	Assumptions	Area of seabed impacted during installation (km^2)	
			Temporarily impacted	Permanently impacted
1	12 x semi-submersible anchors	Assumes the area of disturbance when positioning each anchor is 10 m x 10 m. As the anchors will be recovered at the end of the drilling campaign, the impact is considered temporary.	0.0012	N/A
2	12 x semi-submersible anchor lines	Assumes a maximum of 1,000 m of each anchor line impacting on the seabed. As the anchors will not be relocated when moving from the first to the second well it is assumed that part of the anchor chains will scrape across the seabed whilst the rig is being skidded between wells. As a worst case a corridor width of 50 m along each anchor line is assumed to be impacted during the anchor line layout and skidding activities.	0.4	N/A
3	Cement deposits	Discharged cement at top of each well associated with cementing of the top hole section. Assumes an area with a radius of 7.5 m is impacted.	N/A	0.00035
4	Manifold	Dimensions: 20 m (L) x 10 m (W). To assess the temporary area of disturbance a worst case of 2 m on either side of the structure is assumed.	0.00014	0.0002
5	Two wellheads and associated Xmas trees and protective structures	Dimensions: 5 m (L) x 4 m (W). Includes protection structure. A worst case of temporary disturbance of 2 m on each side of each structure is assumed.	0.00010	0.00004
6	Option 1 Surface laid with spot rock cover	Surface laid 6” gas lift flowline with a maximum of 8,000 te of spot rock providing cover to 10% of the flowline i.e. covering 700 m (c. 15,000 te of rock). Assume at each spot rock location a 7 m corridor of permanent impact, and an additional 7 m temporarily impact each side of the spot rock as a result of disturbed sediments.	0.035	0.00118
		Out with the spot rock locations, assume permanent disturbance of full length of flowline (7 km) with external diameter of 0.168 m. Temporary disturbance assumes corridor width of 10 m.	0.0098	0.0049

Item number	Infrastructure	Assumptions	Area of seabed impacted during installation (km^2)	
			Temporarily impacted	Permanently impacted
7	Option 2 Rock cover of gas lift flowline	150,000 te of rock cover. Assumes a worst case for the 7 km gas lift line with a 7 m corridor of permanent impact, and an additional 7 m temporarily impact each side of the berm as a result of disturbed sediments.	0.098	0.049
8	Option 4: Gas lift flowline trenched and buried with 10% spot rock cover	Gas lift flowline trenched using a mechanical plough. ES assumes a corridor width of 20 m temporarily disturbed during trench and bury activities. Assumes 15,000 te of rock is laid across 10% of the flowline (spot rock covered) permanently impacting a corridor width of 7 m. Temporary area of disturbance caused by rock placement activities is considered to be within area temporarily impacted by the trench and bury activities.	0.14	0.0049
9	Mattresses	Anticipated up to 280 mattresses will be required (measuring 6 m (L) x 3 m (W)). As a worst case it is assumed that an additional area of 2 m on each side of each mattress will be temporarily impacted during installation.	0.0104	0.0036
10	Grout bags	70 te of grout bags (3,000 x 25 kg) to be used. Assessment assumes 1 te of grout bags permanently impacts on 1 m^2 of seabed and temporarily impacts on an additional 1 m^2 during installation.	0.00007	0.00007
11	Trawls sweeps and over trawl trials.	Assumes a worst case whereby for Option 3 (trench and bury) clay berms are produced and trawl sweeps and over trawl trials are commissioned. Assumes a corridor width of impact of 100 m along the full length of the flowline. The impact is considered temporary as ecosystem recovery is expected to commence once the trawl sweep/over trawl trials have been completed.	0.7	N/A
	Totals	**Option 1**	**0.461**	**0.012**
		Option 2	**0.514**	**0.055**
		Option 4	**1.256**	**0.011**

Note:
With respect to Options 2, 3 and 4 the gas lift flowline will surface laid and rock covered or trench and buried, the area of seabed impacted by the flowline itself is within the footprint of that covered within line items 6 or 7. Therefore, a separate line item has not been added for the flowline.
As the spools and umbilical jumpers will be protected by mattresses and grout bags, the area of seabed impacted by the spools and umbilical jumpers themselves is within the footprint of that covered within line items 9 and 10. Therefore, separate line items for the tie-in spools and umbilicals have not been added.

The physical disturbance resulting from the drilling rig's anchors, the installation of the subsea infrastructure and the placement of rock cover, mattresses and grout bags can cause mortality or displacement of motile benthic species in the impacted area, direct mortality of sessile seabed organisms that cannot move away from the contact area and direct loss of habitat. In addition, disturbance from sediment re-suspension will occur in the immediate area when the structures are initially positioned.

Mattresses, rock cover and grout bags have similar impacts in terms of loss of habitat and smothering of the benthos. In addition to causing mortality or displacement of benthic animals the stabilisation features (i.e. rock cover, mattresses and grout bags) may also create habitats for benthic organisms that live on hard substrates e.g. sponges, soft corals and tubeworms, sea slugs, hermit crabs and brittle stars (Coolen *et al*., 2018).

The installation of the anchors associated with the drilling rig will likely cause some scars on the seabed. The anchors will, however, be subsequently recovered such that the substrate in the area will not change. Should the gas flow line be trenched and buried, the sediment quality will temporarily decrease, however, will recover due to the backfilling of the trench.

The cuttings from the top-hole sections of the wells and the cement deposits that could result on the seabed following cementing of the top-hole sections will result in a change in composition of the seabed in a small area in close proximity to the wells. The drilling activities will result in small pieces of rock ('cuttings') being returned to the seabed. However, given that the area is known to comprise sandy mud/muddy sand, shell fragments with occasional pebbles, cobbles and boulders (Section 3.3.3), the addition of these 'pieces' of rock and cement are not expected to significantly change the composition of the seabed sediments in the area.

As only two wells will be drilled and as the proposed drilling operations will take place within an existing brownfield area, it was agreed with OPRED and JNCC that modelling of the fate of the discharged cuttings was not deemed necessary to inform the ES (see Table 1-3). It is expected that following cessation of drilling the area of risk will be relatively small and will primarily be associated with burial and changes in grain size.

The discharge of drill cuttings is expected to result in a very localised temporary reduction in water quality in the lower part of the water column (approximately 10 m above the seabed), primarily due to an increase in suspended solids (barite). On the seabed, discharged cuttings will change the grain size in the immediate vicinity of the wells and is expected to result in a burial thickness that could be a risk to some of the animals in the area. In addition, some benthic animals may be impacts by chemical concentrations and oxygen depletion. Modelling studies carried out to support other environmental statements generally predict that following completion of drilling, the area where the combined risk to more than 5 % of the most sensitive species in the sediment reduces rapidly over time due to re-colonisation by opportunistic species.

It is possible that disturbed sediment particles may be transported via tidal currents for re-settlement over adjacent seabed areas. This may have indirect negative effects on the benthic ecology in the vicinity, including smothering and scour of seabed communities causing a loss of species diversity, abundance and biomass in effected areas. Sessile epifaunal species may be particularly affected by increases in suspended sediment concentrations as a result of potential clogging or abrasion of sensitive feeding and respiratory apparatus (Nicholls *et al*., 2003). Larger, more mobile animals, such as crabs and fish, are expected to be able to avoid any adverse suspended solid concentrations and areas of deposition. Re-suspended sediments could have a negative impact on suspension feeding organisms such as sea pens and bivalves including *A. islandica* both of which are known to occur in the area (see Section 3.4.2). Within Marine Scotland's Feature Activity Sensitivity Tool (FeAST) *A. islandica* are described as having a high sensitivity to sub-surface abrasion and siltation changes although damage is related to body size with larger specimens being more vulnerable. Although *A. islandica* burrow into the sediment, they use a short inhalant siphon which sits above the sediment surface for feeding and respiration (Taylor, 1976). Surface abrasion and siltation may therefore damage/clog the inhalant siphon, however it should be noted that following smothering/burial (up to 40 cm), they are able to burrow to the surface (Powilleit *et al*., 2009). *A. Islandica* is considered not sensitive to smothering (of up to 30 cm of material added to the seabed in a single event) (Tyler-Walters & Sabatini, 2017). Given the widespread distribution of *A. islandica* across the CNS, any mortality caused to individual specimens as a result of the proposed activities is not considered significant given the relatively limited area of impact.

Recovery times for faunal communities following disturbance resulting from the installation activities are difficult to predict, although some studies have attempted to quantify timescales. Collie *et al*. (2000) examined impacts on benthic communities from bottom towed fishing gear and concluded that, in general, sandy sediment communities were able to recover rapidly, although this was dependent upon the spatial scale of the impact. It was estimated that recovery from a small-scale impact, such as a fishing trawl, could occur within about 100 days. It was assumed that recolonisation was through immigration into the disturbed area rather than from settlement or reproduction within the area.

Where avoidance by fish is not possible the sensitivity to suspended sediments varies greatly between species and their life history stages, and depends on sediment composition (particle size and angularity), concentration and the duration of exposure (Newcombe and Jensen, 1996). Being the major organ for respiration and osmoregulation, gills are directly exposed to and affected by suspended solids in the water. If sediment particles are caught in or on the gills, gas exchange with the water may be reduced leading to oxygen deprivation (Essink 1999; Clarke and Wilber 2000). This effect is greatest for juvenile fish as they have small easily clogged gills and higher oxygen demand (FeBEC 2010).

IOGP report 543 (IOGP, 2016) examines evidence relating to the effect of cuttings discharges on early stage fish life, and concludes that WBM generally have a low toxicity to pelagic invertebrates and early life stages of fish. Studies on early life stages of sea scallops, lobsters and haddock (Cranford *et al.,* 1998) showed a slight reduction in survival of haddock and fed (but not unfed) lobster after 96 hours exposure at 100 mg/l of drilling fluid suspension and no effect on fertilisation, survival or growth of sea scallops.

The ability for organisms including fish species to detect predators may be reduced as a result of low visibility associated with suspended sediments. In instances of persistent and widespread suspended sediments there is the possibility of reduced feeding success among juvenile fish which may influence survival, year-class strength, recruitment and overall condition (Clarke and Wilber, 2000). However as the proposed activities are relatively short term any impacts from low visibility are expected to be temporary and are not considered significant.

Given the presence of designated species in the area e.g. *A. islandica* which is considered an OSPAR threatened and or declining species and a number of PMFs (see Section 3.5.2), receptor sensitivity in the area is considered Medium (b). Any changes to the receptors impacted are not considered significant in that at most receptors are expected to be impacted at an individual level rather than a population level and once drilling and installation activities are completed, recovery of the ecosystem is expected to commence such that the magnitude of effect of disturbance to the seabed from all activities is considered Minor (2). Combining a Medium sensitivity with a Minor magnitude of effect the impact significance is considered Low such that any environmental impacts are considered to be negligible.

8.6 Cumulative and Transboundary Effects

The drilling activities and infrastructure to be installed as part of the proposed Murlach Field Development will increase the footprint of the infrastructure associated with the Heron Cluster Area including the footprint of rock. However, the increase in impacts has been minimised where possible e.g. by tying into existing infrastructure where possible, sharing the Seagull control umbilical and surface laying the jumpers and spools, such that the overall cumulative effect is kept to a minimum. Given that other rock berms exist in the area, the introduction of an additional rock berm (should the gas lift line be surface laid and rock covered) will not introduce a substrate that is not already in the area such that no new ecosystems are expected to develop as a result of the new rock to be added.

Given the distance (*c.* 27 km) from the UK / Norway median line no transboundary seabed impacts are associated with the proposed activities.

8.7 Mitigation Measures

The following mitigation measures are proposed to minimise the impacts associated with disturbance to the seabed resulting from the proposed development.

Proposed Mitigation Measures

- Pre-deployment surveys will be undertaken to identify suitable locations for the drilling rig anchors in the event a semi-submersible drilling rig is utilised;
- Tie-ins to existing infrastructure where possible; and
- The use of mattresses, rock cover and grout bags will be minimised through optimal project design.

Applying the risk assessment methodology described in Section 4 and taking account of the mitigation measures listed above, the significance of impact of the seabed disturbance resulting from the proposed activities is considered low.

The proposed project will be conducted in compliance with all NMP policies; an assessment against the relevant NMP objectives is given in Appendix A.

9. UNDERWATER SOUND

This chapter assesses the impact of sound associated with the proposed Murlach Field Development, using the risk assessment methodology outlined in Section 4.

9.1 Introduction

Marine fauna use sound for navigation, communication and prey detection (Southall *et al*., 2007; Richardson, *et al*., 1995). Therefore, the introduction of anthropogenic underwater sound has the potential to impact on marine animals by interfering with the animal's ability to use and receive sound (OSPAR, 2009b). Offshore exploration and production activities invariably generate underwater sound; for example, during geophysical exploration, during drilling activities or piling operations and from the vessel operations. The level and frequency range of sound generated varies with the type of activity.

It is generally accepted that exposure to anthropogenic sound can induce a range of adverse effects on marine life (e.g. OSPAR, 2009b). The type and extent of potential impact associated with sound on an animal depends on many factors including the level and frequency characteristics of the sound, hearing sensitivity and behaviour of the species, propagation characteristics of the operational area and whether or not marine species are using the areal extent of the sound field. Potential impacts can vary from insignificant impacts such as temporary avoidance or small changes in behaviour to significant impacts such as auditory and physical injury (Southall *et al.,* 2007; Southall *et al.,* 2019; National Marine Fisheries Service (NMFS), 2018; Richardson *et al.,* 1995).

The Offshore Marine Regulations 2007 (as amended, 2010) make it an offence to injure or disturb EPS (including all marine mammals), where disturbance has a likelihood of impairing their ability to survive, to breed or reproduce, to rear or nurture their young, or to migrate. It also includes the likelihood of significantly affecting the local distribution or abundance of the species. New developments must assess if their activity, either alone or in combination with other activities, is likely to cause an offence involving an EPS.

9.2 Sound Sources Associated with the Proposed Project

Activities associated with the proposed Murlach Field Development, resulting in the generation of underwater sound, include:

- Drilling activities;
- Vessel operations; and
- Possible piling activities for the manifold installation.

There are no explosives or seismic activities associated with the proposed project. Should a requirement for seismic profiling be identified at a later date, a geological survey permit application would be submitted to OPRED prior to execution. The application would be supported by determining the impact that sound generated during the seismic profiling would have on marine mammals.

9.2.1 Vessel and Drilling Operations

Vessel traffic can be considered a substantial contributor to general anthropogenic sound scape with the primary sources of sound coming from the propellers, propulsion and other machinery (Ross, 1976; Wales and Heitmeyer, 2002).

There will be some sound and vibration associated with drilling operations. This sound will propagate from any rotating machinery such as generators, pumps and the drilling unit and risers (McCauley, 1998). Drilling sounds, although of a relatively low level, will be continuous and generated for long periods throughout the drilling phase.

9.2.2 Piling Activities

As discussed in Section 2.6.2, the new manifold may be a piled structure. Piling requires a hydraulic hammer to forcibly drive tubular steel piles into the seabed, resulting in substantial levels of pulsed underwater sound being generated. The level of this sound depends on numerous factors such as the size and operating energy level of the hammer, the diameter and length of the piles, the sub-surface depth of pile, number of hammer strikes, and the physical factors that will influence sound propagation (such as bathymetry, type of seabed substrate, water temperature and salinity).

The exact details of the piling activity (e.g. size of piles, hammer energy, rate of blows etc.) was not known at the time of writing the ES, but the following parameters have been assumed based on experience. The piles required for installation of the Murlach manifold are expected to be up to 24” in diameter and up to 30 m in length. A maximum of four piles will be required to install the manifold. It is expected that each pile will take a maximum of 8.3 hours (503 minutes) and all piles will be installed within 2 to 3 days. The estimated maximum hammer energy required to install all piles is 150 kJ.

Piling of the manifold will be the loudest sound source associated with the proposed Murlach Field Development and will be the activity that results in the largest extent of potential injury or behavioural disturbance to marine mammals and fish. Therefore, underwater sound propagation modelling has been conducted to estimate the potential impacts of piling the manifold (Appendix D).

9.3 Impact of Underwater Sound

The potential impact of underwater sound on receptors depends on the actual level of sound received by the receptor relative to background sound level and other sound sources/activities, as well as the receptor’s sensitivity and response to that sound.

Applying the assessment methodology presented in Section 4, the sensitivity of marine mammals and fish in the area is considered Medium (b) given the cetaceans are EPS whilst a number of fish species in the area e.g. Sandeel, Cod and Mackerel are considered PMFs (see Section 3.5.2).

9.3.1 Marine Mammals

Section 3.4.5 discusses the abundance, distribution and seasonal occurrence of marine mammals known to occur in the Murlach Field area. Marine mammals have been grouped by the National Oceanic and Atmospheric Administration (NOAA) according to the hearing range for the species in Table 9-1 (NMFS, 2018) indicating which activities present during the development may produce sounds within the hearing range of the various hearing groups. In many species sensitive to underwater sound, sensitivity is related to their use of high frequency sound for echolocation.

Table 9-1: Marine mammal known to occur in the Murlach area and hearing group.

Functional hearing group	Generalised hearing range	Species known to occur in the Murlach area	Activities producing sound in this band*
Low-frequency (LF) cetacean	7 Hz to 35 kHz	Minke whale.	Vessel engine and propulsion Drilling Piling
Mid-frequency (MF) cetacean	150 Hz to 160 kHz	Atlantic white-sided dolphin; White-beaked dolphin.	Vessel dynamic positioning Drilling Piling
High-frequency (HF) cetacean	275 Hz to 160 kHz	Harbour porpoise; Other species while echolocating.	Piling
Phocid Pinnipeds	50 Hz to 86 kHz	Grey seal; Harbour seal.	Vessel engine and propulsion Drilling Piling
* The frequency bands distinguish between very broad categories of sensitivity and sound sources			

9.3.1.1 Vessels

Richardson *et al*. (1995) reviewed the effects of sound from vessels on marine mammals. They noted that it is not always possible to distinguish between effects due to the sound, sight or even smell of a vessel to an animal but there is evidence that sound from vessels has an impact on marine mammals. Animals have been reported to display a range of reactions from ignoring to avoiding the sound. The latter can lead to temporary displacement from an area. Vessel sound can mask communication calls between cetaceans, reducing their communication range (Jensen *et al*., 2009). It is not obvious whether temporary behavioural reactions translate into long-term effects on an individual or population. Exposure to low frequency shipping sound may be associated with chronic stress in whales; Rolland *et al*. (2012) reported a decrease in baseline levels of stress-related faecal hormones concurrent with a 6 dB reduction in underwater sound along the shipping lane in the Bay of Fundy, Canada, when traffic levels decreased.

The area around Murlach presents many background sound sources associated with vessel movements to which marine mammals are exposed. Given that marine mammals are accustomed to the presence of vessels in the area the magnitude of effect of the increased vessel noise on marine mammals is considered Negligible (1). Combining a Negligible magnitude of effect with a Medium sensitivity (Section 9.3) the impact significance is considered Low such that any environmental impacts are considered to be negligible.

9.3.1.2 Piling

Offshore piling has been recognised as an activity that could, under certain conditions, cause disturbance and/or injury to marine mammals (JNCC, 2010a). The potential impact of underwater sound on the marine mammal receptors has been assessed using the recommended JNCC guidance (JNCC, 2010a). To support the assessment of the impact of piling, underwater sound propagation modelling was carried out. Full details of the modelling are available in Appendix D.

The predicted sound levels from piling have been compared with the NOAA (NMFS, 2018) precautionary thresholds for permanent threshold shift (PTS) to marine mammals. These thresholds are based on a comprehensive review of evidence for impacts of underwater sound on marine mammals and are now widely applied as appropriate precautionary criteria for assessing the impact of underwater sound on marine mammals (JNCC, 2010a).

As discussed in detail in Appendix D predicted sound levels from the proposed piling at Murlach have been compared to the NOAA zero-to-peak sound pressure level (SPL) and cumulative sound exposure level (SEL) thresholds for PTS onset. The predicted distances to the NOAA PTS thresholds are summarised in Table 9-2. As the distances shown in Table 9-2 are less than the nominal 500 m mitigation zone radius include in the JNCC Guidelines (JNCC, 2010b), implementation of JNCCs standard mitigation measures (see Section 9.5) will further reduce the likelihood of PTS occurring for all marine mammal groups.

Table 9-2: Predicted maximum distances from the piling location where sound levels decrease to below the NOAA zero-to-peak SPL and cumulative SEL thresholds for potential PTS onset.

Marine Mammal Hearing Group	Predicted Maximum Distance to Threshold [1]	
	NOAA unweighted zero-to-peak SPL thresholds for potential PTS onset	NOAA unweighted cumulative SEL thresholds for potential PTS onset [2]
LF Cetaceans	Sound levels below threshold	440 m
MF Cetaceans	Sound levels below threshold	Sound levels below threshold
HF Cetaceans	80 m	40 m
Phocid Pinnipeds	< 10 m	Sound levels below threshold

[1] Predicted distances have been rounded up to the nearest 10 m.
[2] Estimated for marine mammals swimming away from the piling location at 2 m/s

Table 9-3 presents the results of the modelling for predicting the distances and areas associated with any marine mammal behavioural disturbance due to piling at the Murlach Development. The predicted disturbances are consistent with observations made during piling activities of other developments. The proposed piling activities are expected to be completed within 2 to 3 days of commencement, any marine mammals disturbed are expected to return to the area after cessation of activities and so any disturbance experienced will be temporary. With the application of JNCC guidance any impacts of the proposed piling activities on marine mammals are considered to be short term behavioural impacts rather than resulting in injury such that the magnitude of effect is considered Minor (2). Combining a Minor magnitude of effect with a Medium sensitivity (Section 9.3) the impact significance is considered Low such that any environmental impacts are considered to be negligible. The behavioural disturbance thresholds that have been adopted in this assessment are summarised in Table D-5.

Table 9-3: Predicted distances where sound levels decrease to below the adopted marine mammal behavioural disturbance thresholds and areas of potential disturbance.

Marine Mammal Hearing Group	Maximum Distance to Threshold [1]	Area [2]
LF cetaceans	8 km	201 km^2
MF cetaceans	8 km	201 km^2
HF cetaceans	15 km	707 km^2
Phocid pinnipeds	8 km	201 km^2

[1] Predicted distances have been rounded up to the nearest 1 km.

[2] Predicted areas have been rounded up to the nearest 1 km^2.

9.3.2 Fish

The fish species associated with the project area are identified in Section 3.4.3. Fish species differ in their hearing capabilities depending on the presence of a swim bladder, which acts as a pressure receiver (McCauley, 1994). Most fish can hear within the range of 100 Hz to 1 kHz, with some able to detect lower frequencies. Within this range, the hearing threshold varies from approximately 50 dB re 1 µPa for hearing specialists to 110 dB re 1 µPa for non-specialists. Fish with a connection between the swim bladder and otolith system have more sensitive hearing and may detect frequencies up to 3 kHz (Popper *et al.*, 2003). Many species of fish produce sounds for communication that are typically emitted at frequencies below 1 kHz (Montgomery *et al.*, 2006). This information suggests that sound from vessels, which is primarily between 10 Hz and 10 kHz and is strongest at 50 Hz to 1 kHz, is likely to be within the frequency range of sound detection for most fish species.

Table 9-4: Fish groupings with respect to presence/absence of swim bladder.

Fish group	Species
Fishes with no swim bladder	Mackerel
Fishes with swim bladder involved in hearing	Herring
Fishes with swim bladder not involved in hearing	Anglerfish, blue whiting, cod, haddock, hake, lemon sole, Norway pout, plaice, Sandeels, spurdog and whiting

9.3.2.1 *Vessels*

Anthropogenic sound has the potential to interfere with acoustic communication, predator avoidance, prey detection, reproduction and navigation in fish. The effects of "excessive" sound on fish include avoidance reactions and changes in shoaling behaviour (Slabbekoorn *et al.*, 2010). Prolonged avoidance of an area may interfere with feeding or reproduction or cause stress-induced reduction in growth and reproductive output.

Fish exhibit avoidance reactions to vessels and it is likely that radiated underwater sound is the cause; for example, sound from research vessels has the potential to bias fish abundance surveys by causing fish to move away (de Robertis and Handegard, 2013; Mitson and Knudsen, 2003). Reactions include diving, horizontal movement and changes in tilt angle (de Robertis and Handegard, 2013).

Popper *et al*. (2014) reviewed the effects of vessel sound on fish. They noted that there is no direct evidence of mortality or potential mortality to fish from vessel sound or other continuous sound sources. It was concluded that the likelihood of sound from vessels causing mortality or injury to fish was remote, even for fish in close proximity to vessels, however, it is possible sound from vessels may cause some behavioural disturbance to fish.

Given that fish in the North Sea are accustomed to the presence of vessels in the area the magnitude of effect of the increased vessel noise on fish is considered Negligible (1). Combining a Negligible magnitude of effect with a Medium sensitivity (Section 9.3) the impact significance is considered Low such that any environmental impacts are considered to be negligible.

9.3.2.2 *Piling*

Potential impacts to fish species were also assessed by comparing the underwater sound modelling results presented in Appendix D to the Popper *et al*. (2014) fish injury thresholds. The results summarised in Table 9-5 predicts that any injury to fish will be limited to distances up to a maximum of 40 m from the location of the piling activities. With the implementation of a piling soft-start procedure it is expected that any fish in the area would disperse to areas where injury or mortality would not occur, therefore any occurrence of injury to fish would be low. Furthermore, if fish are disturbed by sound, evidence suggests they will return to an area once the activity causing the disturbance has ceased (Slabbekoorn *et al.*, 2010). Therefore the magnitude of effect of underwater sound associated with the piling activities on fish is considered Negligible (1). Combining a Negligible magnitude of effect with a Medium sensitivity (Section 9.3) the impact significance is considered Low such that any social impacts are considered to be negligible.

Table 9-5: Predicted distances from the piling location where sound levels decrease to below the Popper zero-to-peak SPL thresholds for injury/potential mortality.

Fish Group	Predicted Maximum Distance to Threshold Exceedance *
Fishes with no swim bladder	20 m
Fishes with swim bladder involved in hearing	40 m
Eggs, larvae, and fishes with swim bladder not involved in hearing	40 m
* Predicted distances have been rounded up to the nearest 10 m.	

9.4 Cumulative and Transboundary Effects

The presence of the drilling rig and additional vessel movements will cause a modest increase in activities in the Murlach area which will result in additional underwater sound. However, as the rig and vessels will be located within a well-developed oil and gas area and drilling and installation activities will be relatively short term in nature, any cumulative impacts of underwater sound are not considered significant. Similarly, given the short time period associated with the piling activities, any cumulative impacts of underwater sound from these activities are not considered significant

The Murlach subsea tieback will be located *c.* 27 km from the UK/Norway median line and therefore no transboundary impacts associated with the underwater sound from the drilling rig, vessels or piling activities are expected.

9.5 Mitigation Measures

The following mitigation measures are proposed to minimise the impacts associated with underwater noise sources associated with the proposed activities.

Proposed Mitigation Measures

- Optimise duration of drilling and installation activities in order to minimise vessel use.
- Recommendations of the JNCC protocol for minimising risk or injury to marine mammals from piling noise (JNCC, 2010) will be adopted;
- Use of properly qualified, trained and equipped marine mammal observers (MMOs) to detect marine mammals within a "mitigation zone" and potentially recommend a delay to piling operations. The mitigation zone should be at least 500 m. MMOs should carry out a 30 minute pre-piling survey and if an animal is detected then work should be delayed until it has left the area;
- Soft-start of piling, whereby there is an incremental increase in power and, therefore, sound level. This should be carried out over a minimum period of 20 minutes. This is believed to allow any marine mammals to move away from the piling location and reduce the likelihood of exposing the animal to sounds which can cause injury;
- Repeat of the pre-piling survey and soft-start whenever there is a break in piling of more than 10 minutes; and
- Avoiding commencing piling at night or in poor visibility when marine mammals cannot reliably be detected.

It is possible that short term behavioral effects may be observed among cetaceans and fish as a result of vessel, drilling and piling activities, but the overall impact significance of these sound sources is considered Low with the application of the mitigation measures identified.

The proposed project will be conducted in compliance with all NMP policies; an assessment against the relevant NMP objectives is given in Appendix A.

10. WASTE GENERATION

This section discusses the types of waste likely to be generated as a result of the proposed Murlach Field Development, and the waste management procedures that will be implemented to minimise and monitor the volumes produced and disposed to landfill. Waste will be generated during all phases of the project.

BPEOC is committed to reducing waste production and to managing all produced waste, by applying approved and practical methods and by adhering to a waste hierarchy similar to that shown in Figure 10-1 (Scotland's Environment, accessed 2020). Waste will only be disposed of if it cannot be prevented, reclaimed or recovered. All wastes will be managed in accordance with BPEOC's Waste Management Procedure and via ETAP's existing waste contract. The procedure establishes the controls required to manage the hazards associated with the transportation and disposal of waste from offshore sites and the processes, and verification activities, necessary to confirm that legal obligations are satisfied.

Figure 10-1: Representative schematic of Scotland's Environment waste hierarchy (Scotland's Environment, 2020).

Consent to transfer to the United Kingdom shore is not required but Duty of Care (under the Environment Protection Act 1990) makes it the waste producer's responsibility to ensure that waste is only transferred to an appropriately licensed carrier who should have a Waste Carrier Registration. Transfer of Controlled Waste requires a Transfer Note to be completed (or Consignment Note in the case of Special Waste). The Transfer Note details the type and quantity of waste, from whom and to whom the waste has been transferred, the category of authorised person to whom the waste has been consigned, relevant licence numbers, time, place and date of transfer.

10.1 Vessel Waste

Waste will be generated from a number of vessels associated with the proposed development including AHVs, survey, supply, ERRV and construction vessels. Waste from these vessels will be managed in line with the individual vessel Waste Management Plan (WMP) in accordance with MARPOL requirements, which regulate discharges of waste to sea from ships.

10.2 Drilling Waste

Drilling rigs generate various waste products during routine operations including LTOBM contaminated cuttings, waste oil, chemical and oil contaminated water and scrap metal. Wastes will be minimised by use of appropriate procurement controls, and all wastes will be properly segregated for recycling / disposal / treatment. The appointed waste management contractor will supply monthly reports of waste sent to shore and will complete Controlled Waste Transfer Notes as required, and records of monthly disposals will be maintained. Waste Management Duty of Care audits will also be carried out.

LTOBM contaminated cuttings will be shipped to shore for disposal. The chosen waste contractor will thermally treat the cuttings onshore and any oil that is separated out may be used as an energy source on site. Any excess oil will be stored for onward transportation to oil recyclers. Process water will be used to dampen the dry cuttings before final disposal to landfill.

10.3 Installation and Commissioning Phase

Installation activities will routinely generate a number of wastes including scrap metal, wooden crates etc. All wastes will be properly segregated for recycling/disposal/treatment in accordance with BPEOC's Waste Management Procedure and Controlled Waste Transfer Notes will be completed. The development is not expected to result in a change to the current waste streams occurring at ETAP.

10.4 Production Phase

ETAP conforms with BPEOC's waste management procedures. Controlled waste transfer notes will continue to be completed as required and records on monthly waste disposal activities will be maintained.

10.4.1 General Waste

On ETAP general waste streams are segregated by personnel at the source of generation, and manually handled to the appropriate labelled waste receptacle until transferred onshore for disposal. All waste is segregated in accordance with waste management procedures and controlled waste transfer notes will be completed. Waste Management Duty of Care audits will also be carried out. Production of general waste on ETAP is not expected to change as a result of the proposed Murlach Field Development.

10.4.2 Laboratory Waste

ETAP adheres to 100% reinjection and so there are no PW discharges. Any other chemicals are segregated on site and sent to shore for disposal via a licensed contractor. As for general waste streams, a WMP is in place to minimise laboratory waste. Production of laboratory waste on ETAP is not expected to change as a result of the proposed Murlach Field Development.

10.4.3 Special Waste

ETAP ships to shore a number of hazardous solid and liquid waste streams which may include Naturally Occurring Radioactive Material (NORM) / Low Specific Activity (LSA) scale. The types of hazardous wastes handled on ETAP will not change as a result of the proposed project.

10.5 Decommissioning Phase

The waste generated as a part of the decommissioning activities will be a combination of both hazardous (special) and non-hazardous wastes. As operator, BPEOC will have in place a WMP developed to identify, quantify (where possible) and discuss available disposal options for waste resulting from the decommissioning activities. Where possible, materials will be recycled or sold and reused taking into account a waste hierarchy similar to that shown in Figure 10-1.

It is intended that recovered infrastructure will be returned to shore and transferred to a decommissioning facility, which will have all necessary approvals and licences in place and possess the capability to reuse or recycle the majority of recovered material. The minimisation of waste is a factor considered at every stage of the project.

10.6 Cumulative and Transboundary Effects

Waste will be managed in line with existing procedures and significant cumulative or transboundary impacts are not expected.

10.7 Mitigation Measures

The following mitigation measures are proposed to minimise the waste produced from the proposed Murlach Field Development.

Proposed Mitigation Measures

- BPEOC will apply the principles of the Waste Management Hierarchy during all activities i.e. Reduce, Reuse, Recycle;
- Existing asset and vessel WMPs will be followed;
- Only permitted disposal yards / landfill sites will be used.

As a receptor, landfill sites can be considered a finite resource, such that applying the assessment methodology presented in Section 4, the sensitivity of landfill sites can be considered Medium (b). With the application of the above control measures the magnitude of effect of waste generated throughout the project is considered to be Negligible (1). Given the Low sensitivity and the Negligible magnitude of effect, the impact significance is considered Low such that any environmental impacts associated with waste production are considered to be negligible.

The proposed project will be conducted in compliance with all applicable NMP policies; an assessment against the relevant NMP objectives is given in Appendix A.

11. ACCIDENTAL EVENTS

In line with OPRED Guidance (BEIS, 2021) this ES assesses in detail the impact of a worst-case hydrocarbon release (i.e. a subsea well blowout at the Murlach Field: see Section 11.2 and Appendix C). However, it is acknowledged that other spills could occur either during drilling or subsequent project phases, therefore this section provides an overview of the potential accidental releases of hydrocarbons, as identified in Appendix B, before detailing the environmental risks associated with an accidental hydrocarbon release from a subsea well blowout (Sections 11.2 and 11.3 and Appendix C).

The ETAP platform has an approved OPEP in place (ETAP-PLN-4.6-1002) and this will be amended to capture the proposed Murlach wells including details on the flowrate and interface with the mobile drilling rig. The likelihood of an accidental event at the ETAP platform is not considered to change as a result of the Murlach tie-back.

11.1 Overview of Potential Hydrocarbon Releases

11.1.1 Drilling Phase

11.1.1.1 Loss of contaminated discharges

During drilling, in addition to a potential subsea well blowout (see below), accidental releases of contaminated discharges could include the loss of: cleaning chemicals, mud inventory, brine contaminated with LTOBM, cuttings containing LTOBM and other oily slops. There is also a risk of an accidental spillage of mud or diesel during bunkering operations.

These releases could result in toxic or sub-lethal effects on sensitive organisms and ecosystems. The resultant impacts depend on spill size, prevailing wind, sea state, temperature and sensitivity of environmental receptors affected (e.g. benthic species, fish, marine mammals, birds and protected areas).

Approved operational procedures will be implemented to in order to mitigate the likelihood of such accidental events and to minimise their impact should they occur. For example, the quantities of chemicals stored on the drilling rig will be optimised. COSHH assessments will be completed and Safety Data Sheets (SDS) will be made available. Where possible given technical requirements, chemicals that are PLONOR, have a Risk Quotient (RQ) < 1, or do not carry substitution warnings will be prioritised. Spill kits will be located in close proximity to chemical and oil storage areas to enable a quick response.

Procedures, in line with best industry practice guidelines will be in place to minimise the risk of an accidental spill from bunkering. These will include, for example, regular checks of the integrity of the hose and competence of operators. Trained personnel will undertake bunkering operations in accordance with approved procedures. Containment facilities and drains will be inspected as part of marine assurance standards.

An approved OPEP will be in place to respond to an accidental hydrocarbon release. BPEOC is a member of Oil Spill Response Limited (OSRL) and the Offshore Pollution Liability Association Ltd. (OPOL). Local access to dispersant will be available via the ERRV. OPPC permit requirements will be adhered to. Any accidental hydrocarbon release from a drilling rig at the Murlach field will be responded to in accordance with arrangements set out in the ETAP OPEP.

The environmental impact is considered to vary between the different accidental discharges identified. For example, the severity of impact (Table 4-2) associated with a release of hydrocarbons during bunkering operations is considered to be Serious (3) whilst the impact associated with a loss of LTOBM is considered to be Minor (2). However, when the likelihood of these accidental events taking place is taken into account most are considered to be a low risk. Any risk will be reduced to ALARP and managed under the mitigation measures described such that it is considered acceptable.

11.1.1.2 Well blowout

A well blowout refers to the uncontrolled release of hydrocarbons from a well after the pressure control systems have failed. Primary well control is achieved by maintaining a hydrostatic pressure in the wellbore greater than the pressure of the fluids in the formation being drilled, but less than the formation fracture pressure. In a worst-case scenario, there can be insufficient pressure in the wellbore fluids (i.e. the drilling mud or completion fluids) to resist formation pressure and an influx occurs. Wellbore fluids are carefully designed, monitored and actively managed to prevent such occurrences.

Well blowouts are most likely to occur during drilling operations. In the event of an influx, the flow of reservoir fluids into the well is stopped by closing the BOP which is the initial stage of secondary well control. The BOP has multiple sets of rams that can close off the well bore in an emergency. Secondary well control is completed by circulating the well with kill weight fluid and displacing the influx out of the well. A blowout can occur if primary and secondary well control fails.

DHSVs are in place to seal wells should an unplanned well event occur during production. These DHSVs complement valves contained within the tree. Wells are plugged with cement and decommissioned when production has ceased.

The IOGP has issued datasheets (IOGP, 2019) on well blowout frequencies for drilling operations of a North Sea Standard (NSS), where the operation is performed with a BOP installed and the “two barrier” principle is followed (Table 11-1). The dataset is derived from the Sintef well blowout database where a blowout is defined as an incident where formation fluid flows out of the well or between formation layers after all the predefined technical well barriers or the activation of the same have failed. Well blowout frequencies have been calculated per well drilled in the North Sea and are not an annual frequency. Note that well blowout frequency per total wells drilled is very low, indicating that the likelihood of a well blowout occurring is very remote. The likelihood of a blowout occurring at a maximum flow rate, or for an extended period of time, is lower still.

Table 11-1: Well blowout frequencies for North Sea offshore operations (IOGP, 2019).

Operation	Gas	Oil	Unit
Development drilling (oil)	4.2×10^{-5}	3.4×10^{-5}	Per well drilled
Development drilling (HPHT)	2.6×10^{-4}	2.1×10^{-4}	
Development drilling shallow gas (topside)	1.7×10^{-3}	-	
Development drilling shallow gas (subsea)	1.0×10^{-3}	-	

Oil spill modelling has been undertaken using the Oil Spill Contingency and Response (OSCAR) model, developed by Sintef, to support the assessment of the environmental risk of a subsea well blowout at the Murlach Field Development. Appendix C presents the modelling carried out to support the assessment whilst the results are discussed further in Section 11.3.

11.1.1.3 Loss of fuel inventory from rig

Separate modelling studies have not been undertaken to determine the fate of a loss of fuel inventory at the site, given that any impacts would be expected to be within the envelope of impacts associated with a subsea well blowout (see Section 11.4). The magnitude of effect of such a release is considered to be 3. Given the mitigation measures discussed in Section 5, regarding notifications to be given prior to any drilling rig mobilisations, drilling rig and vessel lighting requirements and the pre-existing 500 m safety zone at the drilling centre the likelihood of a collision resulting in the loss of fuel inventory from the drilling rig is considered to be remote (ranked as R) such that the environmental risk is considered low. This risk will be reduced to ALARP and managed under the mitigation measures described such that it is considered acceptable.

11.1.2 Installation and Commissioning Phase

During the Installation and Commissioning Phase, there is a risk of accidental discharges of water-based hydraulic fluids or treated seawater. This release could result in short-term localised effects on water quality, flora and fauna. To mitigate the potential of such releases occurring, containment facilities will be inspected as part of the vessels HSE Management System audit, and a chemical risk assessment will be undertaken as part of the Pipelines MAT application. Industry standard operating procedures and checks will be carried out to prevent such a release where possible. Chemicals that are PLONOR, have a RQ < 1 and/or do not carry substitution warnings will be prioritised where technically possible.

With the above mitigation measures in place the magnitude of effect of accidental discharges of water-based hydraulic fluids or treated seawater is considered to be 3 whilst the environmental risk is considered to be low (likelihood ranked as remote). The risk is therefore considered acceptable when managed within the additional mitigation measures described.

11.1.3 Production Phase

Potential accidental events associated with the production phase that could occur as a result of the Murlach tie-back were considered in the ENVID. These included snagging of fishing gear on subsea infrastructure, subsea control system failures resulting in small losses of hydraulic fluids, or small volumes of hydrocarbons. The severity of impact associated with each of these potential events was considered to be minor.

Should the option to surface lay the gas lift flowline be selected (Option 1, see Table 2-2), there is a low risk that interaction with fishing gear could cause damage, resulting in a release of lift gas to sea. Based on the volume of the flowline, the ES assumes up to 127 m^3 (7 km x 6” flowline) of gas could be released.

The lift gas will comprise *c.* 74% methane, 13% ethane, 6% propane, 2% CO_2 and 5% other gases. Around 95-99% of the gas is expected to dissolve in the ocean and the fraction of gas reaching the atmosphere will be dependent on the initial pressure of the release, diffusivity, water depth, salinity, ambient temperature and pressure (Tveit, 2020).

Methane released at the seabed is oxidised within sediments by anaerobic and aerobic oxidation (Uhlig *et al*., 2018). Methane which is not oxidised is dissolved in the water column at the sediment surface. The dissolution of methane in seawater may result in localised oxygen depletion which can cause ecological disturbances (Uhlig *et al*., 2018). oxygen depletion has been found to cause an increase oxygen stress in marine organisms, leading to declines in species and changes is species composition (ICUN, 2022).

Given the volume of gas that could be released and the short duration of the release it is not expected that a significant impact would be observed to the benthic communities in the area.

Methane which is not dissolved will rise through the water column to the surface as gas bubbles. The likelihood of this is largely dependent on the ocean depth. Di *et al*., (2019) noted that if water depth is

> 100 m, methane is more likely to be fully dissolved into the water column before reaching the surface and being emitted into the atmosphere.

Methane has a higher global warming potential than CO_2, however, given the relatively small volume of gas that could be released in the event that the gas lift flowline is damaged, and the fact that much of the released gas would be expected to dissolve in the water column, the significance of any impacts on air quality or climate change are considered low.

Mitigation measures were identified including the pre-existing 500 m safety zone at the Murlach Field development area, optimal material selection, operating procedures in place, preference for the use of water-based hydraulic fluids, etc. With these mitigation measures in place the environmental risk of each of these potential accidental events is considered to be low (likelihood of remote) and are therefore acceptable when managed within the mitigation measures described.

11.1.4 Decommissioning Phase

During decommissioning activities, the impact of any accidental events are anticipated to be within the range of impacts discussed in the previous sections.

11.2 Assessment Methodology

Appendix C presents the modelling carried out using the OSCAR model developed by Sintef to support the assessment of the environmental risk of a subsea well blowout at the proposed Murlach Field Development. The Appendix introduces the OSCAR model, provides a description of the methodology applied (e.g. release parameters, hydrocarbon characteristics and metocean data), describes the thresholds applied and presents the results.

OSCAR supports two different types of simulations: stochastic (probabilistic) and deterministic. The stochastic simulation feature of OSCAR allows for a spill scenario to be simulated multiple times over different weather conditions, with the results from each individual stochastic simulation being aggregated, and a number of statistical parameters computed. To analyse a single spill scenario, the deterministic mode of OSCAR allows for a spill scenario to be simulated over a single specified time interval and outputs can be presented in terms of key parameters such as oil thickness on the sea surface, concentrations on the shoreline, in the sediment and in the water column.

Applying the ESRA presented in Section 4, a level of environmental risk is determined for each receptor, with the modelling results being used to determine the magnitude of effect (Table 4-2). Note, taking account of the blowout frequencies presented in Table 11-1, the likelihood of a well blowout is considered to be remote (R) (see Table 4-4).

11.3 Summary of Model Results for Well Blowout

The key parameters used as inputs in the well blowout scenario are summarised in Table 11-2.

Table 11-2: Well blowout release parameters.

Scenario and location	Hydrocarbon type	Release rate	Release duration^2	Total quantity released	Release depth	Release temperature
Seabed blowout 57° 14' 05.933" N 01° 37' 35.699" W	Crude with associated solution gas	16,741 m^3/day oil plus 3,856,365 m^3/day gas	86 days	1,439,691.6 m^3	93.9 m	105.8°C
1. WGS 84 coordinate system 2. Total model duration included an additional 30 days following the end of the discharge.						

Key results from the well blowout simulations undertaken are summarised here (Table 11-3, Figure 11-1, Figure 11-2, Figure 11-3 and Figure 11-4). Overall, hydrocarbons released as a result of a well blowout from the Murlach field extend across a wide area of the North Sea. This is because of the large volume and prolonged duration of the release. While a large portion of hydrocarbons evaporate (486,800 te, 39.09%) or are biodegraded (216,400 te, 17.38%) significant amounts of hydrocarbons are deposited on the seabed (455,400 te, 36.57%) and remain entrained in the water column (74,840 te, 6.01%). A limited amount of hydrocarbon is expected to reach shorelines (9,460 te, 0.76%) and impact approximately 981 km of coastline, mostly in Norway.

The MPAs where the probability of oiling is ≥ 50% (surface, water column and shoreline) and the area of MPAs where concentration of oil on sediment ≥ 5 g/m^2 are summarised in Table 11-4.

Table 11-3: Summary of oil spill simulation.

	Compartment	Mass (te)	Proportion (%)
Mass balance	Evaporated	486,800	39.09
	Surface	2,338	0.19
	Sediment	455,400	36.57
	Biodegraded	216,400	17.38
	Water column	74,840	6.01
	Shoreline	9,460	0.76
	Outside domain	0	0
Thresholds	Surface (μm)	0.3	
	Water column (μg/l)	10	
	Shoreline (kg/m^2)	0.1	
	Sediment (g/m^2)	5	
Shoreline oiling	**Country coastline**	**Maximum probability (%)**	**Minimum arrival time (days)**
	United Kingdom	18	13
	Norway	77	10
	Sweden	61	18
	Denmark	76	12
	Germany	6	30
	Netherlands	2	80
Median line crossings (sea surface)	**Median line**	**Maximum probability (%)**	**Minimum arrival time (days)**
	UK-Norway	100	1
	UK-Denmark	94	10
	UK-Germany	86	10
	UK-Netherlands	72	10
Median line crossings (water column)	**Median line**	**Maximum probability (%)**	**Minimum arrival time (days)**
	UK-Norway	100	1
	UK-Denmark	94	9
	UK-Germany	84	10
	UK-Netherlands	72	13

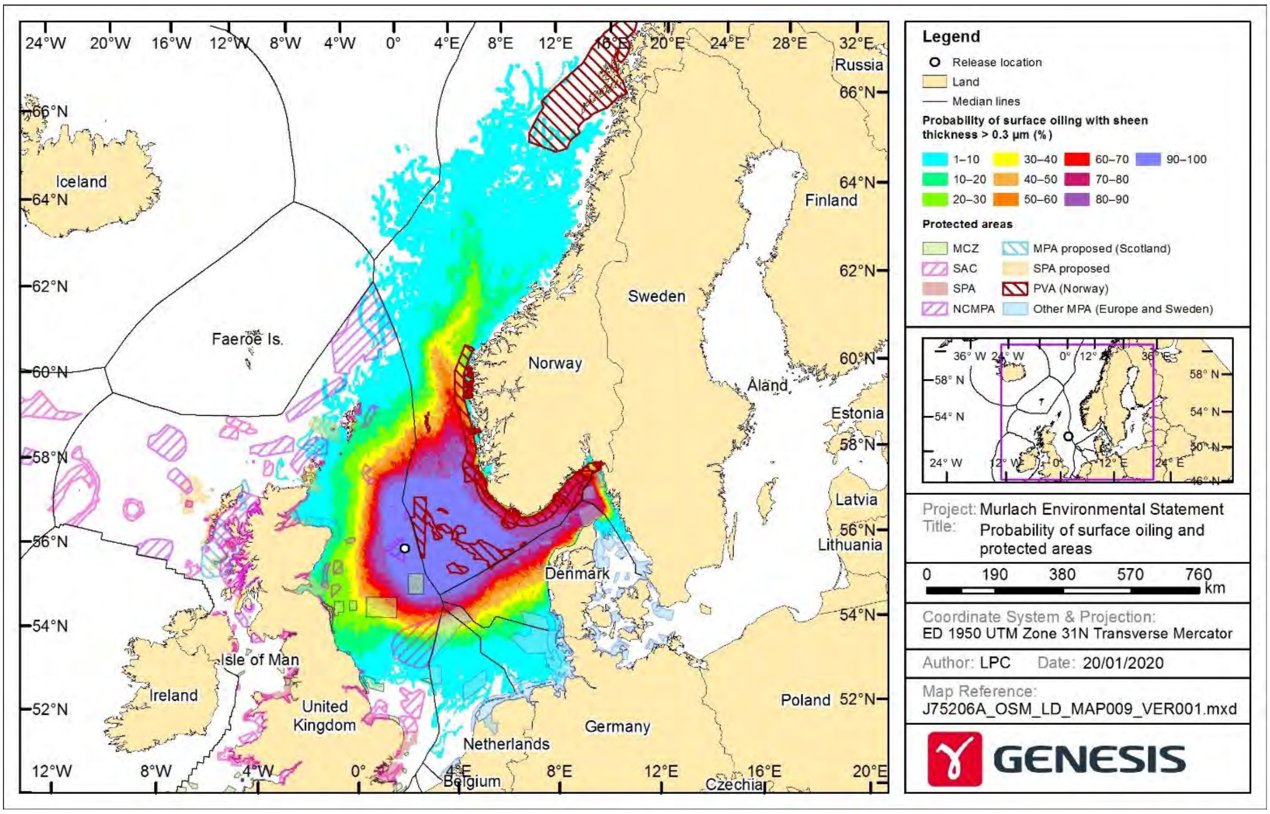


Figure 11-1: Probability of surface sheen presence on the sea surface and protected areas.

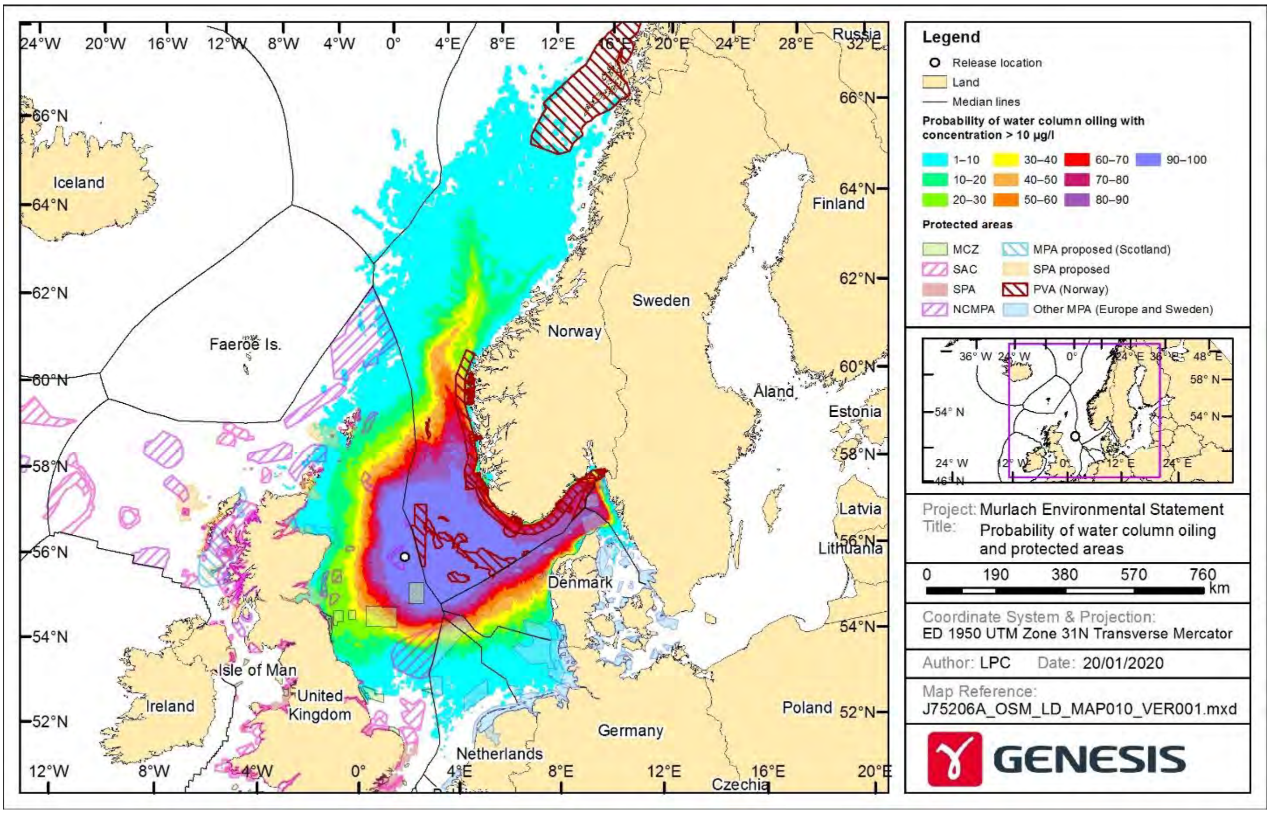


Figure 11-2: Probability of water column oil presence and protected areas.

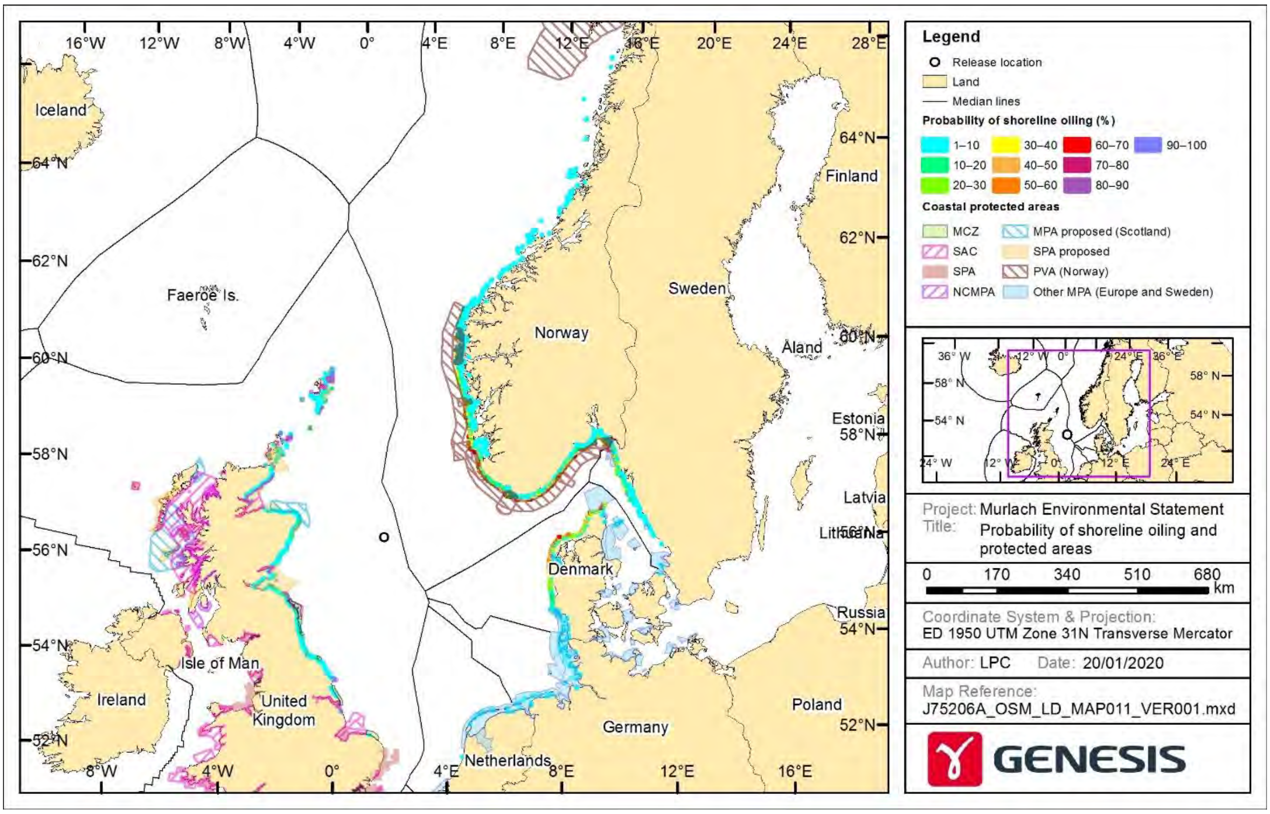


Figure 11-3: Probability of shoreline oiling and protected areas.

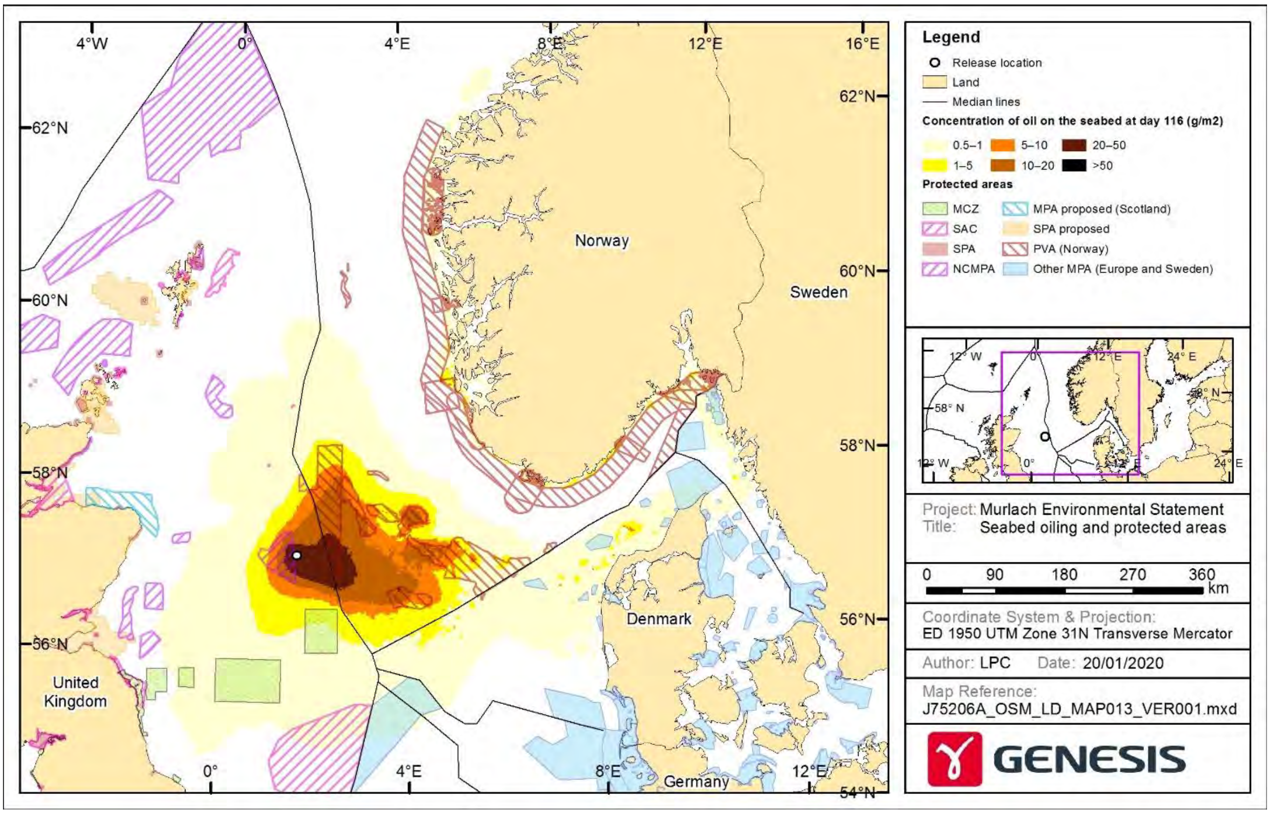


Figure 11-4: Oil concentration in the seabed at 116 days (end of simulation) and protected areas.

Table 11-4: Protected areas where the probability of oiling is ≥ 50% or there is seabed oil concentration exceeding 5 g/m².

Designation	Name	Features	Surface probability ≥ 50%?	Water column probability ≥ 50%?	Shoreline probability ≥ 50%?	Seabed coverage at ≥ 5 g/m²
MCZ	Fulmar	Sediments *Arctica islandica*	Yes	Yes	No	0
	Swallow sand	Sediments Glacial tunnel valleys	Yes	Yes	No	0
SAC	Braemar pockmarks	Submarine structures made by leaking gases	Yes	Yes	No	0
	Dogger Bank	Sandbanks which are slightly covered by sea water all the time	Yes	Yes	No	0
	Scanner pockmark	Submarine structures made by leaking gases	Yes	Yes	No	0
NCMPA	Central Fladen	Sediments Sub-glacial tunnel valley	Yes	Yes	No	0
	East of Gannet and Montrose Fields	Sediments *A. islandica*	Yes	Yes	No	1,668
	Norwegian Boundary Sediment Plain	Sediments *A. islandica*	Yes	Yes	No	0
Particularly Vulnerable Area (PVA)	Gytefelt for makrell	Mackerel spawning	Yes	Yes	No	3,648
	SVO Boknafjorden og Jirstrendene	Breeding, feeding, moulting, passage and wintering of birds Whelping ground for common and grey seal	Yes	Yes	Yes	4
	SVO Eggakanten (Norskehavet og Barentshavet)	Coastal zone	No	Yes	No	0
	SVO Karmwøyfeltet	Spawning of herring	Yes	Yes	Yes	24
	SVO Korsfjorden	Sediments Kelp forests	Yes	Yes	Yes	0
	SVO Kystsonen (Nordsjeen)	Coastal zone	Yes	Yes	Yes	20
	SVO Listastrendene og Siragrunnen	Passage and wintering of birds Varied habitats	Yes	Yes	Yes	0

Designation	Name	Features	Surface probability ≥ 50%?	Water column probability ≥ 50%?	Shoreline probability ≥ 50%?	Seabed coverage at ≥ 5 g/m²
	SVO Skagerrak	Moulting and wintering of birds	Yes	Yes	No	0
	SVO Tobisfelt nord (Vikingbanken)	Habitat and spawning of sandeel Feeding area for whales	Yes	Yes	No	0
	SVO Tobisfelt sjr (Vikingbanken)	Habitat and spawning of sandeel Feeding area for whales	Yes	Yes	No	4,944
	SVO Transekt Skagerrak	Brakish water, seaweed zone, eelgrass beds, kelp forests and corals	Yes	Yes	Yes	0
	SVO Ytre Oslofjord	Ormø–Færder protected landscape Ytre Hvaler national park Breeding, passage and wintering of seabirds Largest inshore cold-water coral reef	Yes	Yes	Yes	0
Other MPAs (Europe and Sweden)	Bratten	Reefs Submarine structures made by leaking gases Sea pens Deep-sea sponges	Yes	Yes	No	0
	Dogger Bank (Germany and Denmark	Sandbanks which are slightly covered by sea water all the time Seals	Yes	Yes	No	0
	Gule Rev	Harbour porpoise Reefs	Yes	Yes	No	0
	Jyske Rev (Lillefiskerbank)	Reefs Sublittoral mixed sediments	Yes	Yes	No	0
	Knudegrund	Submarine structures made by leaking gases	Yes	No	Yes	0
	Kosterfjorden-Väderöfjorden	Subtidal and intertidal habitats Harbour porpoise Harbour seal	No	Yes	Yes	4
	Kosterhavets Nationalpark	Reefs Fish spawning High biodiversity	Yes	Yes	Yes	4

Designation	Name	Features	Surface probability ≥ 50%?	Water column probability ≥ 50%?	Shoreline probability ≥ 50%?	Seabed coverage at ≥ 5 g/m^2
	Løgstør Bredning, Vejlerne og Bulbjerg	Coastal zone	No	No	Yes	0
	Lønstrup Rødgrund	Reefs	Yes	No	No	0
	Sandbanker ud for Thyborøn	Sandbanks which are slightly covered by sea water all the time	Yes	Yes	No	0
	Skagens Gren og Skagerrak	Harbour porpoise Sandbanks which are slightly covered by sea water all the time Sublittoral sands	Yes	Yes	Yes	0
	Store Rev	Harbour porpoise Reefs Sediments	Yes	Yes	No	0
	Thyborøn Stenvolde	Reefs	Yes	Yes	Yes	0

11.4 Impact of a Subsea Well Blowout on Receptors

The modelling results show that a number of environmental receptors will be impacted in the event of a well blowout. The impact on these receptors is discussed below.

11.4.1 Impact on Plankton

The plankton community is composed of a range of microscopic plants (phytoplankton) and animals (zooplankton) that drift with oceanic currents. As hydrocarbon can float on the sea surface and disperse across the ocean as it weathers, plankton may be exposed to both floating hydrocarbon slicks and to small dissolved droplets of hydrocarbon in the water column (Cormack, 1999; Almeda *et al.*, 2013).

Changes in the patterns of distribution and abundance of phytoplankton can have a significant impact on entire ecosystems (Ozhan *et al.*, 2014). Both oil presence and biodegradation can impact phytoplankton in the immediate vicinity of an oil spill. Hydrocarbon slicks can inhibit air-sea gas exchange and reduce sunlight penetration into the water, both of which are essential to photosynthesis and phytoplankton growth (González *et al.*, 2009). PAHs in oil also affect phytoplankton growth, with responses ranging from stimulation at low concentrations (1 mg/l) to inhibition at higher concentrations (100 mg/l, Harrison *et al.*, 1986).

Zooplankton at the surface are thought to be particularly sensitive to oil spills due to their proximity to high concentrations of dissolved hydrocarbon and to the additional toxicity of photo-degraded hydrocarbon products at this boundary (Bellas *et al.*, 2013). Following an oil spill, zooplankton may suffer from loss of food resources in addition to the toxic effects from direct exposure, resulting in mortality or impaired feeding, growth, development, and reproduction (Blackburn *et al.*, 2014 and references therein).

The limited swimming ability of the free floating early life stages (eggs and larvae) of invertebrates such as echinoderms, molluscs and crustaceans renders them unable to escape oil polluted waters. These early life stages are more sensitive to pollution than adults and their survival is critical to the long term health of the adult populations (Blackburn *et al.*, 2014 and references therein).

The distribution of plankton across the UKCS is generally uniform and widespread such that the sensitivity of this receptor is considered Low (a), however when the volume of water that may be potentially impacted by a blowout at Murlach is taken into account the magnitude of effect is considered Serious (3). The impact significance of a well blowout on plankton is therefore considered to be Moderate.

11.4.2 Impact on Benthic Animals

Benthic fauna can either move away from hydrocarbons, tolerate them (with associated impacts on the overall health and fitness), or die in response to exposure (Gray *et al.*, 1988; Lee and Page, 1997). The response to hydrocarbon exposure of benthic species differs depending on life history, feeding behaviour and the ability to metabolise toxins, especially PAHs. However, severe oil pollution typically causes initial massive mortality and lowered community diversity, followed by extreme fluctuations in populations of opportunistic mobile and sessile fauna (Suchanek, 1993).

The occurrence of the OSPAR Threatened and/or Declining Species A. *islandica*, was confirmed during the site survey in 2019 (Fugro, 2019b). *A. islandica* is a burrowing filter feeder and it is expected that any oil in the sediment or water column would impact the species.

The generally widespread distribution of benthic species populations on the UKCS means that they are unlikely to be significantly affected at the population level, rather the impact would be more on an individual animal level. However, given that designated species would be impacted the sensitivity of benthic communities is considered Medium (b). Given the area of seabed where potentially toxic concentrations

(≥ 5 g/m^2, Table 11-3, Figure 11-4), could occur the magnitude of effect is considered Serious (3). The impact significance of a well blowout on benthic species is therefore considered to be Moderate.

11.4.3 Impact on Fish

Hydrocarbon exposure to fish can occur through uptake across the gills, skin and direct ingestion of oil or oiled prey. Pelagic species, which spend the majority of their life-cycle in the water column, are likely to receive the highest exposure to oil that remains near the surface, whereas demersal fish species, associated with the seabed, are more likely to be exposed to particle-bound contaminants.

The chemical components of light oils have a high biological availability (bioavailability) and toxicity impacts are more likely than from heavy crude. At exposure concentrations lower than those sufficient to cause mortality, contamination may lead to sub-lethal effects such as impaired feeding and reproduction (ITOPF, 2014).

The likelihood of adult fish mortality due to open water oil spills is small (IPIECA-IOGP, 2015). Significant effects on wild stocks have seldom been detected and fish are thought to actively avoid hydrocarbons (ITOPF, 2014). However, hydrocarbons have been detected in fish bile over one year after the *Deepwater Horizon* oil spill (Murawski *et al.*, 2014), suggesting that adult fish may accumulate hydrocarbons after a large oil pollution event.

Test results following the Braer oil spill south of Shetland in 1993 showed that a spill of that size (c. 85,000 tonnes), in which the oil is rapidly dispersed through the water column can quickly lead to highly contaminated and tainted fish and shellfish. This differs to the observations made following the Sea Empress spill off the southwest of Wales in 1996 (c. 72,000 tonnes) whereby hydrocarbon and PAH concentrations in all species of finfish, including migratory salmon and sea trout, remained low throughout the incident. Following the Braer incident it was observed that PAH levels in individual sandeels did not differ between samples taken from sites differing in exposure levels. This is presumed to indicate that the rate of metabolism is sufficient to control the accumulation of these substances in fish. Observations on sea bass following the Sea Empress oil tanker spill showed that in the first year sea bass recruitment was reduced, however this impact was short lived with recruitment returning to original levels the following year. Similarly, overall sandeel densities a year after the Braer incident were found to have returned to pre-spill densities. In both instances the finfish fisheries were reopened before the shellfish fisheries.

Following the Braer incident some shellfish (particularly crustaceans) were found to lose hydrocarbons from their tissue as quickly as finfish while others (molluscs) lose their accumulated hydrocarbons much more slowly (Topping et al. 1997). Crabs and lobsters retained significant levels of contamination (up to 225 μg/kg) for a longer period while molluscs were found to accumulate the highest concentrations of PAHs e.g. levels detected in some scallop gonads were up to 20,000μg/kg wet weight. Lower concentrations were seen in whelks which are likely to be a result of the fact that they are carnivores rather than filter feeders, the latter ingesting dispersed oil droplets directly.

An oil spill could have the potential to impact fish spawning success because the eggs and larvae of many species are very sensitive to oil pollution. Joye *et al.* (2016) reported an estimated 2–5 trillion fish larvae were killed as a consequence of the *Deepwater Horizon* oil spill (2010).

PMF fish species known to occur in the area include Norway pout, sandeel, mackerel, blue whiting, cod, whiting, ling and anglerfish (PMF, Section 3.4.3 and 3.5.2) such that the sensitivity of fish as a receptor is considered Medium (b).

In conclusion the Sea Empress, Braer oil and Exxon Valdez oil spills did have adverse effects on the fish and shellfish communities in the areas of the oil spills. However, following a relatively short period, the fin fish fisheries were reopened with recruitment and densities of monitored stocks returning to pre-spill numbers a year later. A well blowout is therefore not expected to affect the favourable conservation status of designated fish species in the area. As fish stocks are expected to recover after a spill the magnitude of effect is considered Serious (3). The impact significance of a well blowout on fish species is therefore considered to be Moderate.

11.4.4 Impact on Marine Mammals

Marine mammals may be exposed to hydrocarbons either internally (swallowing contaminated water, consuming prey containing oil-based chemicals, or inhaling of volatile oil related compounds) or externally (oil on skin and body). The effects of hydrocarbon on marine mammals vary by species but may include:

- Hypothermia due to conductance changes in skin or fur;
- Toxic effects and secondary organ dysfunction due to ingestion of oil,
- Congested lungs;
- Damaged airways;
- Interstitial emphysema due to inhalation of oil droplets and vapour;
- Gastrointestinal ulceration and haemorrhaging due to ingestion of oil during grooming and feeding;
- Eye and skin lesions from continuous exposure to oil;
- Decreased body mass due to restricted diet; and
- Stress due to oil exposure and behavioural changes.

There is little documented evidence of cetacean behaviour being affected by hydrocarbon spills. Evidence suggests they do not necessarily avoid slicks. In the months following the *Exxon Valdez* spill there were observations of harbour porpoises swimming through light to heavy crude oil sheens. Stressed or panicking cetaceans tend to move faster, breathe more rapidly and therefore surface more frequently into oil and increase exposure (Harvey and Dahlheim, 1994).

Cetaceans have smooth skins with limited areas of pelage (hair-covered skin) or rough surfaces. Hydrocarbon tends to adhere to rough surfaces, hair or calluses of animals, so contact may cause only minor adherence. However, cetaceans can be susceptible to inhaling hydrocarbon and hydrocarbon vapour when they surface to breathe. This may lead to damaging of the airways and mucous membrane, lung ailments or even death.

The likelihood that a feeding cetacean would ingest a sufficient quantity of hydrocarbon to cause sublethal damage to its digestive system or to present a toxic body burden is low (IPIECA-IOGP, 2015). Ingestion of subtoxic quantities may have chronic effects and there is potential for PAHs to accumulate in tissues of whales before they are eventually metabolized, and for contaminants to be passed to juveniles through the mother’s milk.

Harbour porpoise has been estimated to occur in the project area at densities of approximately 0.333 individuals/km^2 (Section 3.4.4.1). Minke whale, white beaked dolphin and white sided dolphin regularly occur in the Murlach project area at relatively low densities. Therefore, it is likely that cetaceans would encounter hydrocarbons in the event of a large hydrocarbon release.

Seal abundance in the Murlach area is low (Section 3.4.5.1). However, a well blowout would result in surface oil spreading across the North Sea to areas frequented by seals. Seals are vulnerable to oil pollution because they spend much of their time near the surface and regularly haul out on beaches. Seals have been seen swimming in hydrocarbon slicks during several documented spills (Geraci and St. Aubins, 1990). Most seals scratch themselves vigorously with their flippers but do not lick or groom themselves, so are less likely to ingest hydrocarbon from skin surfaces. However, a seal mother trying to clean an oiled pup may ingest hydrocarbon. Seal pups are most vulnerable to hydrocarbon spills when there is shoreline oiling in breeding colonies. Seals use smell to identify their young in colonies. Abandonment and starvation of a seal pup can occur if its mother cannot identify it due to its scent being masked by hydrocarbons. Oil can impact on the mucous membranes that surround the eyes and line the oral cavity, respiratory surfaces, anal and urogenital orifices of seals. This can cause corneal abrasions, conjunctivitis and ulcers. Consumption of oil-contaminated prey will lead to the accumulation of hydrocarbons in tissues and organs. Lesions characteristic of hydrocarbon toxicity were found in the brains of seals exposed to the *Exxon Valdez* spill (Spraker *et al.*, 1994).

It is considered unlikely that a feeding cetacean would ingest a sufficient quantity of hydrocarbon to cause sublethal damage to its digestive system, or to present a toxic body burden to adults whilst only small amounts of hydrocarbons are predicted to reach the coastlines (where the cetacean and seal abundances will be higher than offshore areas). Consequently impacts to marine mammals from a well blowout are not expected to affect the ability of the species to maintain or reach favourable conservation status.

Given their protected status, the sensitivity of marine mammals as a receptor is considered High (c), whilst the magnitude of effect is considered Major (4). The impact significance of a well blowout on marine mammals is therefore considered High.

11.4.5 Impacts on Seabirds

Seabirds are particularly sensitive to the effects of surface oil pollution, and some oil pollution incidents have resulted in mass mortality of seabirds (for example, Munilla *et al.*, 2011; Votier *et al.*, 2005). Mortality occurs from the ingestion of oil, which results in liver and other organ failure, as well as contamination of plumage, which destroys the insulating properties, leading to hypothermia (Alonso-Alvarez *et al.*, 2007). The impact of oil pollution on seabird populations depends on the numbers of seabirds at sea around the pollution incident and on the seabird species present. Diving seabirds such as seaducks (Anatidae), divers (Gaviidae), cormorants (Phalacracoracidae), grebes (Podicepididae) and auks (Alcidae) are more susceptible than more aerial species such as gulls (Laridae) (Webb *et al.*, 2016).

Northern fulmar and common guillemot (Annex I listed, EC Birds Directive) have been identified at densities of 10–20 individuals/km^2 (Section 3.4.4). They mostly feed on the surface but can also dive and therefore may be exposed to surface and subsurface oiling.

Susceptible species tend to spend a greater proportion of their time at sea and have limited ability to locate alternative feeding sites. At population level, species with small or geographically limited populations, a low potential reproductive rate (productivity) and low adult survival rates are particularly sensitive due to their limited ability to recover (Webb *et al.*, 2016).

The potential extent of the surface sheen area in the blowout event makes exposure of various protected bird species likely. Of these species the conservation status of the Atlantic Puffin is classified as Vulnerable on the IUCN Red List for Birds due to the rapid declines recorded in its European populations. The Atlantic Puffin is vulnerable to oil spills from direct mortality and as a result of successive years breeding failure due to ecosystem degradation leading to reduced numbers of prey species (e.g. herring and sandeels) (Birdlife, 2020). Therefore, the impacts from a large spill from a well blowout could potentially affect the ability of regional populations to propagate and hence recover within a short time. This could have significant adverse effects on the already declining Atlantic Puffin European populations to reach favourable conservation status.

Given the wide area (Table 11-3 and Figure 11-1) that would be impacted by a well blowout, the sensitivity of seabirds as a receptor is considered High (c) whilst the magnitude of effect is considered Major (4). The impact significance of a well blowout on seabirds is therefore considered High.

11.4.6 Impact on Offshore Protected Areas

The Murlach field is located in the CNS and a number of offshore protected areas would be affected by a subsea well blowout in the area. Oil spill simulations revealed the potential to reach 28 offshore protected areas with a probability ≥ 50%. Of those, 19 contain features that could be impacted by a well blowout at the Murlach Project area (Table 11-4, Figure 11-1, Figure 11-2 and Figure 11-4). Eight offshore protected areas are estimated to have deposition of oil on sediment above the threshold. Of those, five are protected for seabed features. Thus, the release can either directly affect the protected species of these areas or impact the environmental quality of the habitats supporting them, and therefore may affect their ability to maintain or reach favourable conservation status. Given that the designated features within some of these protected areas may be impacted, the sensitivity of protected areas as a receptor is considered High (c) whilst the magnitude of effect is considered Major (4). The impact significance of a well blowout on protected areas is therefore considered High.

11.4.7 Impact on Coastal Protected Areas

The shorelines of multiple countries have the potential to receive oil on their shores (Table 11-4 and Figure 11-3). There is a high probability of shoreline oiling (≥ 50%) at 13 coastal protected areas (non UK sites). Given that the designated features within some of these onshore areas may be impacted, the sensitivity of coastal protected areas as a receptor is considered High (c) whilst the magnitude of effect is considered Major (4). The impact significance of a well blowout on coastal protected areas is therefore considered High.

11.4.8 Impact on UK Aquaculture and Shellfish Water Protection Sites

Figure 3-17 shows the location of aquaculture and Shellfish Water Protection Sites in the UK. The results of the modelling indicates a < 20 % chance of UK coastal impacts. The sensitivity of these sites is considered High (c), however given the low probability of the sites being impacted by significant concentrations of hydrocarbons the magnitude of effect is considered Serious (4). The impact significance of a well blowout on UK aquaculture and shellfish water protection sites is therefore considered Moderate.

11.4.9 Transboundary Effects

The well blowout scenario modelled results in significant transboundary impacts. Due to the central location of the Murlach field, the prolonged duration of the release and resulting wide-spread distribution of hydrocarbons result in the potential for the waters of Norway, Sweden, Denmark, Germany and Netherlands to receive some hydrocarbons.

11.4.10 Summary of Impact and Overall Risk to Receptors

Table 11-5 summarises the severity of the environmental impact of a subsea well blowout at the Murlach Field location on the receptors considered.

Table 11-5: Summary of impacts on environmental sensitivities.

Receptor	Impact Significance	Likelihood	Environmental risk
Plankton	Moderate	Remote	Low
Benthos	Moderate		Low
Fish	Moderate		Low
Marine mammals	High		Medium
Seabirds	High		Medium
Offshore protected areas	High		Medium
Coastal protected areas	High		Medium
UK aquaculture and Shellfish Water Protection Sites	Moderate		Low

Following the application of mitigation measures (see Section 11.7 the likelihood of a well blowout is considered remote. The overall environmental risk of a well blowout is therefore considered to be Medium.

11.5 Natural Disasters

Some natural disasters could increase the risk of a major pollution event occurring at the proposed Murlach Field Development. For example, an earthquake could lead to damage to the subsea infrastructure and potential loss of well control. The likelihood of an earthquake of sufficient magnitude on the UKCS to impact seabed infrastructure is extremely remote.

Climate change effects, such as sea level change and extreme weather events, are not considered to alter significantly the range of effects considered. Extreme weather may make accidents to the drilling rig more likely, but the rig has procedures in place for making safe and shutting down operations during extreme weather, along with emergency procedures in the case of rig damage, and a full loss of fuel inventory has been considered in the ETAP platform OPEP.

11.6 Major Environmental Incident Assessment

The Offshore Installations (Safety Case etc.) Regulations 2015 (SCR, 2015) extends the evaluation of Major Accidents Hazards (MAHs) to include their potential consequences on the safety of personnel and the environment (described as a MEI).

An MEI is defined in the SCR (2015) as an "*incident which results, or is likely to result, in significant adverse effects on the environment in accordance with the Environmental Liability Directive 2004/35/EC of the European Parliament and of the Council on environmental liability with regard to the prevention and remedying of environmental damage*".

"Environmental damage" is defined in Directive 2004/35/EC as:

- *"Damage to protected species and natural habitats, which is any damage that has significant adverse effects on reaching or maintaining the favourable conservation status of such habitats or species. The significance of such effects is to be assessed with reference to the baseline condition, taking account of the criteria set out in Annex I";*
- *"Water damage, which is any damage that significantly adversely affects the ecological, chemical and/or quantitative status and/or ecological potential, as defined in Directive 2000/60/EC, of the waters concerned, with the exception of adverse effects where Article 4(7) of that Directive applies";*

- *"Land damage, which is any land contamination that creates a significant risk of human health being adversely affected as a result of the direct or indirect introduction, in, on or under land, of substances, preparations, organisms or micro-organisms";*

A well blowout at the Murlach Field is considered to be a MAH and is therefore assessed here to determine if it is an MEI. Within Sections 11.4.3, 11.4.4, 11.4.5 and 11.4.6 consideration is given to the impacts of a well blowout on the favourable conservation status of designated fish, marine mammals and seabirds and on offshore protected areas respectively. It was concluded that a well blowout at the Murlach Field location could lead to significant impacts that could affect the favourable conservation status of seabirds and offshore protected areas. Therefore such a release is considered to qualify as a MEI as defined in the SCR 2015.

A major release of diesel from the drilling rig (or a vessel) is also expected to result in an MAH. Though modelling of a diesel release was not carried out, given the offshore location, the fact that a large amount of the diesel would evaporate quickly and only limited volumes would enter the sediment, the favourable conservation status of the receptors is not expected to be significant such that a release of diesel from the drilling rig (or a vessel) to sea would not lead to impacts that would qualify as a MEI as defined in SCR 2015.

11.7 Mitigation Measures

The mitigation measures associated with potential accidental events are captured in Sections 5 to 10. More specifically the mitigation measures associated with preventing a subsea well blowout are detailed in Section C.5 and summarised here.

Proposed Mitigation Measures

- Activities will be carried out by trained and competent offshore crews and supervisory teams;
- An approved OPEP will be in place prior to any activities being undertaken;
- Records will be kept of oil spill training and exercises as required by the OPEP;
- Process Safety Assurance Processes will be identified and adhered to;
- A co-ordinated industry oil spill response capability will be available;
- Enhanced sharing of industry best practices via the Oil Spill Response Forum (OSRF) will continue for BPEOC personnel.

Wells specific control measures

- A robust BOP pressure and functional testing regime will be in place; and
- Appropriate mud weights will be used to allow well control to be maintained: and
- A contract will be in place with a well capping advice provider, in case of emergency.

Operations-specific control measures

- Import and export facilities will be secured by topside ESDVs;
- Pipelines will have pressure monitoring and low pressure alarms; and
- Oil spill control measures will be followed as outlined in the OPEP.

11.7.1 Blowout Prevention and Contingency Planning

BPEOC's commitment to protection of the environment is set out in the corporate HSE policy (a copy of which is provided in Section 1). BPEOC follow the International Standards Organisation (ISO) 14001 standard, and has an externally verified EMS. BPEOC's EMS covers BPEOC activities including exploration, drilling and production and will be applied to the proposed Murlach Field Development Project. The Environmental Management System (EMS) governs those aspects of the operations that can be controlled, such as discharges, and establishes a subsequent auditing process.

The activities associated with the proposed development are also covered in a project specific HSE plan. Particular emphasis will be paid to having a robust design, quality equipment, quality construction and operational best practices.

Oil spills can occur at any phase of a project, including drilling, completion, production and export. The following provides a high level overview of proposed areas of planning and preparation that either reduce the probability and/or consequence of a spill/release, including failure of well control.

BPEOC will take measures to minimise the risk of a blowout through well design and well control measures. These include a well control barrier and BOP equipment.

In the event of a blowout, the drilling rig will try to disconnect from the well and move away from location. A second rig or intervention vessel (sourced either from other BPEOC operations or wider industry) would be mobilised to the location with the intention of placing a second BOP or a capping device on the flowing well or by drilling a relief well and re-establishing well control. It is envisaged that sourcing and mobilising a second rig would take a maximum of 21 days.

BPEOC have in place a call off contract with Wild Well Control (WWC), for the provision of well control services. As a member of OSRL, BPEOC will have access to well capping devices to contain the well.

If primary and secondary well control is lost by way of a blowout and oil flows uncontrollably from the well to the environment a relief well may be required to stop the flow of oil and bring the well back under control. A suitable rig would be sourced from the UK market. The wells being drilled would take time to suspend and, as a result, it has been estimated that a relief well would be drilled, at worst, in 86 days (Appendix C). An inventory is maintained by BPEOC and its contractors to confirm that stocks of all materials required for a relief well are available at short notice. BPEOC has insurance provisions in place to cover well control/re-drill situations as well as legal liabilities, and BPEOC is a member of OPOL which provides rapid compensation to parties directly affected by an oil spill.

11.7.2 Oil Spill Contingency Planning

BPEOC's oil spill contingency plans will be fully documented in the OPEPs that will accompany the development and operational phases.

BPEOC recognises three tiers of oil spill incident and response activities as summarised in Table 11-6. BPEOC have contracted the services of OSRL as the oil spill contractor to provide Tier 2 and Tier 3 response resources.

Table 11-6: Three tiers of oil spill incident and BPEOC's response.

	Type of spill	Nature of response	Resources and mobilisation times
Tier 1	Minor spill e.g. diesel spill; vast majority of operational spills	Resources in the field are able to tackle the spill without outside assistance. Response will be short in duration. The preferred option is to observe the oil until complete dispersion.	In the event of a Tier 1 spill, the spill will be monitored and allowed to disperse naturally unless there are compelling reasons to do otherwise. 'Prop washing' may aid dissipation If the spill is relatively small. The ERRV holds 5 t of Type 2/3 dispersant. Dispersant is available for use immediately (within 1 h) if safety is threatened, otherwise following agreement with Marine Scotland (MS-ML). Aerial surveillance can be on scene within 4–6 h to monitor the spill.
Tier 2	Serious spill e.g. pipeline rupture	Requires the mobilisation of external resources to monitor the spilt oil, including possible use of aerial chemical dispersant treatment if sensitive areas threatened. If the coastline is threatened, mobilise to Tier 3 response.	Aerial surveillance and aerial dispersant application capability provided through OSRL. Aerial surveillance service utilising aircraft equipped with infra-red (IR), ultraviolet (UV) etc. sensing equipment and Satcom. Aerial surveillance can be on scene within 4–6 h. Dispersant could be available within 6 h. Separate UKCS dispersant aircraft and dispersant pod and stocks.
Tier 3	Major spill E.g. blowout Requires national resources.	May require rapid mobilisation of regional/international resources to effectively tackle the spill. Response may be of long duration (weeks/months).	Access to all Tier 2 resources plus aerial chemical dispersant treatment from OSRL. Dispersant stocks to be supplemented by O&G UK stocks held by OSRL. Access to well containment device and well control expertise. If shoreline is threatened: specialised mechanical containment and recovery equipment and skilled technicians to lead clean-up operations held by OSRL. 'Unskilled' labour mobilised locally together with general purpose equipment and transport. Response to major spills (10,000 te) within 48 h. Aerial surveillance can be on scene within 4–6 h to monitor the spill.

12. CONCLUSIONS

A detailed assessment of the potential environmental impacts associated with the proposed Murlach Field Development has been carried out. The identification of the potential impacts is based on the nature of the proposed activities and was informed by available literature and guidance documents, industry specific experience and consultation with BEIS and their advisors. The commitments made in this ES will be incorporated into environmental management plans for the drilling, installation and operations phases of the development.

12.1 Environmental Effects

The development area is located in the CNS in a mature oil and gas province.

The potential impacts to the environment from all phases of the project were assessed. The environmental aspects of each of the key activities for each phase of the development were identified and quantified in terms of their effect on receptors and their magnitude of this effect. The results were assessed on the basis of the impact significance (for planned activities) or the risk posed to the environment (for unplanned), and were summarised as being either low, medium or high significance.

The environmental impact assessment considered both planned activities and unplanned events. The assessment showed that the impacts of the planned activities are of low significance whilst a well blowout was found to result in a medium environmental risk.

12.2 Minimising Environmental Impact

Following identification of suitable mitigation and control measures, additional assessment was undertaken for the activities initially identified as medium or high risk. This includes quantification of seabed disturbance and oil spill modelling. Following implementation of identified mitigation and control measures, all residual risks to the environment are considered to be ALARP.

The execution of the proposed Murlach Field Development, incorporating the control measures identified in this ES, is not expected to have a significant impact on the environment.

Routine atmospheric emissions and discharges to sea would be expected to disperse within a limited distance from the development. It is therefore unlikely that planned emissions and discharges will have a transboundary impact given that the nearest median line (UK/Norway median line) is *c*. 27 km from the proposed development. Hence no significant transboundary impacts were identified as a result of planned activities. There is a risk of transboundary impacts associated with an accidental release of oil, as discussed in Section 11. Such releases are rare and measures will be in place to minimise the likelihood of such an event occurring. However, should an unplanned release occur there will be measures in place to help ensure a co-ordinated and co-operative response (Section 11).

12.3 Commitments

Project specific commitments and mitigation measures to minimise the impact of the proposed Murlach Field Development Project on the environment have been highlighted throughout the ES and are summarised in Table 12-1. Commitments over and above normal industry practice will be captured in the project action tracking system, which includes roles and responsibilities for their implementation, and tracked to completion.

Table 12-1: Murlach Field Development project commitments.

Aspect	Commitments
Physical presence	• Notice to Mariners will be circulated prior to rig mobilisation; • The drilling rig will abide by CtL conditions; • A Collision Risk Management Plan will be produced if determined to be required; • All vessels will adhere to COLREGS and will be equipped with navigational aids, including radar, lighting and AIS (Automatic Identification System) etc.; • The drilling rig will be equipped with navigational aids and aviation obstruction lights system, as per the Standard Marking Schedule for Offshore Installations; • Vessel use will be optimised by minimising the number of vessels required and length of time vessels are on site; • A fisheries interaction assessment to aid selection of the optimal flowline installation method will be carried out. In the event that the study identifies an unacceptable risk to flowline integrity or fishing gear, the option to install the flowline exposed on the seabed will not be carried forward; and • Should the gaslift line be trenched and buried, post installation surveys will be carried out to determine if any clay berms remain on the seabed. Similarly should a semi-submersible drilling rig be used, post anchor recovery surveys will be carried out to determine if recovery of the anchors has resulted in any clay berms. In the event that they are detected, BPEOC will discuss appropriate mitigation with OPRED and SFF.
Emissions to air	• The drilling rig and other project vessels will be subject to audits to assess compliance with UK legislation and the BPEOC Marine Operations and Vessel Assurance Standard; • Vessel use will be optimised where possible by minimising the number of vessels required, and their length of time on site; • Vessels will be operated where possible in modes that allow for economical fuel use; and • Minimise flaring during well clean-up operations by sending fluids to ETAP for processing as the base case and preferred option. In accordance with the revised NSTA strategy, and associated Stewardship Expectation 11, as well as with the industry commitments within the NSTD, BPEOC will incorporate the impact of the Murlach production within ETAPs controls, including: • Asset GHG Emission Reduction Action Plans; • Flaring and venting reviews to identify/action zero routine flaring by 2030; • Active flare reduction strategy; • Active vent reduction strategy; • Emission key performance indicators and targets; and • Industry level benchmarking of flaring and venting.
Discharges to sea	• The drilling rig will be audited under BPEOC's marine assurance standards and subject to rig recertification audits; • All vessels used will be MARPOL compliant;

Aspect	Commitments
	• Where technically feasible BPEOC will prioritise the selection of PLONOR, or chemicals with a lower RQ; and • The discharges of any water based hydraulic fluids, sand or chemicals are regulated by the OPPC and/or the OCR regulations and reported through the EEMS. As such, BPEOC will conduct sampling, analysis and reporting in line with the applicable regulations and permit conditions.
Seabed disturbance	• Pre-deployment surveys will be undertaken to identify suitable locations for the drilling rig anchors; • Tie-ins to existing infrastructure where possible; and • The use of mattresses, rockdump and grout bags will be minimised through optimal project design.
Underwater noise	• Optimise duration of drilling and installation activities in order to minimise vessel use. • Recommendations of the JNCC protocol for minimising risk or injury to marine mammals from piling noise (JNCC, 2010) will be adopted; • Use of properly qualified, trained and equipped MMOs to detect marine mammals within a "mitigation zone" and potentially recommend a delay to piling operations. The mitigation zone should be at least 500 m. MMOs should carry out a 30 minute pre-piling survey and if an animal is detected then work should be delayed until it has left the area; • Soft-start of piling, whereby there is an incremental increase in power and, therefore, sound level. This should be carried out over a minimum period of 20 minutes. This is believed to allow any marine mammals to move away from the piling location and reduce the likelihood of exposing the animal to sounds which can cause injury; • Repeat of the pre-piling survey and soft-start whenever there is a break in piling of more than 10 minutes; and • Avoiding commencing piling at night or in poor visibility when marine mammals cannot reliably be detected.
Waste	• BPEOC will apply the principles of the Waste Management Hierarchy during all activities i.e. Reduce, Reuse, Recycle; • Existing asset and vessel WMPs will be followed; • Only permitted disposal yards / landfill sites will be used.
Accidental events	• Activities will be carried out by trained and competent offshore crews and supervisory teams; • An approved OPEP will be in place prior to any activities being undertaken; • Process Safety Assurance Processes will be identified and adhered to; • Records will be kept of oil spill training and exercises as required by the OPEP; • A co-ordinated industry oil spill response capability will be available; • Enhanced sharing of industry best practices via the OSRF will continue for BPEOC personnel; Wells specific control measures:

Aspect	Commitments
	• A robust BOP pressure and functional testing regime will be in place; • Appropriate mud weights will be used to allow well control to be maintained; and • A contract will be in place with a well capping advice provider, in case of emergency. Operations-specific control measures: • Import and export facilities will be secured by topside ESDVs; • Pipelines will have pressure monitoring and low pressure alarms; and • Oil spill control measures will be followed as outlined in the OPEP.

12.4 Overall Conclusion

BPEOC on behalf of itself and its Co-Venturer, NECNSL, is proposing to develop the Murlach Field located *c*. 203 km east of the Aberdeenshire coastline. The hydrocarbon reservoirs at the Murlach Field are well understood (based on the industry's history of drilling and field development in this area of the North Sea) and will be developed using proven technology incorporating current best practices and latest generation equipment. A robust design, strong operating practices and a highly trained workforce will help prevent any significant long-term environmental, cumulative or transboundary effects. Additional measures will also be in place during the operating phase to effectively respond to potential emergency scenarios.

The ES assesses the worst case impact of the project on the environment and is therefore very conservative. Even then, applying the mitigations measures identified it is the conclusion of this ES that the current proposal for the Murlach Field Development can be completed without causing any significant long term environmental impacts or cumulative or transboundary effects.

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APPENDIX A – SCOTLANDS NATIONAL MARINE PLAN

A.1 Scotland's National Marine Plan

Scotland's NMP (Marine Scotland, 2015) covers the management of both Scottish inshore waters (out to 12 nm) and offshore waters (12 to 200 nm). The aim of the NMP is to help ensure the sustainable development of the marine area through informing and guiding regulation, management, use and protection of the NMP areas. The Murlach Field Development activities have been assessed against each of the NMP objectives, details of which can found in Table A-1.

Table A-1: The proposed Murlach Field Development assessed against Scotland's NMP principles.

Scotland's National Marine Plan Principle Number	Applicable?	Assessment Against Principle
GEN 1 General planning principle		
There is a presumption in favour of sustainable development and use of the marine environment when consistent with the policies and objectives of this Plan.	✓	The Murlach Field Development is a tieback to existing infrastructure. The EIA assesses potential impacts to the environment and to other sea users.
GEN 2 Economic benefit		
Sustainable development and use which provides economic benefit to Scottish communities is encouraged when consistent with the objectives and policies of this Plan.	✓	The Murlach Field Development will provide jobs and tax revenues to the economy.
GEN 3 Social benefit		
Sustainable development and use which provides social benefits is encouraged when consistent with the objectives and policies of this Plan.	✓	The Murlach EIA considers impacts to other sea users in decision making e.g. fisheries and pipelines. Lifecycle of the project is assessed for environmental and economic implications.
GEN 4 Co-existence		
Proposals which enable coexistence with other development sectors and activities within the Scottish marine area are encouraged in planning and decision making processes, when consistent with policies and objectives of this Plan.	✓	Tie-back to existing infrastructure. Minimising infrastructure footprint. Consult other sea users e.g. fisheries and other oil and gas operators.
GEN 5 Climate change		
Marine planners and decision makers must act in the way best calculated to mitigate, and adapt to, climate change.	✓	Fuel use associated with vessel movements and the drill rig as well as flaring for well clean up and testing will be minimised as far as possible.
GEN 6 Historic environment		
Development and use of the marine environment should protect and, where appropriate, enhance heritage assets in a manner proportionate to their significance.	✓	Extensive surveys of Field Development area. No heritage assets identified to date.
GEN 7 Landscape/seascape		
Marine planners and decision makers should ensure that development and use of the marine environment take seascape, landscape and visual impacts into account.	×	Subsea Development.
GEN 8 Coastal process and flooding		
Developments and activities in the marine environment should be resilient to coastal change and flooding, and not	×	Offshore Development.

Scotland's National Marine Plan Principle Number	Applicable?	Assessment Against Principle
have unacceptable adverse impact on coastal processes or contribute to coastal flooding.		
GEN 9 Natural heritage		
Development and use of the marine environment must: a) Comply with legal requirements for protected areas and protected species. b) Not result in significant impact on the national status of Priority Marine Features. c) Protect and, where appropriate, enhance the health of the marine area.	✓	Environmental surveys undertaken in the Murlach Field Development area. Design and installation method of the subsea infrastructure informed by these surveys.
GEN 10 Invasive non-native species		
Opportunities to reduce the introduction of invasive non-native species to a minimum or proactively improve the practice of existing activity should be taken when decisions are being made.	✓	All vessels will follow IMO regulations. All vessels, including the drilling rig, will be regulatory compliant, e.g. the International Convention for the Control and Management of Ships' Ballast Water and Sediments, and subject to audit prior to contract award.
GEN 11 Marine litter		
Developers, users and those accessing the marine environment must take measures to address marine litter where appropriate. Reduction of litter must be taken into account by decision makers.	✓	Contractor management plans will be in place. All vessels will follow IMO requirements.
GEN 12 Water quality and resource		
Developments and activities should not result in a deterioration of the quality of waters to which the Water Framework Directive, MSFD or other related Directives apply.	✓	Discharges to sea have been identified and assessed. Murlach will not result in the deterioration of water quality in the Murlach area.
GEN 13 Noise		
Development and use in the marine environment should avoid significant adverse effects of man-made noise and vibration, especially on species sensitive to such effects.	✓	Noise generated from the piling of the manifold modelled and the impacts of this assessed. Results show that with the implementation of JNCCs standard mitigation measures the likelihood of a permanent threshold shift occurring is low for all the marine mammal hearing groups. The appropriate mitigation measures will be adopted in relation to the piling as well as vessel and drill rig noise.
GEN 14 Air quality		
Development and use of the marine environment should not result in the deterioration of air quality and should not breach any statutory air quality limits.	✓	Emissions to air quantified in the EIA. Assessment concludes that they will present a low environmental risk to air quality the duration of which will be minimised as far as possible.
GEN 15 Planning alignment A		
Marine and terrestrial plans should align to support marine and land-based components required by development and seek to facilitate appropriate access to the shore and sea.	×	Offshore tieback to existing infrastructure.
GEN 16 Planning alignment B		
Marine plans should align and comply where possible with other statutory plans and should consider objectives and	×	Applies to inshore waters only.

Scotland's National Marine Plan Principle Number	Applicable?	Assessment Against Principle
policies of relevant non-statutory plans where appropriate to do so.		
GEN 17 Fairness		
All marine interests will be treated with fairness and in a transparent manner when decisions are being made in the marine environment.	×	Competent Authority responsibility.
GEN 18 Engagement		
Early and effective engagement should be undertaken with the general public and all interested stakeholders to facilitate planning and consenting processes.	✓	The Murlach EIA is subject to public and informal consultations. A copy of the ES and the public notice has been made publicly available, as detailed in Section 1.8. Engagement meetings with JNCC, MSS, SFF and OPRED were held in November 2019, January 2020 and November 2021.
GEN 19 Sound evidence		
Decision making in the marine environment will be based on sound scientific and socio–economic evidence.	✓	Environmental baseline prepared with reference to available literature and site-specific survey data.
GEN 20 Adaptive management		
Adaptive management practices should take account of new data and information in decision making, informing future decisions and future iterations of policy.	✓	BPEOC decision making takes into account best understanding of the marine environment through surveys and using latest available scientific data.
GEN 21 Cumulative impacts		
Cumulative impacts affecting the ecosystem of the marine plan area should be addressed in decision making and plan implementation.	✓	Cumulative impacts are considered in the Murlach EIA and are considered proportionate to the size of the development.

A.2 Marine Strategy Framework Directive (MSFD)

The aim of the European Union's MSFD is to protect more effectively the marine environment across Europe. The MSFD outlines a transparent, legislative framework for an ecosystem-based approach to the management of human activities which supports the sustainable use of marine goods and services. The overarching goal of the Directive is to achieve 'Good Environmental Status' (GES) by 2020 across Europe's marine environment. Note following Brexit, the UK has made amendments to the Marine Strategy Regulations 2010, which transpose the requirements of the EU's Marine Strategy Framework Directive into domestic law, so that they continue to be effective now that the UK is no longer part of the EU.

The MSFD does not state a specific programme of measures that Member States should adopt to achieve GES, except for the establishment of MPAs. The MSFD does however outline 11 high level descriptors of GES in Annex I of the Directive. The Murlach Field Development activities have been assessed against each of the GES descriptors details of which can be found in Table A-2.

Table A-2: The proposed Murlach Field Development assessed against the MSFD GES descriptors.

Marine Strategy Framework Directive: Good Environmental Status Objectives	Applicable?	Assessment Against Objective
GES 1		
Biological diversity is maintained and recovered where appropriate. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	✓	Linked to GEN 9. Environmental surveys undertaken in the Murlach area. Design and installation method of the subsea infrastructure informed by these surveys.
GES 2		
Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.	✓	Linked to GEN 10. All vessels will follow IMO regulations. All vessels, including drilling rig, will be regulatory compliant, e.g. the International Convention for the Control and Management of Ships' Ballast Water and Sediments, and subject to audit prior to contract award.
GES 3		
Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.	✓	Linked to GEN 9. Environmental surveys undertaken in the Murlach area. Design and installation method of the subsea infrastructure informed by these surveys.
GES 4		
All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.	✓	Linked to GEN 9. Environmental surveys undertaken in the Murlach area. Design and installation method of the subsea infrastructure informed by these surveys.
GES 5		
Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters.	✓	Linked to GEN 9. Environmental surveys undertaken in the Murlach area. Design and installation method of the subsea infrastructure informed by these surveys.
GES 6		
Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are	✓	Linked to GEN 9. Environmental surveys undertaken in the Murlach area. Design and installation method

Marine Strategy Framework Directive: Good Environmental Status Objectives	Applicable?	Assessment Against Objective
not adversely affected.		of the subsea infrastructure informed by these surveys.
GES 7		
Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.	✓	Linked to GEN 12. Seabed disturbance and potential impact on marine ecosystems assessed in EIA.
GES 8		
Concentrations of contaminants are at a levels not giving rise to pollution effects.	✓	Linked to GEN 12. Murlach will not result in the deterioration of water quality in the Murlach area.
GES 9		
Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.	✓	Linked to GEN 12. Murlach will not result in the deterioration of water quality in the Murlach area.
GES 10		
Properties and quantities of marine litter do not cause harm to the coastal and marine environment.	✓	Linked to GEN 11. Contractor management plans will be in place. All vessels will follow IMO requirements.
GES 11		
Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.	✓	Linked to GEN 13. Piling of the manifold was identified as a significant source of marine noise, and therefore this was modelled and the severity was assessed. Results show that with the implementation of JNCCs standard mitigation measures the likelihood of a permanent threshold shift occurring is low for all the marine mammal hearing groups. The appropriate mitigation measures will be adopted.

A.3 Oil and Gas Marine Planning Policies

Objectives and policies for the Oil and Gas sector should be read subject to those set out in the NMP and the MSFD. It is recognised that not all of the objectives can necessarily be achieved directly through the marine planning system, but they are considered important context for planning and decision making. The Murlach Field Development activities have been assessed against the oil and gas marine planning policies, details of which can be found in Table A-3.

Table A-3: The proposed Murlach Field Development assessed against the Oil and Gas Marine Planning Policies.

Oil and Gas Marine Planning Policies	Applicable?	Assessment Against Policy
Oil & Gas 1		
The Scottish Government will work with BEIS, the new Oil and Gas Authority and the industry to maximise and prolong oil and gas exploration and production whilst ensuring that the level of environmental risks associated with these activities are regulated. Activity should be carried out using the principles of Best Available Technology (BAT) and Best Environmental Practice. Consideration will be given to key environmental risks including the impacts of noise, oil and chemical contamination and habitat change.	✓	Environmental risks addressed/assessed where necessary in the EIA.

Oil and Gas Marine Planning Policies	Applicable?	Assessment Against Policy
Oil & Gas 2		
Where re-use of oil and gas infrastructure is not practicable, either as part of oil and gas activity or by other sectors such as carbon capture and storage, decommissioning must take place in line with standard practice, and as allowed by international obligations. Re-use or removal of decommissioned assets from the seabed will be fully supported where practicable and adhering to relevant regulatory process.	✗	Murlach is a new subsea development tied back to existing topsides facilities.
Oil & Gas 3		
Supporting marine and coastal infrastructure for oil and gas developments, including for storage, should utilise the minimum space needed for activity and should take into account environmental and socio-economic constraints.	✓	Murlach will be an offshore subsea development. Seabed disturbance and physical presence of the infrastructure have been assessed.
Oil & Gas 4		
All oil and gas platforms will be subject to 9 nautical mile consultation zones in line with Civil Aviation Authority guidance.	✗	Murlach will be a subsea development.
Oil & Gas 5		
Consenting and licensing authorities should have regard to the potential risks, both now and under future climates, to oil and gas operations in Scottish waters, and be satisfied that installations are appropriately sited and designed to take account of current and future conditions.	✓	Murlach will be incorporated into the existing ETAP OPEP and Safety Case. A drilling OPEP will be in place during drilling operations.
Oil & Gas 6		
Consenting and licensing authorities should be satisfied that adequate risk reduction measures are in place, and that operators should have sufficient emergency response and contingency strategies in place that are compatible with the National Contingency Plan and the Offshore Safety Directive.	✓	Murlach will be incorporated into the existing ETAP OPEP. A drilling CIP will be in place during drilling operations.

APPENDIX B - ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACT IDENTIFICATION

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Vessels: Drilling, Installation, Topside Modifications and Commissioning																					
Emissions to Air		a														Exhaust emissions from combustion engines (i.e. burning of diesel) and generation of power during vessel operations resulting in emissions of various combustible gases.	Minimise use of vessels through efficient journey planning. Vessel assurance conducted to check that contracted vessels meet BPEOC marine standards and demonstrate relevant compliance requirements for IMO/MARPOL, e.g. IAPP certification.	2	L	N/A	N/A
Physical presence								b	a			a		a		Vessel support for survey, construction and installation. Drilling rig transit and on location and associated supply vessels. Can pose navigation hazard, restriction of fishing operations, disturbance to birds / cetaceans.	Kingfisher notice to mariners prior to operations starting. 500 m safety zone around Skua drill centre is pre-existing and will be used during drilling activities. Optimised vessel use reducing vessel time spent in field. Flotel will be located within existing ETAP 500 m safety zone.	1	L	N/A	N/A

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Noise and Visual Impact							a	b		a						General vessel noise from operations, including DP, generating elevated sound levels. Noise from DP has the potential to cause disturbance to marine mammals and fish in the form of temporary displacement from the area. Marine mammals and fish are expected to return once the vessel(s) has left the area.	Minimise use of vessels through efficient journey planning.	2	L	N/A	N/A
Disturbance to the seabed				a		a										Disturbance to the seabed from the drilling rig. Localised seabed disturbance resulting in some lethal/sub-lethal effects on benthic and epibenthic fauna. Possible smothering of some organisms following settlement of re-suspended particles. Recovery dependent on type of seabed and species present. Area of impact is relatively small and out with any designated areas. Potential anchor scarring from anchors. Little impact on current fishing activity as disturbance will be within the 500 m safety zones currently in place.	Drilling rig and anchor pattern will be designed to minimise disturbance to the seabed.	2	L	N/A	N/A
Discharges to sea: vessel sewage			a	a	a	a	a	b								Discharge of domestic sewage and food waste from the vessels. Organic enrichment and chemical contaminant effects in water column and seabed sediments. Potential food chain impacts, however, may have a positive effect in that nutrients are provided for fauna.	Minimise use of vessels through efficient journey planning and use of relevant vessels for each activity. Vessel assurance conducted to check that contracted vessels meet BPEOC marine standards and demonstrate relevant compliance requirements for IMO/MARPOL.	1	L	N/A	N/A

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Discharges to sea: ballast water			a	a	a	a	a	b								Water quality in immediate vicinity of discharge may be reduced, but effects are usually minimised by rapid dilution in receiving body of water and non-continuous discharge. Possible introduction of invasive species depending on vessel routes.	BPEOC audit procedures will check that the contracted vessels ballasting procedures are in line with the IMO. All discharges shall be monitored and records maintained as per regulatory requirements.	1	L	N/A	N/A
Discharges to sea: biofouling					a	a	a									Bioinvasions as a result of biofouling (accumulation of organisms including plants, algae, or animals such as barnacles) on vessels.	Contracts will be awarded to contractors originating from countries signed up to IMO. As part of BPEOC's auditing process, only vessels adhering to the IMO 2011 Guidelines for the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Species will be used. All member states of IMO are signed up to these Guidelines.	2	L	N/A	N/A
Waste													a			General operational hazardous and non-hazardous waste. Effects associated with onshore disposal are dependent on the nature of the site or process. Landfills – land take, nuisance, emissions (methane), possible leachate, limitations on future land use. Treatment plants – nuisance, atmospheric emissions, potential for contamination of sites.	All wastes to be properly segregated for recycling / disposal / treatment. Waste will be dealt with in accordance with regulatory requirements. Monthly reporting of waste sent to shore. Vessels will conform with their own Waste Management Plans. Minimise use of vessels through efficient journey planning. Vessel audits to check that they meet BPEOC's marine assurance standards. Vessels will be MARPOL compliant.	1	L	N/A	N/A

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Resource Use	a															Diesel usage for power generation.	Minimise use of vessels through efficient journey planning and use of relevant vessels for each activity. Vessel audits to check that they meet BPEOC's marine assurance standards and relevant compliance requirements, i.e. contracted vessels shall be MARPOL compliant.	1	L	N/A	N/A
Unplanned Event: Minor chemical / hydrocarbon release from vessels e.g. from drains.			a				a	a								Water quality deterioration, impact on marine flora and fauna.	Vessels shall comply with applicable IMO / MARPOL requirements and have associated SOPEPs in place. COSHH, Task Hazard Assessments are completed and SDS sheets will be available on the vessel. Standard operating procedures adhered to, e.g. bunkering in good light, regular hose inspection, correct storage and segregation of chemicals etc. Spill kits shall be available on board.	2	L	U	L

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Unplanned event: Major oil / chemical (e.g. fuel oil and diesel) release (potentially due to vessel collision).			a		a	a	a	b	a			a				Pollution of water column, threat to biodiversity harm to surrounding ecosystems, flora and fauna. Fishing impact assessment has been completed with no significant risks identified.	Emergency response plans in place including vessel SOPEPs. Simultaneous Operations (SIMOPS) will be managed through bridging documents and communications (e.g. if vessels are within the 500m safety zone). Vessels shall comply with applicable IMO / MARPOL requirements. Kingfisher bulletins shall be updated with vessel activities. Vessels shall abide with International Collision Regulations. BPEOC subscribes to Oil Spill Response Limited in the event of a Tier 2/3 event. ERRV vessel located in field.	3	M	R	L
Unplanned event: Failure of ROV installation equipment connection resulting in loss of hydraulic fluid to sea.			a	a		a	a	b								Local water quality deterioration, impacts on marine flora and fauna.	Follow standard operating procedures, maintenance and checklists for ROVs. Inventories on ROVs are relatively small.	1	L	U	L
Unplanned events: dropped objects resulting in damage to subsea infrastructure and seabed.			a	b	a	a	a	b			c	a				Local water quality deterioration should existing pipeline be damaged.	Vessels will follow SIMOPs plans and lifting procedures which include assessment / risk of dropped objects. Dropped objects retrieved where possible.	2	M	R	L

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Drilling Operations																					
Physical presence of semi-submersible drilling rig								a	a					a		Physical presence of the semi-submersible drilling rig at the project location. Navigation hazard, disturbance to birds / cetaceans.	A Consent to Locate will be submitted for the semi-sub. The rig will have marking and lighting as per the Standard Marking Schedule for Offshore Installations. The rig will be located within the pre-existing 500 m safety zone. Prior to mobilisation of the drilling rig the coastguard will be notified.	1	L	N/A	N/A
Emissions to air.		a	a													Exhaust emissions from combustion engines (i.e. burning of diesel), generation of power during vessel operations and from well bore clean-up resulting in emissions of various combustible gases. Emissions to atmosphere result in a minor contribution to climate change, acidification and photochemical smog (compared to overall activity in the North Sea).	Optimise use of vessels through efficient journey planning and use of appropriate vessels for the activities. The semi-sub will be reviewed under BPEOC's marine assurance standards and subject to rig recertification audits. The semi-sub will be MARPOL compliant with IAPP requirements.	2	L	N/A	N/A
Discharges to sea; WBM			a	a		a										Deliberate discharge to sea of WBM and WBM contaminated cuttings, brine, cement and completion chemicals required in the drilling and well construction process. Short term impact on local water quality. Smothering of benthic organisms, suspended solids, local water quality deterioration in close proximity to the drilling location. Cuttings piles may be contaminated with chemicals. Impact on species occurring in the water column.	All chemicals used offshore will be subject to the Offshore Chemical Regulations requirements, and will be risk assessed as part of the application for use / discharge.	2	L	N/A	N/A

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Discharges to sea: sewage and waste			a	a		a	a					a				Discharge of domestic sewage and food waste from the drilling rig. Local water quality deterioration, enrichment. High BOD (Biological Oxygen Demand) may have immediate local impact on water quality (deoxygenation), resultant impacts on marine flora and fauna.	The semi-sub shall comply with relevant regulatory (i.e. MARPOL) requirements for discharge of food and sewage wastes.	1	L	N/A	N/A
Discharges to sea: hydrocarbons / chemicals			a	a		a	a					a				Machinery space drainage. Discharge of hydrocarbons / chemicals to sea. Local water quality deterioration, enrichment. High BOD may have immediate local impact on water quality (deoxygenation), resultant impacts on marine flora and fauna. Potential food chain impacts through introduction of an anthropogenic food source, however may have positive effect in that nutrients are provided for fauna.		2	L	N/A	N/A
Seabed disturbance				a		a						a				Impacts of anchors, and anchor chains on the seabed, as part of positioning of the drilling rig. Seabed disturbance due to anchors and anchor chains resulting in potential impact to benthic flora and fauna. Environmental surveys in the area identified no Annex I or II habitats or species. Potential for formation of clay berms with recovery of anchors.	Pre anchor lay surveys. Post anchor recovery surveys to determine if clay berms remain on the seabed. If clay berms formed, BPEOC will discuss appropriate mitigation with OPRED and SFF.	2	L	N/A	N/A

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Noise and visual impact							a	a								Noise and vibration during drilling operations. Generates elevated sound levels which can affect the behaviour of fish and marine mammals in the area.	Optimise drilling campaign to minimise duration.	1	L	N/A	N/A
Waste													b			Hazardous and non-hazardous waste. Drilling rigs generate a number of wastes during routine operations including waste oil, chemical and oil contaminated water, scrap metal, etc. Effects associated with onshore disposal are dependent on the nature of the site or process - land take, nuisance, emissions (methane), possible leachate, limitations on future land use.	All wastes to be properly segregated for recycling / disposal / treatment. Waste will be dealt with in accordance with applicable regulatory requirements and in line with BPEOC waste hierarchy. Monthly reporting of waste data, including volumes sent to shore / landfill etc. The semi-submersible rig shall maintain its Waste Management Plan and Waste Record Book.	1	L	N/A	N/A
Waste: OBM (Oil Based Mud) and OBM contaminated cuttings.		b											b			Additional emissions from transport. Effects associated with onshore disposal are dependent on the nature of the site or process. Landfills - land take, nuisance, emissions (methane), possible leachate, limitations on future land use. Treatment plants - nuisance, atmospheric emissions, potential for contamination of sites.	All OBM section cuttings will be shipped onshore for disposal. OBM will be re-used.	2	L	N/A	N/A
Use of resources: diesel	a															Diesel usage for power generation.	Use of anchors reduces load on dynamic positioning systems and therefore power requirements for vessel stability. The semi-sub power generators are subject to maintenance programs and applicable compliance requirements.	1	L	N/A	N/A

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Unplanned: discharge to sea, OBM			a	a	a	a	a	b	a							Loss of containment of oil-based mud (potentially through a burst hose) resulting in a release to sea. Local water quality deterioration, impact on marine flora and fauna, localised smothering of seabed and associated biota.	Bulk transfers and hoses managed according with selected semi-submersible rig maintenance strategy and procedures.	3	M	**U**	L
Unplanned discharge to sea, hydrocarbons / chemicals			a	a	a	a	a	b				a				Release of hydrocarbons / chemicals to sea (e.g. from drains, bunkering operations etc.). Impacts depend on release size, prevailing wind, sea state, temperature and sensitivity of environmental features affected. Birds are most sensitive offshore receptor. Also affected are plankton, fish / fisheries, seabed animals and marine mammals.	The semi-sub will have an approved OPEP in place. Rig assurance and recertification audits include review of applicable maintenance and safety requirements upon rig. ERRV will be located in field. BPEOC is a member of Oil Spill Response Limited in the event of Tier 2/3 incident. Procedures in place for bulk transfers and maintenance strategies for hoses. Standard operating procedures adhered to, e.g. bunkering in good light, regular hose inspection, correct storage and segregation of chemicals etc.	**2**	M	U	L

Aspect	Receptor Sensitivity: Environmental											Receptor Sensitivity: Societal				Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Unplanned discharge to sea, major release of fuel			a	a	a	a	a	b	a		b	b				Major release to sea of drilling rig fuel hydrocarbon inventory in the result of a vessel collision. Local water quality deterioration, impact on marine flora and fauna.	500 m safety zone in place whilst rig is on station. ERRV will be located in field. The rig will have marking and lighting as per the Standard Marking Schedule for Offshore Installations. Notice will be sent to the Northern Lighthouse Board, HSE, Coastguard and Kingfisher of any drilling rig moves and vessel mobilisation associated with the mobilisation and demobilisation of the drilling rig.	3	M	R	L
Unplanned discharge to sea, influx of hydrocarbons into wellbore			a	b	a	b	a	a			b					Influx of hydrocarbons into wellbore (loss of hydrostatic overbalance). Controlled hydrocarbon flow to surface / controlled venting of hydrocarbon e.g. via diverters. Local water quality deterioration, impact on marine flora and fauna.	Wells designed and drilled as per BPEOC Global Wells Organisation (GWO) safety standards and practices, e.g. Well design notification / examination schemes. Regular BOP testing. Training and competency of drill crews, including regular well control drills and well control self-verification processes.	**2**	M	R	L

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Unplanned discharge to sea, well blowout		a	a	c	c	c	c	c	c	b	c	c		c	c	Well blowout (uncontrolled hydrocarbon release in the event of loss of well control). Damage to commercial fisheries, sediment and water quality impairment and release of atmospheric emissions. Impacts on marine flora and fauna.	Wells designed and drilled as per BPEOC GWO safety standards and practices, e.g. well design notification / examination schemes. Use of blowout preventer with testing and maintenance programs. Relief well planning, and well capping device available. Training and competency of drill crews, including regular well control drills and well control self-verification processes. Semi-sub will be subject to rig assurance and recertification requirements. Approved OPEP in place. Member of Oil Spill Response Limited in the event of a Tier 2/3 event.	4	H	R	M
Unplanned seabed disturbance				a		a										Dropped objects from drilling rig resulting in physical damage to subsea environment. Loss of seabed habitat, smothering of benthic organisms.	Lifting risk assessments shall be conducted prior to equipment transfer, including potential risk of dropped objects and / or potential impact to existing infrastructure.	1	L	U	L

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Subsea Installation																					
Physical presence						b	a					a				Physical presence of all subsea infrastructure (includes wells, manifold, gas lift line, tie-in spools, rock dump, mattresses, grout bags etc.). Restriction of fishing operations, snagging risk to fishing nets. Loss of habitat and possible smothering of fish species and benthic communities. * Following the results of the Contract & Procurement stage, the contractor suggested rock dump rather than trench and bury. BPEOC therefore held extra consultation with OPRED, SFF, JNCC and MSS to discuss the impacts of this option selection. Potential for clay berms to be created should the gas lift pipeline be trenched and buried.	Infrastructure will be subject to PWA requirements. Pipeline routes shall be added to admiralty charts, Kingfisher database, etc. Infrastructure will be designed as fishing friendly. 500m exclusion zones shall continue to be present at the new Manifold. Use of rock cover and mattresses will be optimised. Pipeline installation methodology has been assessed for environmental and social impacts as part of analysis for alternatives. In the event that clay berms are formed as a result of trench and burying, BPEOC will discuss appropriate mitigation with OPRED and SFF e.g. use of chain mats to break up the berms.	2	L	N/A	N/A
Discharges to sea			a	a	a	a	a	a								Discharge of chemicals (e.g. Monoethylene Glycol (MEG)) during leak testing of pre-filled pipelines. Local water quality and sediment quality deterioration, impacts on marine flora and fauna.	Chemical selection process shall comply with relevant regulations. The use and / or discharge of all chemicals will be subject to risk assessment and permitting. Low toxicity and / or PLONOR chemicals will be used where possible and deemed technically feasible.	2	L	N/A	N/A

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Discharges to sea			a	a	a	a	a	a								Release of hydraulic fluid during subsea valve operation and maintenance. Local water quality and sediment quality deterioration, impacts on marine flora and fauna.	Hydraulic fluid selection for the Murlach Field Development will be aligned with the existing ETAP subsea infrastructure processes and chemical permits. Use of water-based hydraulic fluid.	1	L	N/A	N/A
Seabed disturbance			a	a	a	c	a									Disturbance associated with installation of subsea infrastructure e.g. manifold, gas lift line, jumpers, rock dump, mattresses etc. Local water quality and sediment quality deterioration, impacts on marine flora and fauna. The largest impact will come from the gas lift line which will possibly be surface laid and rock dumped.	Environmental baseline and habitat surveys have been completed. Use of rock cover and mattresses will be optimised. Pipeline installation methodology has been assessed for environmental and social impacts as part of analysis for alternatives.	2	M	N/A	N/A
Resource Use	b															Consumption of finite materials (e.g. steel) during construction of gas lift line and other subsea infrastructure. Use of non-renewable resources.	Design life of infrastructure used will meet the duration of the field life.	1	L	N/A	N/A
Noise							b	b								Piling of the manifold causing disruption to marine mammals and fish species.	Optimise duration of piling activities. Use of properly qualified, trained and equipped marine mammal observers to detect marine mammals within a mitigation zone. Soft start piling, with incremental increases in power and sound level.	2	L	N/A	N/A

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental										Societal										
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Production																					
Physical presence																Vessel requirements for servicing and running of the field. Relative to existing requirements there will be no increase in vessel requirements at ETAP during production as a result of the Murlach Field Development.					
Emissions to Air		a	a													Emissions to air as a result of flaring. Small increase due to the increased hydrocarbon inventory	Minimise shut downs that can result in flaring. Minimise shut downs that can result in flaring.	1	L	N/A	N/A
Noise and visual impact																Change to noise and visual impact as a result of the Murlach Field Development.					
Waste																Change to waste generation as a result of the Murlach Field Development. Relative to existing waste production at ETAP, there is no anticipated increase in waste as a result of the Murlach Field Development.					
Unplanned Events: Murlach flowline rupture and subsequent release of hydrocarbons to sea.			a	b	b	c	c	b	b		c	a				Local water quality deterioration, impacts on marine flora and fauna.	Design of lines and materials selection. Integrity management system, inspection and maintenance. Structural and cathodic corrosion protection will be implemented. Follow standard operating procedures and checks. Use of Emergency Shutdown System. Design Hazard Management Plan. Pipelines Integrity Management System.	4	H	R	M

Aspect	Receptor Sensitivity															Observations	Industry and Project Mitigation	Magnitude of Effect	Impact Significance	Likelihood (unplanned event)	Environmental Risk (unplanned)
	Environmental											Societal									
	Resource Availability	Air Quality	Water Quality	Sediment Quality	Plankton	Benthic Communities	Fish	Marine Mammals	Seabirds	Coastal Marine Communities	Designated Areas	Fisheries	Landfill Resources	Shipping	Cultural Heritage						
Unplanned Events: Snagging or dragging of Murlach infrastructure			a	b		b	a					c				Snagging or dragging of Murlach wellheads, gas lift line or umbilical resulting in seabed disturbance. Local water quality deterioration due to disturbance of sediment into the water column, impacts on marine flora and fauna. Fisheries score based on assumption of a loss of trawl gear from the trawler.	500 m safety zone at the Manifold in place. Pipeline routes added to admiralty charts, Kingfisher database. A fisheries interaction assessment to aid selection of the optimal flowline installation method will be carried out. In the event that the study identifies an unacceptable risk to flowline integrity or fishing gear, the option to install the flowline exposed on the seabed will not be carried forward.	2	M	R	M
Unplanned Events: Murlach subsea control system failure			a	a	a	b	a	a			a					Murlach subsea control system failure resulting in a minor release to sea of hydraulic / control fluid. Local water quality deterioration, impacts on marine flora and fauna.	Integrity management systems, inspection and maintenance. Design and materials selection. Follow standard operating procedures and checks. Chemical risk assessment undertaken as part of the Production Operations MAT submission. Use of water-based hydraulic fluid. Use of Engineered Installation Procedures.	2	L	P	L
Unplanned Events: Murlach subsea system failure			a	b	a	b	a	a			a					Murlach subsea system failure resulting in a small release of liquid and / or gas hydrocarbons to sea. Local water quality deterioration, impacts on marine flora and fauna.	Integrity management systems, inspection and maintenance. Design and materials selection. Follow standard operating procedures and checks. Chemical risk assessment undertaken as part of the Production Operations MAT submission. Use of Engineered Installation Procedures.	2	L	U	L

APPENDIX C - OIL SPILL MODELLING

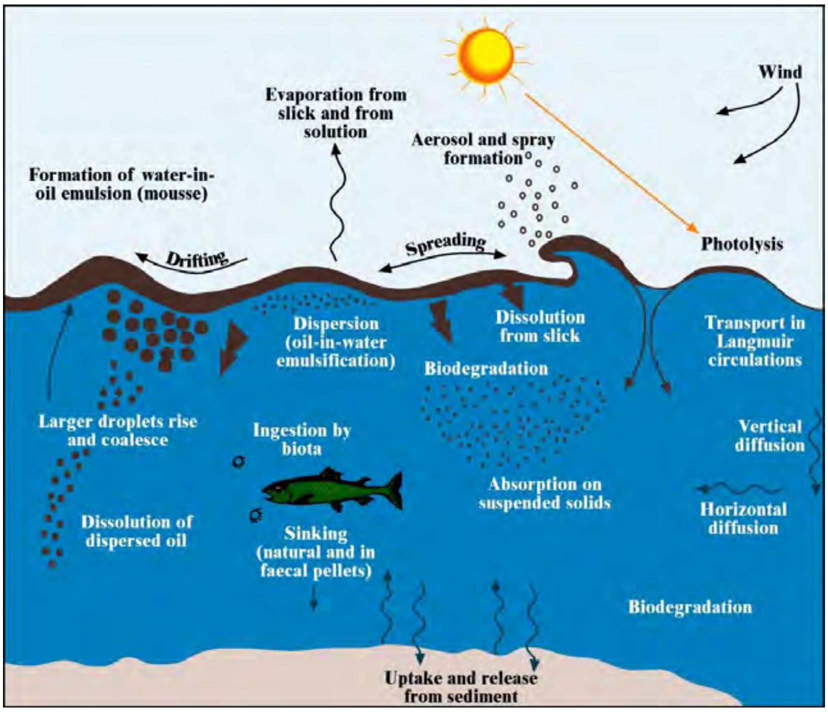
This Appendix describes the oil spill simulations undertaken in order to determine the environmental risk associated with the accidental release of hydrocarbons at the proposed Murlach Field Development. A single well blowout scenario has been modelled using the OSCAR model developed by Sintef.

The aims of the modelling were to understand:

- Where hydrocarbons are likely to travel;
- How hydrocarbons are likely to disperse over time (both on the sea surface and in the water column);
- The extent to which hydrocarbons are likely to arrive on any shoreline;
- Where hydrocarbon concentrations could exceed certain thresholds on the sea surface, in the water column, shorelines and in sediments; and
- To inform the assessment of potential environmental impacts.

C.1 Introduction to the OSCAR Model

When crude oil is spilled on the surface of the sea it is subjected to a number of processes including: spreading, evaporation, dissolution, emulsification, natural dispersion, photo-oxidation, sedimentation and biodegradation. The fate and effect of crude oil depend on its physico-chemical properties and the changes to which it is subjected vary depending on the oil type, volume spilled and metocean conditions. Some of these changes lead to its removal from the sea surface while others, e.g. emulsification, may cause it to become more persistent. The various processes that oil is subjected to after a release at sea are highlighted in Figure C-1. These processes are modelled in OSCAR to predict the fate and behaviour of released hydrocarbons over time.



Source: adapted from Koops *et al.* (1985).

Figure C-1: Fate and behaviour of spilled hydrocarbons at sea.

OSCAR supports two different types of simulations: stochastic (probabilistic) and deterministic. The stochastic simulation feature of OSCAR allows for a spill scenario to be simulated multiple times over different weather conditions, with the results from each individual stochastic simulation being aggregated, and a number of statistical parameters computed. The stochastic simulation results presented in this Appendix examine the probability of oil above a predefined threshold:

- Appearing on the sea surface;
- Being present throughout the water column; and
- Arriving on the shoreline.

To analyse a single spill scenario, the deterministic mode of OSCAR allows for a spill scenario to be simulated over a single specified time interval and outputs can be presented in terms of key parameters such oil thickness on the sea surface, concentrations on the shoreline, in the sediment and in the water column. One deterministic scenario was selected based on the individual stochastic run which gives the worst case shoreline oiling (i.e. the greatest mass of oil arriving onshore).The deterministic model results presented in this Appendix examine the maximum:

- Thickness of oil appearing on the sea surface;
- Concentrations of oil present in the water column;
- Concentrations of oil reaching the shoreline; and
- Concentrations of oil being deposited in the sediment.

C.2 Modelling Methodology

This section details the model input data for the well blowout scenario. The specific release parameters and hydrocarbon characteristics that have been used to model the spill scenario are discussed, along with the various environmental factors that have been accounted for in the simulation.

C.2.1 Release Parameters

The main release parameters for the well blowout scenario are summarised in Table C-1. In the unlikely event of a blowout, the release would likely be subsurface (i.e. the drill rig would quickly detach from the well at the emergency disconnect package at the seabed). A release at the seabed was modelled for the purpose of assessing the impact of this scenario as it represents a worst-case in terms of impacts on the water column and sediments, while having limited influence on the ultimate fate of the hydrocarbons on the sea surface and along coastal areas.

Table C-1: Release parameters.

Scenario and location[1]	Hydrocarbon type	Release rate	Release duration[2]	Total quantity released	Release depth	Release temperature
Seabed blowout 57° 14’ 05.933” N 01° 37’ 35.699” W	Crude with associated solution gas	16,741 m^3/day oil plus 3,856,365 m^3/day gas	86 days	1,439,691.6 m^3	93.9 m	105.8°C

1. WGS 84 coordinate system
2. Total model duration of 116 days included an additional 30 days following the end of the discharge.

The well blowout scenario was modelled using the same estimated release duration as was used for the ETAP OPEP oil spill model. The release duration was based on the estimated time to source and mobilise a rig, drill a relief well, and kill and cement the well. The anticipated time to complete these activities is shown in Table C-2 and was estimated to be 86 days in total. The model was run for an additional 30 days after the blowout was terminated to determine the ongoing fate of the hydrocarbons following cessation of the release.

Table C-2: Estimated timeline to kill well and terminate blowout.

Event	Duration (days)
Mobilise Rig	21.00
Prepare for drilling	10.50
Drill top hole	1.50
Run conductor	1.50
Drill 17 ½" section	4.50
Run 13 ³/₈"	2.25
Run blowout preventer (BOP)	3.00
Drill 12 ¼" section	6.00
Run 9 ⁵/₈"	3.75
Drill 8 ½" (including ranging runs) and intersect well	20.00
Kill well	12.00
Total	**86.00**

The model described in Table C-1 assumed no intervention (i.e. no response efforts were included in the simulation) as required by OPRED. The results in terms of estimated impacts can therefore be considered to be conservative.

C.2.2 Hydrocarbon Characteristics

The fate of oil depends on its physico-chemical properties, which are accounted for in the model inputs. OSCAR contains a database of various oil types that can be used in the modelling. A suitable analogue was selected from the OSCAR database to represent Murlach crude properties.

Key hydrocarbon properties of the Murlach crude and the analogue oil that was in the model are shown in Table C-3. Balder Blend (2010) was selected as the analogue for Murlach crude as its properties were considered to represent the best fit overall. Given that oil emulsification will generally only take place if the asphaltene content of the oil is greater than 0.5% it was considered important to select an analogue with an asphaltene content greater than 0.5%. The specific gravity and viscosity of Balder Blend are higher than that of Murlach crude and therefore will provide a conservative result. The wax content of Balder Blend is lower than that of Murlach crude but given that the other parameters are conservative this is considered acceptable. Balder Blend provided the best fit among available analogues. A sensitivity run was undertaken with a waxier analogue (see Section C.3.6).

Table C-3: Oil properties of Murlach crude and selected OSCAR analogue.

Oil type	Specific gravity	API (°)	Viscosity and ref. temp (cP, °C)	Pour point (°C)	Wax content (% wt)	Asphaltene content (% wt)
Murlach crude	0.820	40.4	4.1 (30); 23.4 (13)	-3	6.7	0.7
Balder Blend (2010)	0.864	32.2	32.0 (13)	3	3.53	0.77

C.2.3 Modelling parameters

The OSCAR simulation parameters used here are outlined in Table C-4. The OSCAR near-field plume model was included in the simulation out of an orifice of specified diameter and orientation.

Table C-4: Well blowout simulation parameters

Parameter	Value
Time step	1 hour
Output interval	3 hours
Grid size	1200 km × 2000 km
Cell size	2 km × 2 km × 10 m deep
Near-field model	On
Grid depth	200 m
Liquid/solid particle count	20,000
Dissolved particle count	10,000
Gas particle count	5,000

C.2.4 Metocean Data

The OSCAR model takes into account the effect of various environmental factors such as bathymetry, current and wind speed and direction, water column salinity and temperature, as well as seabed and coastal sediment types. Such metocean data, specific to the environment surrounding the proposed Murlach Field Development, have been obtained from a variety of sources as discussed here.

C.2.4.1 Bathymetry data

The default bathymetry data in the OSCAR model was used (Sea Topo 8.2).

C.2.4.2 Current data

Three-dimensional water column current data for the region was obtained from the Hybrid Coordinate Ocean Model for years 2009–2013. The dataset contains 3D ocean currents with one-day temporal resolution (i.e. currents change speed and direction at daily intervals).

C.2.4.3 Wind data

Wind data have been obtained from the European Centre for Medium-Range Weather Forecasts for years 2009–2013. OSCAR also uses winds to generate waves for surface turbulent mixing processes.

C.2.4.4 Temperature and salinity data

Annual average salinity and temperature data for surface and bottom waters was obtained from NMPi. Annual average surface and bottom water temperatures were 9.60 and 7.17°C, respectively. Annual average salinity was 35.00 g/kg.

C.2.5 Output Thresholds

The OSCAR model can track the fate of oil in decreasing concentrations and masses (over time and space), beyond the point where oil represents a significant risk or is even detectable against background levels. To ensure the model outputs are proportionate to the risks, while still retaining a precautionary approach, output thresholds are normally applied to thickness of surface oil and to hydrocarbon concentration in the water column. Both these thresholds are applied prior to running the model and further information is provided in Sections C.2.5.1 and C.2.5.2.

In addition, a number of thresholds are also used during the analysis of model outputs in order to assess potential environmental risk. These are explained in Sections C.2.5.3 and C.2.5.4.

C.2.5.1 Surface Thickness

A surface thickness threshold of 0.3 µm has been applied. This threshold is based on the Bonn Agreement oil appearance code (Bonn Agreement, 2016), which states that a rainbow sheen could be visible above this threshold (Table C-5). Hydrocarbon thickness below this value becomes unlikely to be visible in many conditions and oil thicknesses of less than 0.04 µm are considered “not visible” even under good conditions. The BEIS Oil OPEP guidelines (BEIS, 2019) state that oil spill model results must be displayed to an oil thickness of 0.3 µm and therefore this threshold has been adopted for the present study.

Table C-5: Bonn Agreement Oil Appearance Code.

Code	Appearance description	Layer thickness (µm)	Litres per km^2
1	Sheen (silver/grey)	0.04 – 0.3	40 – 300
2	Rainbow	0.3 – 5.0	300 – 5,000
3	Metallic	5.0 – 50	5,000 – 50,000
4	Discontinuous true oil colour	50 – 200	50,000 – 200,000
5	Continuous true oil colour	> 200	> 200,000

Source: Bonn Agreement, 2016

C.2.5.2 Oil in Water Concentration

A range of standards for oil in water have been considered, which are summarised in Table C-6. A total oil in seawater concentration (in the water column) above 10 µg/l has been used as the threshold for the current model. This is based on the no observed effect concentration (NOEC) highlighted by Patin (2004). The NOEC is the level at which biological effects are either absent or manifest themselves as physiological and biochemical responses. A threshold of 10 µg/l is considered conservative given it is at the lower end of the range of standards shown in Table C-6.

Table C-6: Standards or oil concentration in the water column

Region	Source	Context	Parameter	Standard
North Sea and North East Atlantic	OSPAR Agreement 2014/05 (OSPAR, 2014)	Predicted no-effect concentrations (PNEC) of substances in produced water	Dispersed oil	NOEC 70.5 µg/l
International	Patin (2004)	Fate and effect of crude oil spills	Total Petroleum Hydrocarbons	NOEC 10 µg/l
Norway	Sintef	Pre-defined toxicity levels of oil components in OSCAR database	Any hydrocarbon component	Acute toxicity PNEC 50–15,500 µg/l. Chronic toxicity PNEC 5–1,550 µg/l

C.2.5.3 Shoreline Oil Concentration

No threshold has been applied to the shoreline oil concentration in stochastic simulations as it is considered best practice, in the interest of transparency, to report all shoreline oiling (however small) in the results. However, to allow an assessment of impacts when reviewing model outputs, a mass of oil on the shoreline ≥ 0.1 kg/m^2 has been considered as potentially significant. This is considered to be an impact threshold for oiling of birds by the US Army Corps of Engineers (2003) and is reinforced by McCay (2009) who notes that 0.1 kg/m^2 would be enough to coat benthic epifaunal invertebrates living in intertidal habitats on hard substrates. It is also inferred from the level of 'light' oiling defined by ITOPF (2014).

C.2.5.4 Oil in Sediment

No threshold has been applied to sediment concentrations in the model. However, to allow an assessment of impacts when reviewing model outputs, a mass of oil of 50 mg/kg, has been taken as the level above which toxic effects on benthic fauna may begin to be discernible. This threshold was adopted by OSPAR (2006) and UKOOA (1999) in the context of oil-based mud contamination. Given that deposition will distribute vertically through the surface of the seabed, this equates to 5 g/m^2 assuming that the oil will distribute through a 5 cm sediment layer and assuming a sediment density of 2.0 te/m^3. Therefore, 5 g/m^2 is applied as the threshold above which toxic effects are considered to begin to be discernible.

C.3 Model Results

This section presents the results obtained from the OSCAR simulations for the well blowout scenario, detailed in Table C-1. Both stochastic and deterministic simulation results are presented. The stochastic simulations comprised 100 individual deterministic simulations, which were evenly spread throughout the four years of current and wind data.

Spatial plots from the stochastic model runs are presented as maps of probability. These represent the probability of particles reaching a given location at specified thresholds (0.3 µm thickness for surface oil and 10 µg/l for water column oil concentration) during the 100 stochastic simulations. Particles that do not exceed the threshold in each case do not contribute to probability calculations (e.g. a cell of the model domain reached by surface oil particles thicker than 0.3 µm on 90 out of the 100 simulations will result in a probability calculated as 90%).

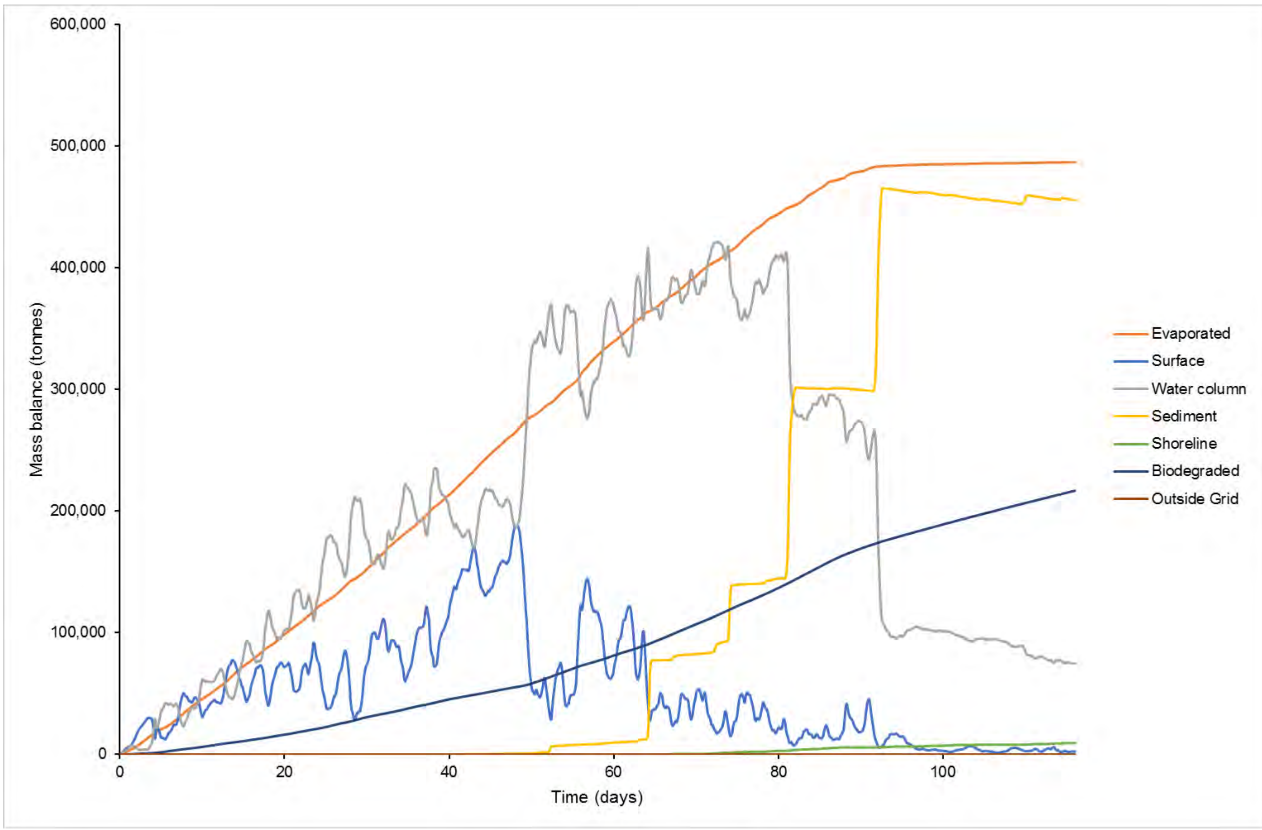
Based on the results from the stochastic simulations, one deterministic simulation was undertaken to further analyse the spill scenario and evaluate oil behaviour and ultimate fate in a worst-case scenario. A second deterministic simulation using the same metocean conditions and a different oil analogue was undertaken to compare the effect of analogue choice. The blowout starting time for deterministic scenarios corresponded to the individual stochastic simulation that resulted in the greatest mass of oil arriving onshore. A mass balance plot (as a function of time) was obtained from the deterministic simulation rather than the stochastic simulation to include the concentration of hydrocarbons in the sediment which is not calculated in the stochastic simulation.

Spatial plots from the deterministic simulation run show the maximum area impacted over the complete simulation duration, also referred to as the swept path. This does not represent the area of the plume/surface slick at any single instance in time (which would be significantly smaller).

C.3.1 Mass balance

A mass balance as a function of time by mass of fluid released and by percentage of total mass of fluid released has been calculated (deterministic simulation, Figure C-2). Here, the concentration of oil deposition on the seabed and maximum surface sheen thickness are calculated (unlike in the stochastic simulation). The mass balance at day 116 of the simulation is as follows:

- Evaporated: 39.09% (486,800 te);
- Surface: 0.19% (2,338 te);
- Water column: 6.01% (74,840 te);
- Sediment: 36.57% (455,400 te);
- Shoreline: 0.76% (9,460 te);
- Biodegraded: 17.38% (216,400 te); and
- Outside domain: 0.00% (0 te).



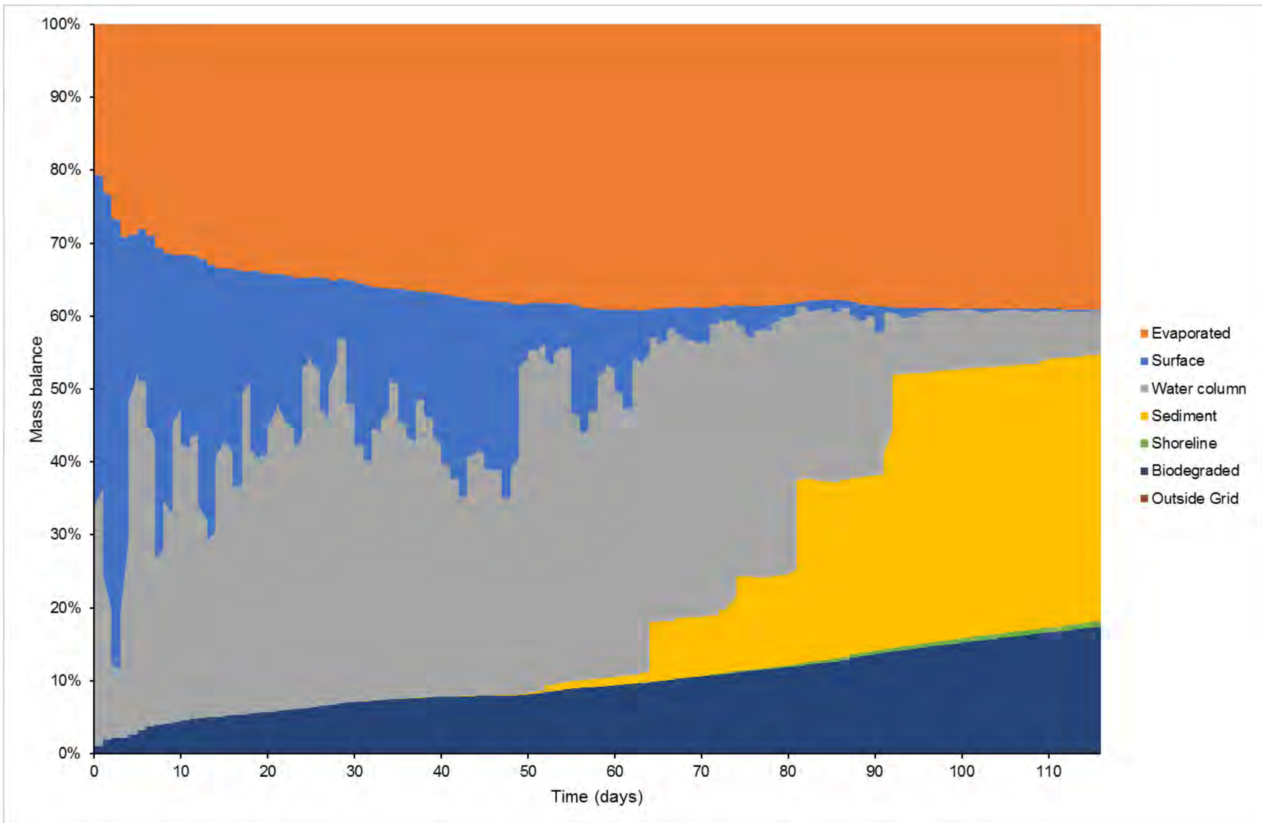


Figure C-2: Mass balance of oil by mass (top) and by percentage (bottom) over time (deterministic simulation).

C.3.2 Oil on the Sea Surface

A visible surface sheen is estimated to extend approximately 429 km east of the release location with a probability of 90–100% (Table C-7 and Figure C-3). The minimum time of arrival of the surface sheen to the median line was estimated at 1 day (Table C-7 and Figure C-4).

Table C-7: Probability and arrival times of surface sheens (≥ 0.3 μm thick) to median lines (stochastic simulation)

Median line	Maximum probability (%)	Minimum arrival time (days)
UK-Norway	100	1
UK-Denmark	94	10
UK-Germany	86	10
UK-Netherlands	72	10

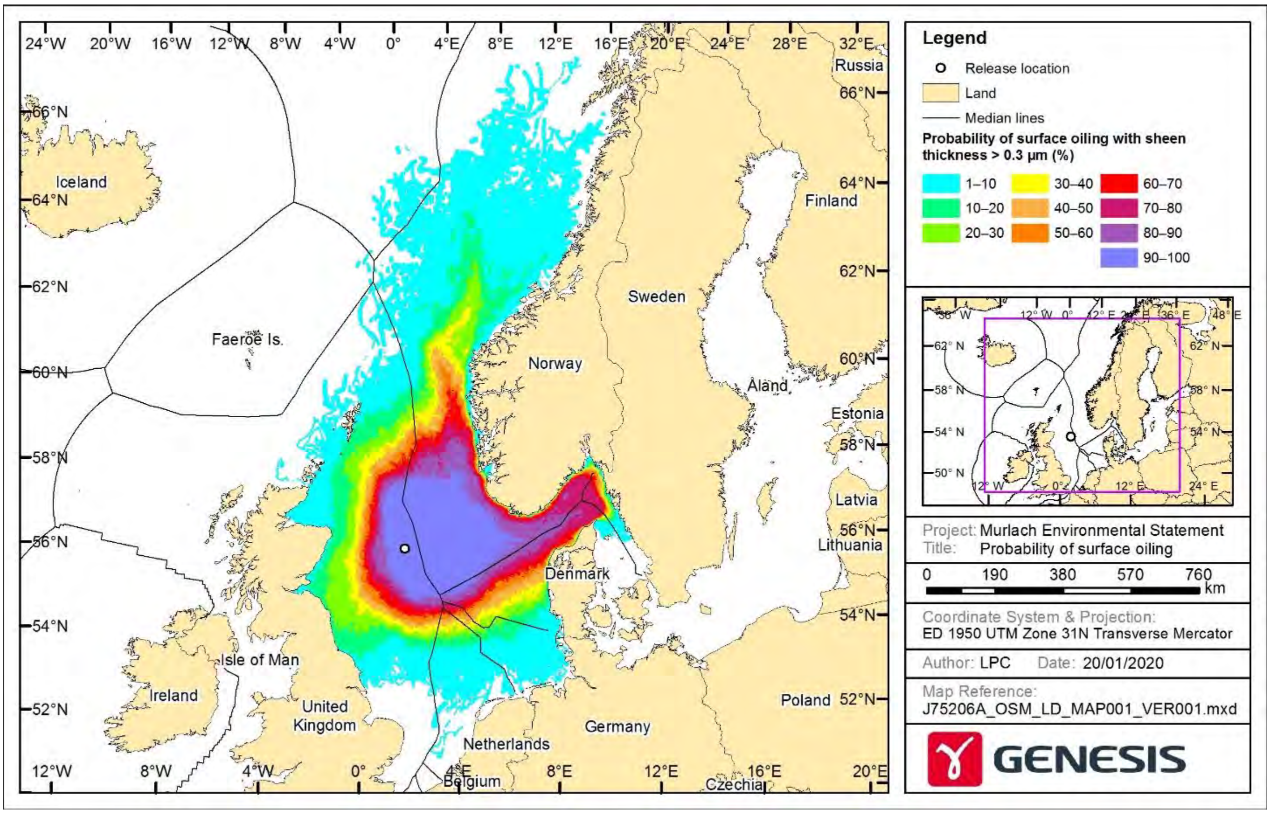


Figure C-3: Probability of surface sheen presence on the sea surface (stochastic simulation).

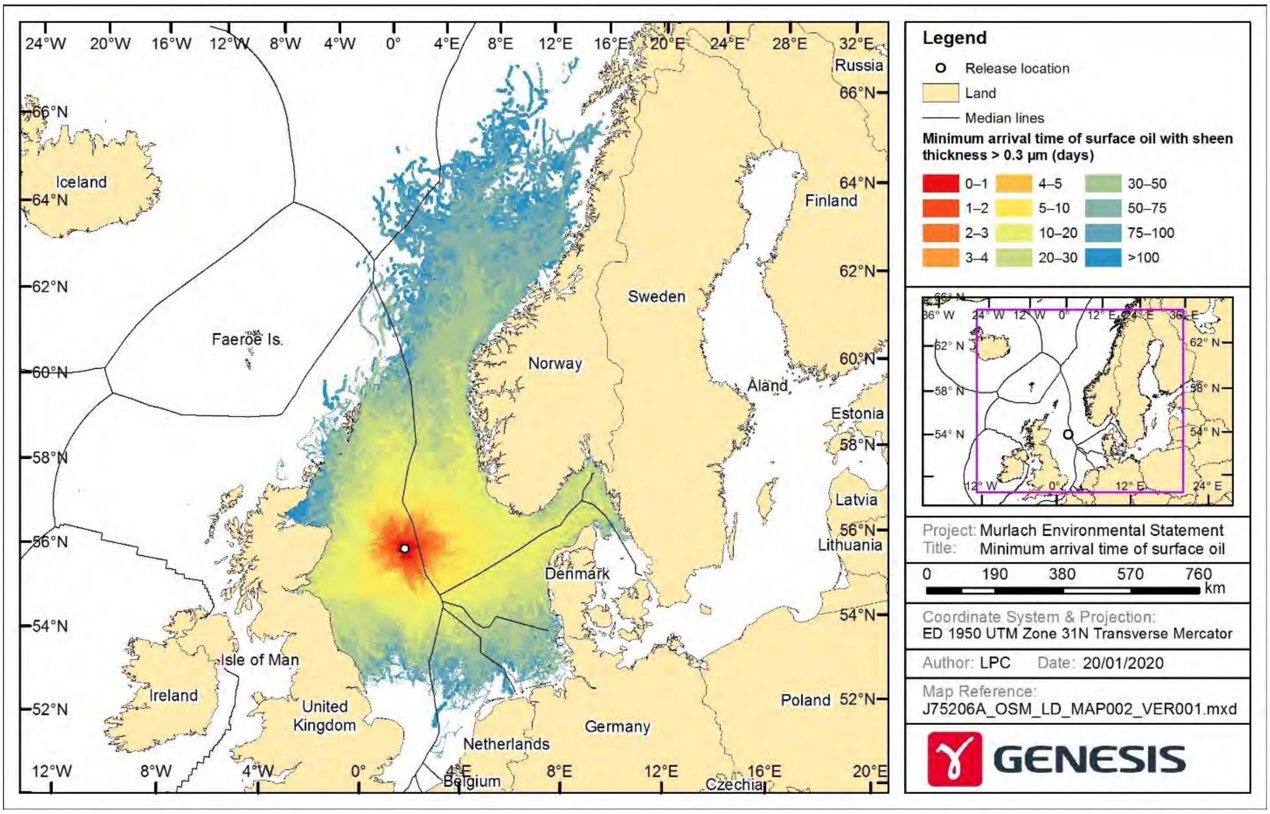
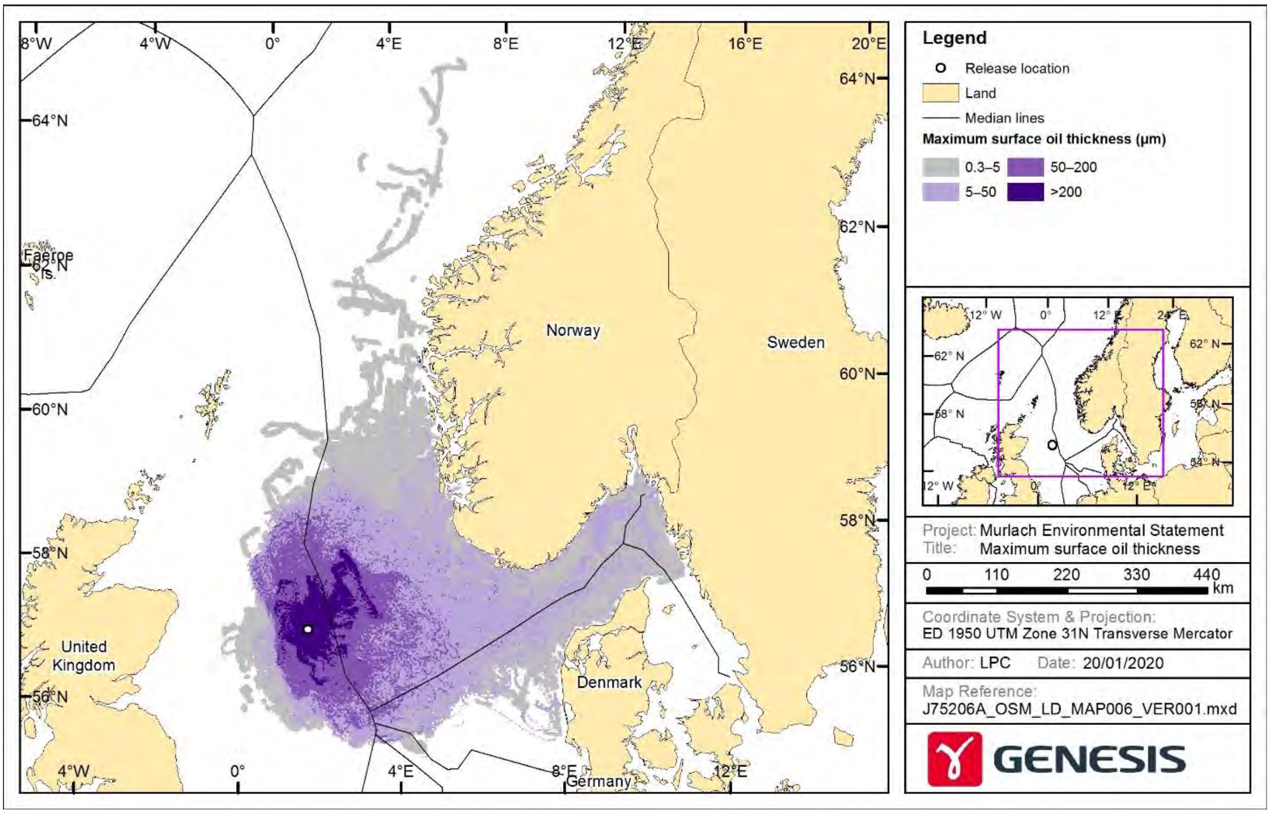


Figure C-4: Minimum arrival time of surface sheen (stochastic simulation).

The total sea surface area that could be covered by an oil sheen in the event of a well blowout was estimated to be 215,000 km² with a maximum thickness of 1,909.897 µm (1.91 mm) at any given location (deterministic simulation; Figure C-5). Note this is the total area impacted over the compete simulation duration (i.e. 116 days) and does not represent the area of sea surface covered by the surface slick at a specific point in time (which would be smaller).



Note: Sheens < 0.3 µm thick are not necessarily visible and will likely represent isolated patches of emulsified oil separated by unaffected sea surface.

Figure C-5: Maximum surface sheen thickness (deterministic simulation).

C.3.3 Water Column Concentrations

The oil plume is estimated to extend approximately 431 km east of the release location (Table C-8 and Figure C-6) with a probability of 90–100%. There is a 100% probability that oil entrained in the water column will cross the UK-Norway median line with a minimum arrival time of 1 day.

Table C-8: Probability and arrival times of oil plume to median lines (stochastic simulation).

Median line	Maximum probability (%)	Minimum arrival time (days)
UK-Norway	100	1
UK-Denmark	94	9
UK-Germany	84	10
UK-Netherlands	72	13

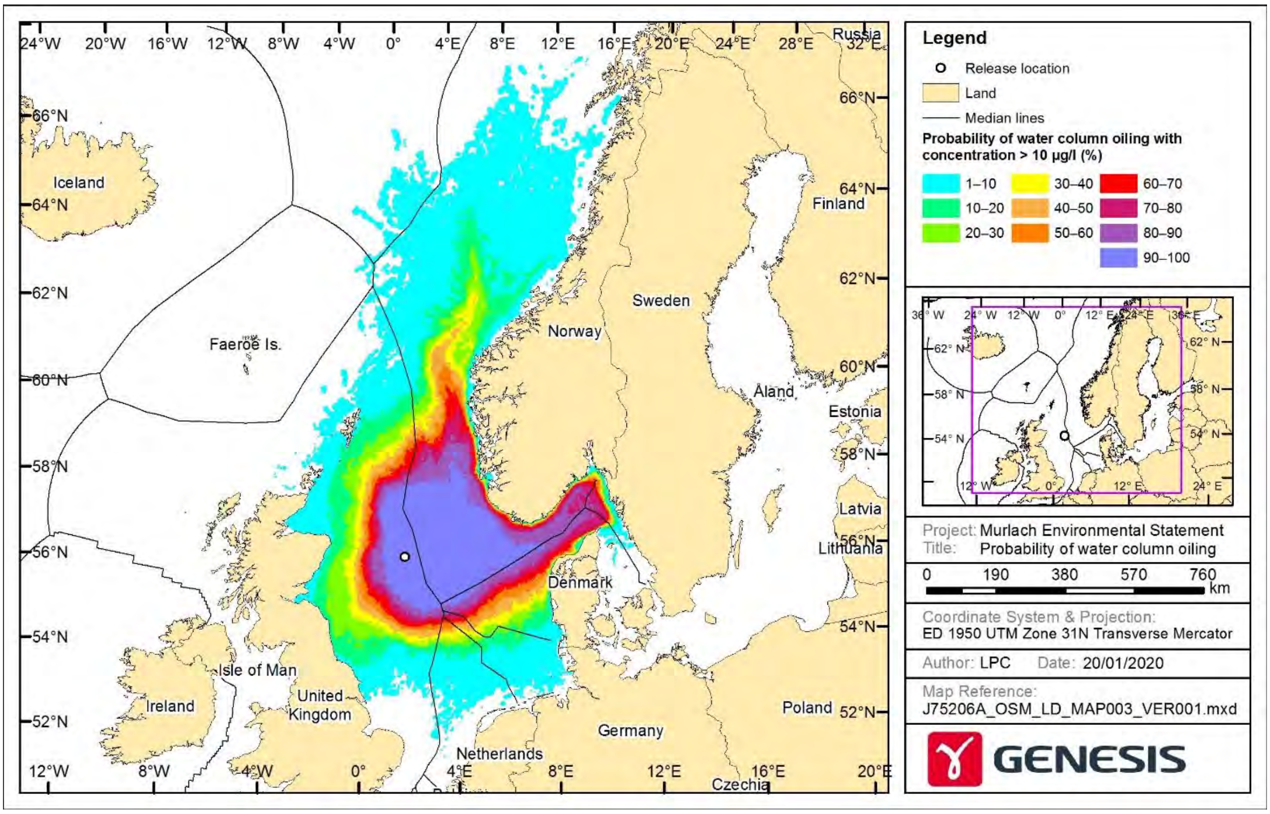


Figure C-6: Probability of oil plume presence in the water column (stochastic simulation).

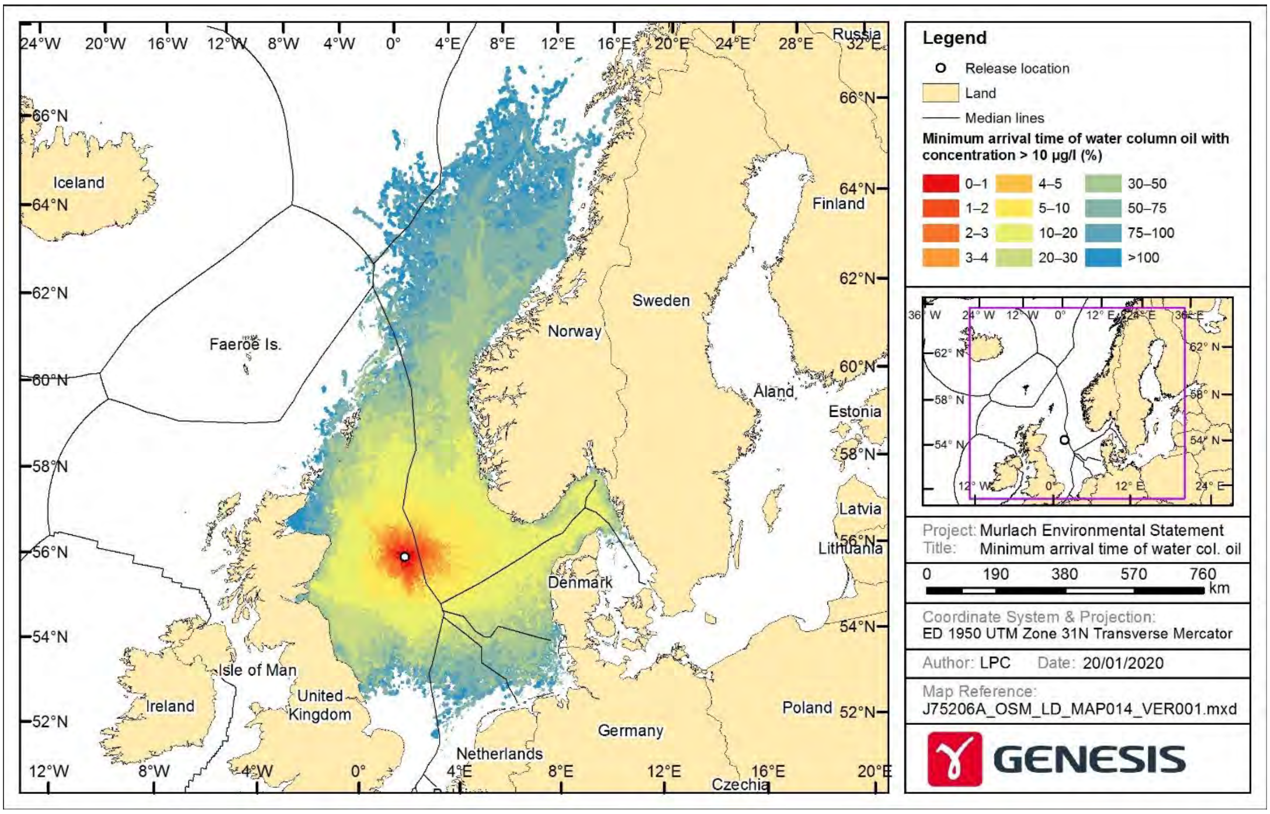


Figure C-7: Minimum arrival time of oil plume presence in the water column (stochastic simulation).

The total water column volume where oil concentration ≥ 10 µg/l in the event of a well blowout was estimated to be 11,300 km^3 (deterministic simulation; Figure C-8). This is the total volume impacted over the complete simulation duration (116 days) and does not represent the volume of water where 10 µg/l is exceeded at a particular point in time (which would be smaller).

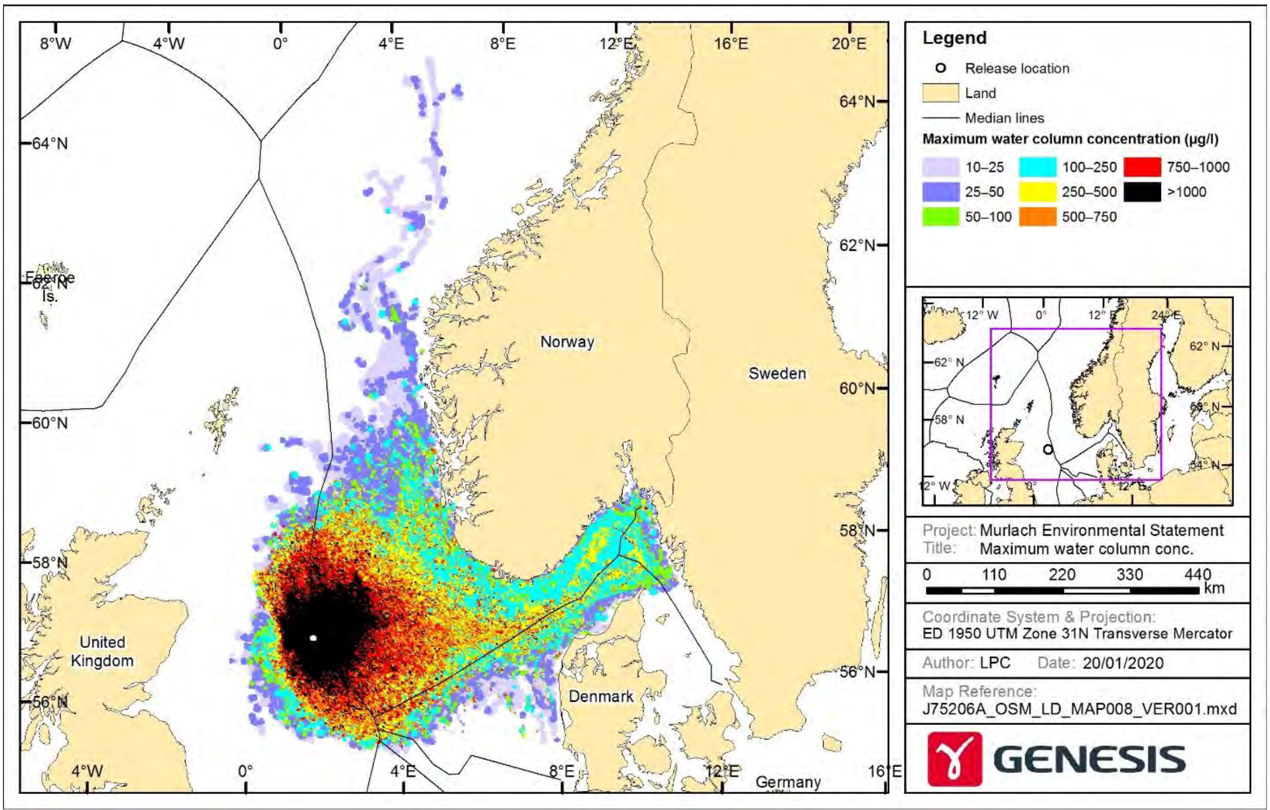


Figure C-8: Maximum oil concentration in the water column (deterministic simulation).

C.3.4 Shoreline Beaching

It was estimated that shoreline oiling in United Kingdom is unlikely (maximum probability = 18%, stochastic simulation) and the estimated minimum arrival time of oil to the UK coastline was 13 days (Table C-9 and Figure C-9). The highest probability of oil reaching shorelines in Norway was 77% and its estimated minimum arrival time was 10 days. The probabilities of shoreline oiling and the minimum arrival times of oil to shorelines have been summarised by country (Table C-9 and Figure C-10).

Table C-9: Maximum probability of oiling and minimum arrival times of oil to shorelines by region (stochastic simulation).

Country coastline	Maximum probability of oiling (%)	Minimum arrival time of oil (days)
United Kingdom	18	13
Norway	77	10
Sweden	61	18
Denmark	76	12
Germany	6	30
Netherlands	2	80

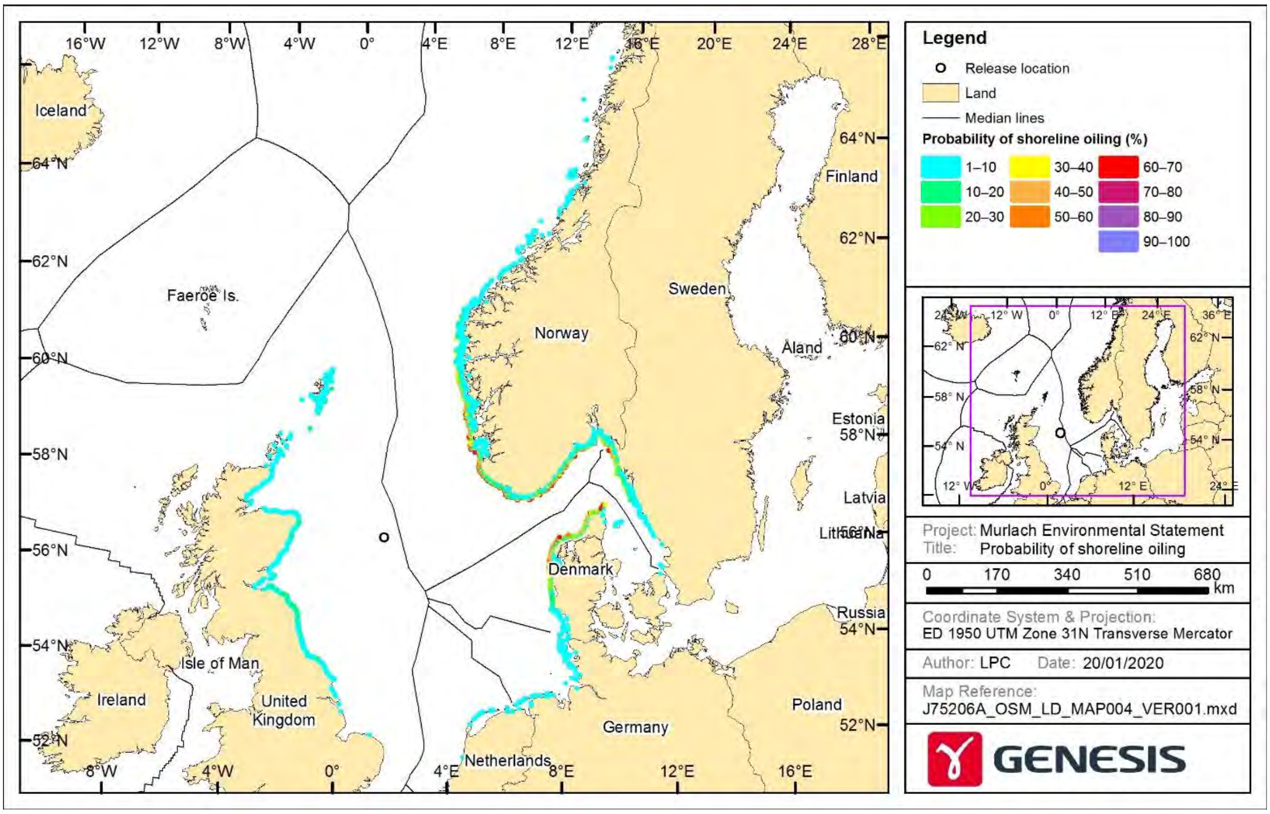


Figure C-9: Probability of shoreline oiling (stochastic simulation).

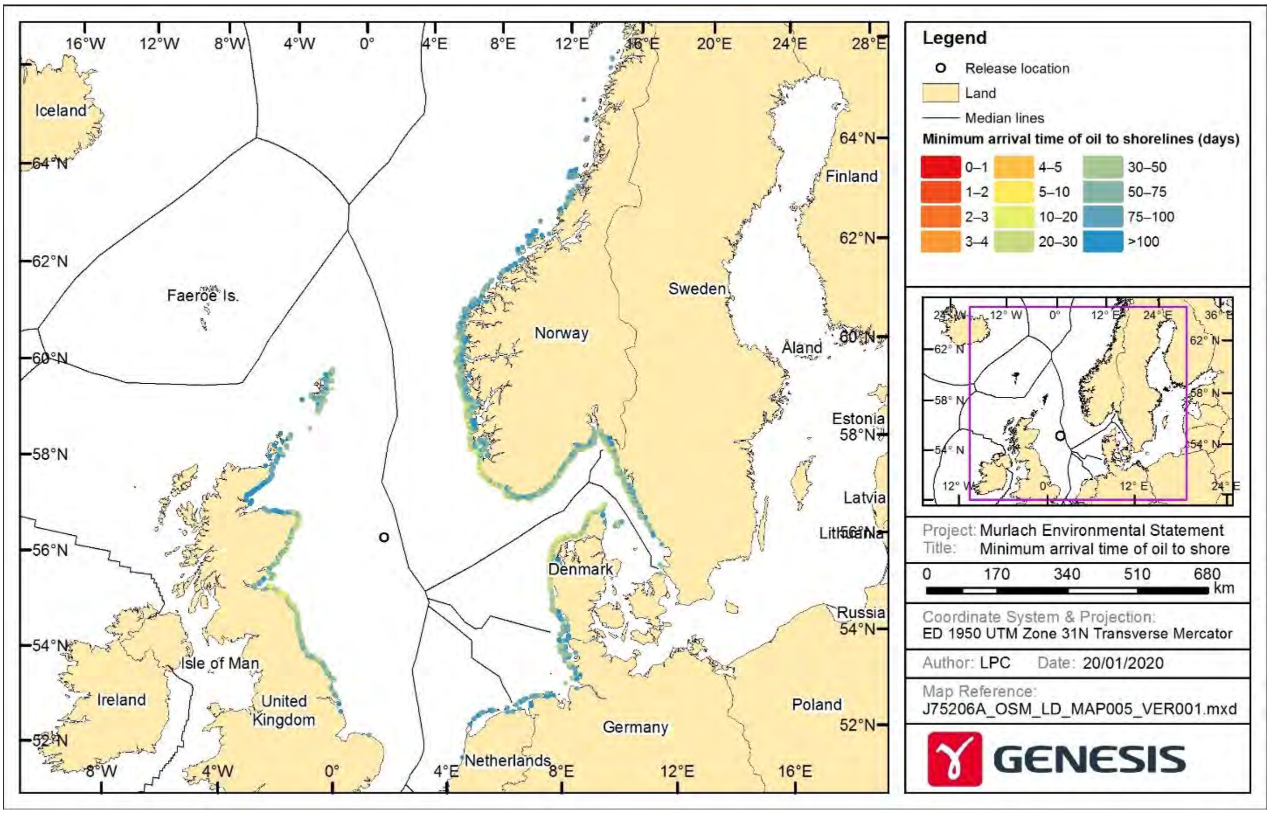


Figure C-10: Minimum arrival time of oil (stochastic simulation).

It was estimated that the total mass of oil on shorelines was 9,460 te and the maximum concentration of oil on shorelines was 7.36 kg/m^2. The combined non-continuous length of coastline where the concentration of oil ≥ 0.1 kg/m^2 at 116 days was approximately 981 km (Figure C-11).

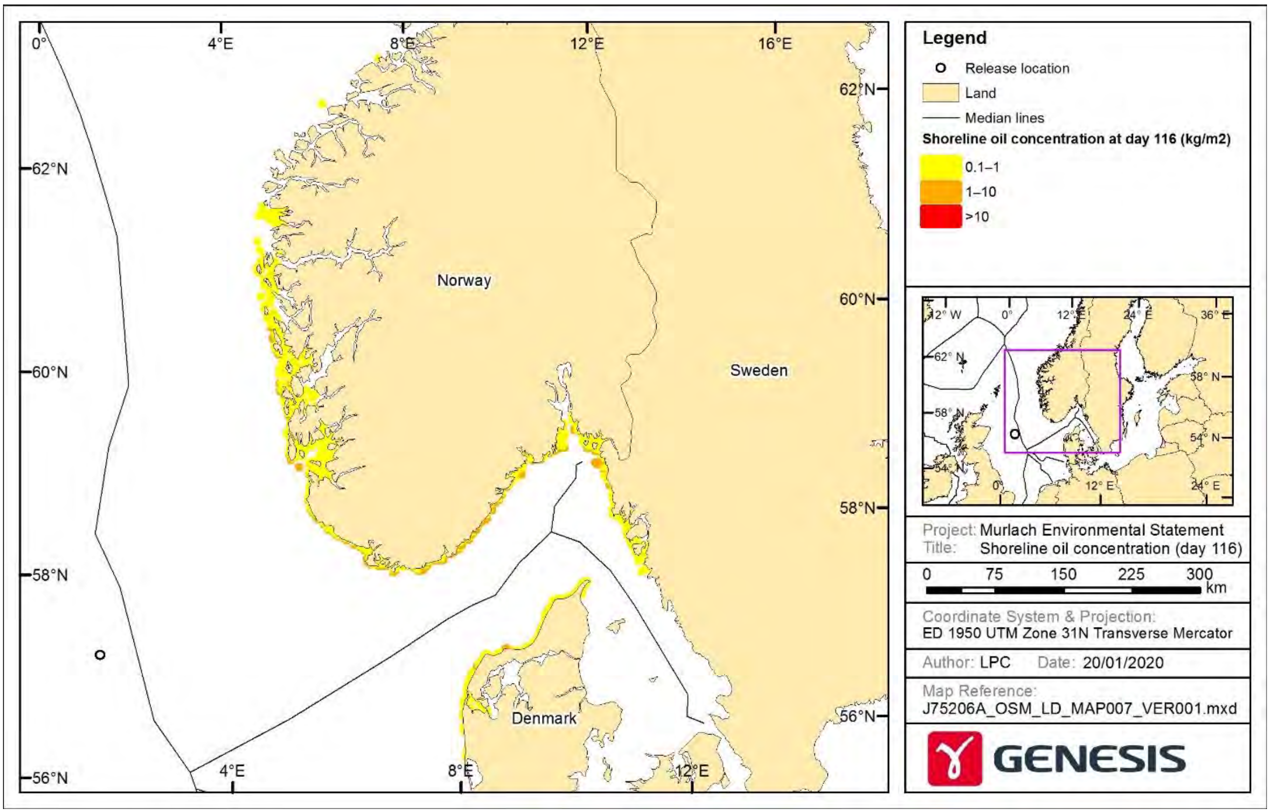


Figure C-11: Maximum oil concentration on shorelines at 116 days (deterministic simulation).

C.3.5 Deposition of Oil in the Sediment

It was estimated that the area where oil concentration in the seabed ≥ 5 g/m² was 27,108 km² (Figure C-12). The maximum concentration of oil on the seabed was 49.74 g/m².

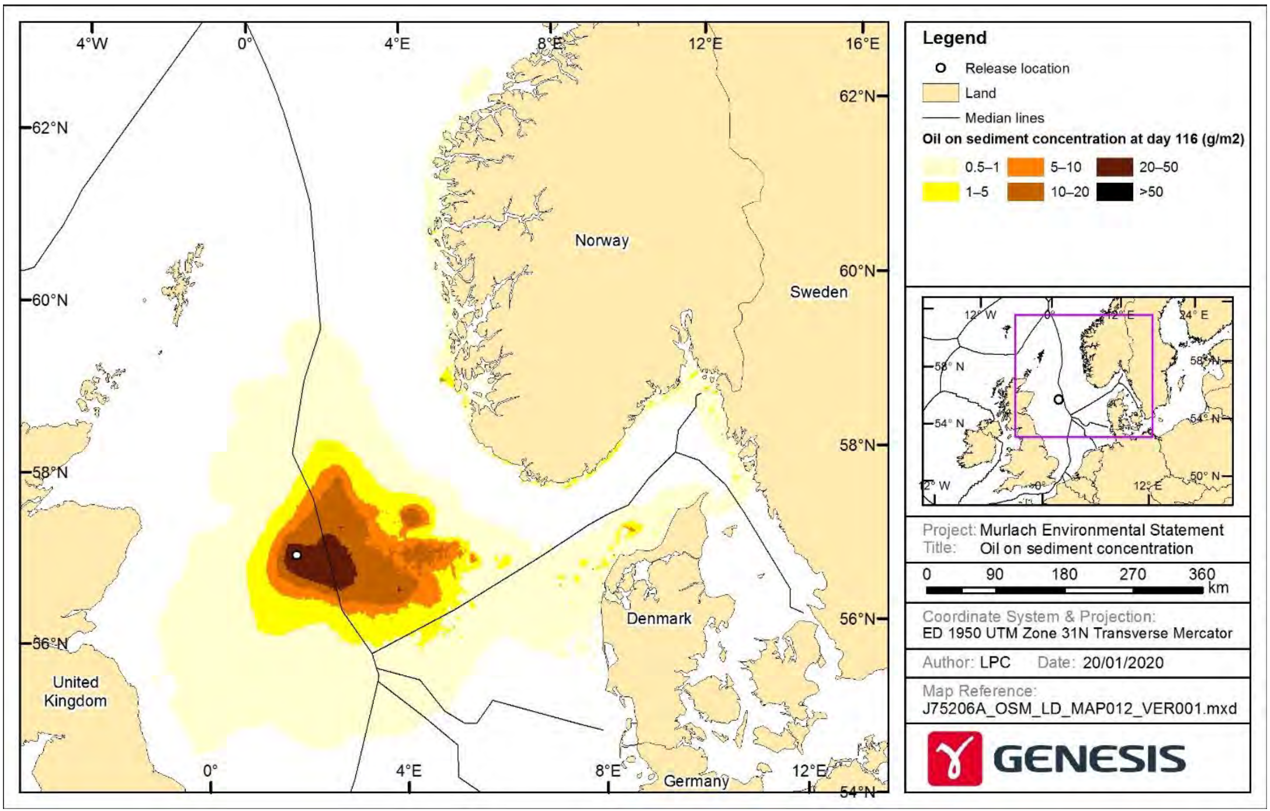


Figure C-12: Oil concentration in the seabed at 116 days (deterministic simulations).

C.3.6 Uncertainties

C.3.6.1 Oil Characterisation

The pour point and wax content of Balder Blend (chosen analogue) were higher and lower, respectively, than those of Murlach crude. However, the asphaltene content of Balder Blend (2010) was a close match to the asphaltene content of Murlach crude (Table C-10). This was considered a key parameter due to crude oils typically emulsifying when asphaltene content ≥ 0.5%. The other candidate analogue (Gyda (2000) crude) had a lower pour point and higher wax content but lower asphaltene content (Table C-10).

Table C-10: Comparison of key oil properties of Murlach crude and candidate analogues for oil spill modelling.

Parameter	Murlach crude	Balder Blend (2010)	Gyda (2000)
Pour point (°C)	-3	3	-15
Wax content (%)	6.70	3.53	7.42
Asphaltene content (%)	0.70	0.77	0.21

A sensitivity simulation using Gyda was undertaken to compare the worst-case deterministic simulation undertaken using Balder Blend. The same metocean conditions were selected such that simulation results would be comparable. Due to Gyda having a lower asphaltene content than Balder Blend, less emulsion was formed, which facilitated biodegradation and therefore approximately 10% more oil of the total release was biodegraded in the Gyda-analogue simulation than in the Balder Blend one (Table C-11). Due to a higher asphaltene content in Balder Blend, more emulsion is formed, resulting in more oil retained at the sea surface in the Balder Blend-analogue simulation. Therefore, the stochastic simulations undertaken using Balder Bland as an analogue oil are more conservative than if they had been undertaken using Gyda as an analogue oil.

Table C-11: Comparisons of oil fate with the two candidate analogues for the worst-case deterministic scenario derived from the stochastic simulations.

Oil fate	Balder Blend simulation (%)	Gyda simulation (%)
Evaporated	39.09	37.70
Surface	0.19	0.03
Water column	6.01	3.10
Sediment	36.57	32.60
Shoreline	0.76	0.03
Biodegraded	17.38	26.53
Outside domain	0.00	0.00

C.3.6.2 Metocean Data

Currents and wind data used in the model were modelled for the years 2009–2013. Therefore, future currents and winds may differ from those used here. A simulation with more recent data (days before the event if possible) or forecasting data should ideally be used in the event of a real oil spill to aid the response effort. However, for the purposes of this modelling exercise, which uses currents across multiple years to calculate various probabilities, the metocean data used is considered acceptable.

C.4 Summary of Results

The modelling results discussed in Section C-3 have been summarised below (Table C-12). Overall, hydrocarbons released as a result of a well blowout from the Murlach field extend across a wide area of the North Sea. This is because of the large volume and prolonged duration of the release. While a large portion of hydrocarbons evaporate (486,800 te, 39.09%) or are biodegraded (216,400 te, 17.38%) significant amounts of hydrocarbons are deposited on the seabed (455,400 te, 36.57%) and remain entrained in the water column (74,840 te, 6.01%). A limited amount of hydrocarbon is expected to reach shorelines (9,460 te, 0.76%) and impact approximately 981 km of coastline, mostly in Norway.

Table C-12: Summary of modelling results.

	Compartment	Mass (te)	Proportion (%)
Mass balance	Evaporated	486,800	39.09
	Surface	2,338	0.19
	Sediment	455,400	36.57
	Biodegraded	216,400	17.38
	Water column	74,840	6.01
	Shoreline	9,460	0.76
	Outside domain	0	0
Thresholds	Surface (µm)	0.3	
	Water column (µg/l)	10	
	Shoreline (kg/m^2)	0.1	
	Sediment (g/m^2)	5	
Shoreline oiling	**Country coastline**	**Maximum probability (%)**	**Minimum arrival time (days)**
	United Kingdom	18	13
	Norway	77	10
	Sweden	61	18
	Denmark	76	12
	Germany	6	30
	Netherlands	2	80
Median line crossings (sea surface)	**Median line**	**Maximum probability (%)**	**Minimum arrival time (days)**
	UK-Norway	100	1
	UK-Denmark	94	10
	UK-Germany	86	10
	UK-Netherlands	72	10
Median line crossings (water column)	**Median line**	**Maximum probability (%)**	**Minimum arrival time (days)**
	UK-Norway	100	1
	UK-Denmark	94	9
	UK-Germany	84	10
	UK-Netherlands	72	13

APPENDIX D - UNDERWATER SOUND MODELLING

This appendix presents results from underwater sound modelling that has been carried out to assess any potential impacts to marine mammals and fish from piling at the Murlach Field Development site. The modelling focusses on piling activity since this will generate the highest levels of sound during the installation process.

The exact details of the piling have not yet been determined and so a worse-case scenario has been assumed for the purposes of modelling. It has been assumed in the modelling that four 24” diameter piles of 30 m length will be required at the Murlach manifold. A hammer with a maximum blow energy of 150 kJ has been modelled based on previous piling studies of a similar nature.

Sound modelling results are presented in terms of peak SPL and cumulative SEL during installation of the four piles. In the modelling, it has (conservatively) been assumed that the hammer will operate continuously throughout the piling with no down time between each pile (i.e. the modelling does not account for any gaps in piling due to e.g. time to deploy and recover the hammer).

D.1 Piling Source Characterisation

A pile under percussive driving is a very complex underwater acoustic source. The sound levels generated during piling depend on many factors, such as hammer energy, mechanical properties and dimensions of the pile, water depth, and seabed properties. The hammer energy has the biggest influence on the sound levels generated during piling, with higher energy hammers generating increased sound levels (Robinson *et al*., 2007).

To derive source levels for use in the adopted propagation model, a representative third octave band SEL frequency spectrum measured during pile-driving with an 800 kJ hammer (Ainslie *et al*., 2012) has been used. The measured SEL spectrum from Ainslie *et al*., (2012) has been scaled to account for the fact that piling of Murlach will be conducted using a smaller hammer with only 150 kJ capacity, which will generate lower sound levels. The SEL of the scaled spectrum is computed from

$$SEL_2 = SEL_1 - 10\log\left\{\frac{E_1}{E_2}\right\} ,$$

where SEL_1 is the SEL of the measured spectrum in Ainslie *et al*., (2012) for the hammer energy of $E_1 = 800$ kJ, and SEL_2 is the SEL of the scaled spectrum for the hammer energy of $E_2 = 150$ kJ. The adopted scaling is such that a doubling of hammer energy results in a doubling of acoustic energy (which corresponds to an increase in SEL of approximately 3 dB). Such a scaling has been demonstrated by measurements made during a pile-driving ramp-up procedure in Robinson *et al*. (2007 and 2009). The third octave band SEL spectrum for the 800 kJ hammer measured in Ainslie *et al*., (2012) and the scaled SEL spectrum for the 150 kJ hammer that has been used to model piling at Murlach are shown in Figure D-1. The scaled spectrum is approximately 7 dB lower than the spectrum from Ainslie *et al*., (2012).

During piling, a soft-start of the hammer is typically employed where the hammer initially starts at a reduced energy and ramps up in energy over a set period of time. JNCC suggest that the soft-start period should be no less than 20 minutes (JNCC, 2010b). The soft-start of the hammer has been included in the modelling. It has been assumed that the hammer will initially start at 20% of the maximum blow energy and ramp up to maximum blow energy in 20 minutes. The details of the soft-start procedure included in the modelling is shown in Table D-1. As discussed previously, the SEL source levels shown in Table D-1 have been obtained by scaling the measured broadband source level from Ainslie *et al*., (2012). The zero-to-peak SPL source levels have been estimated based on measurements made in Gardline (2010) and have been obtained by adding 26 dB to the SEL source levels.

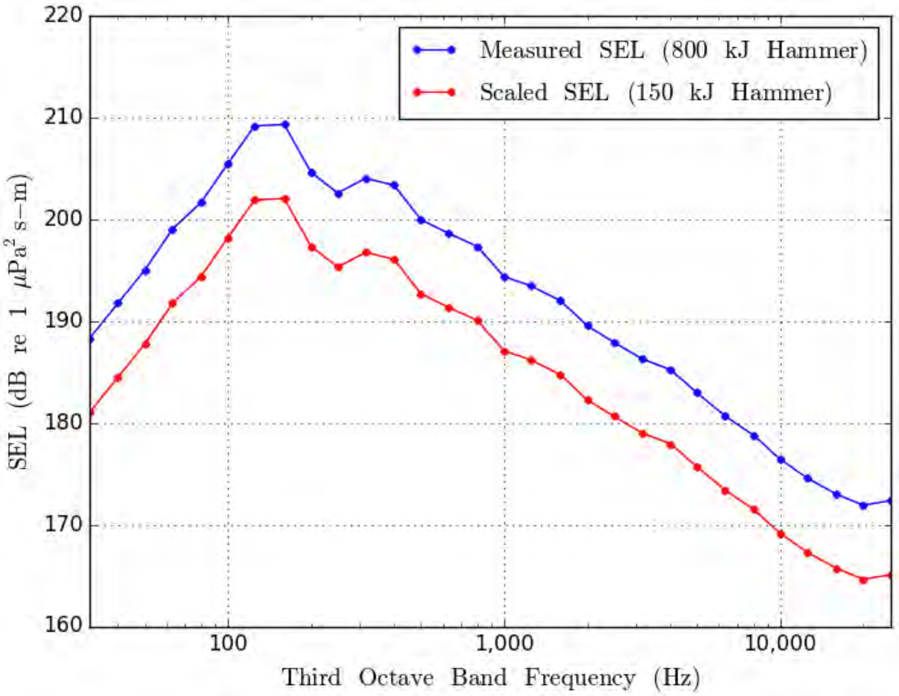


Figure D-1: Measured third octave band SEL spectrum for 800 kJ hammer and scaled third octave band SEL spectrum for 150 kJ hammer.

Table D-1: Soft-start procedure included in the modelling.

Hammer Energy	Duration (minutes)	Pulse Interval (seconds)	Source Level	
			SEL (dB re 1 μPa²s-m)	Zero-to-peak SPL(dB re 1 μPa²s-m)
30 kJ (20% of maximum blow energy)	5	4	201.2	227.2
60 kJ (40% of maximum blow energy)	5	4	204.2	230.2
90 kJ (60% of maximum blow energy)	5	3	206.0	232.0
120 kJ (80% of maximum blow energy)	5	3	207.2	233.2
150 kJ (100% of maximum blow energy)	220	2	208.2	234.2

D.2 Sound Propagation Model

The Genesis in-house software FARAM (Faunal Acoustic Risk Assessment Model) has been utilised for modelling sound propagation. FARAM is an underwater sound propagation model that incorporates site-specific environmental data such as a full bathymetric grid, varying water column temperature and salinity profiles, and geo-acoustic properties of the seabed. By explicitly modelling the factors affecting sound propagation, results can be obtained that are more accurate and relevant to the area of interest than would be obtained with more simplistic models (e.g. simple spreading models). FARAM contains implementations of a parabolic equation (PE) and ray tracing algorithms, which have been used to estimate received sound levels from piling.

D.2.1 Parabolic Equation Algorithm

PE models approximate the wave equation, allowing a solution to be found computationally (Jensen *et al*., 2011). This is one of the most popular wave-theory techniques for modelling sound propagation in spatially-varying environments (Jensen *et al*., 2011). The computational scheme used in this assessment is based on the Range-dependent Acoustic Model (RAM) implementation of the PE (Collins, 1993).

PE techniques are complex and require careful selection of environmental parameters (e.g. variation in bathymetry and sound speed profiles) and computational parameters (e.g. depth and range resolution) to ensure that the solution is accurate. The PE algorithm is best suited to calculation of low frequency sound propagation since the computational complexity (and hence implementation time) of the PE method significantly increases with frequency. The PE model has been used to estimate the propagation of frequencies up to 1 kHz. A ray tracing algorithm has been utilised for sound propagation of frequencies above 1 kHz. The ray tracing method that has been utilised for modelling higher frequencies is the Bellhop Gaussian beam ray tracing model (Porter and Liu, 1994).

D.2.2 Ray Tracing Algorithm

Bellhop is a ray tracing solution that is well suited for the modelling of higher frequency sound sources. The theory of ray tracing is derived from the wave equation when some simplifying high frequency approximations/assumptions are introduced. The high frequency approximation essentially means that the Bellhop algorithm is inherently good at treating high frequency sources. Despite being derived under a high frequency approximation, the model can also provide accurate results for low frequency propagation in certain circumstances.

Similar to the RAM PE algorithm, Bellhop also estimates acoustic propagation effects resulting from range dependent sound speed depth profiles and geo-acoustic properties. Bellhop also accounts for increased sound attenuation due to volume absorption. This type of sound attenuation becomes more prominent at higher frequencies and cannot be neglected without over estimating received levels at large distances from the sound source.

D.3 Environmental Input Data

The implemented propagation algorithms account for various site-specific environmental properties including a bathymetric grid, geographically and depth varying sound speed profiles and geo-acoustic properties of the sediment. In order to model the effects of these environmental properties, input data is required that describes the surrounding environment.

D.3.1 Water Column Profile

A major factor that influences the propagation of sound in water is the speed of sound through the water column, which influences how an acoustic wave refracts. The model used in this study allows for geographically and depth varying sound speed profiles through the water column. Sound speed profiles for the model location were derived from temperature and salinity profiles taken from the World Ocean Atlas (WOA) database (WOA, 2013). WOA is an objectively analysed 1° resolution database where temperature and salinity data are given based on historical data. The empirical formula in (Jensen *et al*., 2011) has been used to calculate sound speed profiles based on temperature, salinity and depth.

D.3.2 Bathymetry

Accurate bathymetry data is important for sound propagation modelling since the seabed strongly influences the propagation characteristics of sound. In shallow water regions, there is significant interaction of the sound with the seabed through reflections and scattering effects, and strong attenuation may occur as sound penetrates the seabed. In deep water regions, there is typically less interaction of sound with the seabed and attenuation due to bottom loss is small, which can result in longer propagation distances.

The bathymetry data that has been used in the modelling is provided by the General Bathymetric Chart of the Oceans (GEBCO) 30 arc-second grid (GEBCO, 2014), which is a continuous terrain model for ocean and land with a spatial resolution of 30 arc seconds.

D.3.3 Sediment Properties

The modelling has assumed a sandy seabed in line with the expected sediments in the area and the main geo-acoustic properties associated with the seabed that have been used in the modelling are shown in (Jensen *et al.*, 2011).

Table D-2: Geo-acoustic parameters used in the propagation model.

Geo-acoustic Parameter	Value
Predominant Sediment	Sand
Sediment Density	1,900 kg/m^3
Sound speed in sediment	1,650.0 m/s
Sound attenuation in sediment	0.8 dB/wavelength

D.4 Impact Assessment Methodology

The assessment method used here is largely based on the JNCC guidance on the protection of marine EPS from injury and disturbance (JNCC, 2010a).

D.4.1 Assessment Criteria for Marine Mammals

Potential impacts to marine mammals have been assessed using a number of thresholds for injury and disturbance. The thresholds that have been used in this assessment are based on a comprehensive review of evidence for impacts of underwater sound on marine mammals.

D.4.1.1 PTS Thresholds

Numerous studies have been conducted to estimate the sound levels that can potentially cause injury to marine mammals. A commonly used approach in estimating potential impacts to marine mammals is by comparing received sound levels to the thresholds proposed by Southall *et al.*, (2007) for the potential onset of PTS. Since its publication, comparison of received sound levels with the Southall thresholds has become common practice for impact estimation and these thresholds were endorsed by the JNCC guidelines (JNCC, 2010a).

However, more recently, newer thresholds for estimating potential impacts to marine mammals have been suggested by the NOAA (NMFS, 2018). It should be noted that the NOAA guidance was co-authored by many of the same authors from the Southall *et al*. (2007) paper and effectively updates its criteria for assessing the risk of auditory injury. The new NOAA thresholds are based on more recent scientific studies and have now largely replaced the older Southall thresholds. Therefore, only the NOAA thresholds are considered in this assessment for estimating potential impacts to marine mammals.

The NOAA guidance has grouped marine mammals into four main functional hearing groups: LF cetaceans, MF cetaceans, HF cetaceans, and Phocid Pinnipeds. Table D-3 shows the generalised hearing range for the different marine mammal hearing groups proposed by NOAA (NMFS, 2018), and also shows marine mammal species that could potentially be present in the area during the Murlach piling (Reid *et al*., 2003; Hammond *et al*., 2017).

Table D-3: Generalised hearing range for the marine mammal hearing groups proposed by NOAA.

Marine Mammal Hearing Group	Generalised Hearing Range	Marine Mammal Species
LF Cetaceans	7 Hz to 35 Hz	**Minke whale**
MF Cetaceans	150 Hz to 160 Hz	**White-beaked dolphin**, **white-sided dolphin**
HF Cetaceans	275 Hz to 160 Hz	**Harbour porpoise**
Phocid Pinnipeds	50 Hz to 86 Hz	Harbour seal, grey seal
*species in bold are known to occur in the vicinity of the proposed project.		

The NOAA thresholds that have been adopted for estimating the potential for PTS to occur in marine mammals are summarised in Table D-4. The thresholds are expressed in terms of both unweighted zero-to-peak SPL and cumulative weighted SEL. The potential onset of PTS is considered to occur when either threshold is exceeded (JNCC, 2010a; NMFS, 2018).

The unweighted zero-to-peak SPL thresholds are used to assess the potential for injury to occur in marine mammals due to instantaneous fluctuations in pressure and do not take into consideration the hearing range of any marine mammals. In contrast, the cumulative weighted SEL metric takes the hearing capability of the species under consideration by weighting the received SEL sound levels using generalised auditory weighting filters. Different weighting filters have been proposed by NOAA and are shown in Figure D-2.

Table D-4: NOAA thresholds for the potential onset of PTS in marine mammals (NMFS, 2018).

Marine Mammal Hearing Group	Sound Metric	PTS Threshold
LF Cetaceans	Unweighted zero-to-peak SPL	219 dB re 1 μPa
	Cumulative weighted SEL	183 dB re 1 μPa^{2}s
MF Cetaceans	Unweighted zero-to-peak SPL	230 dB re 1 μPa
	Cumulative weighted SEL	185 dB re 1 μPa^{2}s
HF Cetaceans	Unweighted zero-to-peak SPL	202 dB re 1 μPa
	Cumulative weighted SEL	155 dB re 1 μPa^{2}s
Phocid Pinnipeds	Unweighted zero-to-peak SPL	218 dB re 1 μPa
	Cumulative weighted SEL	185 dB re 1 μPa^{2}s

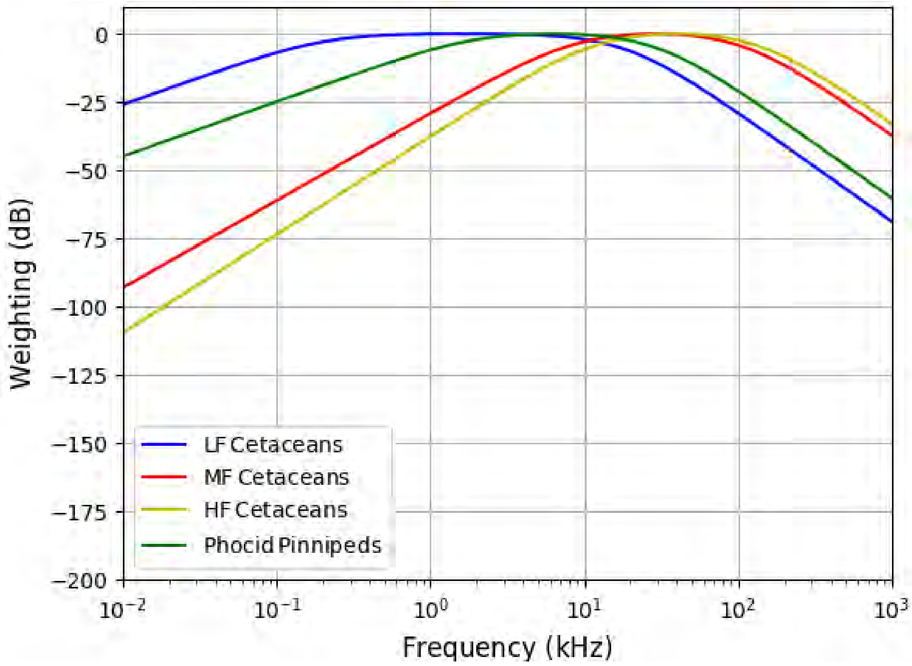


Figure D-2: Auditory weighting functions for LF cetaceans, MF cetaceans, HF cetaceans and Phocid pinnipeds (NMFS, 2018).

Since the publication of the NOAA thresholds in NMFS (2018), more recent guidelines and thresholds have been published in Southall *et al.,* (2019). The thresholds and auditory weighting filters proposed by Southall *et al.,* (2019) are precisely the same as those proposed by NOAA (although it is noted that Southall names the hearing groups slightly differently to NOAA). In the following assessment, the thresholds and auditory weighting filters adopted are referred to as the NOAA thresholds and auditory weighting filters. However, it should be understood that the adopted thresholds and auditory weighting filters proposed by NOAA are the same as those recently proposed by Southall *et al.,* (2019).

D.4.1.2 Behavioural Disturbance Thresholds

Another important consideration in assessing the impacts of sound on marine mammals is the mammals' behavioural response. However, it was concluded in Southall *et al*., (2007) that thresholds for behavioural disturbance were more difficult to conclusively define. The difficulty in defining thresholds for behavioural disturbance lies primarily in the fact that behavioural disturbance can range greatly from low level minor disturbance, such as changes in swimming behaviour and vocalisation, to higher levels of disturbance such as strong avoidance of an area. Southall *et al*., (2007) concluded that the available data on marine mammal behavioural responses were too variable and context-specific to justify proposing single disturbance criteria for broad categories of taxa and sounds. The newer NOAA and Southall *et al.,* (2019) guidelines made no attempt to define behavioural disturbance thresholds for marine mammals (NMFS, 2018). Southall *et al.* (2007) recommended assessing whether sound from a specific source could cause disturbance to a particular species by comparing the circumstances of the situation with empirical studies reporting similar circumstances.

Thompson *et al.,* (2013) showed that harbour porpoise (which are HF cetaceans) exhibited avoidance from a commercial 2D seismic survey at SEL sound levels between 145 - 151 dB re 1 μPa^{2}s. Lucke *et al.,* (2008) have also reported that a captive harbour porpoise consistently showed behavioural responses at SEL levels exceeding 145 dB re 1 μPa^{2}s. A threshold of 145 dB re 1 μPa^{2}s has therefore been used in this assessment to signify areas of likely avoidance by HF cetaceans.

The studies reviewed by Southall *et al.,* (2007) suggest that LF cetaceans could exhibit behavioural responses at root mean square (rms) SPLs from 150 - 160 dB re 1 μPa and would likely show avoidance at rms SPL above 160 dB re 1 μPa. An rms SPL threshold of 160 dB re 1 μPa has therefore been used to signify areas of likely avoidance by LF cetaceans. This threshold is also adopted by NMFS, (1995) as a threshold for significant disturbance to all marine mammals from impulsive sound.

There have been limited observations or measurements of sound levels that elicit behavioural responses in MF cetaceans and phocid pinnipeds. The studies reviewed by Southall *et al.,* (2007) suggested that MF cetaceans would only show strong avoidance for rms SPL sound levels exceeding 170 dB re 1 µPa and pinnipeds would likely show avoidance at rms SPL sound levels exceeding 190 dB re 1 µPa. However, given the lack of specific data for these species, the NMFS threshold of 160 dB re 1 µPa has been adopted as a conservative threshold for signifying areas where MF cetaceans and pinnipeds may possibly show avoidance behaviours.

The behavioural disturbance thresholds that have been adopted in this assessment are summarised in Table D-5. The rms SPL thresholds shown in Table D-5 have been converted to equivalent SEL thresholds for easier comparison with the predicted SEL sound fields from the propagation model. The conversion from rms SPL to SEL is dependent on the pulse width of the received signal. It is well known that the pulse width of a piling pulse elongates (spreads in time) as it propagates away from the piling location (Robinson *et al*., 2007). The integration time of most marine mammals' ears is approximately 125 ms (Tougaard *et al*., 2015). As a conservative measure, a smaller integration time of 100 ms has been used to convert rms SPL thresholds to equivalent SEL thresholds. This is conservative because, for a given rms SPL threshold, a smaller integration time results in a lower equivalent SEL threshold.

Table D-5: Marine mammal behavioural disturbance thresholds adopted in this assessment.

Marine Mammal Hearing Group	Behavioural Disturbance Thresholds		Possible Response
	rms SPL (dB re 1 µPa)	SEL (dB re 1 µPa²s)	
LF Cetaceans	160	150	Likely individual and/or group avoidance
MF Cetaceans	160	150	Possible individual and/or group avoidance
HF Cetaceans	N/A	145	Likely individual and/or group avoidance
Phocid Pinnipeds	160	150	Possible individual and/or group avoidance

[1] rms SPL converted to SEL assuming a pulse width of 100 ms.

D.4.2 Assessment Criteria for Fish

Anthropogenic sound may interfere with acoustic communication, predator avoidance, prey detection, reproduction and navigation in fish (e.g. Slabbekoorn, *et al*., 2010). The effects of sound on fish include short term startle response (Wardle et. al., 2001), varying levels of avoidance reactions and changes in shoaling behaviour (see Slabbekoorn *et al*., 2010).

Fish species differ in their hearing capabilities depending on the presence of a swim bladder, which acts as a pressure receiver, and whether the swim bladder is connected to the otolith hearing system, which further increases hearing sensitivity (McCauley, 1994). Most fish can hear within the range of 100 Hz to 1 kHz. Fish with a connection between the swim bladder and otolith system have more sensitive hearing and may detect frequencies up to 3 kHz.

D.4.2.1 Injury Thresholds

Popper *et al*. (2014) have defined criteria for injury to fish based on a review of publications related to impacts to fish, fish eggs, and larvae from various high-energy sources including air gun arrays. Popper *et al.,* (2014) is the most comprehensive review available for potential impacts to fish species. The hearing capability of fish largely depends on the presence or absence of a swim bladder. Different injury thresholds are derived in Popper *et al*., (2014) for the following categories:

- Fishes with no swim bladder or other gas chamber;
- Fishes with swim bladders in which hearing involves a swim bladder or other gas volume;
- Fishes with swim bladders in which hearing does not involve the swim bladder or other gas volume; and
- Fish eggs and larvae.

The thresholds for injury to fish proposed in Popper *et al*., (2014) have been used in this assessment and are shown in Table D-6.

Table D-6: Thresholds for potential fish injury (Popper at al., 2014).

Fish Group	Sound Metric	PTS Threshold
Fishes with no swim bladder	Unweighted zero-to-peak SPL	213 dB re 1 µPa
	Cumulative weighted SEL	219 dB re 1 µPa2s
Fishes with swim bladder involved in hearing	Unweighted zero-to-peak SPL	207 dB re 1 µPa
	Cumulative weighted SEL	207 dB re 1 µPa2s
Fishes with swim bladder not involved in hearing	Unweighted zero-to-peak SPL	207 dB re 1 µPa
	Cumulative weighted SEL	210 dB re 1 µPa2s
Eggs and larvae	Unweighted zero-to-peak SPL	207 dB re 1 µPa
	Cumulative weighted SEL	210 dB re 1 µPa2s

D.4.2.2 Behavioural Disturbance Thresholds

Documented behavioural effects of sound on fish behaviour are variable, ranging from no discernible effect (Wardle *et al.,* 2001) to startle reactions followed by immediate resumption of normal behaviour (Wardle *et al.,* 2001; Hassel *et al.,* 2004). Avoidance of fish to sound has also been observed (Hassel *et al.,* 2004).

Despite some documented behavioural effects of sound on fish species, there are no well-established criteria or thresholds for assessing behavioural disturbance to fish. In fact, it was concluded in Popper *et al.* (2014) that there lacked sufficient evidence to recommend thresholds for fish disturbance. Given this lack of evidence, behavioural disturbance to fish will not be considered further in this assessment. However, it is noted that fish are mobile animals that would be expected to be able to move from a sound source that had the potential to cause disturbance. If fish are disturbed by sound, evidence suggests they will return to an area once the activity causing the disturbance has ceased (Slabbekoorn *et al.,* 2010).

D.5 Assessment of Potential Impacts

This section presents the underwater sound propagation modelling results and discusses any potential impacts to marine mammals and fish from the Murlach piling.

D.5.1 Marine Mammals

The modelling has predicted distances to the NOAA zero-to-peak SPL and cumulative SEL thresholds associated with PTS onset, within which impacts may occur to marine mammals if they are present.

D.5.1.1 PTS Onset

Received sound levels in terms of unweighted zero-to-peak SPL have been predicted during the Murlach piling to identify distances from the piling location at which sound levels will decrease to below the threshold values associated with PTS. As a worst case, the zero-to-peak SPL has been predicted for the hammer operating at maximum capacity of 150 kJ. It is noted that the maximum possible hammer energy is not usually achieved during a piling sequence and only occurs for short durations if it is (Gardline*,* 2010; Bailey *et al.,* 2010).

Figure D-3 shows the predicted maximum zero-to-peak SPL when the hammer is operating at the maximum capacity of 150 kJ. The contours in the graphic highlight the NOAA (NMFS, 2018) zero-to-peak SPL thresholds for the potential onset of PTS to marine mammals.

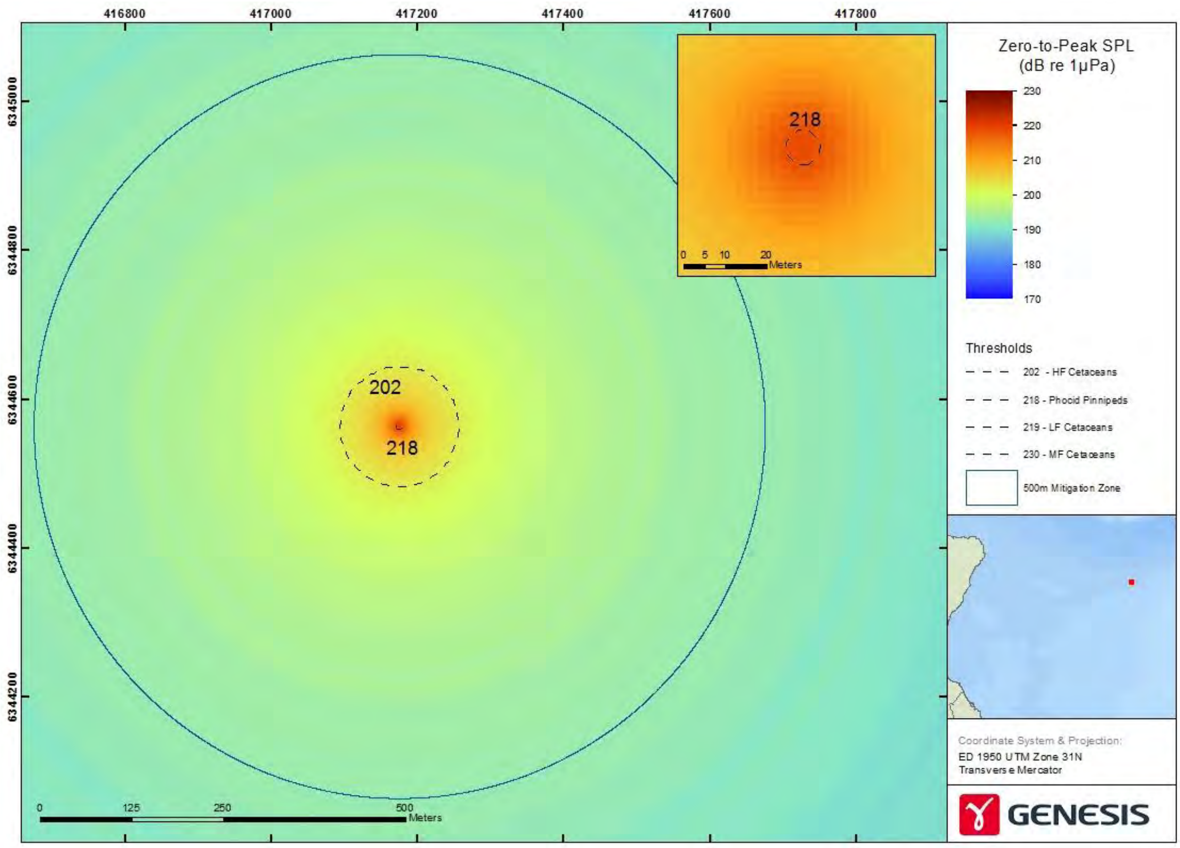


Figure D-3: Predicted maximum unweighted zero-to-peak SPL with the hammer operating at 150 kJ. The highlighted contours indicate the NOAA thresholds for the potential PTS onset.

The predicted distances at which the sound level decreased to below the NOAA zero-to-peak SPL threshold values are shown in Table D-7 for the hammer operating at the maximum energy of 150 kJ. The modelling predicts that zero-to-peak SPL will decrease to below the NOAA thresholds well within the nominal 500 m mitigation zone. The potential for PTS to occur due to zero-to-peak SPL is therefore considered to be low, since commencement of piling will be delayed if any marine mammals are observed within the mitigation zone.

Table D-7: Predicted maximum distances from the piling location where the zero-to-peak SPL decreases below the NOAA thresholds for potential PTS onset to marine mammals.

Marine Mammal Hearing Group	PTS Threshold	Predicted Maximum Distance to Threshold *
LF Cetaceans	219 dB re 1 µPa	Sound levels below threshold
MF Cetaceans	230 dB re 1 µPa	Sound levels below threshold
HF Cetaceans	202 dB re 1 µPa	80 m
Phocid Pinnipeds	218 dB re 1 µPa	< 10 m

* Predicted distances have been rounded up to the nearest 10 m.

Following the NOAA guidance (NMFS, 2018), potential impacts from cumulative SEL have been assessed by considering an animal's hearing frequency sensitivity by weighting modelled SEL results with the auditory weighting functions shown in Figure D-2.

The cumulative SEL received by an animal is dependent on numerous factors such as the hammer energy and blow rate, as well as the duration of sound exposure and movement of the animal relative to the sound source. The cumulative SEL received by marine mammals has been estimated for mammals swimming away from the piling location at a constant swim speed and calculating the cumulative (weighted) SEL it receives over the full piling sequence. The soft-start procedure of the piling (see Table D-1) has been included in the cumulative SEL modelling, which allows for animals to move away from the sound source and lowers the risk of them being subject to sound levels that could cause the potential onset of PTS.

Table D-8 shows the maximum initial distances that marine mammals must be at the start of piling (i.e. safety distances) in order for weighted cumulative SEL to be below threshold values for PTS onset when they swim away from the piling location at a constant speed of 2 m/s. The predicted distances where cumulative SEL sound levels will be below the NOAA thresholds for PTS are within the nominal 500 m mitigation zone that is generally employed during piling operations (JNCC, 2010b). If any marine mammals are observed within this mitigation zone, the piling will be delayed for at least 20 minutes following the last sighting of any mammal. Given this mitigation measure, it is expected that the risk of PTS onset to marine mammals will be low.

Table D-8: Predicted initial starting distances from the piling location where received cumulative SEL sound levels are below the NOAA thresholds for potential PTS onset to marine mammals.

Marine Mammal Hearing Group	PTS Threshold	Predicted Maximum Distance to Threshold *
Marine mammals swimming away from the piling location at 2 m/s		
LF Cetaceans	183 dB re 1 μPa²s	440 m
MF Cetaceans	185 dB re 1 μPa²s	Sound levels below threshold
HF Cetaceans	155 dB re 1 μPa²s	40 m
Phocid Pinnipeds	185 dB re 1 μPa²s	Sound levels below threshold
* Predicted distances have been rounded up to the nearest 10 m.		

D.5.1.2 Behavioural Disturbance

To predict potential behavioural disturbance to marine mammals, received sound levels in terms of unweighted SEL have been estimated and compared to the adopted behavioural disturbance thresholds (see Table D-5). As a worst case, the unweighted SEL has been calculated for the hammer operating at maximum blow energy of 150 kJ. Figure D-4 shows the predicted unweighted SEL when the hammer is operating at maximum capacity. The contours in this graphic highlight the adopted behavioural disturbance thresholds and signify areas where animals may exhibit behavioural responses to the piling sound (see Table D-5).

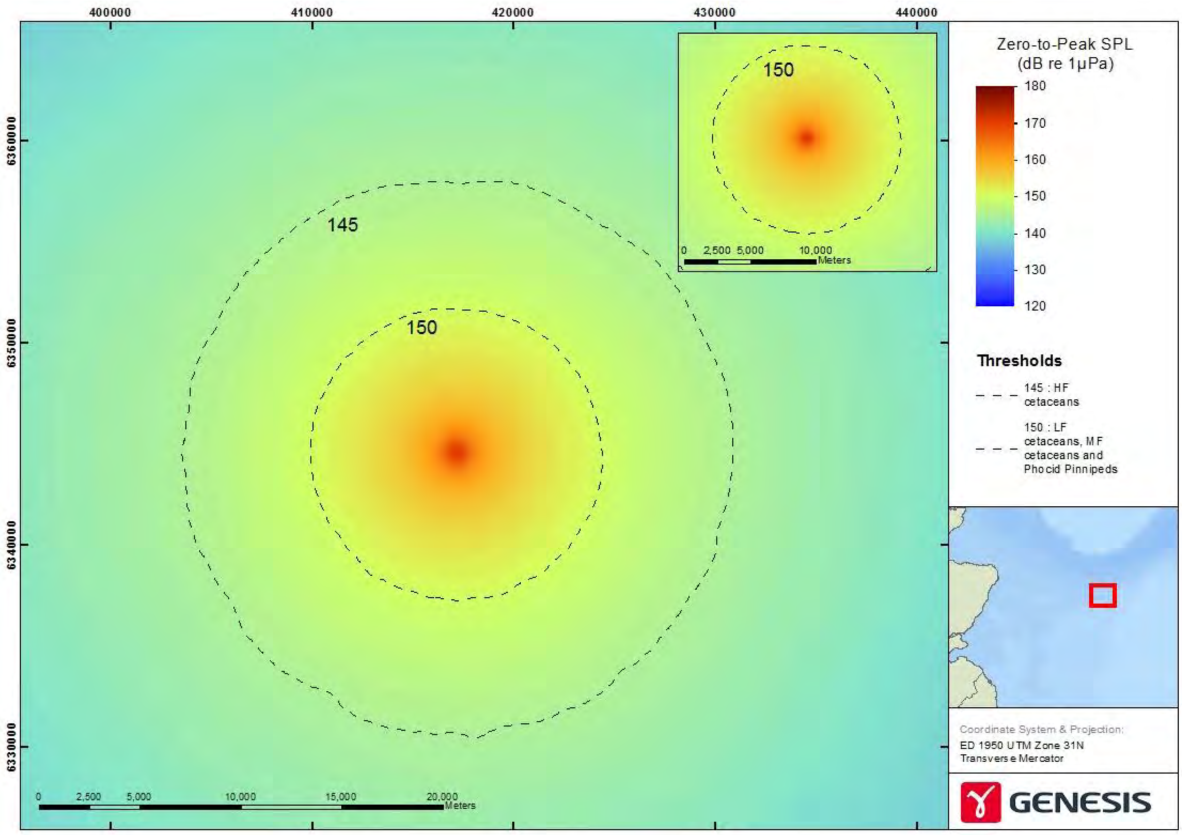


Figure D-4: Predicted unweighted SEL for the hammer operating at 150 kJ. The highlighted contours indicate the adopted behavioural disturbance thresholds.

The predicted distances where the sound levels decrease to below the marine mammal behavioural disturbance thresholds are shown in Table D-9 as well as the possible areas where marine mammals may exhibit behavioural disturbance. The modelling predicts that LF cetaceans, MF cetaceans and phocid pinnipeds could experience behavioural disturbance within 8 km from the location of the piling operations. HF cetaceans are predicted to experience behavioural disturbance within 15 km of the piling activity location.

Table D-9: Predicted distances where sound levels decrease to below the adopted marine mammal behavioural disturbance thresholds and areas of potential disturbance.

Marine Mammal Hearing Group	SEL Threshold	Maximum Distance to Threshold [1]	Area [2]
LF cetaceans	150 dB re 1 µPa^{2}s	8 km	201 km^2
MF cetaceans	150 dB re 1 µPa^{2}s	8 km	201 km^2
HF cetaceans	145 dB re 1 µPa^{2}s	15 km	707 km^2
Phocid pinnipeds	150 dB re 1 µPa^{2}s	8 km	201 km^2

[1] Predicted distances have been rounded *up* to the nearest 1 km.

[2] Predicted areas have been rounded *up* to the nearest 1 km^2.

The predicted disturbance areas seem to be consistent with observations made in the field during piling. Harbour porpoise (which are HF cetaceans) were observed to show behavioural reactions out to 18 km during piling at the Horns Reef 2 Offshore Wind Farm with a maximum hammer energy of 900 kJ (Brandt *et al.,* 2011). Aerial surveys conducted during piling with a 500 kJ capacity hammer at the Alpha Ventus Offshore Wind Farm showed that harbour porpoise were displaced out to distances of 15 to 25 km (Dahne *et al.,* 2013). It should be noted that the maximum hammer energy used during the Murlach piling will be 150 kJ and it should be expected that displacement of marine mammals will be reduced compared to that observed at the Horns Reef 2 and Alpha Ventus wind farms.

The number of animals that could potentially be disturbed and/or exhibit behavioural responses have been calculated based on the predicted disturbance zones in Table D-9 and estimated densities of animals in the area taken from SCANS III (Hammond *et al.,* 2017). The estimated number of animals that could potentially be disturbed and/or exhibit behavioural responses is shown in Table D-10, which also shows the percentage of the relevant MU Populations (IAMMWG, 2015) that could potentially be disturbed. The number of marine mammals that could potentially be disturbed and/or experience behavioural changes is considered to be relatively small compared to the total MU population.

Disturbance will only be temporary, since the proposed piling is only expected to last for 1 working day, and any animal disturbed from the area would likely return after cessation of activities. This is supported by studies undertaken during piling at the Horns Reef 2 Offshore Wind Farm (Brandt *et al.,* 2011) and the Alpha Ventus Offshore Wind Farm (Dahne *et al.,* 2013). Brandt *et al.,* (2011) observed that harbour porpoise returned to areas of displacement within 1 to 3 days from the end of piling at the Horns Reef 2 Offshore Wind Farm. At the Alpha Ventus Offshore Wind Farm, harbour porpoise returned to areas of displacement within 16 hours of activity cessation (Dahne *et al.,* 2013). There are numerous other studies which indicate that marine mammals displaced by sound from piling return to the area within relatively short periods of time once the piling has ceased (Tougaard *et al.* 2006, Thompson *et al.* 2010).

It is concluded that any potential disturbance caused by piling at Murlach will impact on a very small proportion of the MU populations, it will be temporary, short term and will therefore not have any significant impact on any marine mammal population.

Table D-10: Estimated number of animals in predicted disturbance zones and MU population potentially disturbed.

Species	Disturbance Area	Density (Individuals/km^2) [1]	Number of Individuals Disturbed	MU Population [2]	Percentage MU Population Disturbed [3]
Harbour Porpoise (HF Cetacean)	707 km^2	0.33	234	227,298	0.103%
Minke Whale (LF cetaceans)	201 km^2	0.007	2	23,528	0.009%
White-beaked dolphin (MF cetaceans)	201 km^2	-	-	15,895	-
Atlantic white-sided dolphin (MF cetaceans)	201 km^2	-	-	69,293	-

[1]Densities taken from SCANS-III (Hammond *et al*., 2017). SCANS-III densities are only available for harbour porpoise and minke whale in the Murlach Field area. No densities for white-beaked dolphin or Atlantic white-sided dolphin were reported in SCANS-III although the Reid *et al.,* (2003) data suggests that these species could be present in the area.

[2] MU populations taken from IAMMWG, (2015).

[3]The percentage of MU populations for white-beaked dolphin and Atlantic white-sided dolphin could not be estimated since there are no densities available for these species from SCANS-III. However, the estimated disturbance zones from piling at Murlach are significantly smaller than the MU area for these species and its therefore unlikely that the piling will impact a significant portion of the MU populations.

D.5.2 Fish

The potential for injury to fish has been predicted by comparing estimated received sound levels to the fish injury thresholds established by Popper *et al*., (2014).

D.5.2.1 Injury

Figure D-5 shows the predicted maximum zero-to-peak SPL during piling of Murlach with the hammer operating at maximum capacity. The contours in this graphic highlight the Popper *et al.,* (2014) zero-to-peak SPL thresholds for potential injury to fish (see Table D-6).

The predicted distances where sound levels decrease to below the Popper *et al.,* (2014) zero-to-peak SPL thresholds are exceeded are detailed in Table D-11. The modelling predicts that fish injury will be limited to distances of 40 m or less. It is expected that the piling soft-start would disperse any fish to distances beyond which sound levels are below threshold values associated with either injury or mortality.

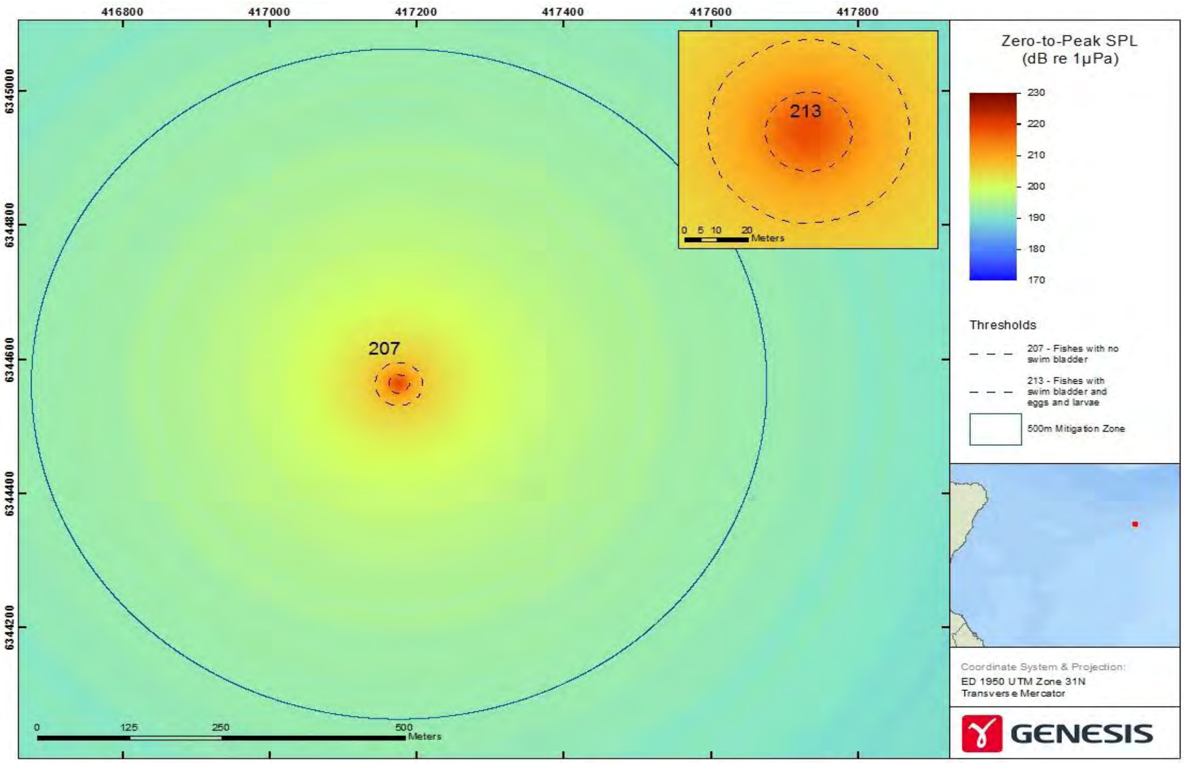


Figure D-5: Predicted maximum unweighted zero-to-peak SPL with the hammer operating at 150 kJ. The highlighted contours indicate the Popper *et al.,* (2014) thresholds for fish injury.

Table D-11 Predicted distances from the piling location where sound levels decrease to below the Popper zero-to-peak SPL thresholds for injury/potential mortality.

Fish Group	Threshold for Potential Mortality/Injury	Predicted Maximum Distance to Threshold *
Hammer energy of 30 kJ (Hammer energy at start of piling sequence)		
Fishes with no swim bladder	213 dB re 1 µPa	Threshold not exceeded
Fishes with swim bladder involved in hearing	207 dB re 1 µPa	20 m
Eggs, larvae, and fishes with swim bladder not involved in hearing	207 dB re 1 µPa	20 m
Hammer energy of 150 kJ (Hammer energy at start of piling sequence)		
Fishes with no swim bladder	213 dB re 1 µPa	20 m
Fishes with swim bladder involved in hearing	207 dB re 1 µPa	40 m
Eggs, larvae, and fishes with swim bladder not involved in hearing	207 dB re 1 µPa	40 m
* Predicted distances have been rounded up to the nearest 10 m.		

D.5.2.2 Behavioural Disturbance

Behavioural disturbance to fish could not be predicted from the propagation modelling since there are no well-established disturbance thresholds for fish. However, fish are mobile animals that would be expected to move away from a sound source that had the potential to cause them harm. If fish are disturbed by sound, evidence suggests they will return to an area once the activity generating the sound has ceased (Slabbekoorn *et al*., 2010). The proposed piling at Murlach is expected to last for a maximum of two working days, and any disturbance to fish will therefore be short term. It is concluded that the proposed piling will not have a significant impact on any fish species.

APPENDIX E – BASE CASE PRODUCTION PROFILES

The base case production profiles are presented in this appendix.

E.1.1 Oil Base Case Oil Production Profiles

Table E-1 and Figure E- 1 show the anticipated base case oil production rates from the Murlach Field, assuming start-up in 2025.

Table E-1: Murlach base case and ETAP oil production rate.

Year	Oil Production Rate (te/day)		
	ETAP without Murlach	Murlach	ETAP with Murlach
2025	3,895	1,117	5,012
2026	3,496	1,885	5,381
2027	2,818	1,198	4,015
2028	2,230	852	3,081
2029	1,543	483	2,027
2030	1,251	498	1,749
2031	1,009	406	1,415
2032	839	344	1,183
2033	673	299	972
2034	562	262	824
2035	477	233	710

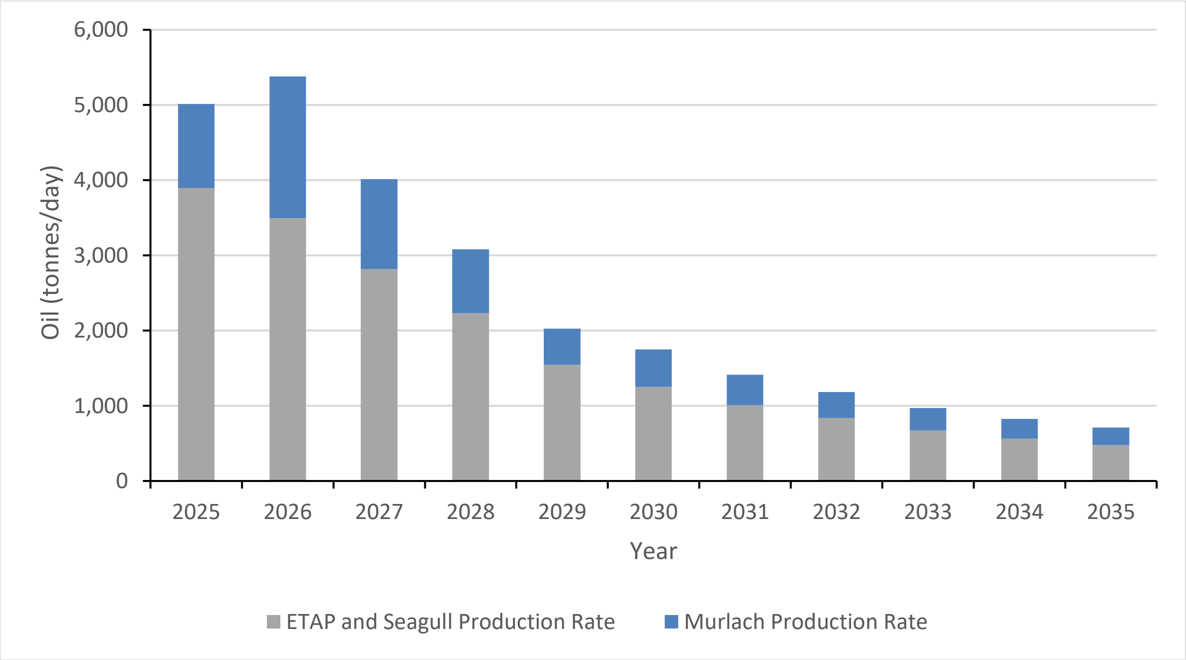


Figure E- 1: ETAP oil production rate alone and with Murlach base case oil production rate.

E.1.2 Base Case Gas Production Profiles

Table E- **1** and Figure E- **2** show the anticipated base case gas production rates from the Murlach Field, assuming start-up in 2025.

Table E- 1: Murlach base case and ETAP gas production rate.

Year	Gas Production Rate (Mm^3/day)		
	ETAP without Murlach	Murlach	ETAP with Murlach
2025	2.69	0.20	2.89
2026	2.56	0.34	2.90
2027	2.25	0.22	2.46
2028	1.86	0.15	2.01
2029	1.53	0.09	1.62
2030	1.57	0.09	1.66
2031	1.53	0.07	1.60
2032	1.51	0.06	1.57
2033	1.52	0.05	1.57
2034	1.39	0.05	1.44
2035	1.28	0.04	1.32

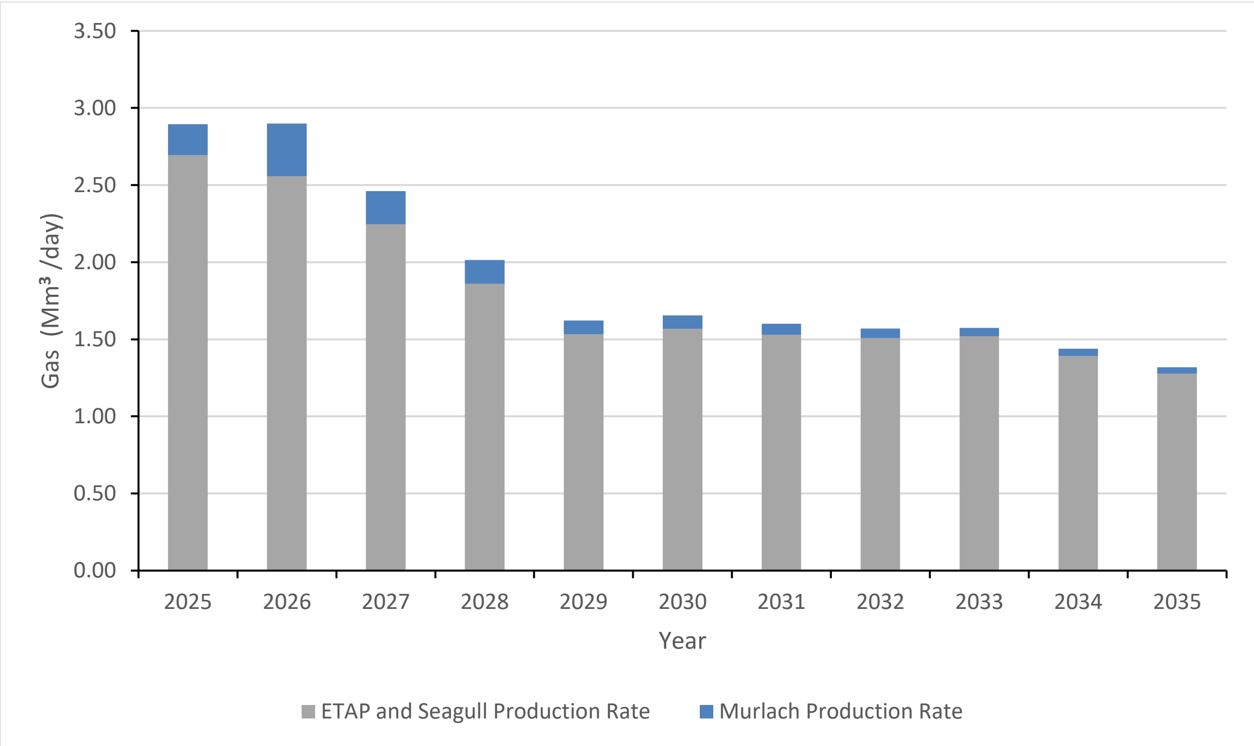


Figure E- 2: ETAP gas production rate alone and with Murlach base case production rate.

E.1.3 Water Production Profiles Associated with the Base Case Oil Production Rates

Table E- 2 and Figure E- 3 show the anticipated water production profiles associated with the base case oil production rates from the Murlach Field.

Table E- 2: Base case water production rate.

Year	Water Production Rate (te/day)		
	ETAP without Murlach	Murlach	ETAP with Murlach
2025	5,275	41	5,316
2026	4,920	195	5,115
2027	4,848	262	5,110
2028	4,780	316	5,096
2029	4,625	279	4,905
2030	4,587	329	4,917
2031	1,629	329	1,958
2032	1,528	329	1,857
2033	1,452	329	1,781
2034	1,426	329	1,755
2035	1,532	329	1,862
Based on a density of 1.1 kg/m^3			

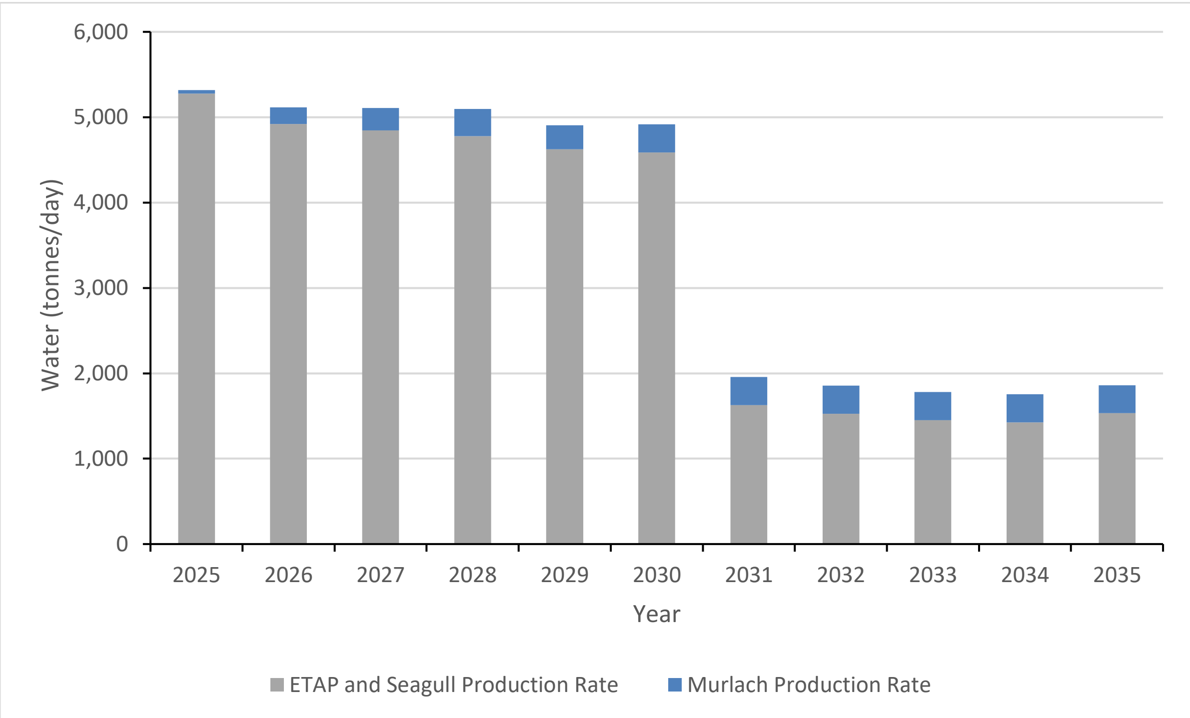


Figure E- 3: ETAP water production rate alone and with Murlach base case production rate.