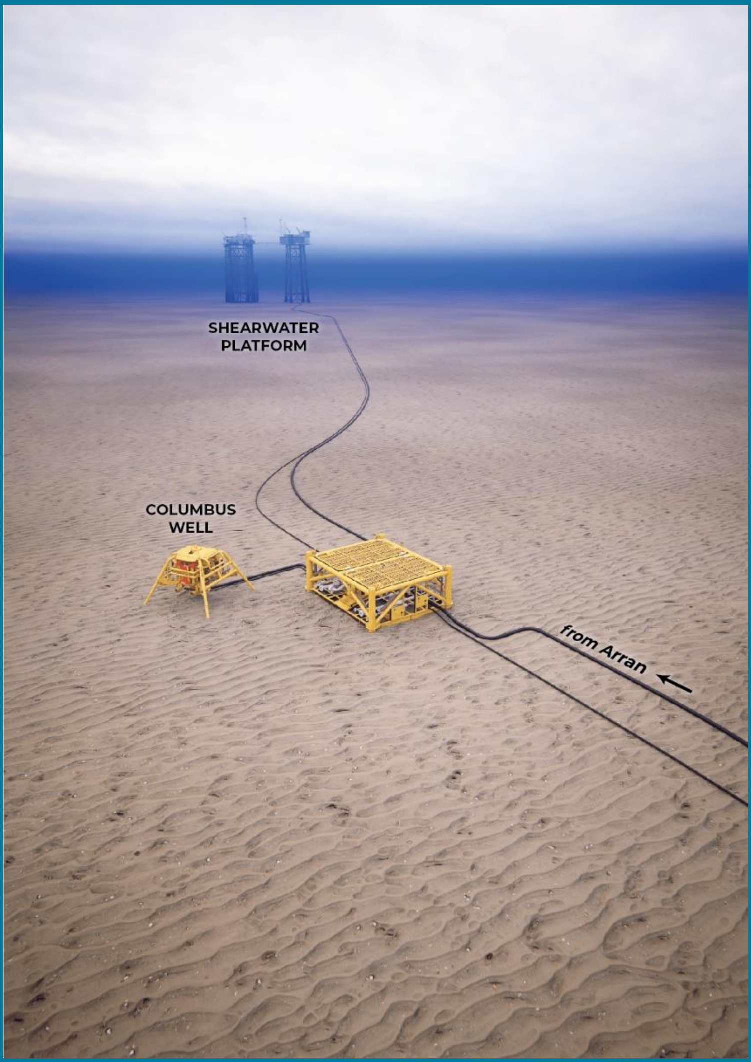
Serica Energy (UK) Limited

Columbus Field Development
Environmental Statement



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Document Control Page

Company:	Serica Energy (UK) Limited

Report Title:	Columbus Field Development ES

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ENVIRONMENTAL STATEMENT DETAILS

Section A: Administrative Information

A1 – Project Reference Number

Number: D/4221/2018

A2 – Applicant Contact Details

Company Name: Serica Energy (UK) Limited

Contact Name: Fergus Jenkins

Contact Title: Columbus Development Manager

A3 – ES Contact Details (if different from above)

As above.

A4 – ES Preparation

Please confirm the key expert staff involved in the preparation of the ES:

Name	Company	Title	Relevant Qualifications / Experience
Fay Dobson	Orbis Energy Limited	Director	Fay has over 15 years HSE management consultancy experience in the oil and gas industry having graduated with a first class honours degree in Environmental Science from Lancaster University in 2000.
Baptiste Galmiche	Orbis Energy Limited	Principal Consultant	Baptiste has 10 years of experience in HSE management in the upstream oil and gas sectors. He has a Bachelor of Science (Hons) in Environmental Health and is a Graduate Member of IEMA.
Susanna Black	Orbis Energy Limited	Senior Consultant	Susanna joined Orbis in 2012 having graduated with a first-class honours degree in Geography (BSc) from the University of Southampton.
Christina Platt	Orbis Energy Limited	Graduate Consultant	Christina joined Orbis in early 2018 having graduated with an upper-second class Master's degree in Environmental Science (MSc) from the University of East Anglia.

A5 – Licence Details

a) Please confirm licence(s) covering proposed activity or activities

Licence number(s): P1314 and P101

b) Please confirm licences and current equity

Licence Number: P1314 and P101	
Licensee	**Percentage Equity**
Serica Energy (UK) Ltd	50%
Endeavour Energy UK Ltd	25%
EOG Resources United Kingdom Ltd	25%

Section B: Project Information

B1 – Nature of Project

a) Please specify the name of the project.

Name: Columbus Field Development

b) Please specify the name of the ES (if different from the project name).

As above.

c) Please provide a brief description of the project:

Serica Energy (UK) Limited (hereafter referred to as 'Serica') is the operator of United Kingdom Continental Shelf (UKCS) Licences P1314 and P101, which contains the Columbus field, located in Block 23/16f and 23/21a in the central North Sea.

The Columbus field was originally discovered in 2006 and was subsequently appraised by Serica. Serica is now proposing to develop the Columbus field and is progressing with engineering studies with the aim to deliver first production from Columbus in 2021.

The development concept for Columbus comprises a single subsea production well connected by a spool piece to the proposed Arran to Shearwater subsea pipeline via a tie-in structure. A chemical injection umbilical will run alongside the Arran to Shearwater pipeline from the Shell operated Shearwater platform to the Columbus wellhead. Fluids from the Columbus field will be processed at the Shearwater platform, located approximately 43 km to the south west of Columbus.

The proposed Arran to Shearwater pipeline forms part of the Arran Development, the licence operator for which is Dana Petroleum (E&P) Limited (hereafter referred to as 'Dana'). Dana is currently seeking consent for the Arran Development. A small section of the proposed Arran to Shearwater pipeline route will need to be deviated to accommodate the Columbus Development. Sanction of the Columbus Field Development is therefore subject to sanction of the Arran Development.

Columbus reservoir fluids (gas and condensate) will be processed on the Shearwater platform and exported to shore via existing infrastructure. Produced water will be discharged at the Shearwater platform via existing facilities.

Annual gas production from the Columbus Development is expected to peak around Year four with a rate of around 337 million cubic metres (11.9 billion cubic feet) of gas per year and around Year two for condensate with around 82,177 cubic metres per year of condensate (P10 case). Following these peaks, gas and condensate production is expected to decrease as field life continues. Annual water production from the Columbus Development is expected to peak at around 15,899 cubic metres (0.1 million barrels) per year (P10 case).

The Columbus subsea infrastructure will have a design life of minimum 15 years and the economic field life is expected to be up to 14 years. On cessation of production, the Columbus facilities will be decommissioned in accordance with the requirements of the prevailing UK and International law.

B2 – Project Location

a) Please indicate the offshore location(s) of the main project elements.

Quadrant numbers(s): 23

Block numbers(s): 16f and 21a

Latitude: 57° 20' 58.728" N; **Longitude:** 2° 05' 11.906" W (ED50 UTM Zone 31N)

Distance to nearest UK coastline (km): 230

Which coast? Scotland

Distance to nearest international median line (km): 8

Which line? UK / Norway

B3 – Previous Applications

If the project, or an element of the project, was the subject of a previous consent application supported by an ES, please provide details of the original project.

Columbus Environmental Statement Licence P.1314 & Licence P.101, DECC Project Reference Number D/4085/2010, submitted in January 2011. This concept included two near-horizontal wells, tied back to a new bridge linked platform at the Lomond platform located in Block 23/21. The ES and FDP covering this option were submitted to the regulator by Serica and subsequently approved; however, the project was later cancelled by the Lomond operator and development of the Columbus field was put on hold for commercial reasons.

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Table of Contents

APPENDICES

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Abbreviations

%	Per cent
°	Degree
°C	Degrees Celsius
°F	Degrees Fahrenheit
<	Less than
≥	Greater than or equal to
$\mu g\ g^{-1}$	Micrograms per gram
µm	Micrometre
ACA	Action Co-ordinating Authority
AET	Apparent Effects Threshold
Al	Aluminium
AP	Alkylphenols
API	American Petroleum Institute gravity
As	Arsenic
Ba	Barium
BAC	Background Assessment Criteria
BAT	Best Available Technology
bbl	Barrels
BC	Background Concentration
bcf	Billion cubic feet
BEIS	Department of Business, Energy and Industrial Strategy
BOP	Blowout Preventer
BP	British Petroleum
BSG	British Geological Survey
CATS	Central Area Transmission System
Cd	Cadmium
CDev-1	Columbus Development 1
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CH_4	Methane
CHARM	Chemical Hazard Assessment and Risk Management
CMAPP	Corporate Major Accident Prevention Policy
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_{2e}	Carbon dioxide equivalent

CPA	Closest Point of Approach
Cr	Chromium
CTIS	Columbus Tie-In Structure
Cu	Copper
Dana	Dana Petroleum (E&P) Limited
dB	Decibel
dB re 1 µPa	Decibels relative to one micro-Pascal
dB re 1 µPa.m	Decibels relative to one micro-Pascal referred to 1 metre
DECC	Department for Energy and Climate Change
DEPCON	Deposit Consent
DP	Dynamically Positioned
DSV	Dive Support Vessel
DTI	Department for Trade and Industry
DWT	Dead Weight Tonnes
E&P	Exploration & Production
EBS	Environmental Baseline Survey
EC	European Commission
ED50	European Datum 1950
EEA	European Environment Agency
EEMS	Environmental Emissions Monitoring System
EHC	Electrical, Hydraulic and Chemical
EIA	Environmental Impact Assessment
EPS	European Protected Species
ERL	Effects Range Low
ERRV	Emergency Rescue and Recovery Vessel
ES	Environmental Statement
EU	European Union
EUNIS	European Nature Information System
FDP	Field Development Plan
FEAST	Feature Activity Sensitivity Tool
FEED	Frond End Engineering Design
FFS	Fishing Friendly Structure
FLO	Fisheries Liaison Officer
FPS	Forties Pipeline System
GAEL	Graben Area Export Line

GWP	Global Warming Potential
GWP_{100}	100-year Global Warming Potential
H_2CO_3	Carbonic Acid
H_2S	Hydrogen Sulphide
HDJD	Heavy Duty Jack-Up
Hg	Mercury
Hs	Significant Wave Height
HSE	Health and Safety Executive
HSEQ	Health, Safety, Environment and Quality
Hz	Hertz
IAMMWG	Inter-Agency Marine Mammal Working Group
ICES	International Council for the Exploration of the Sea
IMCA	International Marine Contractors Association
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
ITOPF	International Tanker Owners Pollution Federation Limited
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
kHz	Kilohertz
km	Kilometre
km^2	Kilometre Squared
kW	Kilowatt
LAT	Lowest Astronomical Tide
LTOBM	Low Toxicity Oil Based Mud
m	Metre
m^2	Metre Squared
m^3	Cubic Metre
MAHs	Major Accident Hazzard
MAT	Master Application Template
MCZ	Marine Conservation Zone
MDAC	Methane-derived Authigenic Carbonate
MEG	Mono-ethylene Glycol
MEI	Major Environmental Incident
MMb	Million barrels
MMstb	Million stock tank barrels

MMO	Marine Mammal Observer
MODU	Mobile Offshore Drilling Unit
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
MU	Management Units
MW	Megawatt
N/A	Not Applicable
N_2O	Nitrous Oxide
NC MPA	Nature Conservation Marine Protected Area
Ni	Nickle
nm	Nautical Mile
NMPi	National Marine Plan Interactive
NNR	National Nature Reserves
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxides
OGA	Oil and Gas Authority
OMR	Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (as amended)
OMS	Operations Management System
OPEP	Oil Pollution Emergency Plan
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
OSPAR	Oslo and Paris Commission
OVID	Offshore Vessel Inspection Database
PAH	Polycyclic Aromatic Hydrocarbon
Pb	Lead
PDCA	Plan-Do-Check-Act
PETS	Portal Environmental Tracking System
PL	Production Licence
PMF	Priority Marine Feature
PTS	Permanent Threshold Shift
PWA	Pipeline Works Authorisation
ROV	Remotely Operated Vehicle
SAC	Special Area of Conservation
SAT	Subsidiary Application Template
SCANS	Small Cetaceans in European Atlantic waters and the North Sea
SCM	Subsea Control Module

SCOS	Special Committee on Seals
SEA	Strategic Environmental Assessment
SEAL	Shearwater Elgin Area Line
SEGAL	Sheel Esso Gas and Associated Liquids
SEL	Sound Exposure Level
SFF	Scottish Fishermen's Federation
SIMOPS	Simultaneous Operations
Sn	Tin
SNH	Scottish Natural Heritage
SO_2	Sulphur Dioxide
SOPEP	Ship Oil Pollution Emergency Plan
SOSI	Seabird Oil Sensitivity Index
SOx	Sulphur Oxides
SNCB	Statutory Nature Conservation Bodies
SNH	Scottish Natural Heritage
SPA	Special Protected Area
SPL	Sound Pressure Level
SPL_{peak}	Peak Sound Pressure Level
SSIV	Subsea Isolation Valve
SSS	Side Scan Sonar
SSSI	Sites of Special Scientific Interest
THC	Total Hydrocarbons
TOC	Total Organic Carbon
TOM	Total Organic Matter
TTS	Temporary Threshold Shift
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
UTM	Universal Transverse Mercator
V	Vandium
VMS	Vessel Monitoring System
VOC	Volatile Organic Compound
WBM	Water-Based Mud
WOAD	Worldwide Offshore Accident Database
Xmas	Christmas
Zn	Zinc

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Non-Technical Summary

Introduction

Serica Energy (UK) Limited (hereafter referred to as Serica) is the operator of the United Kingdom Continental Shelf (UKCS) Petroleum Production Licences P1314 and P101, which contain the Columbus field, located in Block 23/16f and 23/21a in the central North Sea. The Columbus field is located approximately 230 km east of Peterhead on the Scottish coastline. The nearest international boundary to the development is the UK/Norwegian median line, which lies approximately 8 km to the east-north-east of the proposed Columbus Development location (Figure 1).

The Columbus field was originally discovered in 2006 and was subsequently appraised by Serica. Serica, along with its partners (Endeavour Energy UK Ltd and EOG Resources United Kingdom Ltd), is now proposing to develop the Columbus field and is progressing with engineering studies with the aim to deliver first production from Columbus in 2021.

An Environmental Statement (ES) has been prepared to present the findings of the Environmental Impact Assessment (EIA) carried out for the proposed Columbus Development, as required under The Offshore Petroleum Production and Pipelines (Assessment of Environmental Effects) Regulations 1999 (as amended). The ES has been prepared by Serica in conjunction with Orbis Energy Limited (the EIA Consultant). This document forms the non-technical summary of the ES.

Project Description

The development concept for Columbus comprises a single subsea production well connected by a spool piece to the proposed Arran to Shearwater subsea pipeline via a tie-in structure. A chemical injection umbilical will run alongside the Arran to Shearwater pipeline from the Shell operated Shearwater platform to the Columbus wellhead. Fluids from the Columbus field will be processed at the Shearwater platform, located approximately 43 km to the south west of Columbus.

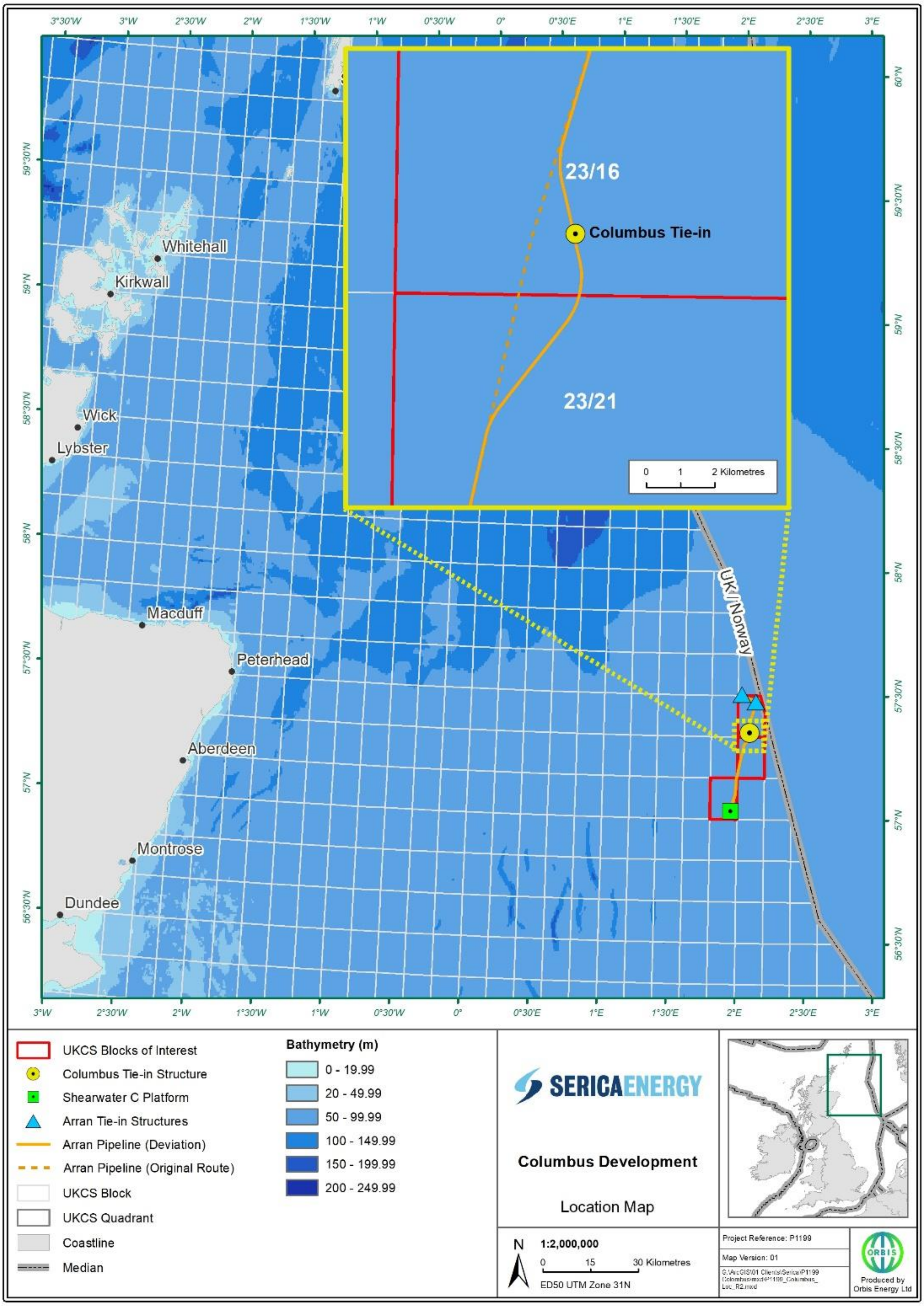
The proposed Arran to Shearwater pipeline forms part of the Arran Development, the licence operator for which is Dana Petroleum (E&P) Limited (hereafter referred to as 'Dana'). Dana is currently seeking consent for the Arran Development. A small section of the proposed Arran to Shearwater pipeline route will need to be deviated to accommodate the Columbus Development (refer to Figure 1 for original Arran to Shearwater pipeline route and deviated section). Sanction of the Columbus Field Development is therefore subject to sanction of the Arran Development.

It is proposed that the Columbus development well (termed the 'CDev-1 well') will be drilled during the initial field development phase, with the earliest spud date anticipated to be in Q4 2020. Well design work is still being progressed; however, for the purposes of the EIA a long deviated well has been assumed, the total length of the well is expected to be around 6,608 m with the total vertical depth subsea of around 2,986 m. It is anticipated that the well will take approximately 79 days to complete.

It is currently proposed that the pipeline and umbilical will be laid in two separate trenches. The pipeline will be buried with backfill soil to prevent upheaval buckling. It is proposed that the umbilical will be left in an open trench to naturally backfill over time. Protective stabilisation material will be required in the form of mattress protection and rock dumping to ensure the integrity of the infrastructure in certain places. The vessels used during the installation process could either be dynamically positioned (DP) or anchored. A Dive Support Vessel (DSV) will also be required to install the subsea Columbus tie-in structure and to support tie-in and pre-commissioning activities. It is currently anticipated that the pipeline and umbilical installation will occur in Q2 to Q3 2020 and that the installation of Columbus subsea infrastructure, as well as hook-up and commissioning activities will occur in Q2 2021.

Reservoir fluids (gas and condensate) will be processed on the Shearwater platform and exported to shore via existing infrastructure. No significant modifications to the Shearwater platform are required in preparation of the tie-in of the Columbus Development, other than those being undertaken to accommodate the proposed Arran Development. Produced water will be discharged at the Shearwater platform via existing facilities. Additional atmospheric emissions will be generated at Shearwater as a result of processing the Columbus fluids due to additional fuel use and temporary increases in flaring as a result of Columbus production coming online and from unplanned shut down and start-up.

Figure 1. Location of the Proposed Serica Field Development



The Columbus subsea infrastructure will have a design life of minimum 15 years and the economic field life is expected to be up to 14 years. On cessation of production, the Columbus facilities will be decommissioned in accordance with the requirements of the prevailing UK and International law.

Concept Selection

From initial screening it was clear that a 'topside' option would not need to be considered further for Columbus, as a subsea development option could easily be achieved and construction of new export facilities to shore was commercially unviable. A subsea development tied back to existing infrastructure with export facilities was therefore the optimum solution.

Serica and its partners have explored various options to develop the Columbus field over the past decade. In 2010, a comprehensive concept selection process was undertaken to select the optimum development option for the field. A number of factors were reviewed to compare the options, including tie-back length, host processing capability, host impact, host tie-in capacity, host export routes, schedule impact and cost.

After the review of the available infrastructure, tieback to Lomond or Mungo were considered the only viable options for Columbus. These options were also considered the best environmentally as they had the shortest export pipeline routes and therefore the smallest seabed footprint. However, the Mungo platform was subsequently deemed to have insufficient spare capacity for Columbus and therefore, the Lomond offtake option was selected for tieback of the Columbus Development. An ES (Ref: D/4085/2010) and FDP covering the Lomond offtake option were submitted to the regulator by Serica in 2011 and subsequently approved; however, the project was later cancelled by the Lomond operator and development of the Columbus field was put on hold for commercial reasons.

More recently, two alternative development options have been technically evaluated by Serica and their partners:

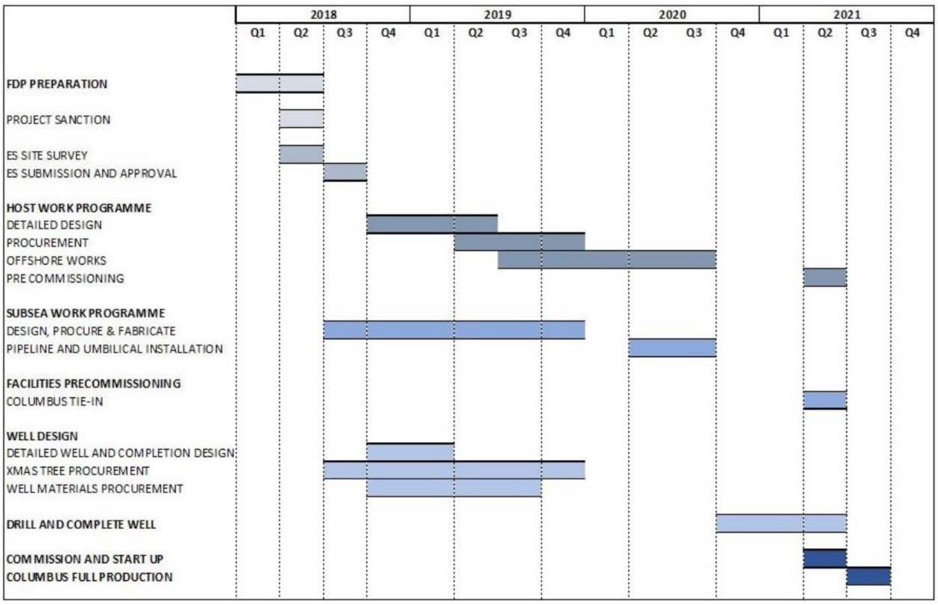
- A subsea development well tied back to the proposed Arran to Shearwater pipeline;
- An extended reach well drilled from the Lomond Platform.

Following technical and commercial evaluations, development via the proposed Arran to Shearwater pipeline has been selected as the preferred option. The primary driver for the decision was the risk that there would not be a reliable export route for Columbus via Lomond because of ongoing waxing issues with the Lomond to Everest condensate line.

Project Schedule

The preliminary schedule for the proposed Columbus Development is provided in Figure 2. .

Figure 2. Preliminary Schedule for the Columbus Development



The schedule is dependent on obtaining the necessary consents and approvals, and will be dependent on weather windows. As such, it is subject to change

The Existing Environment

The EIA process requires a comprehensive review of the existing environment in order to provide a basis for assessing the potential interactions between a project and the receiving environment. A high-level summary of the environmental sensitivities within the vicinity of the proposed Columbus Development area is provided below.

The description of the baseline environment is based on a combination of the historic site survey data and existing published literature. In addition, a number of site surveys have previously been conducted in the area between 2006 and 2015. The purpose of these was to identify baseline environmental conditions in the area in preparation for drilling and development activities and to determine if there were any species or habitats of conservation importance within the area. In May 2018, Serica also undertook a habitat assessment and EBS within the vicinity of the proposed CDev-1 well location and along the deviated section of the Arran to Shearwater pipeline. At the time of writing this ES, the results of 2018 survey are not yet available. However, given the large number of surveys which have previously been conducted in the Columbus area, the stability of the benthic environment and the general homogeneity of the seabed sediments in this part of the central North Sea, it is considered that the historic surveys provide an accurate assessment of the environmental conditions in this area and that sufficient data has been gathered and analysed to acquire a good understanding of the surrounding area upon which to undertake the EIA. The results of the 2018 habitat assessment and EBS will be made available to interested parties once available.

Physical Environment

The proposed Columbus Development is located in the central North Sea, approximately 230 km from the nearest landfall at Peterhead on the Scottish coast. The UK/Norwegian median line is approximately 8 km to the north east of the proposed Development (refer to Figure 1 above). The water depth in the vicinity of the proposed CDev-1 well location is approximately 85 metre (m) below Lowest Astronomical Tide (LAT) and ranges from 85 m to 87 m LAT across the proposed deviated section of the Arran to Shearwater pipeline. The seabed in the vicinity of the proposed Columbus Development and along the deviated section of the pipeline undulates gently with seabed gradients observed of <1°.

Seabed sediments in the Columbus Development area are silty sand with intermittent areas of clay outcrop with gravel, shells and cobbles. No contamination of the seabed sediments is expected in the Development area, except potentially in the direct vicinity of the previous drilling operation location; namely wells 23/16f-11 and 23/16f-12 drilled in 2006 and 2007 respectively.

The residual surface current in the vicinity of the proposed Columbus Development tends to be in an easterly direction. However, occasional strong south easterly winds can push the near surface current in the opposite direction. Tides in the central North Sea are predominately semi-diurnal and tidal waters offshore in this area flood southwards and ebb northwards.

The prevailing wind direction are variable throughout the year, but winds deriving from a southerly direction are most frequent. The annual mean surface temperature within the vicinity of the Columbus Development is around 9.6°C, whilst annual mean seabed temperature is about 6.9°C.

Biodiversity

The collective term plankton describes the plants (phytoplankton) and animals (zooplankton) that live freely in the water column and drift passively with the water currents. Plankton form the base of the food chain, therefore changes in the abundance and composition of the planktonic community can have impacts on higher consumers. Zooplankton is a primary food source for fish, seabirds and whales.

Benthos describes the organisms that live within and on the seabed. Benthic organisms can be classified further into infauna, organisms that live within the sediment, and epifauna, organisms that live on top of the seabed (attached or mobile). In general, the seabed faunal community in the vicinity of the Columbus Development is expected to be relatively abundant and diverse; characteristic of fine muddy North Sea sediments. Species including hermit crab, sea urchin, sea pen, dead man's finger and anemones have previously been observed in the area and the infaunal community is expected to be dominated by worms (polychaetes).

A number of fish species are likely to be present within the Columbus Development area. Fishing landings data suggests that adult populations of the pelagic species (living in open water) herring and the demersal species (living at or close to the seabed) haddock, plaice, whiting, lemon sole, monks/anglers, witch, turbot, saithe and cod are relatively abundant in this area. Fish species spawning within the area include: cod, lemon sole, mackerel, Norway Pout, plaice and sandeels. In addition, the following species use the area as nursery grounds: anglerfish (monkfish), blue whiting, cod, European hake, haddock, herring, horse mackerel, ling, mackerel, Norway pout, plaice, sandeel, spotted ray, spurdog and whiting. Species of sharks, skates and rays may also be present in the vicinity of the Columbus Development, these include basking sharks, blue shark, common skate, cuckoo ray, spurdog and tope shark.

A number of seabirds are present in the vicinity of the Columbus Development area throughout the year; with the most abundant species being fulmar and kittiwake. In addition, the area potentially lies within the breeding season foraging ranges of fulmar, Manx shearwater and gannet. Offshore areas have been assigned a value for seabird sensitivity to oil pollution for each month, based on seabird survey data and individual seabird species sensitivity index. Seabird sensitivity to oil pollution within the Columbus Development area is considered to be low throughout the year.

Species of marine mammals likely to be present in this area of the central North Sea include the bottlenose dolphin, harbour porpoise, killer whale, minke whale, Risso's dolphin, white-beaked dolphin and white-sided dolphin. Of these, the most frequently sighted are harbour porpoise, white-beaked dolphin and white-sided dolphin. Seals are widely distributed along the east coast of Scotland; however, studies of grey and harbour seals have indicated that their density within the proposed Columbus Development area is low.

The closest protected area to the Columbus Development is the East of Gannet and Montrose Fields Nature Conservation Marine Protected Area (NC MPA), located approximately 33 km to the west of the proposed CDev-1 well. This site is designated for ocean quahog (*A.islandica*) aggregations, but given the distance to the development area it is not anticipated to be impacted. It should be noted that ocean quahog have been recorded within the vicinity of the proposed Columbus Development area during the previous site surveys undertaken in the area. Ocean quahog is; however, commonly found within the North Sea and when compared with other areas, the abundance of ocean quahog recorded within the vicinity proposed Columbus Development area is relatively low.

Human Environment

Fishing effort in the vicinity of the Columbus Development is considered to be variable with low effort in winter, moderate effort from March to May and August to September and high effort in June and July. The area is utilised by both the UK and international fishing fleets. Fishing activity in the Columbus Development area is dominated by trawls. The Columbus Development area is within an area of moderate intensity of demersal mobile gear fishing alongside low levels of herring fishing activity. The dominant species landed include herring, plaice, lemon sole and haddock.

Commercial shipping activity within the vicinity of the Columbus Development is considered to be low, with the majority of vessels consisting of cargo vessels, followed by offshore support vessels and tankers.

Oil and gas infrastructure in this region of the central North Sea is well developed. The nearest offshore infrastructure is the Mungo Platform, approximately 6.1 km to the northwest of the Columbus Development. In addition, the Lomond platform is located approximately 8.8 km south east of the proposed CDev-1 well. A number of existing pipelines are also present in the vicinity of the Columbus Development but none will be crossed by the deviated section of the Arran to Shearwater pipeline/umbilical route. The active 'CNS Fibre Optic' telecom cable passes approximately 5 km to the east of the proposed CDev-1 well.

There are no planned, consented or operational offshore wind farms within the vicinity of the proposed Columbus Development area. In addition, there are no military Practice and Exercise Areas.

Identification and Assessment of Potentially Significant Impacts

The EIA process undertaken for the Columbus Development has aimed to identify and assess all potentially significant impacts on the environment or other users of that environment arising from the proposed project (both from planned and unplanned (accidental) events). Cumulative and transboundary impacts have also been considered.

The EIA has assessed potentially significant environmental impacts from:

- Drilling, commissioning and operation of the CDev-1 well;
- Installation, commissioning and operation of the Columbus spool piece and subsea manifold structure designed to tie the CDev-1 well into the Arran to Shearwater pipeline;
- Installation of the deviated section of the proposed Arran to Shearwater pipeline;
- The incremental emissions at the Shearwater platform as a result of processing the Columbus fluids.

The environmental impact of the installation of the remainder of the Arran to Shearwater pipeline, along with the commissioning, operation and maintenance of the entire pipeline, is assessed within Dana's Arran Project ES (Dana, 2018).

The significance of potential impacts has been determined by calculating the risk; combining the likelihood of occurrence (frequency / probability) with the magnitude of impact (consequence). When determining the significance, it has been assumed that some mitigation measures (termed Standard Operating Procedures) are implemented as standard practice for UKCS oil and gas activities to comply with regulatory requirements.

The majority of aspects (or issues) were found to be of low risk to the environment (i.e. not significant) and were therefore not considered for further assessment in the ES. Some issues, however, were considered to be of medium risk to the environment (i.e. potentially significant) and have been assessed in detail in the ES. For these issues, mitigation measures have been identified to either remove the potentially significant impacts by design, or minimise or manage the potentially significant impacts through operational measures. The significance of these impacts was then re-assessed to determine the remaining or residual impact.

A summary of the main findings of the EIA process is as follows:

- **Physical Presence:** The physical presence of the Columbus Development, both above and below the sea surface, has the potential to interfere with the activities of other users of the sea (specifically shipping and fishing). The temporary presence of the mobile offshore drilling unit (MODU) and other working vessels at the surface can pose a navigation hazard to shipping and fishing vessels, and may lead to an accidental event such as a collision. The risk of a collision will be minimised by implementing measures, including marking of the 500 m exclusion zone on appropriate navigation charts and following standard maritime communication and notification measures. Below the sea surface the physical presence of the mooring system of MODU (if a moored semi-submersible is used) or installation vessels and the long term presence of the seabed development infrastructure will pose a snagging hazard to fishing gears in the area. Fishing activity will also be excluded from the 500 m exclusion zone in place around the wellhead and tie-in structure during the life of the Columbus field. The total area that will be lost, however, represents a very small proportion of the entire fishing area available in the central North Sea. All seabed infrastructure will be designed to be fishing friendly. In addition, the pipeline will be trenched and mechanically backfilled, to further minimise the risk to fishing gears. In conclusion, no significant adverse residual impacts to other sea users (shipping and fishing) are predicted as a result of the physical presence of the Columbus Development.
- **Seabed Disturbance:** A number of activities will have the potential to cause seabed disturbance including mooring of the MODU (if a moored semi-submersible is used) / installation vessels, the discharge of drill cuttings, muds and cements, and the installation of seabed infrastructure (deviated section of the pipeline, tie-in structure etc.) and protective structures (concrete mattresses, rock dump material). Impacts to the marine environment include direct mortality of organisms and habitat loss within the installation corridor and indirect effects including a decline in water quality due to increased turbidity and smothering of organisms and habitats from re-suspended sediments. The total area of seabed that may be impacted by the Columbus Development is estimated at 0.4 square kilometres, although the majority of disturbance will be temporary, occurring during the drilling and installation phases. The impact of smothering on seabed communities associated with the silty sand sediments of the Columbus Development are expected to be less than on those species found in a hard or gravely location. In addition, the relatively low seabed current speeds in the deeper waters of the central North Sea, indicate that smothering effects on seabed fauna due to the settlement of suspended material will be localised to the vicinity of operations. Furthermore, it is anticipated that recovery of the affected areas of seabed will be relatively rapid once operations have ceased. The long term presence of the

wellhead, tie-in structure and subsea protection material will, however, amount to a change in habitat type and could lead to a change in community structure to species that prefer a hard substratum such as sessile epifaunal species that can colonise the hard structures. However, the area that will experience a change in habitat type is very small (less than 0.01 square kilometres). In conclusion, particularly given the limited scale of the Development, no significant adverse residual impacts to seabed communities are predicted as a result of seabed disturbance during the Columbus Development operations.

- **Noise and Vibration:** Underwater noise generated during the proposed Columbus Development has the potential to disturb, or cause injury to, a number of species in the marine environment, particularly fish and marine mammals. Significant levels of underwater noise may be generated and transmitted considerable distances in the marine environment during piling activities when the Columbus tie-in structure is being installed and when there is a requirement for vessels to use Dynamic Positioning thrusters, although both these activities will be temporary in nature. Serica will implement a range of measures to mitigate any potential impacts including adherence to the Joint Nature Conservation Committee (JNCC) guidelines for minimising injury and disturbance to marine mammals. In conclusion, no significant adverse residual impacts to fish and marine mammals are predicted from noise associated with the Columbus Development operations.
- **Atmospheric Emissions**: Major sources of atmospheric emissions from the Columbus Development include power generation for the MODU, support and installation vessels and flaring of the CDev-1 well during well testing and clean-up. In addition, atmospheric emissions will be generated at Shearwater from additional fuel use as a result of processing Columbus fluids, as we as temporary increases in flaring as a result of Columbus production coming online and from unplanned shut down and start-up. Atmospheric emissions have the potential to impact the environment at local (air pollution) and wider scale (climate change). However, worst-case atmospheric emissions from the Columbus Development will represent only a relatively small proportion of emissions typically arising from oil and gas activities on the UKCS. Emissions are likely to disperse rapidly from the source given the open and dynamic metocean environment in the central North Sea. In conclusion, no significant adverse residual impacts to air quality are predicted from the potential atmospheric emissions associated with the Columbus Development.
- **Marine Discharges:** planned operational discharges to sea will occur during all lifecycle phase of the Columbus Development, although the aspects which have the potential to result in significant impacts to the marine environment are limited to discharge of produced water at the Shearwater platform during the production operations. Discharges of produced water can contain potentially harmful concentrations of oil and other chemicals; however, a number of studies have shown that any impacts will be limited to the local area in the immediate vicinity of the release location and therefore no significant adverse residual impacts are predicted. In addition to this, the produced water concentrations and discharge rates assessed in the ES are a worst case estimate, based on the peak produced water production which will occur for a short duration over the life of the Columbus field.
- **Accidental Releases:** All offshore activities associated with the Columbus Development will carry a potential risk of hydrocarbon pollution to sea; however, hydrocarbon spills from normal oil and gas operations are uncommon and can be effectively mitigated against. In planning its activities, Serica's primary focus is to ensure that all practicable measures are taken to prevent the occurrence of such accidental events and, should they occur, mitigate their effects. The consequences of an accidental release will vary depending on the quantity and type of oil spilt, the wind speed and direction and sea state and the sensitivity of receptors depending on the time of year. The worst-case spill scenario from the Columbus Development would be an uncontrolled flow of condensate from the proposed CDev-1 well (i.e. a well blowout). Oil spill modelling has been conducted to determine the fate of Columbus condensate released from this worst case scenario. As the UK/Norwegian median line is located approximately 8 km to the east northeast of the proposed Columbus Development there is the potential for a surface slick of condensate to cross the median line. In addition, there is a low probability that a worst case spill could beach on the east coast of the Shetland Islands (up to 6%), Aberdeenshire (up to 5%) and the Highlands region (up to 1%), with the shortest arrival time to shore being 596 hours (over 24 days). However, the Columbus condensate is a light oil and, as such, it would be rapidly broken up by wind and wave action and evaporate. The risk of an accidental release occurring from the Columbus Development will be minimised through the implementation of physical barriers such as downhole safety valves, maintenance to minimise leaks, and the development and implementation of

handling and operational procedures and training. Measures to respond to a spill from the MODU or the Columbus subsea facilities once operational will be covered in approved oil pollution and emergency plans, which will be prepared in advance of drilling operations commencing offshore. As such, the overall risk to the marine environmental from an accidental release of hydrocarbons from the Columbus Development is considered to be **low** and not significant.

Environmental Management

Serica conducts all of its activities and operations in accordance with an integrated Operations Management System (OMS). This system provides the structured management framework within which environmental impacts are identified, assessed, controlled, and monitored.

The Serica OMS is the mechanism that ensures the company standards are maintained, that the commitments specified in the ES are met and that unforeseen aspects of the proposed Columbus Development are detected. This structured management approach will be used to ensure that the on-going process of identification, assessment and control of environmental risks will continue throughout planning and operations of the field development.

Conclusion

In summary, it is concluded that the proposed Columbus Development will not result in any significant environmental impacts (including transboundary and cumulative impacts) provided that all identified mitigation measures are implemented.

1 Introduction

1.1 Background

Serica Energy (UK) Limited (hereafter referred to as Serica) is the licence operator of the United Kingdom Continental Shelf (UKCS) Petroleum Production Licences P1314 and P101, which contain the Columbus field, located in Block 23/16f and 23/21a in the central North Sea. The current equity interests of the field are as follows:

- Serica Energy (UK) Ltd: 50%;
- Endeavour Energy UK Ltd: 25%;
- EOG Resources United Kingdom Ltd: 25%.

The Columbus field comprises gas condensate stratigraphically trapped within sandstone reservoirs of the Palaeocene Forties Formation. It was discovered in 2006 by well 23/16f-11 and subsequently appraised by wells 23/16f-12, 23/16f-12z, 23/21a-7x and 23/21a-7z. Serica is proposing to develop the Columbus field and is progressing with engineering studies with the aim to deliver first production from Columbus in 2021.

As part of the consenting process for the Columbus Development, Serica is required to submit a Field Development Plan (FDP) to the Oil and Gas Authority (OGA). To support the FDP, an Environmental Statement (ES) must also be submitted to the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) for approval under The Offshore Petroleum Production and Pipelines (Assessment of Environmental Effects) Regulations 1999 (as amended) as the proposed Columbus Development will produce more than 500,000 cubic metres (1.8 million cubic feet) of gas per day and more than 500 tonnes (approximately 3,750 barrels) of condensate.

This document is the ES for the proposed Columbus Development and presents the findings of the Environmental Impact Assessment (EIA) undertaken to assess the development's potentially likely significant effects on the environment. It has been prepared by Serica in conjunction with Orbis Energy Limited (the EIA Consultant).

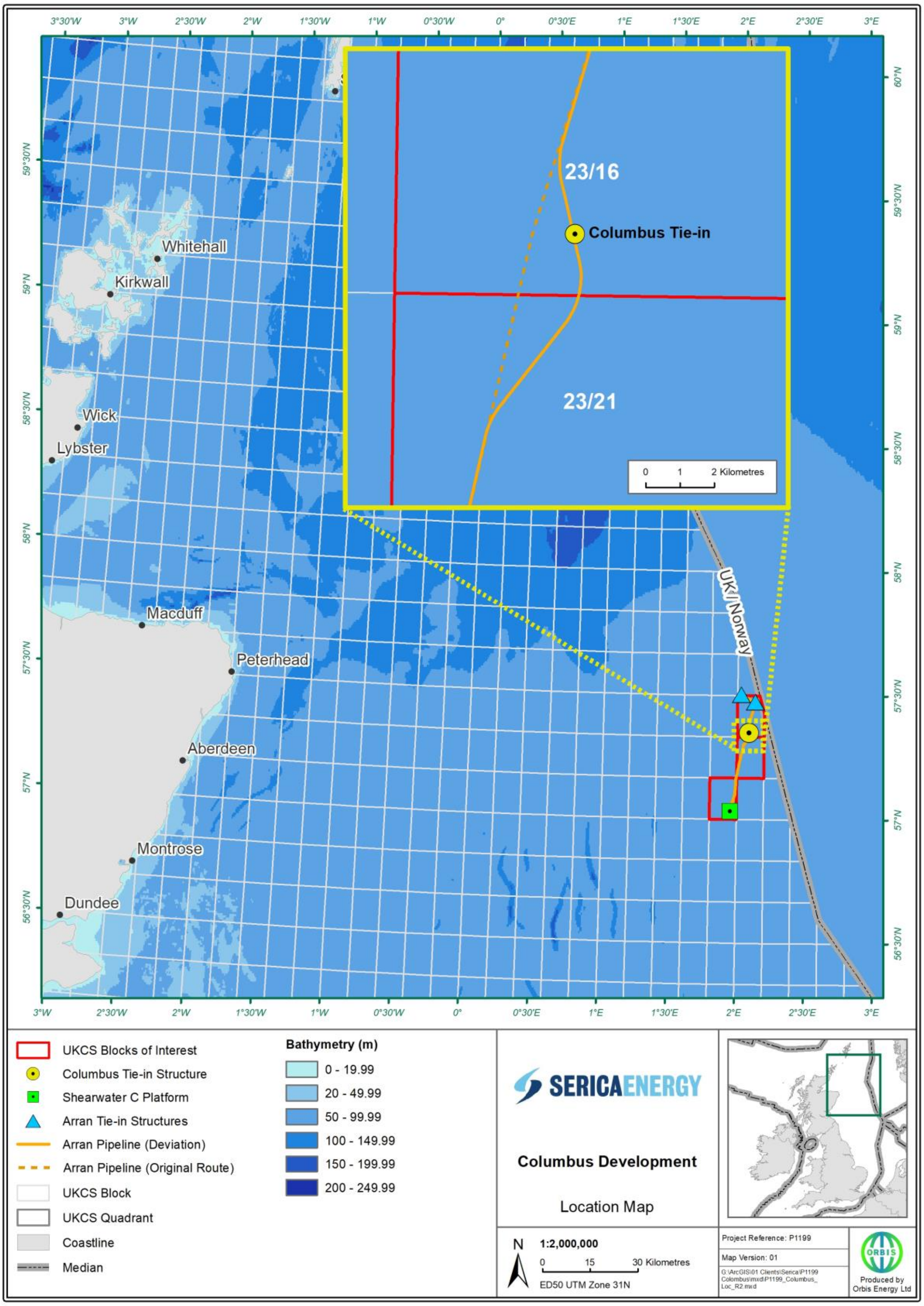
1.2 Project Overview

The proposed Columbus Development is located in the central North Sea, approximately 230 km east of Aberdeen on the eastern Scottish coastline (Figure 1.1). The nearest international boundary to the Development is the UK/Norwegian median line, which lies approximately 8 km to the east-north-east of Columbus.

The development concept for Columbus comprises a single subsea production well connected by a spool piece to the proposed Arran to Shearwater subsea pipeline via a tie-in structure. A chemical injection umbilical will run alongside the Arran pipeline from the Shell operated Shearwater platform to the Columbus wellhead. Fluids from the Columbus field will be processed at the Shearwater platform, located approximately 43 km to the south west of Columbus. The Columbus gas will then be compressed and exported to St. Fergus via the Shell Esso Gas and Associated Liquids (SEGAL) system. Columbus associated condensate will be exported to the Forties Pipeline System (FPS) via the Graben Area Export Line (GAEL). Columbus produced water will be discharged at Shearwater via existing facilities.

The proposed Arran to Shearwater pipeline forms part of the Arran Development, the licence operator for which is Dana Petroleum (E&P) Limited (hereafter referred to as 'Dana'). Dana is currently seeking consent for the Arran Development from the OGA and has recently submitted an ES to OPRED for consideration (Ref: D/4197/2017). A small section of the proposed Arran to Shearwater pipeline route, approximately 7.65 km in length, will need to be deviated to accommodate the Columbus Development (refer to Figure 1.1 for original Arran to Shearwater pipeline route and deviated section); the installation of which has been assessed in this ES. Sanction of the Columbus Field Development is therefore subject to sanction of the Arran Development.

Figure 1.1: Location of the Proposed Columbus Field Development



The location of the proposed Columbus infrastructure and Shearwater host facility is summarised in Table 1.1.

Table 1.1: Location of Proposed Columbus Development Infrastructure

Aspect	Columbus Tie-in Structure	Shearwater Platform
Location (Lat/Long) [1]	57° 20' 58.728"N 2° 05' 11.906"E	57° 1' 51.77" N 1° 57' 17.78" E
Block	Block 23/16f	Block 22/30b
ICES rectangle	43F2	43F1
Distance to UK coast	230 km	225 km
Distance to UK / Norway median line	8 km	26 km

[1] Coordinates given are based on international spheroid, European Datum 1950 (ED50), Central Meridian 3°E, Universal Transverse Mercator (UTM) projection, zone 31 North.

The proposed Columbus Development well (CDev-1) will be drilled from a either an anchored semi-submersible Mobile Offshore Drilling Unit (MODU) or a heavy duty drilling jack-up (HDJU). Subject to the necessary consents and approvals, Serica intends to drill the CDev-1 well sometime between Q4 2020 and Q2 2021. It is estimated that it will take 79 days to drill and complete the well. The well will then be suspended until installation of subsea infrastructure and hook-up in Q2 2021. First production is expected to be within the first half of 2021.

Columbus peak production rates are anticipated to be 337 million cubic metres (11.9 billion cubic feet) of gas per year by around Year four and 82,177 cubic metres of condensate per year by around Year two (P10 case). The peak produced water rate is 15,899 cubic metres (0.1 million barrels) of water per year (P10 case).

The Columbus subsea infrastructure will have a design life of 15 years and the economic field life is expected to be up to 14 years. On cessation of production, the Columbus facilities will be decommissioned in accordance with the requirements of the prevailing UK and International law.

1.3 Scope

The overall aim of the EIA is to assess the potentially significant environmental effects that may arise from development of the Columbus field and to identify any mitigation measures required to prevent or reduce what might otherwise be significant adverse effects on the environment.

The EIA process is integral to the project, assessing potential impacts and alternatives, and identifying design and operational elements to help reduce the potential impacts of the project on the environment as far as reasonably practicable.

On the 23rd May 2018, Serica met with BEIS to discuss the status of the Columbus Development project and the approach regarding the ES. The outcome of this meeting was used to inform the scope of the EIA and content of this ES.

The scope of the EIA undertaken for the Columbus Development includes:

- Drilling, commissioning and operation of the CDev-1 well;
- Installation, commissioning and operation of the Columbus spool piece and subsea manifold structure designed to tie the CDev-1 well into the Arran to Shearwater pipeline;
- Installation of the deviated section of the proposed Arran to Shearwater pipeline;
- The incremental emissions at the Shearwater platform as a result of processing the Columbus fluids.

The environmental impact of the installation of the remainder of the Arran to Shearwater pipeline, along with the commissioning, operation and maintenance of the entire pipeline, is assessed within Dana's Arran Project ES (Dana, 2018).

Impacts relating to the future decommissioning of the proposed Columbus Development are also outside of the scope of this ES; however, Section 2 outlines how future decommissioning requirements have driven the initial design of the project.

It is worth noting that the Columbus Development has previously been the subject of an ES (BEIS Ref: D/4085/2010). This assessed the development of the field via two subsea wells tied back to a new bridge linked platform (BLP) at the Lomond platform in UKCS Block 23/21. Although the ES was approved by the regulator, the project was later cancelled by the Lomond operator and development of the Columbus field was put on hold for commercial reasons. However, the views of a number of organisations, namely the Department of Energy and Climate Change (now the Department of Business, Energy and Industrial Strategy; BEIS), the Joint Nature Conservation Committee (JNCC), Marine Scotland, The Scottish Fisheries Federation (SFF) and the Ministry of Defence (MoD), were solicited prior to submission of the previous ES. The key issues raised during this consultation process (as documented in Appendix B) have been considered and addressed when relevant in this ES.

1.4 The Applicant

Serica Energy (UK) Limited is a subsidiary of Serica Energy plc, a British-based independent upstream oil and gas company. Its main focus is on production and development in the UKCS, complemented by a portfolio of oil and gas exploration opportunities, including interests in offshore licence blocks in the UK North Sea, Ireland and Namibia. Serica has been actively involved in exploration in the UKCS since 2001.

Serica is a partner with Chevron and Chrysaor in the producing Erskine field in the UK Northern North Sea and has also recently announced the purchase of interests in the Bruce, Keith and Rhum fields from BP. On completion of the transaction, Serica will take over as operator of the fields. Completion of the transaction is expected to occur in Q3 2018.

It is the policy of Serica Energy plc to manage all its activities and operations in a responsible manner that provide a safe, reliable and responsible operating environment for the well-being of staff and contractors, and comply with, or strive to surpass, all applicable legislation and industry best practices. Serica expects that all personnel and third-party organisations working for Serica share the values of protecting the environment and one another. The Columbus Development will therefore be undertaken in accordance with Serica's integrated Operations Management System (OMS) (refer to Section 11 for further details).

As the licence operator, Serica is responsible for the Columbus Development during all lifecycle phases of the project. Serica will also be the appointed well operator, subject to approval from the OGA, under The Offshore Petroleum Licensing (Offshore Safety Directive) Regulations 2015, and will manage the development drilling and well completion operations, as well as any future well intervention (maintenance) and subsequent well abandonment operations.

1.5 Legislation and Policy Framework

1.5.1 Environmental Legislation

The Petroleum Act 1998 establishes the regulatory regime which is applicable to oil and gas exploration and production in the UK. It vests all rights to the nation's petroleum resources in the Crown, but permits the Secretary of State for Business, Energy and Industrial Strategy to grant licences that confer exclusive rights to 'search and bore for and get' petroleum. The Petroleum Act is supplemented by various environmental Acts and Regulations, with which Serica will need to ensure compliance with.

As noted in Section 1.1, the EIA undertaken for the Columbus Development as reported in this ES has been carried in accordance with The Offshore Petroleum Production and Pipelines (Assessment of Environmental Effects) Regulations 1999 (as amended). These regulations require the undertaking of an EIA and production of an ES for certain types of oil and gas activities including developments which will produce 500 tonnes (approximately 3,750 barrels) or more per day of oil or 500,000 cubic metres or more per day of gas (not including well testing). Of note, is that The Offshore Petroleum Production and Pipe-lines (Environmental Impact Assessment and other Miscellaneous Provisions) (Amendment) Regulations 2017 have recently come into force implementing European Directive 2014/52/EU on the assessment of the effects of certain public and private projects on the environment (the "EIA Directive"). Changes to the legislation have been considered during the EIA process for Columbus.

Other environmental Acts and Regulations pertinent to the proposed Columbus Development and therefore considered during the EIA process include, but are not limited to:

- The Energy Act 2008 (as amended);
- The Marine (Scotland) Act 2010;
- The Marine and Coastal Access Act 2009;
- The Merchant Shipping (Oil Pollution Preparedness, Response and Cooperation) Regulations 1998 (as amended);
- The Merchant Shipping (Prevention of Pollution by Garbage) Regulations 1998;
- The Merchant Shipping (Prevention of Air Pollution from Ships) Regulations 2008 (as amended);
- The Offshore Chemicals Regulations 2002 (as amended);
- The Offshore Combustion Installations (Pollution Prevention and Control) Regulations 2013;
- The Offshore Installations (Emergency Pollution Control) Regulations 2002;
- The Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations 2015;
- The Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (as amended);
- The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (as amended);
- The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended);
- The Offshore Petroleum Licensing (Offshore Safety Directive) Regulations 2015.
- The Petroleum Licensing (Production) (Seaward Areas) Regulations 2008;
- The Marine Strategy Regulations 2010 (which implement the European Marine Strategy Framework Directive).

Further detail on these Acts and Regulations, as well as other international treaties and agreements such as the Oslo and Paris (OSPAR) Convention, and their applicability to the Columbus Development is provided in Appendix A.

1.5.2 Marine Planning

Scotland's National Marine Plan was published in March 2015. It sets out strategic policies for the sustainable development of Scotland's marine resources out to 200 nautical miles from the shore, with the aim of trying to achieve the UK's vision of having 'clean, healthy, safe, productive and diverse seas; managed to meet the long term needs of nature and people'. Appendix A outlines those policies which are applicable to the Columbus Development and have therefore been considered during the EIA process.

1.6 Structure of the ES

The structure of this ES is summarised in Table 1.2.

Table 1.2. ES Structure

Section Content	Content
Non-Technical Summary	A high level summary of the EIA to allow the non-specialist reader to understand the proposed Columbus Development and its potential environmental impacts.
Main Document	
Section 1: Introduction	Explains the background and purpose of the Columbus Development, introduces Serica and summaries the key issues raised during the stakeholder engagement process.
Section 2: Project Description	Provides an overview of the chosen field layout and the operations associated with each phase of the Columbus Development. It also outlines the main concept options (alternatives) considered for the Columbus Development.
Section 3: The Existing Environmental Baseline	Describes the current condition of the environment in the proposed Columbus Development area, with particular emphasis on those aspects which are likely to be affected by the proposed development operations.
Section 4: Assessment Methodology	Presents the impact assessment methodology used for the EIA.
Sections 5 – 10: Assessment Sections	These sections fully assess the identified potentially significant environmental impacts, define the proposed mitigation measures that will be implemented and evaluate residual impacts (i.e. they document the assessment results). Where relevant transboundary and cumulative impacts are also discussed.
Section 11: Environmental Management	Describes Serica's OMS and the management processes that will be applied throughout the Columbus Development project to ensure the safety and protection of people and the environment.
Section 12: Conclusions	Outlines the key findings of the EIA process.
Section 13: References	Provides a bibliography of data sources referenced in the ES.
Appendices	
Appendix A: Legislation and Marine Policy	Provides an overview of the key legislation and policy pertinent to the project.
Appendix B: Columbus Development Consultation Responses	Summarises the responses to the consultation process carried out as part of the previous Columbus Development ES (BEIS Ref: D/4085/2010).
Appendix C: Environmental Aspects Registers	Provides the environmental aspects registers for the project.
Appendix D: Survey Data	Provide a summary of the environmental survey data previously gathered in the vicinity of the Columbus Development.
Appendix E: Noise Propagation Modelling	Details the results of the simple noise propagation modelling undertaken for the project.
Appendix F: Atmospheric Dispersion Modelling	Provides a description of the simple atmospheric dispersion screening model used in this ES.
Appendix G: Oil Spill Modelling Study	Details the results of the oil spill modelling study undertaken for the project.

1.7 Contact

Requests for additional copies of this ES should be sent to the following e-mail address: fergus.jenkins@serica-energy.com.

Comments on the ES may be sent to OPRED by letter, fax or email and should be marked for the attention of:

Environmental Management Team
Department for Business, Energy and Industrial Strategy
Offshore Petroleum Regulator for Environment & Decommissioning
AB1 Building
Crimon Place
Aberdeen
AB10 1BJ

Email: EMT@beis.gov.uk

Fax: 01224 254019

2 Columbus Project Description

2.1 Columbus Reservoir

The Columbus field, located in UKCS Blocks 23/16f and 23/21a in the central North Sea, was discovered in November 2006 by the well 23/16f-11. The well found 82.90 metres of Forties sandstones and shales, of which approximately 40 metres was found to be hydrocarbon bearing.

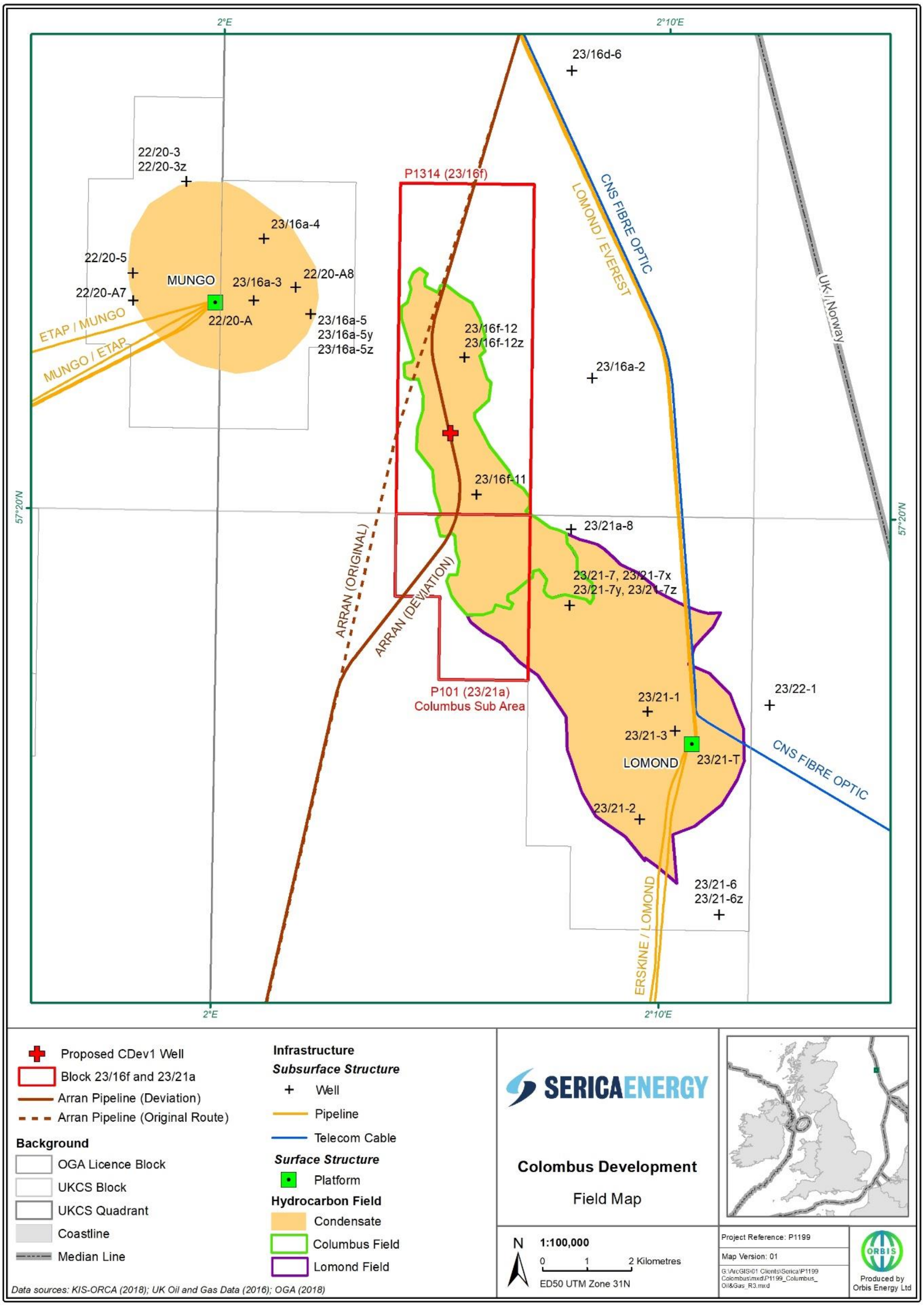
Following the Columbus discovery, appraisal drilling commenced in 2007. Two appraisal wells, 23/16f-12 and 23/16f-12z were drilled and both were successful. Well 23/16f-12 was drilled as a vertical well approximately three kilometres north of the Columbus discovery well and encountered gas/condensate-bearing Paleocene sands at a higher elevation than those tested in well 23/16f-11. The 23/16f-12 well was then sidetracked (12z) to a bottom hole location approximately 2.2 kilometres north of the Columbus discovery well and also encountered gas/condensate- bearing Palaeocene sands, similar to those found in 23/16f-11. The field was then further appraised by wells 23/21a-7x and 23/21a-7z. The Columbus field, license area and locations of the previous appraisal wells are illustrated in Figure 2.1.

The condensate from the Columbus reservoir has a 47°API gravity (ITOPF Group 1 oil) (Table 2.1). The reservoir fluids from the Columbus field are expected to have a low hydrogen sulphide (H_2S) concentration (<3 parts per million) and no sand production is anticipated.

Table 2.1: Columbus Condensate Assay

Property	Columbus Condensate
Water Content	0.36 %
Density (relative 60°F)	0.7893 gram/cubic centimetre
Molecular Weight	126 gram/mole
Upper Pour Point	-36 °C
C_7 Asphaltenes	<0.15 % weight
Wax Content	3.3 % weight
Salt Content	15 milligrams/mg
Total Acid Number	<0.05 milligrams of potassium hydroxide/gram
Sulphur Content	0.05 % weight
Mercaptans	<1 ppm
Calcium	1.8 mg/kg
Iron	0.31 mg/kg
Nickel	<0.5 mg/kg
Vanadium	<0.2 mg/kg

Figure 2.1: Columbus Field, License Area and Appraisal Well Locations



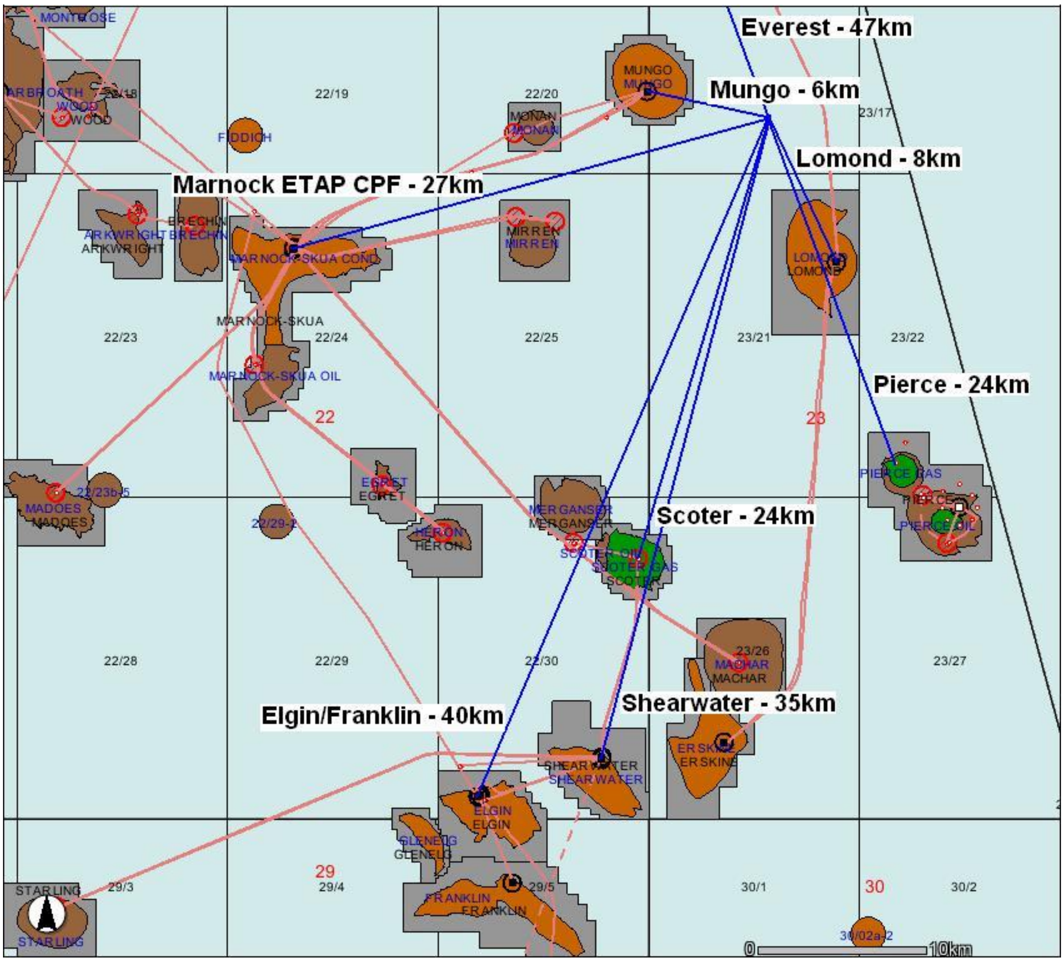
2.2 Project Alternatives

Serica and its partners have explored various options to develop the Columbus field over the past decade. In 2010, a concept selection study was undertaken to determine the optimum development plan for the field in terms of economics and technical risk/operability, with consideration also given to the potential for health, safety and environmental impacts.

The option to develop the field via a stand-alone platform at Columbus was discarded from the start of the study as the field's reserves are insufficient to make this option economic. The most efficient development involves utilisation of third party infrastructure, including pipelines and processing facilities.

A subsea development concept was therefore chosen to develop the field. Eight potential offtake routes were identified, involving four different pipeline export hosts to shore; the Central Area Transmission System (CATS) pipeline, the SAGE pipeline, the Graben Area Export Line and the Forties Pipeline System (FPS). These routes are presented in Figure 2.2.

Figure 2.2: Export Route Options Originally Considered in 2010 (RPS, 2011)



A number of factors were reviewed to compare the offtake options, including:

- **Tie-back length:** Flow assurance, installation (pipelines and umbilical) costs, pipeline crossings and environmental impact (seabed footprint);
- **Host processing capability:** Ullage (gas, oil and water), risers, slug handling, metering (for co-mingling and well testing), arrival pressure/temperature;
- **Host impact:** Back-out of production from existing facilities;

- **Host tie-in capacity:** Bedding, shutdown windows, existing equipment opportunities, heavy lift requirements;
- **Host export routes:** Gas and condensate;
- **Schedule impact:** Commercial agreements, engineering/fabrication/installation time;
- **Cost:** Life of field costs associated with the above (DEVEX including CAPEX and OPEX).

An initial screening based on environmental, economic and technical risk/operability considerations eliminated four of the options as outlined in Table 2.2.

Table 2.2: Columbus Field Development Options Eliminated

Offtake Route	Distance to Columbus	Reasons for Elimination
Everest	47 km	• High environmental impact due to very long export pipeline route required; • Too far away to support flow assurance requirements.
Pierce	24 km	• High environmental impact due to fairly long export pipeline, and due to emissions from tankers travelling to/from FPSO; • Extensive modifications to asset plans required; • Very high cost; • High Installation risk.
Shearwater	35 km	• High environmental impact due to very long export pipeline route required; • Extensive modifications to asset plans required; • Very high cost; • High Installation risk; • Disruption to gas export line during installation.
Elgin/ Franklin	40km	• High environmental impact due to very long export pipeline route required; • Extensive modifications to asset plans required; • Very high cost; • High Installation risk; • Disruption to gas export line during installation.

The remaining four options were considered further:

- Connection to ETAP CPF through existing gas riser and umbilical with methanol / corrosion inhibitor, wax inhibitor and new topsides metering, pipework and compression upgrade;
- Connection to Mungo platform through new topsides systems, export via CATS/FPS;
- Connection to Lomond platform with new bridge linked platform, export via CATS/FPS;
- Connection to Scoter sub-sea manifold with umbilical supplying chemicals, power and hydraulics connected to Shearwater.

Of these, the Mungo and Lomond offtake options were considered the best options in terms of environmental impact as they had the shortest export pipeline routes and therefore the smallest seabed footprint. However, the Mungo platform was deemed to have insufficient spare capacity for Columbus and possible tiebacks from additional field developments in the area. Therefore, the Lomond offtake option was selected for tieback of the Columbus Development.

An ES (RPS, 2011; Ref: D/4085/2010) and FDP covering the Lomond offtake option were submitted to the regulator by Serica and subsequently approved; however, the project was later cancelled by the Lomond operator and development of the Columbus field was put on hold for commercial reasons.

More recently, two alternative development options have been technically evaluated by Serica and their partners:

- A subsea development well in Block 23/16f tied back to the proposed Arran to Shearwater pipeline;
- An extended reach well drilled from the Lomond Platform operated by Chrysaor.

Following technical and commercial evaluations, development via the proposed Arran to Shearwater pipeline has been selected as the preferred option. The primary driver for the decision was the risk that there would not be a reliable export route for Columbus via Lomond because of ongoing waxing issues with the Lomond to Everest condensate line.

In addition, analysis was conducted to see whether two wells at Columbus would produce significantly more gas; however, it was concluded that the level of incremental production is insufficient to justify the second well, consequently the single well option remains the preferred development solution.

It should be noted that the Columbus project is subject to sanction of the Arran project. The Arran project is currently finalising Front End Engineering Design (FEED) and the Arran Project ES (Dana, 2018) was submitted to OPRED in April 2018.

2.3 Overview of the Columbus Facilities

The development strategy for Columbus is to drill a single, north-to-south, horizontal well (CDev-1) along the centre of the field which is designed to access reserves from the majority of the field. The well will be tied-in to the proposed Dana operated Arran to Shearwater pipeline via the Columbus Tie-In Structure (CTIS). Production from the CDev-1 well will comingle with production from the Arran field in a 12" pipeline to the Shell operated Shearwater platform, located approximately 43 km to the south west of Columbus. At Shearwater, the production stream will undergo separation into wet gas and liquid streams. The Columbus gas will be compressed and exported to St. Fergus via the Shell Esso Gas and Associated Liquids (SEGAL) system. Columbus associated hydrocarbon liquids will be exported to the Forties Pipeline System (FPS) via the Graben Area Export Line (GAEL). Columbus produced water will pass to the existing produced water system. No modifications to the Shearwater processing systems are required to accommodate Columbus (refer to Section 2.5).

The proposed Arran to Shearwater pipeline route (as detailed in the Arran Project ES; Dana, 2018) will need to be adjusted to pass adjacent to the Columbus well. It is not possible to tap into the existing proposed route via a short section of pipeline from the proposed CDev-1 well due to a flow assurance issue; a short dead-leg would result in hydrate formation issues in the dead leg in the event the CDev-1 well is shut-in and the line cools down under pressure. Re-routing the proposed Arran to Shearwater pipeline minimises this risk.

The Columbus Development field schematic and its interaction with the Arran Development is shown in Figure 2.3.

Figure 2.4 shows the tie-in arrangement at Columbus. A spool piece will connect the CDev-1 well to the CTIS.

Coordinates for key elements of the Columbus Development are provided in Table 2.3.

The design life of the Columbus subsea infrastructure is a minimum of 15 years and the economic field life is expected to be up to 14 years.

Table 2.3: Location of Columbus Infrastructure

Location	Geographical [1]		UTM Zone 31N	
	Latitude	Longitude	Easting	Northing
Columbus Tie-In Structure	57° 20' 58.728"N	2° 05' 11.906"E	445 035	6 356 820
CDev-1 Well	57° 20' 58.483"N	2° 05' 13.767"E	445 066	6 356 812

[1] Coordinates given are based on international spheroid, European Datum 1950 (ED50), Central Meridian 3°E, Universal Transverse Mercator (UTM) projection, zone 31 North.

Figure 2.3: Overview of the Combined Arran and Columbus Infrastructure

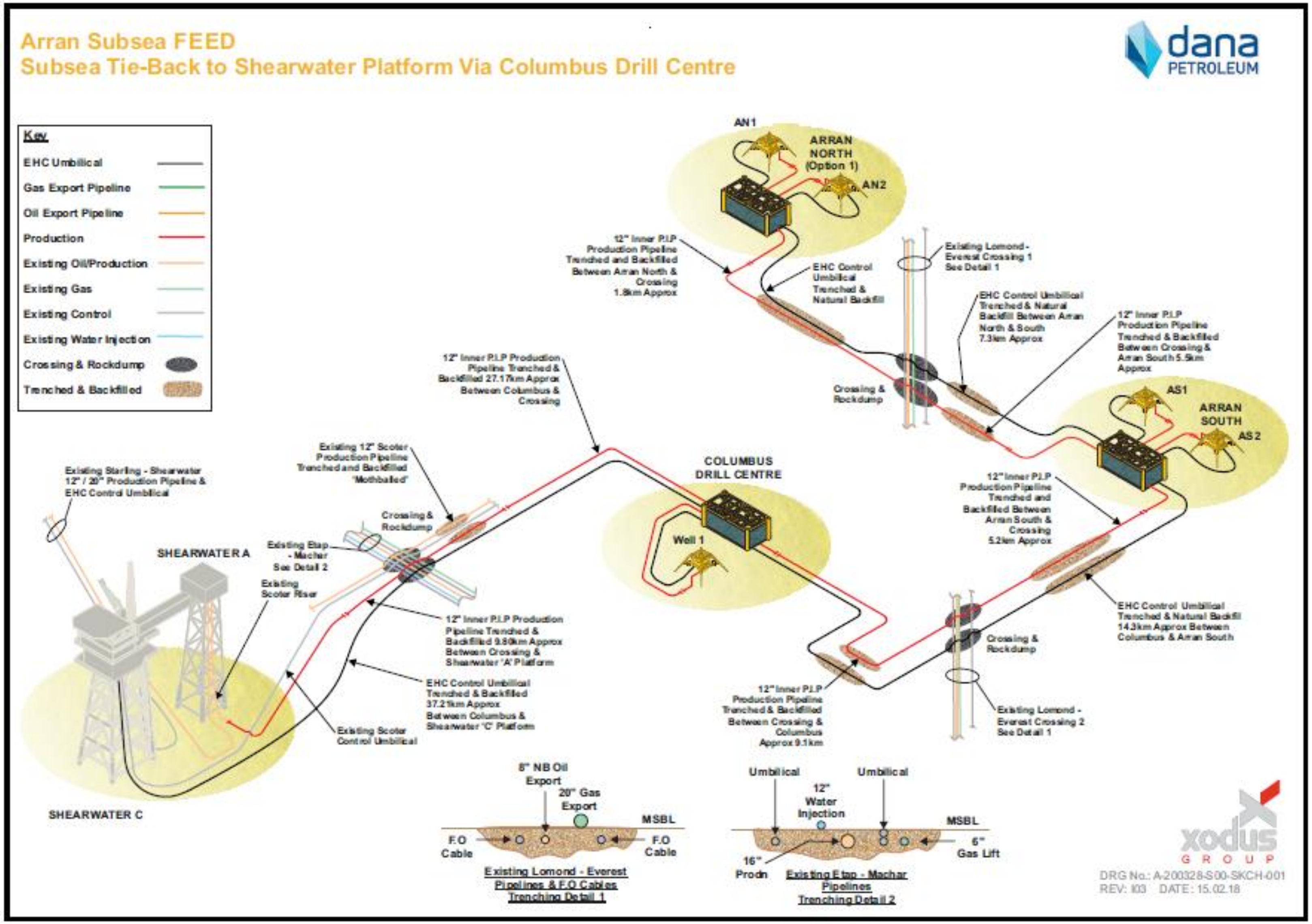
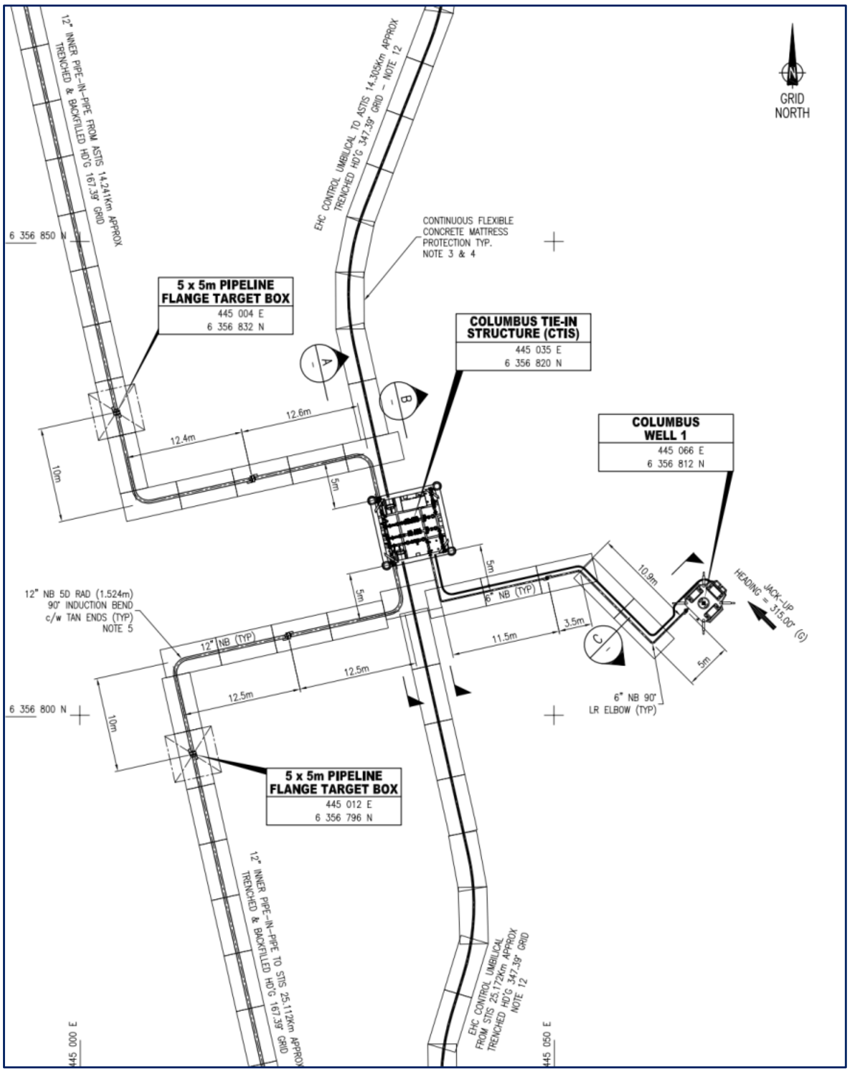


Figure 2.4: Columbus Tie-in General Arrangement



2.4 Subsea Infrastructure Description

2.4.1 Well Head and Christmas Tree

The CDev-1 well will have a Christmas (Xmas) tree installed on top of its wellhead. The subsea tree is the main barrier between the reservoir and the primary well control element, and also provides a mechanism for flow control and well entry.

During drilling, the subsea tree will be controlled from the drill rig whilst during production the subsea tree will be remotely controlled from Shearwater.

The well will have a down-hole safety valve installed which is an isolation device that is hydraulically operated and fail-safe closed. Primary well control will be achieved through an arrangement of hydraulically operated valves (including the downhole safety valve) to provide pressure integrity barriers between reservoir and surface.

The Xmas tree will be fitted with a Subsea Control Module (SCM) for the control of the valves and monitoring of the well. The SCM is provided with hydraulic and electrical supply from the common Arran and Columbus umbilical from Shearwater via the subsea distribution unit located at the CTIS. As the system will be open loop (i.e. fluids are discharged on each actuation), hydraulic fluid will be selected with due consideration to potential environmental impact. Manual (diver) and ROV operable valves will also be provided to facilitate isolation and intervention.

The wellhead and Xmas tree system will be protected by industry standard fishing friendly structure (FFS) measuring in the order of 9.5 m (length) by 9 m (width) by 5.5 m (height), designed to ensure the tree and its connections are not damaged by dropped objects or impacts and snagging loads associated with fishing gear. Of note is that the FFS is installed as an integrated structure with the Xmas tree. The legs are locked in position by remotely operated vehicle (ROV) and are gravity-deployed with the leg strakes embedding into the seabed, hence there is no piling requirement.

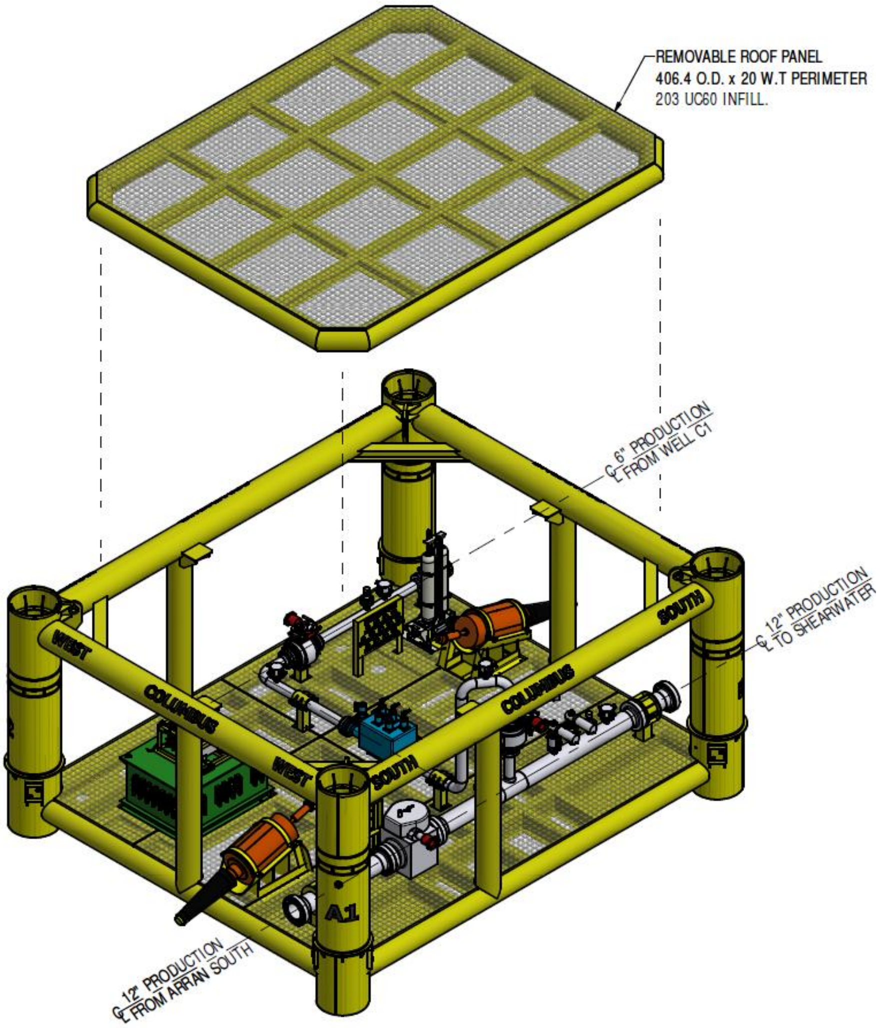
2.4.2 Tie-In Structure

The CTIS will comprise pipework and valves which permit the commingling of fluids from the CDev-1 well into the Arran to Shearwater pipeline. In addition, it will provide the distribution point for the umbilical services (hydraulic fluid, chemical injection and communication capabilities) to the Xmas tree.

The CTIS will be of slab sided 'fishing friendly' design with snag free details to limit potential for fishing gear snagging and allow gear to be recovered in the event that interaction with fishing gear occurs. The structures and foundations will be designed for potential fishing gear snag loads and will therefore incorporate piled foundations to resist these potential loads. Roof panels will be provided to avoid ingress of fishing gear into the structures and provide protection from dropped objects.

The precise design of the CTIS is still to be determined; a preliminary view is shown in Figure 2.5.

Figure 2.5: Isometric View on CTIS



The indicative dimensions of the CTIS structure are 9 m (length) by 7.5 m (width) by 4.5 m (height).

It is anticipated that the subsea CTIS structure will be held in place by four pin piles, one at each corner, each with a diameter of 0.6 m and length of 20 m. Structure installation will be from a construction vessel, with a ROV used during piling.

It is Serica's intention to apply for a 500 m safety zone to be in place around the well and CTIS to minimise the potential for fishing interactions.

2.4.3 Pipeline and Umbilical

Production from the Columbus wellhead will flow to the CTIS via a dedicated tie-in spool (approximately 36 m in length). The CTIS will tie-in to the proposed Arran-Shearwater pipeline where Columbus production will be comingled with Arran production.

The Arran to Shearwater pipeline consists of 12 inch diameter internal pipe contained with an outer carrier pipe, up to 18 inch in diameter, with insulation within the annulus forming what is called a 'pipe-in-pipe' system. A 4.5 inch (outside diameter) chemical injection and control umbilical will run alongside the Arran pipeline from the Shearwater platform to the Columbus wellhead. A scale inhibitor tank and pump on Shearwater will provide scale and wax inhibitor to Columbus, as required. The umbilical will be connected to the umbilical terminal assembly in the CTIS. The umbilical terminal assembly will then distribute the required hydraulic fluid, chemical injection and communication capabilities to Xmas tree (refer to Section 2.4.1).

As discussed in Section 2.3, the proposed Arran to Shearwater pipeline route, along with the umbilical route, will need to be deviated to accommodate the CTIS. The deviated section of the route is described and assessed in this ES, with the remainder of the route described and assessed in the Arran Project ES (Dana, 2018).

The deviated section of the Arran to Shearwater route is approximately 7,650 m in length. The deviation adds approximatively 800 m to the overall Arran to Shearwater route length. Coordinates for the northern end and the southern end of the deviated section of the pipeline are provided in Table 2.4.

Table 2.4: Location of Northern and Southern End of the Deviated Pipeline Section

Location	Geographical [1]		UTM Zone 31N	
	Latitude	Longitude	Easting	Northing
Northern Deviation of Arran to Shearwater Pipeline	57° 22' 06.732"N	2° 04' 40.229"E	444 534	6 358 934
Southern Deviation of Arran to Shearwater Pipeline	57° 18' 01.605"N	2° 02' 48.013"E	442 553	6 351 376

[1] Coordinates given are based on international spheroid, European Datum 1950 (ED50), Central Meridian 3°E, Universal Transverse Mercator (UTM) projection, zone 31 North.

Figure 2.6 presents the location of the CDev-1 well within the overall field layout and Figure 2.7 shows the deviated section of the Arran to Shearwater pipeline.

Figure 2.6: Overall Field Layout Including Columbus Development Location

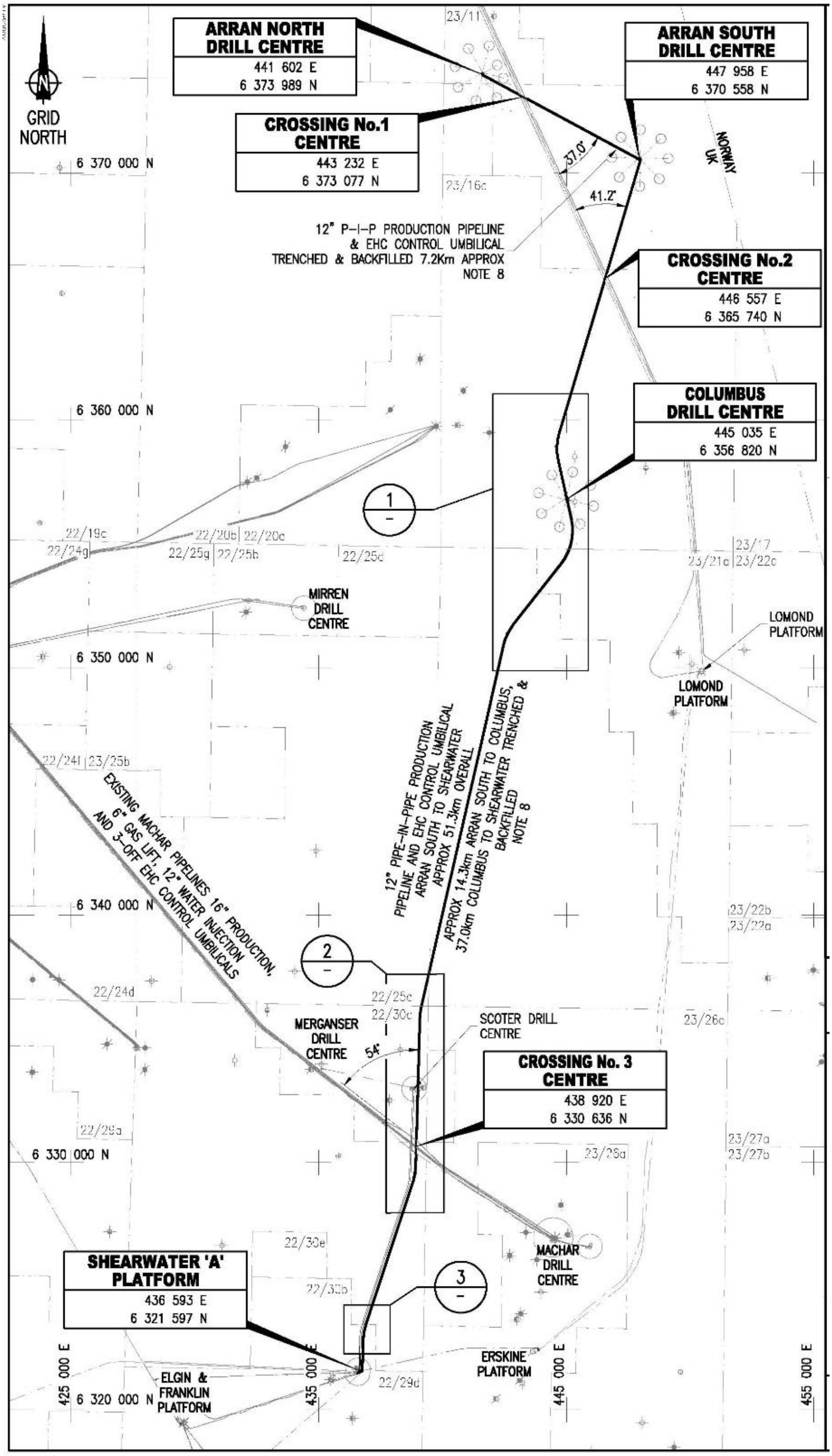
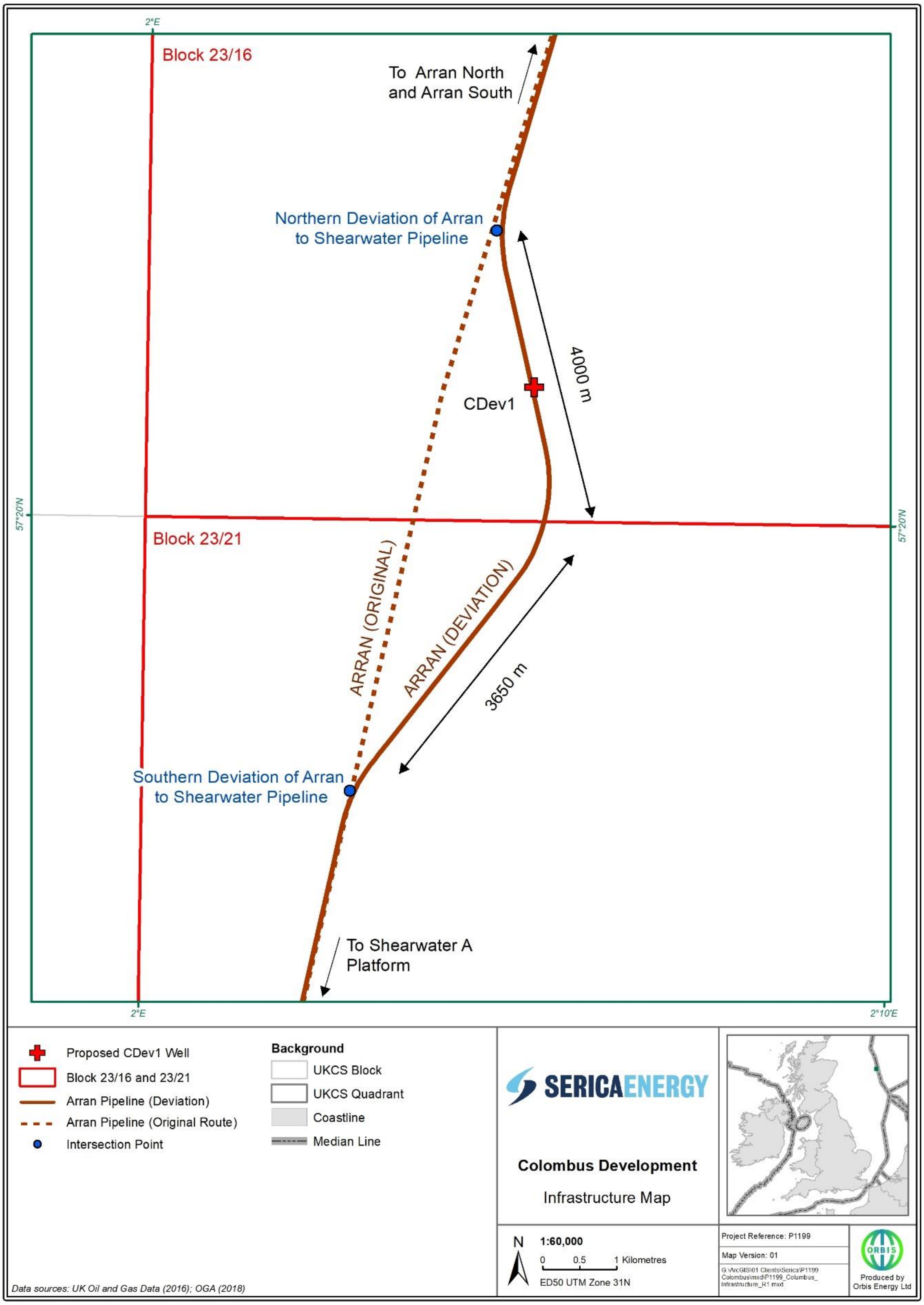


Figure 2.7: Deviated Section of Arran to Shearwater Pipeline



2.5 Host Facility

It is proposed that the Columbus reservoir fluids will be processed on the Shearwater C platform and exported to shore via existing infrastructure. Shearwater C is a Shell-operated normally manned Process, Utilities and Quarters platform that is bridge linked to Shearwater A, a Wellhead Platform (Figure 2.8). The platform is located in UKCS Block 22/30, approximately 225 km east of the Scottish coastline and 26 km from the UK/Norway median line. The proposed Arran pipeline will tie back to the existing Scoter riser on the Shearwater A platform.

As described in the Arran Project ES (Dana, 2018), the predicted flow rates and operating conditions of the combined Arran and Shearwater production can be handled by the existing Shearwater topsides, with the exception of the produced water handling system. As such, there are limited modifications to be made at Shearwater:

- Shearwater A:
  - A new multiphase flow meter may be required as a replacement to the existing wet gas meter currently installed on the Scoter pipework. Alternatively, a change will be made to the instrumentation on the existing venture meter to provide the necessary flow range.
- Shearwater C:
  - Additional produced water handling capacity;
  - A new topside umbilical termination unit will link the electrical, hydraulic, chemical and communication components of the umbilical to the Shearwater topsides;
  - Three additional chemical injection pumps and tanks for methanol and corrosion and scale inhibitor;
  - New hydraulic power unit to deliver hydraulic control fluid to the Arran field;
  - A new electrical power unit to supply the necessary power to the subsea system at Arran North and South; and
  - Replacement Master Control Station (for controlling and retrieving data from the subsea equipment).

To support this work, an anchored walk to work vessel (an accommodation vessel that will connect to the platform by a hydraulic gangway) will be present for approximately 42 days in 2020.

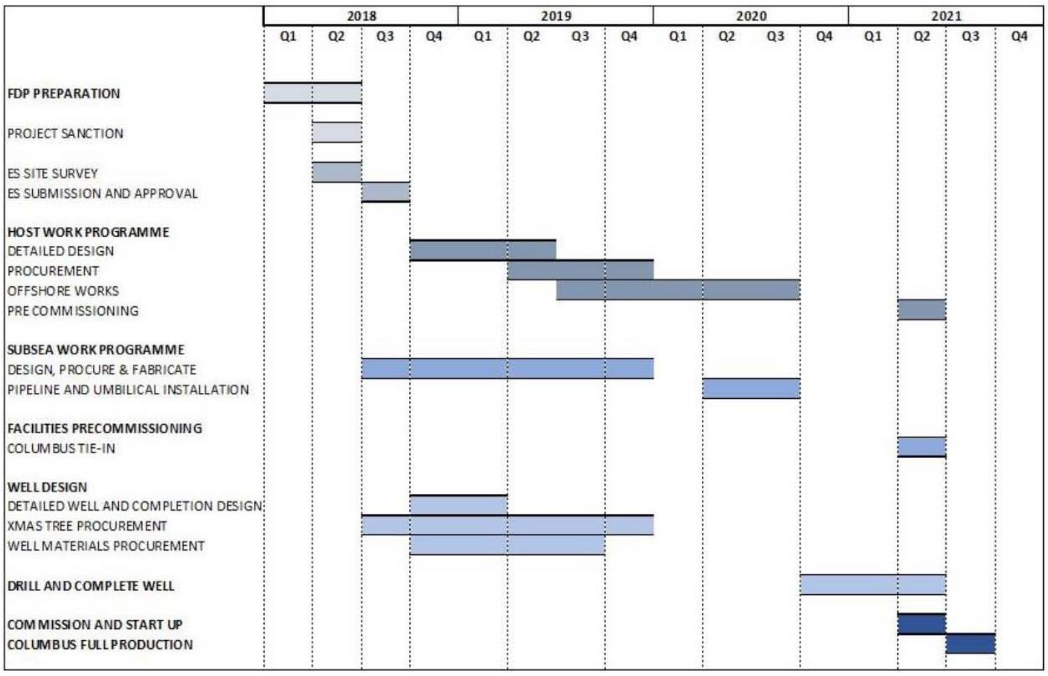
The environmental impacts of these modifications and associated activities have been assessed in the Arran Project ES (Dana, 2018). No additional significant modifications to the Shearwater platform are required in preparation of the tie-in of the Columbus Development.

Figure 2.8: Shearwater A (right) and Shearwater C (centre) (with a jack-up in attendance

2.6 Project Schedule

The Columbus Development schedule is dependent upon the progress of the Arran Development. An indicative project schedule is provided in Table 2.5. The Columbus well cannot be connected to the Arran system until the latter is in place and a definitive schedule for installation of the Arran facilities is not yet available. For technical reasons Columbus will normally flow only when Arran is flowing, so the schedule is based upon Columbus first production after the Arran field has started up and is producing satisfactorily. For these reasons the schedule in Table 2.5 is indicative only.

Table 2.5: Preliminary Schedule for the Columbus Development



In summary, subject to obtaining the necessary consents and approvals, Serica intends to drill the CDev-1 well sometime between Q4 2020 and Q2 2021. Once complete, the well will be suspended and left until installation of subsea infrastructure, hook-up and commissioning in Q2 2021. First production is expected to be within the first half of 2021.

2.7 Drilling Operations

2.7.1 Overview of Proposed Drilling Operations

Serica is proposing to drill one horizontal production well, the CDev-1 well, in UKCS Block 23/16f to develop the Columbus field. Well design work is still being progressed; however, for the purposes of this assessment a long deviated well has been assumed, the total length of the well is expected to be around 6,608 m with the total vertical depth subsea of around 2,986 m.

The CDev-1 well will be drilled during the initial field development phase, with the earliest spud date anticipated to be in Q4 2020.

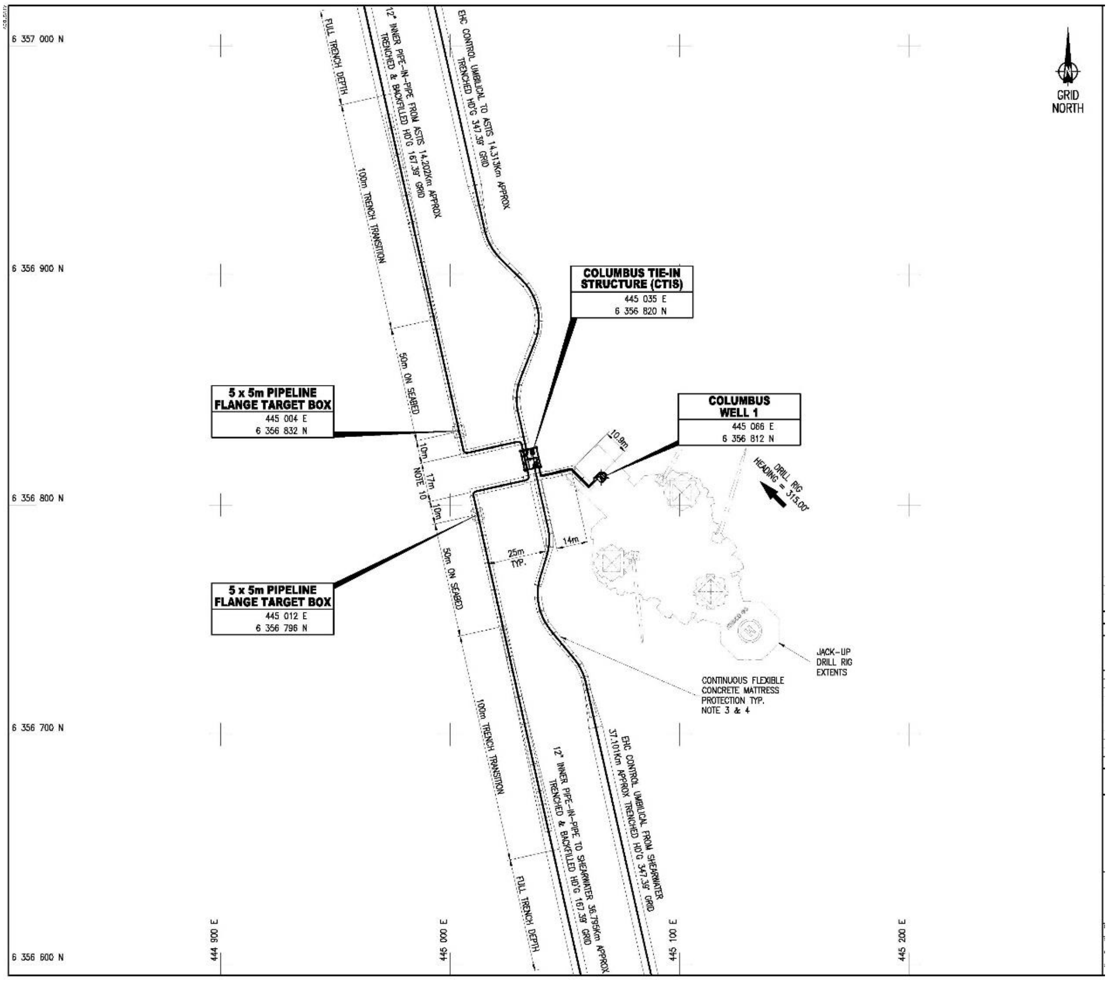
The drilling of the CDev-1 well is likely to be conducted using a semi-submersible MODU or a Heavy Duty Jack-Up (HDJU). It is anticipated that the well will take approximately 79 days to complete. This is a conservative estimate, used for assessing the worst-case environmental impact.

If a semi-submersible MODU is selected, it will be moored in position using eight anchors (each anticipated to be around 2,500 m in length). Three anchor handling vessel will be required to tow and moor the MODU in place. The exact MODU to be used for the drilling programme has yet to be confirmed and therefore, the anchor patterns are not currently available.

If the HDJU is selected this will use spud cans to remain on location; typically, HDJU's have three or four spud cans.

Figure 2.9 shows the location of the MODU in relation to the Columbus infrastructure; this is indicative only. The positioning of the MODU will be finalised at a later stage depending on the specifications of the MODU involved in the drilling operation.

Figure 2.9: Location of the MODU in Relation to the Columbus Infrastructure



2.7.2 Well Design

The well will be drilled using lengths of steel pipes and tools which comprise the drill string. A drill bit is situated at the end of the drill string which rotates to penetrate the seabed and the underlying geological formations. The type of drill bit can be changed depending on the characteristics of the rock formations being targeted. The drill string is hollow in order for drill fluids (termed 'muds') to be circulated into the wellbore in front of the drill bit and then back up the annulus (the gap between the drill string and the casing) to be cleaned and recycled on the MODU. Drilling mud serves a number of functions including cooling the drill bit, circulating rock fragments back up to the rig, maintaining hydrostatic pressure within the wellbore, and lubricating the drill bit and drill string.

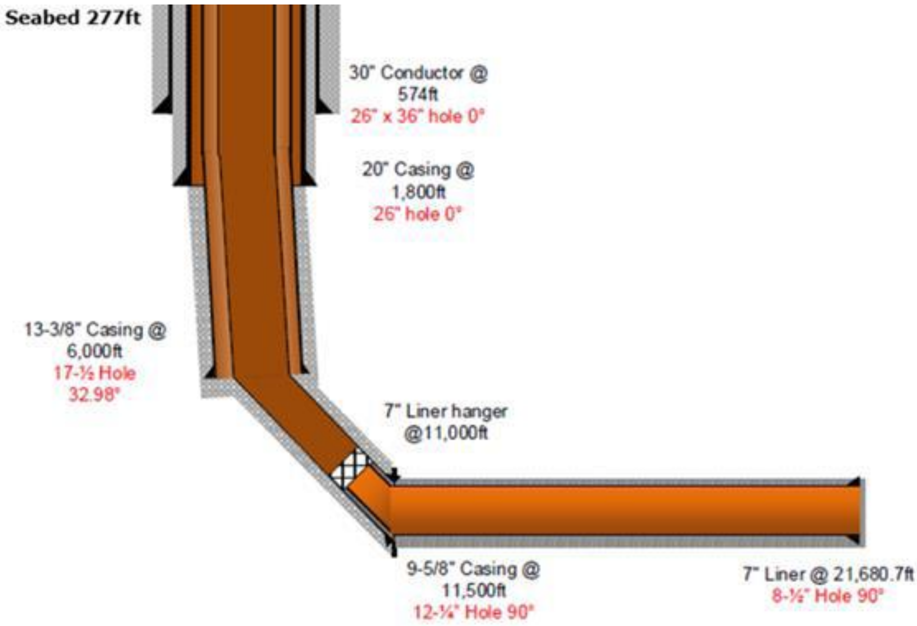
The CDev-1 well is planned as a standard North Sea configuration subsea well, completed with either a horizontal or vertical xmas tree system (refer to Section 2.4.1). The well will be drilled in sections, with each section decreasing in diameter towards the reservoir section, or 'payzone'. To assess the worst case scenario, it is assumed that the length of the horizontal payzone section will be extended to 11,000 ft (3,353 m), thus maximising the production zone.

Once each section of the well is completed, the drill string will be lifted and protective steel pipe or casing will be lowered into the well and cemented into place. The steel casing helps to strengthen and maintain the stability of the hole, isolating unstable formations from the wellbore and also helps to reduce mud losses from the wellbore into surrounding rock formations.

The proposed well design and well profile for the CDev-1 well are detailed in Figure 2.10 and Table 2.6 respectively. For the CDev-1 well a 36 inch-diameter top-hole section will be drilled, into which a 30 inch-diameter conductor pipe will be cemented. A 26 inch section will then be drilled through the conductor and a 20 inch-diameter steel casing will be installed and cemented into place. Following this, the wellhead and blowout preventer (BOP) will be installed, and a marine riser (a conduit from lengths of steel pipe) will connect the wellhead and BOP to the MODU. The riser will also allow drilling mud to be returned for treatment on the MODU and to be cycled repeatedly through the well.

A 17½ inch section will then be drilled through the conductor and a 13⅜ inch-diameter steel casing will be installed and cemented into place, followed by the drilling of a 12¼ inch section and the installation of a 9⅝ inch-diameter casing. Finally, the 8½ inch wellbore section will be drilled through the reservoir and a 7 inch-diameter liner will be installed in place.

Figure 2.10: Indicative Design of CDev-1 well



No sand production is anticipated therefore no sand screens will be required and a low H_2S concentration (<3 parts per million) is expected in the Columbus reservoir fluids.

Table 2.6: Indicative Profile of CDev-1 well

Well Section Hole Diameter (inches)	Casing Diameter (inches)	Casing Type	Indicative Section Length (ft)	Indicative Section Length (m)
36	30	Conductor	574	174
26	20	Casing	1,226	373
17½	13⅜	Casing	4,200	1,280
12¼	9⅝	Casing	5,500	1,676
8½	7	Production liner	10,181	3,103
		Total	**21,681**	**6,608**

2.7.3 Drilling Fluids and Chemicals

During drilling operations, a variety of chemicals will be used to facilitate the drilling processes and the safe completion of the well including drilling fluid (or mud) chemicals, cementing chemicals, well clean-up and completion chemicals. In addition, a number of chemicals will be used on the MODU for maintenance, such as detergents to wash the MODU and lubricants for certain equipment and machinery. Each BOP will also requires chemicals for control and operation in the form of hydraulic fluids.

The use and discharge of these chemicals in offshore waters are regulated through The Offshore Chemicals Regulations (2002) (as amended) (refer to Appendix A). Prior to drilling the well, Serica will seek consent for the use and discharge of specific chemicals during the proposed drilling operations via a Drilling Operations Master Application Template (MAT) and associated Chemical Permit Subsidiary Application Template (SAT) via the Portal Environmental Tracking System (PETS) on the UK Oil Portal. Chemicals will be subject to an environmental risk assessment, where applicable and products with an improved environmental profile will be preferentially selected for use.

The following sections provide a summary of the expected drilling mud and chemicals for the CDev-1 well.

Drilling Muds

Drilling muds perform a number of functions including maintenance of downhole pressure, removal of drill cuttings, lubricating the drill string and drill bit, and depositing an impermeable cake on the side of the wellbore thus sealing and stabilising the formations being drilled.

For the CDev-1 well the top-hole sections (36 and 26 inch) will be drilled with a water-based mud (WBM) and will be drilled without a marine riser connecting the wellbore to the MODU. As such, the WBM will be pumped through the hollow drill-string and out into the wellbore through nozzles in the drill bit. Periodically, small volumes of the WBM will be pumped through the borehole to flush drilled material from the borehole. Without a riser, the associated cuttings and drill fluids, will return to the seabed from the wellbore. It is expected that most, if not all, WBM chemicals will comprise naturally occurring products (such as barite and bentonite) that are either biologically inert or readily dispersible or biodegradable, posing little or no threat to the environment.

Following the completion of the 26 inch section, a BOP and marine riser will be installed and the lower sections of the well will be drilled with low toxicity oil-based mud (LTOBM) due to the presence of unstable shale formations in the well bore. A typical LTOBM contains base oil, calcium chloride brine, an emulsifying surfactant, lime and organophillic clay.

Cuttings contaminated with LTOBM will be returned to the MODU to pass through the mud return line and will be processed by a series of solids control equipment. This will separate the rock fragments (cuttings) from the drilling mud, with the cuttings being contained in enclosed skips on the MODU until they can be skipped and shipped to shore for onshore processing and disposal at a licenced treatment and landfill site. The recovered LTOBM will be recycled downhole by the mud pump in a closed loop system, ensuring that the mud is continuously recycled during the drilling programme.

Estimates of cuttings generated and the proposed disposal route are summarised in Table 2.7.

Table 2.7: Estimated Quantity of Cuttings Generated from Drilling the Columbus Well

Well Hole Diameter (inches)	Mud Type	Fate	Estimated Weight of Cuttings (tonnes) [1]
36	WBM	Returns to seabed	297
26	WBM		332
17½	LTOBM	Ship to shore	516
12¼	LTOBM		331
8½	LTOBM		295
		Total	**1,772**
		Total WBM Cuttings	**629**
		Total LTOBM Cuttings	**1,143**

[1] Density of cuttings is assumed to be 2.6 tonnes per cubic metre.

It is anticipated that around 2,661 tonnes of drilling mud may be required for the CDev-1 well, with around 19% of the mud discharged. However, these are figures are indicative only and subject to change as at the time of writing this ES detailed engineering studies covering the CDev-1 drilling program have not yet been carried out.

Cement

Following completion of each well section, the steel casings will be cemented in place to form a seal between the casing and formation. Most cement will remain in the annulus between the casing and the rock formation but some will be discharged as excess cement is pumped which may reach the seabed and provides visual confirmation that the cement job is complete. Some cement and chemicals may be discharged as the cementing unit is cleaned between sections. The quantity discharged will be minimised by constant monitoring of the cementing operation and mixing of the cement as required.

It is anticipated that around 80.5 tonnes of cement may be required for the CDev-1 well, with around 10 % of cement discharged. However, as mentioned above, detailed engineering studies were not available at the time of writing this ES and therefore, these figures are indicative only.

Well Testing and Clean-Up

Prior to production, the well will be cleaned up to remove any waste and debris remaining in the well to prevent damage to the pipeline or topsides production facilities. A well test may then be conducted at the MODU to obtain reservoir information and fluid samples. The likely sequence of events for well testing and clean-up will be as follows:

- Open well and flow;
- Initially the well will produce only sodium chloride brine which will be discharged to sea via the drilling rig;
- The water/hydrocarbon interface fluids will be captured and tested:
  - If oil in water concentration is equal to or below 30 milligrams per litre (mg/l) then the fluids will be discharged overboard in accordance with permits; or
  - If oil in water concentration is above 30 mg/l they will be filtered until they are below 30 mg/l for overboard discharge.
- Produced hydrocarbons will be flared;
- Clean-up will be monitored to capture data on the amount of water and suspended solids in the produced fluids (called the basic sediment and water specification);
- After the well has been cleaned up, the well may be flowed for a test period of up to 96 hours, during which time up to 2,000 tonnes of equivalent hydrocarbon may be flared; and
- Close well in, ready for production.

Should further detailed well test design identify the need for well clean-up and flow testing more than 2000 tonnes or longer than 96 hours to achieve the test objectives, an application for Consent for Test Production will be submitted, with such application for “Consent” setting out the timetable and objectives of the test and quantities of oil and gas to be produced, saved or flared. If undertaking an extended well test, Serica will ensure that the rate of oil production complies with the requirements of the Consent for Test Production (EWT).

2.7.4 Solid Wastes

As well as drilling fluids and cuttings, a number of other waste materials will be generated during drilling operations. These will be stored on the MODU and returned to shore for recycling and disposal. Wastes are segregated into hazardous (special) and non-hazardous groups. Non-hazardous waste includes:

- Segregated recyclables (paper, glass, cardboard and aluminium cans);
- Scrap metal; and,

- Non-hazardous paints and chemicals.

Examples of hazardous wastes include:

- Oils and lubricants;
- Hazardous chemicals and drums/containers containing hazardous residues; and,
- Batteries and electrical equipment.

The typical amount of waste generated during a drilling campaign is about 30 tonnes per month.

2.7.5 Support Operations

Table 2.8 presents an overview of the vessels that will be required during the drilling phase of the Columbus Development.

Assuming that a semi-submersible drilling rig will be used, three anchor handling vessels will be used to tow and moor the MODU in place.

For the duration of the drilling programme, an Emergency Rescue and Recovery vessel (ERRV) will be stationed in the vicinity of the rig to assist in the event of an emergency. The ERRV will be able to accommodate the entire complement of the MODU personnel and, if required, will come alongside the MODU to assist in the event of an emergency.

In addition, the MODU will also be supported by a single supply vessel operating out of a supply base in Aberdeen. It is anticipated that the supply vessel will visit the MODU three times per week during the drilling operations.

Rig crews will be transferred to and from the MODU by helicopter. Typically around four scheduled flights will be made to the MODU per week from Aberdeen for the duration of the drilling programme.

Table 2.8: Vessel and Helicopter Overview for Columbus Drilling Campaign

Vessel	Function	Typical Fuel Consumption	Typical POB	Duration in Field
MODU	Drill CDev-1 well	15 tonnes / day [1]	100	79 days
ERRV	Assist in the event of an emergency	8 tonnes / day [2]	15	79 days
Anchor handling vessel (x3)	Moor MODU	50 tonnes / day [2] (150 tonnes / day for 3 vessels)	10	6 days
Supply vessel	Logistic support and transportation of goods, tools, equipment	20 tonnes / trip[2]	15	3 visits / week (68 days)
Helicopter	Transfer crew to and from MODU	0.655 tonnes / hour [3]	-	4 return flights / week

[1] Based on diesel fuel use by example of MODU (Sedco 704).
[2] Typical fuel consumption based on maximum (in transit) values from IoP (2000).
[3] Based on speed of 262.6 km per hour (*Eurocopter, 2009*).

2.7.6 Discharge and Emissions Summary

Table 2.9 provides a worst-case estimate of the emissions to atmosphere arising from routine operations associated with the proposed Columbus drilling operations. The atmospheric emissions associated with the well clean-up operation are based on the maximum volume of 2,000 tonnes of gas being flared within a 96 hour period.

Table 2.10 provides a summary of the main marine discharges and carbon dioxide (CO_2) and waste emissions arising from routine operations associated with the proposed Columbus drilling operations.

Table 2.9: Estimated Atmospheric Emissions during Columbus Drilling Operation (based on values in Table 2.8)

Emission Source	Total Emissions (tonnes) [1 2]							
	CO_2	CO	NO_X	N_2O	SO_2	CH_4	VOC	CO_{2e}[3]
Fuel Usage: 3,454 tonnes of diesel	11,912	57.8	218.4	0.84	14.9	0.7	7.4	12,173
Flaring: 2,000 tonnes of gas	5,600	13.4	2.4	0.16	0.03	90	10	7,898
Total:	17,512	71.2	220.8	1	14.9	90.7	17.4	20,071

[1] Emissions factors from DECC (2008).
[2] Assumes four return flights to Aberdeen, located 255km from CDev-1 well, per week.
[3] Carbon dioxide equivalent (CO_{2e}) is a term for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gas, CO_{2e} signifies the amount of CO_2 which would have the equivalent global warming impact (refer to Section 8.4.1).

Table 2.10: Estimated Quantification of Key Discharges and CO_2 Emissions Associated with the Columbus Drilling Operations

Discharge / Emission		Estimated Quantity Disposed / Discharged	Fate
WBM	Drilling fluids	507 tonnes	Discharged to sea
	Cuttings	632 tonnes	Discharged to sea
LTOBM	Drilling fluids	2,154 tonnes	Returned to shore
	Cuttings	1,143 tonnes	Returned to shore
Cement[1]		8 tonnes	Discharged to sea
Power generation (Table 2.9)		20,071 tonnes	CO_{2e} emitted to atmosphere
Wastewater (greywater and blackwater) [2]		3,845 cubic metres	Discharged to sea
Solid waste (bulk waste e.g. garbage, scrap etc.) [3]		79 tonnes	Returned to shore

[1] Assumes that 10 % of cement volumes used are discharged to the marine environment, the rest will remain downhole.
[2] Assumes 200 litres of greywater and blackwater generated per person per day and based on values in Table 2.8.
[3] Based on an estimated average solid waste production of 30 tonnes per month.

2.8 Installation, Hook-up and Commissioning Operations

2.8.1 Installation, Hook-up and Commissioning Overview

As described in the Arran Project Environmental Statement (Dana, 2018), the installation of the Arran to Shearwater pipeline and umbilical will be carried out by four main vessels and additional support vessels. Table 2.11 estimates the total duration of involvement of these vessels in the installation of the Arran to Shearwater pipeline and umbilical and the additional duration required by these vessels to install the deviated section of the line to tie-in the Columbus Development. The vessels used could either be dynamically positioned (DP) or anchored.

Table 2.11: Vessel Overview for the Pipeline and Umbilical Installation Campaign

Vessel	Function	Typical Fuel Consumption	Typical POB	Duration Involved in Arran Project	Additional Duration Required for the Columbus Deviation
Survey vessels	Pipeline and Umbilical Survey	8 tonnes / day [1]	20	60 days	0.5 days
Pipelay vessels	Flowline installation	15 tonnes / day [2]	50	72 days	7 days
Umbilical lay vessel	Umbilical installation	15 tonnes / day [2]	50	25 days	3 days
Trenching support vessel	Pipeline trenching, mattress installation, crossing preparation	15 tonnes / day [2]	50	81 days	2 day
Rock dump vessel	Deploy rock-dump material	15 tonnes / day [3]	50	16 days	1 day
Fishing Guard Boat	Guard vessels	0.8 tonnes / day [4]	10	220 days	10

[1] Typical fuel consumption based on maximum (in transit) values from IoP (2000). Given that survey vessels are not listed in IoP (2000), the value for safety vessels was used based on the size of the vessel.
[2] Typical fuel consumption based on maximum (working) values from IoP (2000). Given that unbilical lay vessels and trenching support vessels are not listed in IoP (2000), the value for pipelay vessels was used based on the size of the vessel.
[3] Typical fuel consumption based on maximum (working) values for rock-dump vessel from IoP (2000).
[4] Typical fuel consumption based on maximum (transit) values for standby vessel vessel from IoP (2000).

A Dive Support Vessel (DSV) will be required to install the subsea infrastructures and the subsea tie-in of the Columbus Development and to support the pre-commissioning. The characteristics of the DSV are shown in Table 2.12.

Table 2.12: Vessel Overview for the Columbus Subsea Infrastructure Installation and Pre-Commissioning

Vessel	Function	Typical Fuel Consumption	Typical POB	Duration in Field
Dive Support Vessel (DSV)	Subsea structures installation, subsea tie-in and pre-commissioning [1]	22 tonnes / day [2]	70	20 days

[1] Note that the Xmas tree installation will be done during well drilling operations by MODU. Emissions and discharges for this aspect are therefore discussed in Section 2.7.7.
[2] Typical fuel consumption based on maximum (in transit) values from IoP (2000).

It is currently anticipated that the pipeline and umbilical installation will be in Q2 to Q3 2020 and that the installation of Columbus subsea infrastructure, hook-up and commissioning will be in Q2 2021.

2.8.2 Subsea Positioning

The placement of the subsea components requires a high degree of accuracy and to facilitate their positioning transponders will be installed on the structures prior to load out. Prior to installation a visual Remote Operating Vehicle (ROV) survey will be carried out to verify the seabed condition and ensure no obstacles are present which may prevent successful installation. The position of the structure during deployment will be determined by the vessels acoustic positioning system and positioning transponders mounted on the structure. Heading and attitude of the structure will be determined using a high accuracy subsea gyro which may be mounted on the structure, or on an ROV which rigidly docks onto the structure. The use of a dead man anchor (DMA) deployed on the seabed and orientation rigging may be required to achieve heading positional accuracy.

2.8.3 Installation of CTIS

CTIS installation will be carried out by a DSV after the Arran to Shearwater production pipeline and umbilical have been installed. Once the CTIS has been delivered to the field, the ROV will carry out a footprint survey to ensure that the proposed location is free of debris or obstructions.

The CTIS will be overboarded and held in place by four piles to ensure its structural integrity on the seabed. Each pile will measure approximately 0.6 m in diameter and approximately 20 m in length.

It is anticipated that piling operations to install the CTIS will last maximum 48 hours.

The tie-in of pipeline to the CTIS and tie-in of the CTIS to the CDev-1 well will be carried out by the DSV. The tie-in spools will be installed and will be laid directly on the seabed.

2.8.4 Installation of Pipeline and Umbilical

Seabed Preparation

Geophysical and geotechnical surveys will be carried out along all pipeline and umbilical routes and the final routes will be confirmed during FEED. A pre-lay survey will be carried out prior to pipeline and umbilical installation to determine whether any new obstructions have appeared. During installation, boulders may need to be moved away from the pipeline and umbilical corridors, although this probability is very low.

Pipeline and Umbilical Lay

It is anticipated that the pipeline and umbilical will be laid in two separate trenches. The pipeline will be buried with backfill soil to prevent upheaval buckling. It is proposed that the umbilical will be left in an open trench to naturally backfill over time. Further work may be undertaken during FEED to determine if the pipeline and umbilical can be laid in the same trench as the pipeline.

The pipeline and umbilical will be trenched using a plough or other mechanical trenching tool, and then mechanically backfilled. The target trench depth and cover requirements will be determined during detailed design.

The pipeline is expected to be laid by an S-lay vessel, although reel lay of the pipeline or the use of an anchored vessel may still occur depending on the final contractor selection. S-lay installation involves individual sections of the pipeline being welded together onboard the pipelay vessel before being guided off the vessel parallel to the sea surface as the vessel moves along the pipeline route. The upper bend of the pipeline is maintained by the curvature of a support platform (stinger) and the lower bend by vessel positioning and lay vessel pipe tensioners.

As the pipeline curves through the water column to the seabed it forms an 'S' shape that gives the method its name. The majority of pipeline S-lay installation vessels make use of dynamic positioning systems.

However potential remains that a pipelay vessel which uses anchors for station keeping may be utilised. The vessel would deploy twelve anchors that are used to pull the barge along. The anchors have to be retrieved and redeployed continuously with an anchor handling vessel as the barge typically can only move 500 m with anchors deployed in this manner. The use of an anchor barge requires a pre-lay anchor corridor to be surveyed as the anchors can be up to 1,000 m either side of the vessel which would be out with the surveyed route corridor width of 540 m (270 m either side of the route centre line).

A DP construction vessel with a carousel will carry out umbilical installation. It is proposed that the umbilical will be pulled up an existing J-tube on Shearwater 'C' and laid directly to the CTIS. The installation method has yet to be finalised; the umbilical could be laid into a pre-cut trench or trenched into the seabed as soon as possible after laying. The potential for simultaneous umbilical lay and trenching exists, but its adoption would depend upon which installation contractor undertakes the work.

Lay between CTIS and Arran South can be in either direction. The umbilical will subsequently be pulled in and connected to the relevant subsea structure with diver assistance. Once the pipeline and umbilical are laid, the route of each will be surveyed to confirm its location.

2.8.5 Subsea Infrastructure Protection

The installation of protective stabilisation material will be required in the form of mattress protection and rock dumping to ensure the integrity of the infrastructure in certain places.

For the pipeline, as noted above, burial will assist in protection against upheaval buckling, where temperature changes cause the pipeline to move to relieve the expansion forces. Burial, when of sufficient depth, provides sufficient download to prevent upwards movement of the pipeline by resisting the expansion forces.

The potential for upheaval buckling is directly related to the as-trenched shape of the pipeline where deviations in height away from a perfectly straight pipe are susceptible to upheaval buckling. The pipeline burial depth should be sufficient to prevent upheaval buckling for the majority of deviations in height. For larger imperfections, the backfill cover height provided by the backfilled sediment may not, on its own, be sufficient to resist upheaval buckling and at these locations additional placement of rock may be required. Rock is considered the most appropriate mitigation measure for upheaval buckling. Whilst trenching to a greater depth could reduce the requirement for rock, experience from the wider area within which Columbus is located suggests that burial to a greater depth is not likely to be guaranteed, and rock dump would likely still be required to ensure that snagging points did not present themselves.

The rock dump material will comprise inert rock material, containing minimal fines.

The Arran Project ES (Dana, 2018) has assessed the potential impact of rock placement alongside the Arran to Shearwater pipeline. Whilst design work to date suggests that further protection by rock may not be required alongside the Arran to Shearwater pipeline to mitigate for upheaval buckling, by way of considering a worst-case environmental interaction, it has been assumed that up to 50,000 tonnes of rock placement could be required (Dana, 2018). Deviating the Arran to Shearwater pipeline to accommodate the Columbus Development will not increase the amount of rock required.

The most likely locations for the spot rock placement are not yet known and it is thus assumed that the spot rock placement may be required at any point along the pipeline. Any rock dump will be sited within the 20 metre wide installation corridor. A pre-rock-dump survey will be performed to determine the exact as-found coordinates and the pre-dump profile of the target areas using the ROV equipped with scanning equipment. This will provide information for the detailed rock-dump plan. The rock-dump material will then be deployed, according to the rock-dump plan, from the rock-dump vessel using a fall pipe lowered to the working depth above the relevant structures. The rate and locations of deployment will be controlled on board the vessel and monitored using the ROV.

The umbilical will not require any rock placement provided it is suitably trenched below mean seabed level.

For the Columbus Development, where the pipeline and umbilical exit the trenches adjacent to the CTIS, concrete protection mattresses will be required. In addition mattresses will be required for protection of the pipe spools between the CTIS and the Xmas tree. It is anticipated that up to 120 mattresses of approximately 6 m x 3 m will be required in total for the un-trenched sections of pipeline and umbilical and for the exposed structure and subsea tree tie-in spools.

A summary of the stabilisation material that may be required for the Columbus Development is presented in Table 2.13.

Table 2.13: Summary of Stabilisation Material (Worst Case)

Protective Structure	Dimensions (m)	Indicative Quantity	Footprint (m^2)
Concrete mattresses	6 (L) x 3 (W) x 0.15 (H)	120 mattresses	2,160
Rock-dump material	-	6,583 tonnes[1] for the upheaval buckling mitigation alongside the deviated section of the pipeline	6,451[1]

[1] Based on the length of the deviated section of the pipeline (i.e. 7,650m), with 50,000 tonnes for the upheaval buckling mitigation used alongside the whole Arran to Shearwater pipeline and placed over a 49,000 m^2 footprint area (Dana, 2018).

2.8.6 Subsea Infrastructure Hook-Up and Pre-Commissioning

In advance of the pipeline being readied to carry the produced fluids, a series of pre-commissioning activities will be undertaken of the Arran to Shearwater pipeline and umbilical. Some of these will be undertaken onshore (such as filling of manifold and well tie-in spools with MEG-based gel) with the following required once in the field:

- Flooding, cleaning and gauging of the new Arran to Shearwater pipeline;
- Hydrostatic strength testing of the new Arran to Shearwater pipeline;
- Installation of potable water-based gels in all pipeline ends;
- Hydrostatic leak testing of the combined Arran to Shearwater pipeline system;
- De-watering of up to 4,000 m^3 via the Shearwater platform and mono-ethylene glycol (MEG) swab of the combined Arran to Shearwater pipeline system;
- Displacement of the Arran to Shearwater pipeline system using nitrogen. The pipeline shall be left filled with nitrogen at a minimum pressure of 1 bar above seabed ambient pressure. The pipeline may then be further pressurised with nitrogen if required to facilitate start-up operations.

These activities have been assessed within the Arran Project Environmental Statement (Dana, 2018) and will not change as a result of the route deviation to accommodate the Columbus Development.

The pre-commissioning of the Columbus subsea infrastructure will be supported by the DSV. The list of the chemical use and discharge for the pre-commissioning of the Columbus infrastructure is shown in Table 2.14.

Table 2.14: Chemical use and discharge for Pre-Commissioning of the Columbus Infrastructure

Activity	Chemical use	Chemical discharge to sea
Install spools and tie-in structures	• MEG-based gel; and • Dye sticks.	Discharged to sea at the Shearwater platform.
Barrier test CTIS and CDev-1 well and leak test complete pipeline system	• MEG/water; and • Tracer dye.	Discharged to sea at the seabed.

Activity	Chemical use	Chemical discharge to sea
Installation and post-installation testing	• Water based hydraulic control fluid; and • MEG/water.	The hydraulic control fluid remains in the umbilical cores during operation of the field, with small intermittent discharges occur during opening and closing of the hydraulic valves (i.e. this is an open loop system). Most of the MEG/water will be moved into the Arran pipeline during chemical (Methanol) core displacement and onto the Shearwater process system for discharge during production. The remaining MEG/water will stay in the umbilical spare chemical cores for the life of field unless the spare umbilical cores are utilised.

The use and discharge of chemicals during pipeline operations will be detailed and assessed in the Pipeline Operations MAT and Production Operations MAT (as appropriate) and associated Chemical Permit SATs in accordance with the Offshore Chemicals Regulations 2002 (as amended). Chemicals will be subject to an environmental risk assessment, where applicable and products with an improved environmental profile will be preferentially selected for use.

2.8.7 Installation, Hook-Up and Commissioning Emissions and Discharge Summary

Table 2.15 presents the calculated emissions to the atmosphere (based on the values in Table 2.11 and Table 2.12) from vessel movements associated with the installation, hook-up and commissioning phase of the Columbus Development including the deviated section of the Arran to Shearwater pipeline. Atmospheric emissions from vessel movements associated with the installation, hook-up and commissioning of the Arran Development are captured and assessed in the Arran Project Environmental Statement (Dana, 2018).

Table 2.16 provides a summary of the main marine discharges and CO_2 and waste emissions arising from routine operations associated with Columbus installation, hook-up and commissioning phase.

Table 2.15: Estimated Atmospheric Emissions from the Columbus Development Installation, Hook-up and Commissioning Operations (based on values in Table 2.11 and Table 2.12)

Total Fuel Consumption (tonnes)	Emissions (tonnes) [1]							
	CO_2	CO	NO_X	N_2O	SO_2	CH_4	VOC	CO_{2e}[2]
647	2,070.4	10.2	38.4	0.1	2.6	0.1	1.3	2,116

[1] Emissions factors from DECC (2008).
[2] Carbon dioxide equivalent (CO_{2e}) is a term for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gas, CO_{2e} signifies the amount of CO2 which would have the equivalent global warming impact (refer to Section 8.4.1).

Table 2.16: Estimated Quantification of Key Discharges and CO_2 Emissions Associated with the Columbus Development Installation, Hook-up and Commissioning Phase

Aspect	Estimated Quantity Disposed or Discharged	Fate
Power generation (Table 2.15)	2,116 tonnes	CO_2 equivalent Emitted to atmosphere

Aspect	Estimated Quantity Disposed or Discharged	Fate
Wastewater (greywater and blackwater) [1]	432 cubic metres	Discharged to sea

[1] Assumes 200 litres of greywater and blackwater generated per person per day and based on values in Table 2.11 and Table 2.12.

2.9 Production

The potential emissions and discharges and overall impact assessment is based on the high case (P10) production estimates, which produce the highest rates for gas, condensate and produced water. At the time of writing the ES, well design work is ongoing and consideration is being given to a well which has a completion that is c. 5,000 ft shorter than the one presented in Section 2.7. The production profiles presented below may therefore be higher than those in the FDP, but are considered worst case.

2.9.1 Production Profiles

Reservoir simulations run forecasting a total of 16 years' production have been undertaken to understand how the Columbus reservoir might behave over this period. Figure 2.11 shows the predicted P10 (maximum) case, P90 (minimum) case and reference (central) case for average daily production rates of gas and condensate from the Columbus reservoir for 16 years. According to the P10 case, annual gas production from the Columbus Development is expected to peak around Year four with a rate of around 337 million cubic metres (11.9 billion cubic feet) of gas per year and around Year two for condensate with around 82,177 cubic metres per year of condensate. Following these peaks, gas and condensate production is expected to decrease as field life continues (Table 2.17).

The highest annual water production rate for the Columbus field is also associated with the P10 case. Annual water production from the Columbus Development is expected to peak at around 15,899 cubic metres (0.1 million barrels) per year (Table 2.17).

Figure 2.11: Columbus Annual Gas and Oil Production Profiles

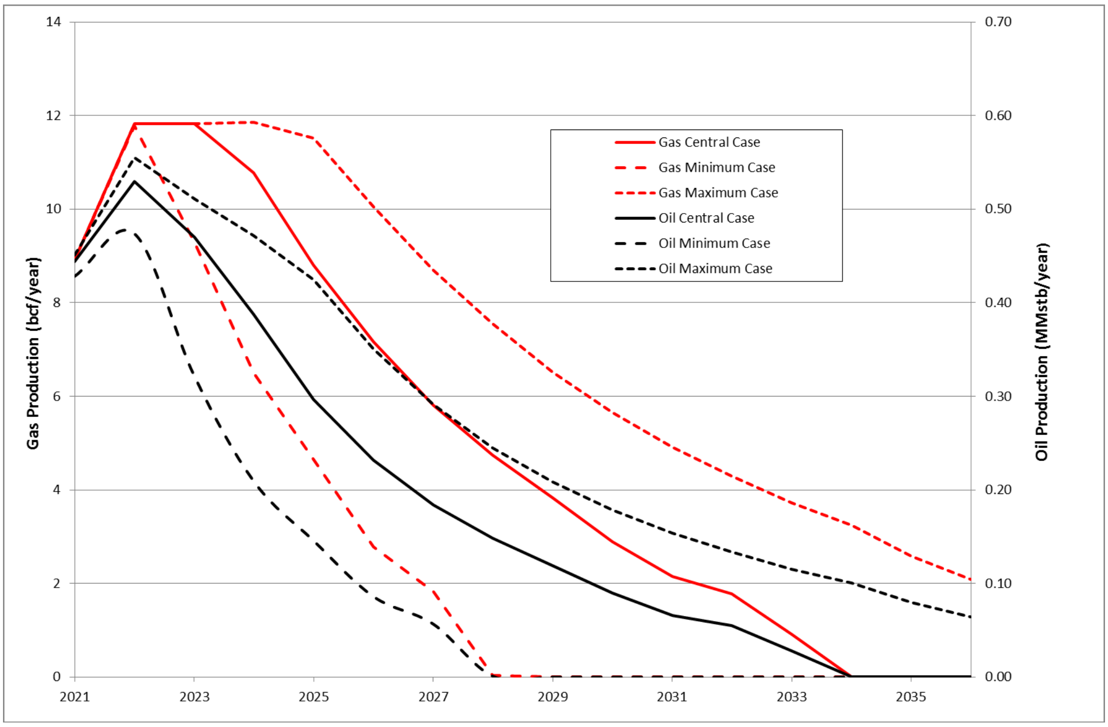


Table 2.17: Columbus Field P10 Production Profile

Year	Annual Production					
	Gas		Condensate		Produced Water	
	bcf	kscm	scm	tonnes	MMb	kscm
2021	8.9	252,020	66,696	52,690	0.1	15.90
2022	11.8	334,139	82,177	64,920	0.1	15.90
2023	11.8	334,139	75,620	59,740	0.1	15.90
2024	11.9	336,971	69,873	55,200	0.1	15.90
2025	11.5	325,644	62,835	49,640	0.1	15.90
2026	10.1	286,000	51,835	40,950	0.1	15.90
2027	8.7	246,357	43,114	34,060	0.1	15.90
2028	7.5	212,376	36,304	28,680	0.1	15.90
2029	6.5	184,060	30,835	24,360	0	0.00
2030	5.7	161,406	26,430	20,880	0	0.00
2031	4.9	138,753	22,772	17,990	0	0.00
2032	4.3	121,762	19,797	15,640	0	0.00
2033	3.7	104,772	17,089	13,500	0	0.00
2034	3.3	93,446	14,835	11,720	0	0.00
2035	2.6	73,624	11,785	9,310	0	0.00
2036	2.1	59,465	9,532	7,530	0.1	15.90
TOTAL	**115.3**	**3,264,933**	**641,532**	**506,810**	**1**	**158.99**

2.9.2 Atmospheric Emissions

Atmospheric emissions during the Columbus production phase will mainly arise from power generation. The power required to operate the subsea Columbus Development will be generated onboard the Shearwater platform.

The existing combustion equipment on Shearwater includes gas turbines for main power generation and compressor drive and diesel engines for air compression, emergency power and for driving fire pumps. There will be an incremental power demand from bringing the Columbus production online against the current requirement at Shearwater but no new power generation facilities will be required.

The Shearwater flare system comprises both a low pressure and high pressure flare system that accepts hydrocarbons under the following conditions:

- Base load – this includes all the gas used for safe and efficient operation of the process facility and flare system under normal operating conditions;
- Operational changes – this includes gas flaring resulting from the start up and planned shut-down of equipment during production amongst others; and
- Emergency shutdown – this includes any gas flared during an emergency.

Apart from the base load flare required for the safe and efficient operation of the process and flare systems under normal operating conditions, gas is flared on Shearwater only during emergency pressure relief, during periods of process instability typically after start up and shut down, or during unavailability of the gas compression system.

The production from the Columbus field will not change the current operating conditions at Shearwater with respect to flaring. However, there will be temporary increases in flaring as a result of Columbus production coming online due to:

- Initial start-up;
- Planned shut down and start-up; and
- Unplanned shut down and start-up.

Unplanned shut down and start-up is anticipated to occur on average one and a half time per year, with shut down flaring anticipated to take a maximum of approximately 30 hours and start-up flaring a maximum of approximately 60 hours.

The Shearwater installation does not currently vent and there will be no changes to this venting requirement as a result of Columbus production.

Table 2.18 presents the calculated yearly emissions to the atmosphere emitted at the Shearwater platform associated with the power generation required for the Columbus field production, which will be a proportion of the total power generation at Shearwater, and associated with the flaring of the Columbus gas, which will be a proportion of the gas flared at Shearwater during unplanned shut down and start-up. These emissions are based on the P10 Production Profile (refer to Section 2.9.1) which forecast the highest quantity of atmospheric emissions and therefore represent the worst case scenario. Of note is that the quantity of atmospheric emissions associated with the Columbus production increases significantly from 2029 because Columbus's share of total Shearwater throughput increases significantly as Fram, Shearwater and Arran production diminishes or stops.

Table 2.18: Estimated Atmospheric Emissions Emitted from Shearwater during Columbus Production Associated with the Power Generation of the Columbus Field and Flaring of the Columbus Gas (P10)

Year	Estimated Atmospheric Emissions from Shearwater Associated with the Power Generation of Columbus Field and Flaring of Columbus Gas (tonnes)[1]						
	CO_2	CO	NO_X	N_2O	SO_2	CH_4	VOC
2021	24,581	57.90	10.37	0.70	0.11	86.41	86.41
2022	36,050	84.91	15.21	1.03	0.16	126.73	126.73
2023	39,352	92.69	16.60	1.12	0.18	138.34	138.34
2024	49,664	116.97	20.95	1.41	0.22	174.59	174.59
2025	56,762	133.69	23.94	1.62	0.26	199.54	199.54
2026	39,795	93.73	16.79	1.13	0.18	139.89	139.89
2027	40,873	96.27	17.24	1.16	0.18	143.68	143.68
2028	49,969	117.69	21.08	1.42	0.22	175.66	175.66
2029	102,412	241.21	43.20	2.92	0.46	360.01	360.01
2030	101,127	238.18	42.66	2.88	0.46	355.50	355.50
2031	85,219	200.72	35.95	2.43	0.38	299.58	299.58
2032	136,283	320.99	57.49	3.88	0.61	479.08	479.08
2033	140,849	331.74	59.42	4.01	0.63	495.14	495.14
2034	140,054	329.87	59.08	3.99	0.63	492.34	492.34
2035	138,958	327.29	58.62	3.96	0.63	488.49	488.49
2036	138,501	326.21	58.43	3.94	0.62	486.88	486.88
Total:	1,320,450	3,110.04	557.02	37.60	5.94	4,641.86	4,641.86

[1] Emission factors from DECC (*2008*).

2.9.3 Flow Assurance

Shearwater will provide a dedicated chemical injection package for the Columbus Development. Scale inhibitor and start-up methanol will be required with dedicated injection cores in the subsea umbilical. There will also be a provision for wax inhibitor if required later on in the field life. For compatibility reasons where possible these chemicals will be the same as those already used on Shearwater.

Gas condensate from Columbus will be susceptible to hydrate formation at a temperature above the minimum seabed ambient. The pipeline will be insulated using a high specification pipe-in-pipe system which will enable fluids to arrive above hydrate formation temperature through the expected field life. The operating philosophy will be that depressurisation of the pipeline will not be required after a planned shutdown, or within a given length of time following an unplanned shutdown. However, if an unplanned shutdown exceeds this given length of time then the flowline system will be depressurised and restarted at low pressure until the water in the pipeline has been dosed with methanol. Methanol will be injected at start-up to inhibit hydrates caused by low temperatures, and will be required until the pipeline is warmed up to operating temperature.

Water analysis has shown there is a possibility of some scale formation downhole. Scale inhibitor will be available via the umbilical and injected at the bottom of the well.

Despite the pipeline being constructed from a corrosion resistant alloy, there is still a requirement for injection of corrosion inhibitor to protect the existing carbon steel Scoter riser at Shearwater. Corrosion inhibitor will be added at the wellhead and the chrome tubing well completion will prevent corrosion downhole.

It is recognised that, as a result of Shell bringing the Fram field online, there may be a requirement for the specific chemicals that are currently used at Shearwater (and which the Columbus field will make use of) to be changed. Should this be required, any such changes would be subject of further assessment by both Shell and Serica as part of the chemical permitting process and they are not discussed further herein.

2.9.4 Marine Discharges

Produced water will be disposed of via the existing Shearwater produced water system. The processing of Columbus fluids alongside the Arran fluids at Shearwater will increase produced water volumes compared to the current case without Columbus and Arran fluids and additional produced water handling capacity will be required on the Shearwater C platform. This additional produced water handling capacity is assessed in the Arran ES (Dana, 2018).

The following requirements will continue to be met at Shearwater once Columbus production is brought on line:

- The use and/or discharge of all production chemicals will be subject to risk assessment and permitting under the Offshore Chemicals Regulations;
- Oil in water discharge via the produced water system will be within the existing approved limits, which currently include:
  - A maximum monthly average of oil (dispersed) in water content of 30 mg/l or less;
  - The maximum concentration not to exceed 100 mg/l at any time; and
  - Quantity of dispersed oil in produced water discharged must not exceed 1 tonne in any 12 hour period.

Taking the production profiles for Columbus shown in Section 2.9.1, the estimated discharge of oil that could be discharged to sea via the produced water system over the life of the Columbus field is determined in Table 2.19.

Table 2.19: Maximum Oil Discharged to Sea during the Columbus Production Phase

Production Scenario	Produced Water Flow Rate (cubic metres per day)	Volume Discharged to Sea (cubic metres per day)	Oil-in-Water Discharged (tonnes per year) [1]
P10 Case, Year 1 to 8	43.6[2]	43.6	0.48
Average over 16 years	24.5[2]	24.5	0.27

[1] Assumes a maximum oil-in-water content of 30 milligrams per litre.

[2] Calculated based on yearly peak production of produced water of 15,899 cubic metres during Year 1 to 8 and Year 16 and no production of produced water from Year 9 to 15 (refer to Table 2.17).

Of note is that the produced water volumes will be dependent on the rate of oil and gas production from the reservoir and how the reservoir behaves. The estimates provided are an extreme worst case as they are based on the peak produced water production at a small point over the life of the field.

2.9.5 Wastewater and Solid Waste

It is not anticipated that there will be an increase in the marine utility discharges at the Shearwater platform, as a result of Columbus.

It is not anticipated that there will be an increase in the quantity of solid waste produced at the Shearwater platform, as a result of Columbus.

2.10 Decommissioning

On cessation of production, the Columbus Development will be decommissioned in accordance with the requirements of the prevailing UK and international law.

Prior to decommissioning, a detailed comparative assessment of all available recommended abandonment options will be undertaken to establish the optimum approach. The comparative assessment will be based on technical feasibility, complexity and risk, safety, environmental impacts, effects on other sea users and cost. An EIA will also be undertaken to ensure that any likely significant environmental effects are minimised, as far as possible.

Decommissioning options have, however, been considered during the design phase of the project. It is currently anticipated that the well will be disconnected from their respective subsea architecture and will then be plugged and abandoned using a semi-submersible MODU or vessel with well intervention capabilities. The wellhead and casings would be cut at a depth below the mudline to remove any obstructions on the seabed.

All subsea infrastructures will be depressurised and flushed to remove residual hydrocarbons and chemicals and left flooded with seawater prior to abandonment, with any contaminated fluids flushed back to the Shearwater platform for treatment or may be flushed downhole.

As the pipeline and umbilical are to be trenched and buried it is assumed they will be disconnected with their ends cut back and buried to ensure there are no obstructions on the seabed.

Serica considers removal to be the base case for mattress during the decommissioning phase of the project. Where technically feasible, an attempt to remove all of the concrete mattresses from the seabed will be made. Where this cannot be achieved safely, a proposal will be made to OPRED to leave the mattresses *in situ*. In the case of rock dump material that has been used to protect subsea development infrastructure, it is assumed that this will remain in place unless there are special circumstances that would warrant consideration of removal, in accordance with the OPRED Decommissioning Guidance (DECC, 2011).

The subsea structures, such as the CTIS and Xmas tree will be removed. Any piles would be cut at a depth below the mudline to remove any obstructions on the seabed.

3 Environmental Description

3.1 Introduction

Understanding the characteristics of the local environment is a key consideration in the planning of the development of the Columbus field, in order to understand the potential for the project to interact with the environment so that appropriate controls can be adopted to mitigate negative impacts.

This section of the ES describes the background physical characteristics in the central North Sea, identifies the flora and fauna likely to be present within the project's zone of influence and describes other sea users within the area. The proposed CDev-1 well and CTIS are located within UKCS Block 23/16 and the proposed deviation to the Arran pipeline route traverses UKCS Blocks 23/16 and 23/21; hence, the description of the environment in this section encompasses baseline conditions for both of these blocks.

3.1.1 Habitat Assessment and Environmental Baseline Surveys

Historic Data

A number of site surveys have previously been conducted in the area. The locations of these surveys in relation to the proposed Columbus Development are displayed in Figure 3.1. Table 3.1 also presents a summary of the existing survey information. These surveys are referred to throughout this report where relevant. Appendix D provides more detailed information on each of the surveys and the data collected.

Table 3.1. Existing Survey Information Referenced in this ES

Survey Name	Details	Referenced in this document	Data Collected	
			Photos	Grabs
23/16f-K Site Survey	23/16f-11 survey for original Columbus exploration well north and south locations. Conducted during July 2006.	Gardline, 2006	Yes	No
23/16f Site Survey	23/16f-12 survey for revised Columbus appraisal well location. Conducted during April 2007.	UTEC, 2007	No	No
Columbus Rig Site Survey, UKCS 23/21	BG pre-drilling rig site survey Environmental Baseline Report. Conducted during July-August 2007.	Gardline, 2007	No	Yes
Columbus Development Pipeline Route Survey, UKCS Blocks 23/16 to 22/24	Pipeline route survey from Columbus wells 12 and 11 to ETAP CPF platform in Block 22/24. Conducted during August 2008.	Gardline, 2008	No	Yes
UKCS Blocks 23/16 and 23/21 Columbus to Lomond BLP Pipeline route survey	Columbus to Lomond BLP Pipeline route site survey Environmental Baseline Report. Conducted during August 2010.	Gardline 2010a, 2010b	Yes	Yes

Survey Name	Details	Referenced in this document	Data Collected	
			Photos	Grabs
UKCS Blocks 23/16 and 23/21 Columbus to Lomond BLP Pipeline Route Survey	Lomond BLP site survey Environmental Baseline Report. Conducted during August 2010.	Gardline 2010c	Yes	Yes
Arran Development – UKCS Quads 22 and 23	Arran North and Arran South Drill Centres site survey, together with two infield pipeline routes and an export pipeline route survey to the Shearwater 'A' Platform, via the Scoter Manifold. Conducted during August-September 2015.	Gardline 2015a, 2015b and 2016a	Yes	Yes

2018 Data

In May 2018, Serica undertook a habitat assessment and EBS within a 3 km by 3 km survey area centred on the proposed CDev-1 well location (site survey) and along an 8 km route corridor centred on the deviated section of the Arran pipeline (route survey).

Geophysical data was acquired over the site and route survey areas using a single and multi-beam echo sounder, side scan sonar (SSS; dual frequency) and magnetometer. In addition, 11 stations were investigated with a camera system (stills photography and video footage), following analysis of the acoustic data, and grab samples were collected at nine of these stations (using a dual Van Veen grab; 2 x 0.1m^2). The sediment samples obtained will be sub-sampled for physico-chemical and macrofaunal analysis.

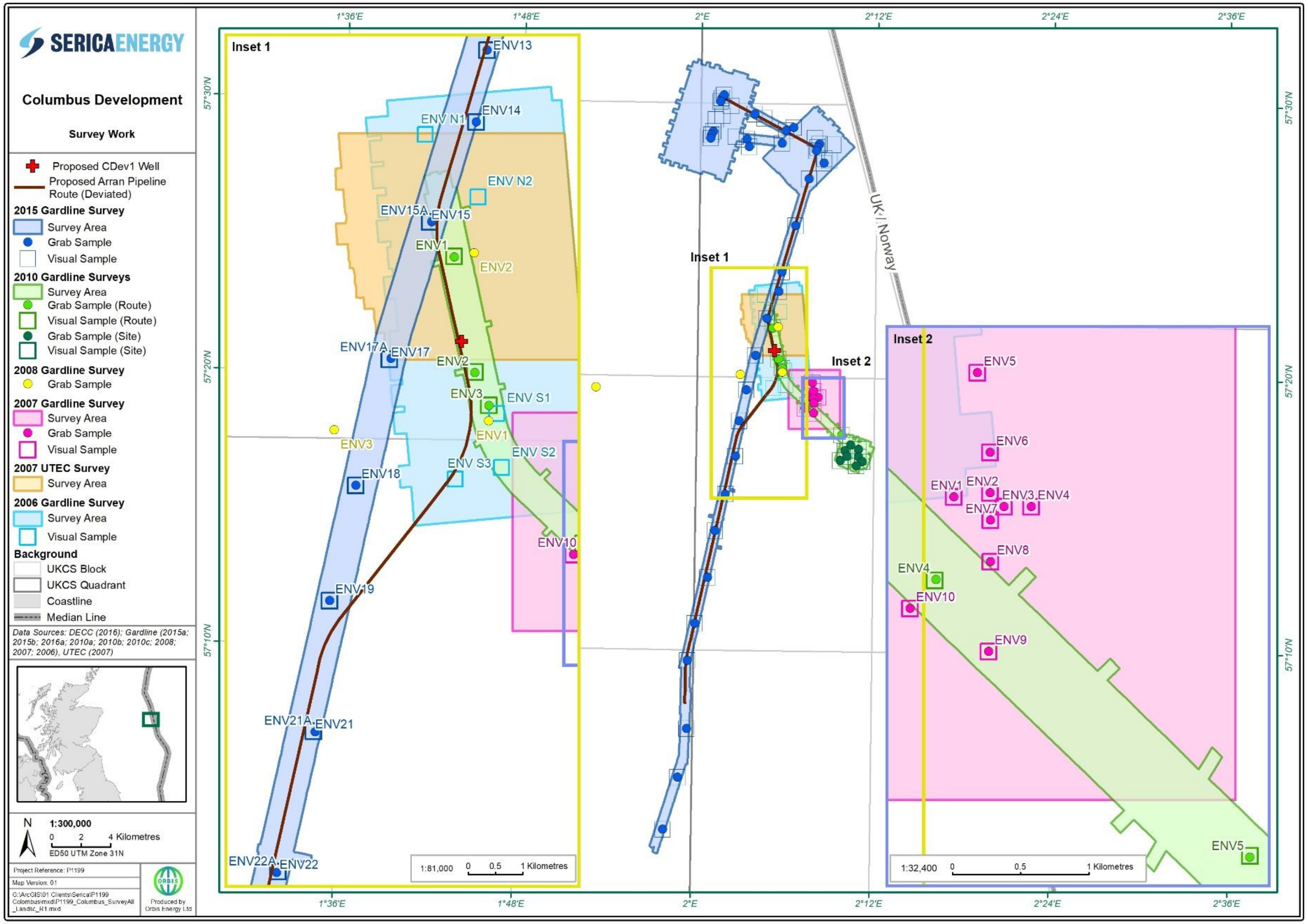
The selection of stations followed an "intelligent design" to ensure sufficient coverage of all habitat types that may be impacted by the proposed Columbus Development.

At the time of writing this ES, the results of the 2018 habitat assessment and EBS are not yet available. However, given the large number of surveys which have previously been conducted in the Columbus area (as referenced in Table 3.1), the stability of the benthic environment in 80-90 m of water depth and the general homogeneity of the seabed sediments in this part of the central North Sea, it is considered that these historic surveys provide an accurate assessment of the environmental conditions in this area. As such Serica considers that sufficient data has been gathered and analysed to acquire a good understanding of the surrounding area upon which to undertake the EIA. The results of the 2018 habitat assessment and EBS will be made available to interested parties as soon as possible.

3.1.2 Other Data Sources

In addition to the surveys listed above, this section of the ES has been prepared using a combination of data sources including published and unpublished literature. In particular, reference has been made to the OPRED Offshore Strategic Environmental Assessment (SEA) Reports (2003-2016). The proposed Columbus Development is located within the SEA2 Region (the area down the central spine of the North Sea which contains the majority of existing UK oil and gas fields) (DTI, 2001) and the OESEA Regional Sea 1 (the 'Northern North Sea' area) (DECC, 2016).

Figure 3.1. Columbus Field Historic Survey Information



3.2 Geography

The proposed Columbus Development is located in the central North Sea, approximately 230 km east of Peterhead on the eastern Scottish coastline (Figure 1.1 in Section 1). The nearest international boundary to the development is the UK/Norwegian median line, which lies approximately 8 km to the east-north-east of the proposed Columbus Development location.

The Scottish coastline between Cape Wrath in the Highlands and St. Cyrus on the Aberdeenshire coast ranges from areas of high rocky cliffs to extensive bands of broad sandy beaches (Barne *et al.*, 1996). The majority of the northern section of the coastline from Cape Wrath to Helmsdale comprises of cliffs with the coastal morphology closely related to changes in bedrock. Of particular note within this section are three large inlets, extending 10-12 km inland, namely the Kyle of Durness and the Kyle of Tongue (both shallow with sand flats exposed at low water) and Loch Eriboll. South of Helmsdale to Peterhead the cliffs give way to stretches of raised beaches, the exception to this being two areas of sandstone cliffs between Hopeman and Lossiemouth and Portgordon and Rosehearty. In addition, areas of extensive sandy forelands and sandy marshes are located between Golspie and Portgordon on the coast of the Moray Firth. At Peterhead the sandy beaches are replaced by a rocky platform which develops into steep cliffs at Boddam. The cliffs continue to Hackley Head where they are replaced by large areas of dune-backed sandy beaches extending south as far as Aberdeen. Between the mouth of the Dee and the Highland Boundary Fault the coast is again dominated by rugged cliffs and south of this the coastline almost entirely comprises of Old Red Sandstone cliffs.

3.3 The Seabed and Bathymetry

3.3.1 Bathymetry

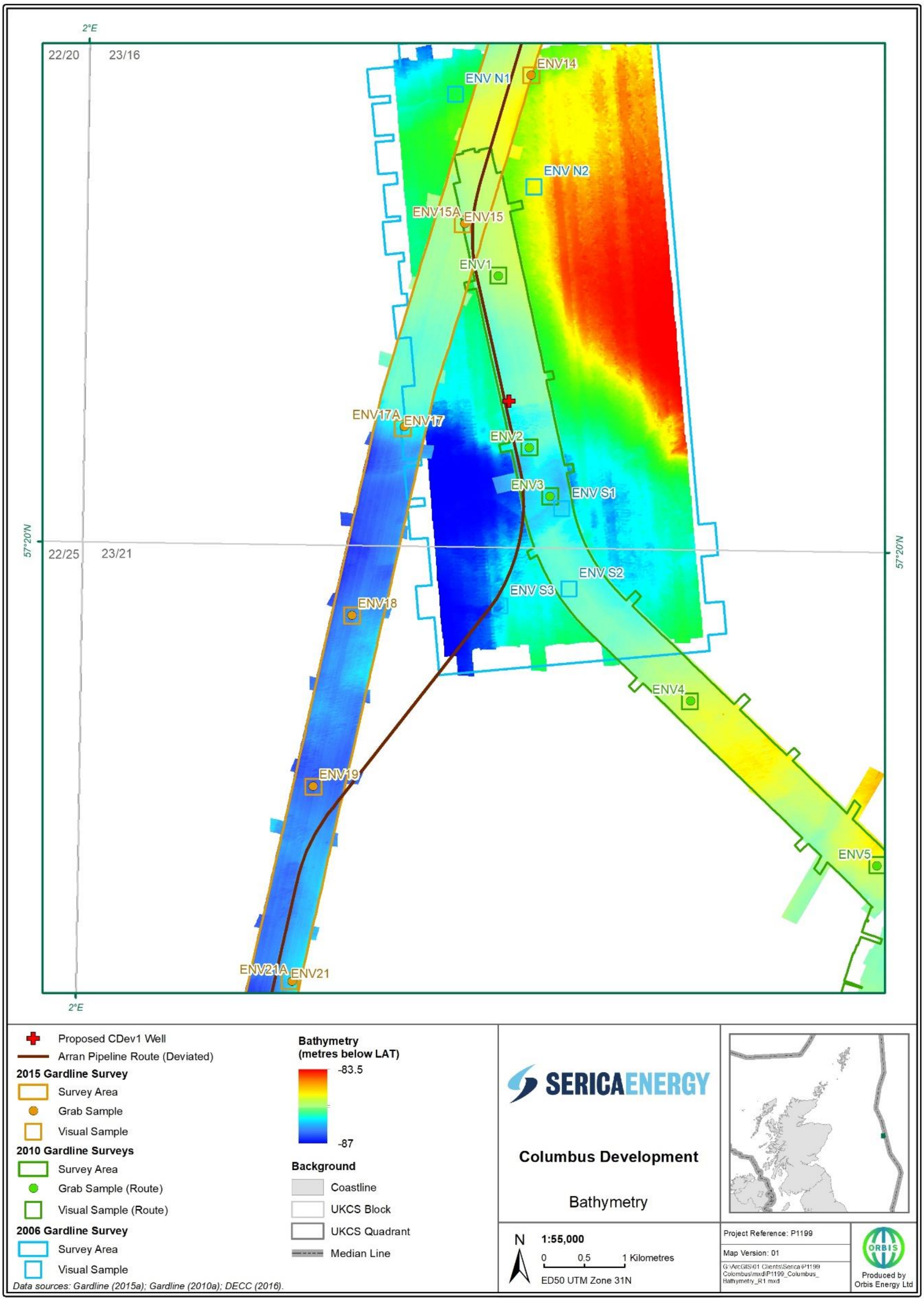
Water depths within the central North Sea are variable with a general increase in depth from the west to the Norwegian channel in the east. The north eastern area of the region is dominated by the Fladen Ground with depths of up to 140 m. To the east of the Aberdeenshire coastal region, water depths gradually increase to approximately 80 m, with localised deeper areas such as the Devil's Hole, which descends to more than 100 m (Martin and Wainwright, 1998).

Charted water depth within the vicinity of the proposed CDev-1 well is approximately 85 m (Hydrographer of the Navy, 2011). Data from the 2010 Columbus to Lomond pipeline route survey indicates that the water depth at the proposed CDev-1 well location is approximately 85.6 m below lowest astronomical tide (LAT) (Gardline, 2010a). The preliminary findings of the 2018 Gardline (site) survey confirm this (Gardline, 2018a).

Charted water depth across the proposed deviated section of the Arran pipeline route is also around 85 m (Hydrographer of the Navy, 2011). Data from the 2008 Columbus Development pipeline route survey (Gardline, 2008), the 2010 Columbus to Lomond pipeline route survey (Gardline, 2010a) and the 2015 Arran Development pipeline route survey (Gardline, 2015a) indicate that water depth along the proposed deviated section of the Arran pipeline route ranges from around 85 m to 87 m. The preliminary findings of the 2018 Gardline (route) survey are in line with this, stating that water depths ranged from 84.5 m to 88.3 m below LAT across the surveyed area (Gardline, 2018b).

Data from the previous surveys in the area indicates that the seabed in the vicinity of the proposed Columbus Development and along the deviated section of the Arran pipeline route undulates gently, with seabed gradients observed of <1° (Gardline, 2010a; 2015a). The preliminary findings of the 2018 Gardline surveys confirm this (Gardline, 2018a; 2018b). Across the wider area the seabed deepens gently from east to west (Gardline, 2006). Figure 3.2 presents the available bathymetry data for the area.

Figure 3.2. Bathymetry in the Vicinity of the Proposed Columbus Development



3.3.2 Seabed Features

In the central North Sea spreads of soft muds are locally characterised by small depressions or ‘pockmarks’, the majority of which are thought to have been formed at times of fluid/gas escape resulting in fine sediment being vented into suspension which is then redeposited away from the site of emission. The largest areas and densities of pockmarks occur in the Fladen Ground or Witch Ground Basin, a large muddy depression between the central and northern North Sea, located to the north and north west of the proposed Columbus Development (DTI, 2001; DECC, 2016).

It is noted, that pockmarks were not recorded during the previous surveys in the vicinity of the proposed Columbus Development or along the proposed deviated section of the Arran pipeline route (Gardline, 2006; 2007; 2008; 2010a; 2010c; 2015a; UTEC, 2007). However, during the 2015 Gardline survey for the Arran Development an area of high reflectivity forming depressions with an extruding point contact were interpreted as probable methane derived authigenic carbonate (MDAC). These were confirmed with camera drops in the areas of highest SSS reflectivity at stations ENV35 and ENV36 (refer to Figure 3.1 and Appendix D), which lie approximately 16 km to the north west of the proposed CDev-1 well. The probable MDAC structures correspond with where shallow gas was observed on sub-bottom profiler and in the water column on the SSS data, interpreted from seismic data to have migrated upwards from a deep salt diaper (Gardline, 2016b).

Scattered boulders/debris up to 1.5 m high have been recorded in the area (Gardline, 2007; 2010a; 2015a; 2018a; 2018b). The nearest recorded SSS contact to the proposed CDev-1 well is an item of linear debris, approximately 495 m to the north east, which is 31 m in length (refer to Figure 3.3; Gardline, 2010a). The preliminary findings of the 2018 Gardline (site) survey noted the nearest SSS contact to be a 0.4 m high boulder, approximately 172 m to the east (Gardline, 2018a).

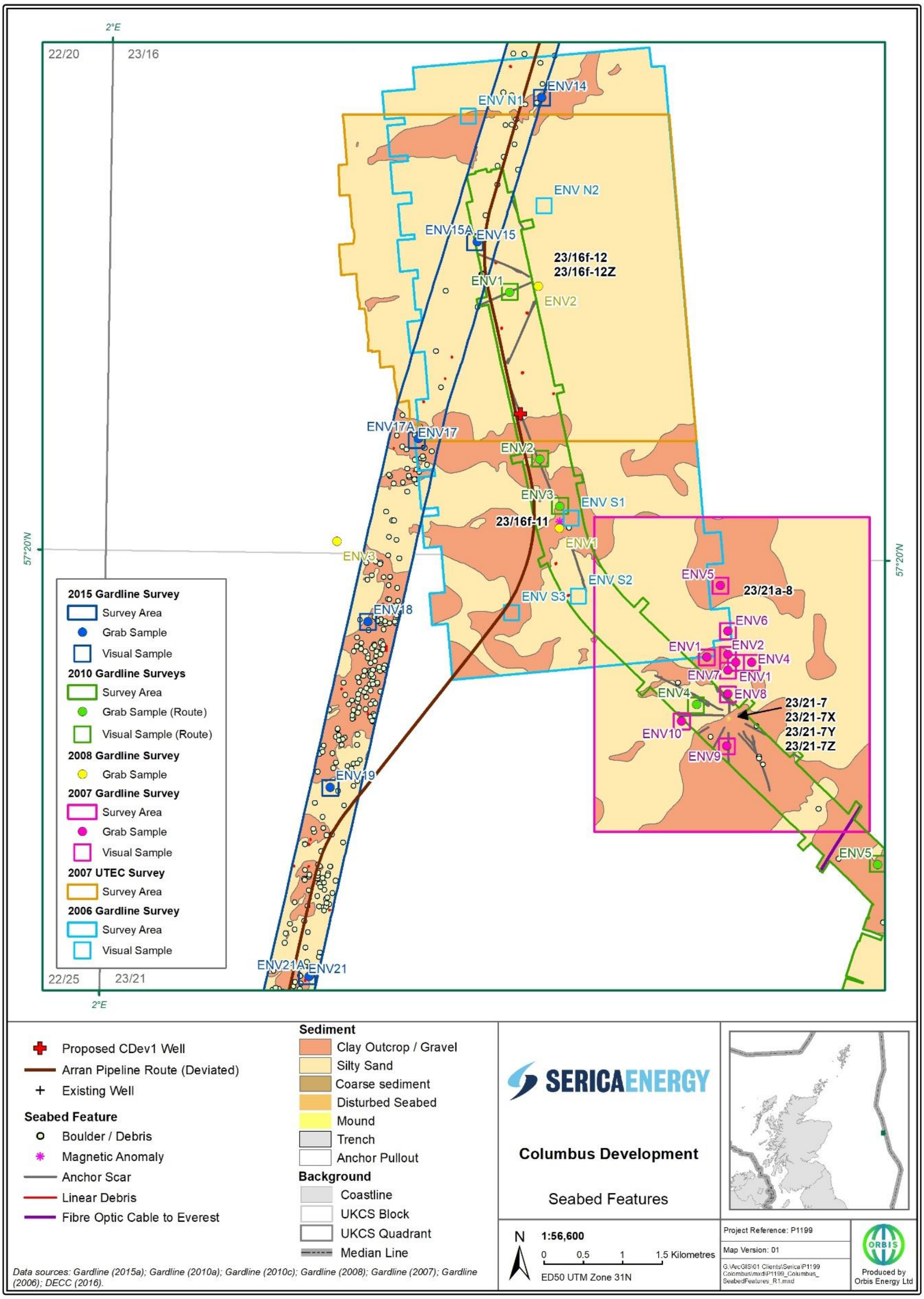
Magnetometer anomalies identified during the 2010 and 2015 Gardline surveys were predominantly related to existing infrastructure (Gardline, 2010a; 2015a). Other magnetometer anomalies correlated with debris observed on SSS data, the remainder may represent buried debris (Gardline, 2015a).

The suspended 23/16f-12 well (location: 57°21'53.710"N, 02°05'29.210"E, European Datum 1950; ED50) is located approximately 1.73 km to the north northeast of the proposed CDev-1 well and 700 m to the east northeast of the proposed deviated section of the Arran pipeline route. This well was observed during the 2008 Gardline survey to have a height of >2.9 m and to be surrounded by a minor area of disturbed seabed. An area of drilling mud/cuttings >350 m by 200 m surrounding the 23/16f-12 well was also noted (Gardline, 2008).

The suspended 23/16f-11 well (location: 57°20'14.294"N, 02°05'47.691"E, ED50) was also detected during the 2008, 2010 and 2018 Gardline surveys. This well is located approximately 1.48 km to the south southeast of the proposed CDev-1 well and 398 m to the east of the proposed deviated section of the Arran pipeline route. This wellhead was observed during the 2008 Gardline survey to have a height of 3.8 m and to be surrounded by a small area of disturbed seabed with no significant debris in the vicinity (Gardline, 2008). While the wellhead was not observed during the 2010 Gardline survey, a small mound of disturbed seabed was noted at this location (Gardline, 2010a). The preliminary findings of the 2018 Gardline (site) also noted this well in the bathymetry data as a low relief mound and on the SSS (Gardline, 2018a).

Radiating anchor scars were also observed in the vicinity of both the 23/16f-11 and 23/16f-12 wells in 2008 and 2010 surveys (Gardline, 2008; 2010a). The preliminary findings of the 2018 Gardline (site) survey also noted the presence of occasional anchor scars within the survey area (Gardline, 2018a).

Figure 3.3. Seabed Features and Sediments in the Vicinity of the Proposed Columbus Development



3.3.3 Seabed Sediments

The nature of the local seabed sediments is an important factor in providing information to help assess the potential for sediment movement and is a determining factor in the flora and fauna present. The nature of the sediments and the amount of sediment transport can also provide evidence as to the potential effects from the planned development, such as the propensity for accumulation of any discharged drill cuttings or the extent of natural backfill.

The sediment distribution in the North Sea reflects the glacial history and more recent hydrodynamic processes of the area. Seabed sediments in the central North Sea are a mixture of gravels, sands and muds. The British Geological Survey (BGS) seabed sediment maps show the area in the vicinity of the proposed Columbus Development to be predominately comprised of sand (BGS, 1985).

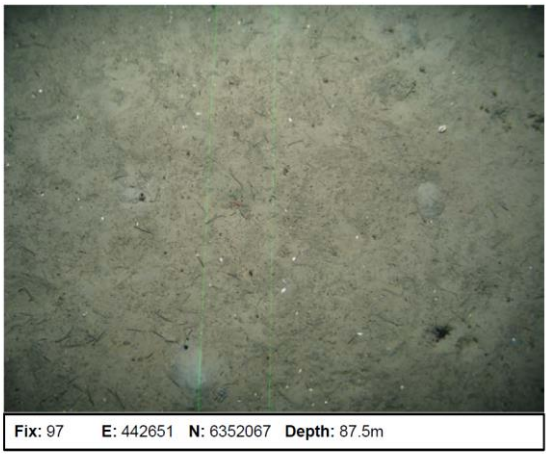
During the 2015 Gardline survey conducted for the Arran Development the dominant seabed type was found to be a <0.5 m thick veneer of Holocene silty sand with occasional cobbles and boulders. Areas of shell, gravel and cobbles were also present (Gardline, 2016a). The other surveys conducted in the area broadly agree with this, indicating that the seabed in the vicinity of the Columbus Development and along the proposed deviated section of the Arran pipeline comprises silty sand with intermittent areas of clay outcrop with gravel, shells and cobbles (Gardline, 2006; 2007; 2008; 2010a; UTEC, 2007).

It can be seen from Figure 3.3 that the proposed CDev-1 well is located in an area of silty sand and the proposed deviated section of the Arran pipeline route passes through both silty sand and areas of shell, gravel and cobbles.

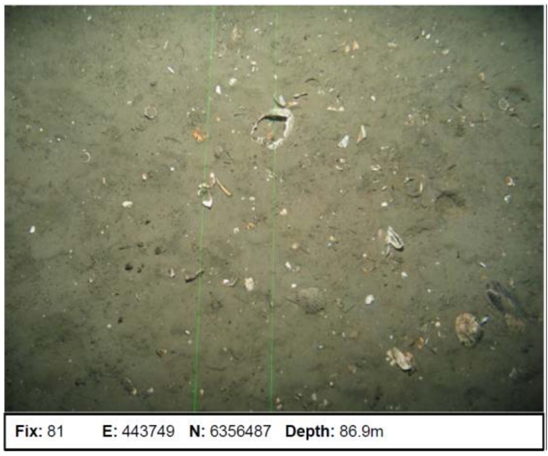
Representative photographs of seabed sediments taken during the 2015 Gardline survey are shown in Figure 3.4.

Figure 3.4. Photographs of Seabed Sediments in the Columbus Area

a) ENV19 (Gardline, 2016b)



b) ENV17 (Gardline, 2016b)



The physico-chemical results from the surveys previously undertaken in the Columbus area are presented below. The results of the sediment sample analysis from the 2018 Columbus EBS are not yet available, but it is anticipated that they will be similar to the previous surveys given the overlap between the survey areas (refer to Figure 3.1) and the homogeneous nature of the seabed sediments across the Columbus Development area.

Particle Size Analysis

Most benthic organisms exhibit preferences for sediment with particular grain size characteristics. In addition, many contaminants, particularly metals and hydrocarbons, are strongly associated with finer fractions in sediment. Determination of sediment particle size across an area is therefore important to understanding the benthic community.

Particle size analysis (PSA) was undertaken on the sediment samples acquired during the 2007, 2008, 2010 and 2015 Gardline surveys. A summary of the results for each survey is presented in Table 3.2 below. It should be noted that, the 2015 Gardline survey covered a greater area than the other surveys and, with it, a slightly greater range of sediments types. As such, the results for the sampling stations closest to the proposed CDev-1 well and the deviated section of the Arran pipeline route (stations ENV14 to ENV21A) are presented separately in Table 3.2 for comparison.

The majority of sampling stations, across all of the surveys, were dominated by sand (63µm to 2mm fraction) with a moderate proportion of fine sediment (<63µm fraction) and a small proportion of gravel (>2mm fraction).

Overall, the sediment sampled across the surveys was found to be poorly sorted and can be classified as 'fine sand' under the Wentworth Classification (refer to Table 3.2).

For sediments that are poorly sorted, the Modified Folk Classification (1954) gives a more realistic indication of the various fractions present and their relative contribution to the overall sediment type. Under this system, sediments across the surveys areas were classified as 'muddy sand', 'slightly gravelly muddy sand', 'gravelly muddy sand', 'sand', 'slightly gravelly sand' and 'muddy sandy gravel'. It should be noted, that 'muddy sandy gravel' was only identified during the 2015 Gardline survey at sampling station ENV11, approximately 13 km north of the proposed CDev-1 well location. Sampling stations from the 2015 survey in the vicinity of the proposed CDev-1 well and the deviated section of the Arran pipeline route (stations ENV14 to ENV21A) were classified as 'sand', 'slightly gravelly sand' and 'muddy sand' (refer to Table 3.2; Gardline, 2016a).

Table 3.2. Summary of Sediment Characteristics for each Survey (Gardline, 2007; 2008; 2010b; 2010c; 2016a)

Survey		Mean Particle Size (µm)	Mean phi	Fine (%)	Sand (%)	Coarse (%)	Sorting [N1]	Wentworth Classification (based on mean phi)	Modified Folk Classifications
2007 Gardline	Min	135	2.24	4.2	84.6	0.0	Mainly poor	Fine sand	Muddy sand Sand
	Max	212	2.89	15.3	95.8	0.7			
	Mean	**160**	**2.66**	**10.8**	**89.0**	**0.2**			
	± SD	*±22*	*±0.19*	*±3.4*	*±3.5*	*±0.2*			
2008 Gardline	Min	69	2.36	8.9	70.6	0.2	Poor	Fine sand	Slightly gravelly muddy sand
	Max	195	3.85	27.8	91.0	2.4			
	Mean	**143**	**2.88**	**15.6**	**83.0**	**1.5**			
	± SD	*±45*	*±0.53*	*±0.7*	*±7.5*	*±1.0*			
2010 Gardline (route)	Min	69	2.52	10.1	68.2	0.0	Mainly poor	Fine sand	Muddy sand Slightly gravelly muddy sand
	Max	174	3.86	31.8	88.1	1.8			
	Mean	**133**	**2.97**	**16.3**	**83.0**	**0.7**			
	± SD	*±39*	*±0.52*	*±8.8*	*±8.4*	*±0.8*			
2010 Gardline (site)	Min	78	2.23	7.9	76.9	0.1	Poor	Fine sand	Muddy sand Slightly gravelly muddy sand Gravelly muddy sand Sand Slightly gravelly sand
	Max	214	3.68	22.9	91.9	5.6			
	Mean	**148**	**2.84**	**15.0**	**83.6**	**1.4**			
	± SD	*±52*	*±0.56*	*±5.4*	*±5.2*	*±2.0*			
2015 Gardline	Min	121	-0.15	4.9	46.1	0.0	Mainly poor	Fine sand	Muddy sand Slightly gravelly muddy sand Gravelly muddy sand Sand Slightly gravelly sand
	Max	1,109	3.05	16.6	94.9	46.1			
	Mean	**208**	**2.43**	**9.6**	**88.1**	**2.4**			
	± SD	*±167*	*±0.55*	*±3.2*	*±8.9*	*±8.2*			

Survey		Mean Particle Size (µm)	Mean phi	Fine (%)	Sand (%)	Coarse (%)	Sorting N1	Wentworth Classification (based on mean phi)	Modified Folk Classifications
									Muddy sandy gravel
2015 Gardline (ENV14 to ENV21A only)[N2]	Min	130	1.37	6.4	86.0	0.0	Poor	Fine sand	Muddy sand Sand Slightly gravelly sand
	Max	178	2.80	13.5	92.0	1.7			
	Mean	**156**	**2.7**	**11.0**	**88.5**	**0.5**			
	± SD	*±17*	*±0.2*	*±2.5*	*±2.2*	*±0.7*			

Notes
SD = Standard Deviation
N1 Sorting according to Folk and Ward (1957)
N2 Stations in the vicinity of the proposed CDev-1 well and the deviated section of the Arran pipeline route.

Organic Matter & Organic Carbon

Determining the organic content of sediments is also important to understanding benthic communities. Organic matter is a food source for suspension and deposit feeders and it's availability in the sediments can therefore influence benthic communities. An overabundance may lead to reductions in species richness, abundance and biomass (Hyland *et al.,* 2005). In addition, many contaminants are strongly associated with organic carbon.

Table 3.3 summarises the results of organic carbon analysis conducted for the surveys in and around the Columbus area.

Both total organic matter (TOM) and total organic carbon (TOC) levels recorded across the Columbus area are relatively low and considered typical of the area (Gardline, 2007; 2010b; 2010c; 2016a).

The mean organic content (equivalent to TOM) recorded in North Sea sediments (between latitudes 55°N and 60°N) as presented by UKOOA (2001) was 1.63%, with 95% of these stations having TOM <4.48%. A total of three stations from the five surveys, ENV6 in the 2008 Gardline survey, ENV3 in the 2010 Gardline (site) survey and ENV5 in the 2010 Gardline (route) survey, had TOM concentrations greater than 1.63%. The highest TOM concentration recorded was 3.4% (Gardline, 2010c). However, given the above, all three stations are within the range considered as background (<4.48%; UKOOA, 2001).

In general, areas of fine sediments tend to be richer in organic matter compared to coarse sands and gravels. Overall, the variations in TOM and TOC concentrations recorded across all of the surveys were generally consistent with the proportion of the more adsorbent fine sediment (63µm fraction) in each sample.

Table 3.3. Summary of Organic Carbon Analysis and Total Hydrocarbon Concentration for each Survey (Gardline, 2007; 2008; 2010b; 2010c; 2016a)

Survey		Fines (%)	Total Organic Matter (%)	Total Organic Carbon (%)	Total Hydrocarbon Concentration (µg.g^{-1} dry weight)
2007 Gardline	Min	4.2	0.4	0.2	2.3
	Max	15.3	0.9	0.3	4.9
	Mean	**10.8**	**0.8**	**0.3**	**4.1**
	±SD	*3.4*	*0.2*	*0.1*	*0.8*
2008 Gardline	Min	8.9	1.0	0.16	5.4
	Max	27.8	2.3	0.31	12.9
	Mean	**15.6**	**1.3**	**0.21**	**8.5**
	±SD	*7.0*	*0.5*	*0.06*	*3.1*
2010 Gardline (route)	Min	10.1	0.6	0.5	7.3
	Max	31.8	1.7	1.2	14.3
	Mean	**16.3**	**1.0**	**0.7**	**9.8**
	±SD	*8.8*	*0.4*	*0.3*	*3.2*
2010 Gardline (site)	Min	7.9	0.6	0.4	4.9
	Max	22.9	3.4	1.6	9.9
	Mean	**15.0**	**1.2**	**0.8**	**8.1**
	±SD	*5.4*	*0.9*	*0.4*	*1.6*

Survey		Fines (%)	Total Organic Matter (%)	Total Organic Carbon (%)	Total Hydrocarbon Concentration (µg.g^{-1} dry weight)
2015 Gardline	Min	4.9	0.09	0.05	2.6
	Max	16.6	0.65	0.23	11.9
	Mean	**9.6**	**0.34**	**0.14**	**6.7**
	±SD	*3.2*	*0.16*	*0.04*	*2.0*
2015 Gardline (ENV14 to ENV21A only)[N1]	Min	6.4	0.18	0.11	4.7
	Max	13.5	0.65	0.2	7.5
	Mean	**11.0**	**0.4**	**0.2**	**5.7**
	±SD	*2.5*	*0.2*	*0.03*	*1.1*

Notes
SD = Standard Deviation.
[N1] Stations in the vicinity of the proposed CDev-1 well and the deviated section of the Arran pipeline route.

Sediment Hydrocarbons

Marine sediments can contain hydrocarbons derived from both natural (geochemical processes and biosynthesise) and anthropogenic sources (e.g. oil spills). The exceedance of background hydrocarbons levels in marine sediments can indicate past and/or present anthropogenic sources. Crude oil is a complex mixture of compounds, including n-alkanes and aromatics (e.g. polycyclic aromatic hydrocarbons; PAHs). These groups can be determined individually, but they may also be analysed as total hydrocarbons (CEFAS, 2001a). A summary of the sediment hydrocarbon concentrations recorded in and around the Columbus area are presented in Table 3.3.

Total hydrocarbons (THC) concentrations recorded across the Columbus area range from 2.3 micrograms per gram (µg g^{-1}) (Gardline, 2007) to 14.3µg g^{-1} at station (Gardline, 2010b; refer to Table 3.3).

UKOOA (2001) reported a mean THC concentration of 9.5µg g^{-1} for stations over 5 km from existing infrastructure in the central North Sea, sampled between 1975 and 1995. The recorded THC concentration at eight stations in all of the surveys exceeded 9.5µg g^{-1}; stations ENV1, ENV2 and ENV6 of the 2008 Gardline survey, ENV3 and ENV4 of the 2010 Gardline (route) survey, ENV2 of the 2010 Gardline (site) survey and ENV24 and ENV42 of the 2015 Gardline survey (Gardline, 2008; 2010b; 2010c; 2016a). The elevated THC levels recorded in the Columbus area are not unexpected given the existing oil and gas infrastructure and historic drilling activity within the vicinity of the surrounding area. It can be seen from Figure 3.1 that the stations with elevated THC concentrations in the vicinity of the proposed CDev-1 well location, ENV1 and ENV2 from the 2008 Gardline survey and ENV3 from the 2010 Gardline (route) survey, lie relatively near to existing wells (23/16f-11 drilled in 2006 and 23/16f-12 drilled in 2007). However, all recorded concentrations in the surveys are well below the UKOOA (2001) 95th percentile value of 40.10µg g^{-1}, indicating that concentrations are within accepted background levels for the central North Sea.

Overall, the 2007 Gardline survey report concluded that the sediments were not unduly contaminated, containing background concentrations of hydrocarbons, mostly of biogenic origin (Gardline, 2007) with a comparatively minor petrogenic component. Similarly the 2008 survey report concluded that, the results of the hydrocarbon analysis suggest an absence of any notable anthropogenic contamination despite the historic drilling activity in the area (Gardline, 2008) and that hydrocarbon concentrations were typical for the region and within background concentrations for North Sea sediments (Gardline, 2008).

The 2010 (route) Gardline survey report noted that hydrocarbons in the sediments were from a mixture of biogenic (natural) and petrogenic (petroleum-related) sources and evidence of well-weathered historic contamination was found at station ENV4 (approximately 4.3 km to the south east of the proposed CDev-1 well location) which could have originated from a non-drilling source (Gardline, 2010b). However, the report again concluded that overall hydrocarbon concentrations within the survey area were considered to be at background concentrations. There was no evidence of fresh, point source anthropogenic contamination (Gardline, 2010b).

The 2010 (site) Gardline survey found a mixture of highly-weathered and biodegraded biogenic and petrogenic material at all stations and evidence of a highly-weathered mineral oil-based mud previously used in drilling activity at Lomond at station ENV5 (approximately 8.8 km to the south east of the proposed CDev-1 well location). However, overall, hydrocarbon concentrations were considered to be within the UKOOA (2001) concentrations considered as background for the central North Sea (Gardline, 2010c).

Finally, the most recent and extensive 2015 Gardline survey, found evidence of a possible additional low-level source of hydrocarbons at stations ENV20 and ENV41 (approximately 15.2 km to the north and 33.3 km to the south southwest of the proposed CDev-1 well location, respectively). Most stations indicated that the majority of hydrocarbons were well-weathered, with the exception of stations ENV9, ENV27, ENV28 and those along the proposed Arran pipeline route between Arran and Scoter which indicated the presence of less-weathered compounds. Calculated carbon preference index and pristane to phytane ratios indicated a dominance of biogenic hydrocarbons at most stations and a virtual absence of petrogenic sources at stations ENV5, ENV9, ENV28, ENV27, ENV21A and ENV23 (Gardline, 2016a). As with TOM and TOC, THC correlated with the natural variation in the more adsorbent finer (63µm) sediment material. A similar pattern was seen in PAH distributions indicating a predominance of pyrogenic hydrocarbons (those produced under conditions involving intense heat), with petrogenic inputs increasing to the south of the route. Both PAH and NPD (naphthalenes, phenanthrenes and dibenzothiophenes) correlated positively with depth and sediment fines content, as well as their co-variants, indicating predominantly natural variation. In addition, it should be noted that the 2015 survey re-visited stations from a previous survey in 2010 (Gardline, 2010d); comparison of the results indicates a reduction and weathering of hydrocarbons at these stations over time (Gardline, 2016a).

Overall, sediment hydrocarbon concentrations at all stations in the 2015 Gardline survey were within background concentrations for the central North Sea (Gardline, 2016a). In addition, gas chromatography (GC) traces for the majority of stations presented typical background levels of hydrocarbon inputs in areas of historic oil and gas exploration such as the North Sea (McDougall, 2000). It was also noted that the THC concentrations recorded were below the minimum threshold value considered for any opportunistic species to be prevalent, but were sufficient to potentially have an influence on faunal community composition through the loss of sensitive species (Gardline, 2016a).

Given the above, it is anticipated that the sediments sampled within the 2018 survey area will contain hydrocarbons from a mixture of biogenic and petrogenic sources, but that hydrocarbon concentrations will be within the background UKOOA (2001) concentrations for the central North Sea.

Heavy and Trace Metals

Heavy metals such as copper (Cu), lead (Pb) and zinc (Zn), are generally persistent and have a tendency to bioaccumulate in the tissues of exposed organisms, particularly species living on or within the seabed sediments, where they can have toxicity impacts on the receptor and subsequently become concentrated through higher levels of the food web. Metal concentrations in uncontaminated marine sediments generally exceed those found in overlying seawater by three to five orders of magnitude, since the buffering effects of saline water cause many metals to be rapidly precipitated out of seawater (Bryan and Langston, 1992).

A summary of the sediment metal concentrations recorded in and around the Columbus area are presented in Table 3.4.

Table 3.4. Total Heavy and Trace Metal Concentrations (micrograms per gram ($\mu g.g^{-1}$) dry weight) (Gardline, 2007; 2008; 2010b; 2010c and 2016a)

Survey	Statistic	Al	As	Ba	Cd	Cr	Cu	Hg [N3]	Ni	Pb	Sn	V	Zn
2007	Mean	-	0.07	349	0.07	15	2.5	<0.07	4	12	0.59	20	12
2008	Mean	-	3.2	428	0.37	14.4	6.6	0.14	4.5	12.5	4.1	15.9	21.8
2010 (route)	Mean	-	3.6	414	NC	18	3	0.01	4.8	12	0.6	20	13
2010 (site)	Mean	-	3.1	561	NC	22	3	0.02	7.5	14	0.7	26	19
2015	Mean	17,821	3.8	297	NC	14.5	6.3	NC	4.9	11.2	NC	24.3	15.6
2015 Gardline (ENV14 to ENV21A only)[N4]	Mean	17,333	3.7	299	NC	15.9	6.7	NC	5.1	11.5	0.6	25.7	15.9
Baseline Metal Concentrations in Marine Sediments													
UKOOA (2001)[N1]	Mean	-	-	348.0	0.76	-	6.32	-	-	12.63	-	21.52	21.28
	95th Percentile	-	-	720.0	1.0	-	-	-	-	26.8	-	-	-
OSPAR (2005)[N2]	BC	-	15.0	-	0.2	60.0	20.0	0.05	30.0	25.0	-	-	90.0
	BAC	-	25.0	-	0.31	81.0	27.0	0.07	36.0	38.0	-	-	122.0
Thresholds for Toxicological Effect on Benthic Communities													
NOAA	ERL	-	8.2	-	1.2	81.0	34.0	0.15	20.9	46.7	-	-	150.0
Buchman (2008)	AET	-	35.0	-	3.0	62.0	390.0	0.41	110.0	400.0	3.4	57.0	410.0
Key													
(shaded)	Exceeds one of the baseline concentrations (i.e. UKOOA or OSPAR) or thresholds (i.e. NOAA or Buchman)												

Notes

BC = Background Concentrations, BAC = Background Assessment Concentrations, ERL = Effects Range Low, AET = Apparent Effects Threshold, NC = Not Calculated

[N1] Background concentrations for the central North Sea.

[N2] Comparison to OSPAR (2005) data required normalisation of metals to 5% aluminium.

[N3] Concentrations determined following nitric acid digest preceded by digestion of organic matter with hydrogen peroxide.

[N4] Stations in the vicinity of the proposed CDev-1 well and the deviated section of the Arran pipeline route.

Of the surveys undertaken in the Columbus area, stations ENV14, ENV15A, ENV17A to ENV19 and ENV21A of the 2015 Gardline survey, stations ENV1 to ENV3 of the 2010 Gardline (route) survey and stations ENV1 to ENV3 of the Gardline 2008 survey lie in closest proximity to the proposed CDev-1 well location and the proposed deviated section of the Arran pipeline route (refer to Figure 3.1). As such, the preceding sub-sections focus on the results from these stations.

Barium

Barite is an essential constituent of drilling muds, and hence barium (Ba) occurs in high concentrations in sediments surrounding drilling activity, particularly when drill cuttings have been disposed of on the seabed. As a result, Ba is used as an indication of drilling activities (Gardline, 2008). UKOOA (2001) reported a mean Ba concentration of 348µg g^{-1} and a 95th percentile Ba concentration of 720µg g^{-1} for background stations within the central North Sea (refer to Table 3.4).

The 2008 Gardline survey report noted that the three stations closest to the 23/16f-11 well (drilled in 2006; OGA, 2018b), the 23/16f-12 well (drilling in 2007; OGA, 2018b) and the ETAP CPF Platform (ENV1, ENV2 and ENV6, respectively) had notably higher Ba concentrations than the remainder of the stations. However, with the exception of ENV2, which is located around 100 m to the south west of well 23/16f-11 and has a Ba concentration of 770µg g^{-1}, values at all stations were below the UKOOA 95th percentile value for the central North Sea (720µg g^{-1}). However, it should be noted that, the Ba concentrations at ENV2 are still relatively low as sediments containing drill cuttings generally contain >2,000µg g^{-1} (Neff, 2005; Gardline, 2008).

The 2010 Gardline (route) survey and the 2015 Gardline survey reports also noted Ba concentrations to be at background levels at all stations, with no station exceeding the UKOOA (2001) 95th percentile value (720µg g^{-1}).

Given the above, elevated Ba concentrations may be encountered in close proximity to the 23/16f-11 and 23/16f-12 wells (which are located within 380 m and 700 m of the proposed deviated section of the Arran pipeline route, respectively). However, barium concentrations across the 2018 Columbus survey area are generally expected to be below the UKOOA (2001) 95th percentile value and therefore representative of the background for the wider area.

Other metals

Where elevated concentrations of metals are found, results may be compared to existing sediment metal toxicity data in order to assess whether particular metals may be exerting a toxicological effect on benthic communities. The Apparent Effects Threshold (AET) to benthic communities, as reported by Buchman (2008), and NOAA ERL (Effects Range Low) concentrations; indicating the lower threshold at which adverse biological effects have been identified from ecotoxicological studies (Buchman, 2008) are also shown in Table 3.4.

During the 2008 survey, with the exception of cadmium (Cd) and mercury (Hg), all metals analysed were present in concentrations lower than values representative of background concentrations (BC) in a "pristine" environment as defined by OSPAR (2005). Both Cd and Hg were present in concentrations above the OSPAR BC and background assessment concentration (BAC) at all stations bar ENV5, which had Cd below the BAC value. The levels of these metals were considered to be above background for the area (Gardline, 2008). It was noted that, both metals are found as natural impurities in drilling muds (Neff, 2005) and therefore may be expected to be in concentrations higher than background in sediments close to drilling activities (Gardline, 2008). In addition, Hg concentrations at stations ENV1, ENV2 and ENV6 exceeded the NOAA ERL concentration (0.15µg g^{-1}), indicating the potential for toxicological effects on the biota at these stations. As previously mentioned, these stations are located relatively close to the 23/16f-11 and 23/16f-12 wells and the ETAP CPF Platform.

The 2010 Gardline (route) survey found all other metals to be at concentrations below their respective background or AET concentrations as reported by UKOOA (2001), OSPAR (2005) or Buchman (2008), with most having substantially lower concentrations (Gardline, 2010b). It was noted that station ENV3, located approximately 1.2 km to the south east of the proposed CDev-1 well location, had the highest concentrations of every metal analysed, except Cd. The report goes on to conclude that, although station ENV3 is located around 200 m to the north of a currently suspended existing well (23/16f-11), it is likely that the elevated metal concentrations observed here are natural and are related to the higher percentage of fines recorded at this station. This is backed up by all hydrocarbons indices being below background levels at this station, In addition, prevailing north northeast to south southwest currents would disperse any potential contaminants from the existing well away from station ENV3 (Gardline, 2010b).

The 2015 Gardline survey found that while some of the metals analysed exceeded their UKOOA (2001) mean values at multiple stations, none exceeded their UKOOA (2001) 95th percentile values. This suggests that all concentrations were representative of background for the wider area (Gardline, 2016a). With regards to the potential for toxicological effect on benthic communities, none of the stations in the vicinity of the proposed CDev-1 well location and deviated section of the Arran pipeline route (ENV14 to ENV21A) recorded metal concentrations above the ERL or AET thresholds. Overall, trends in the data from the 2015 Gardline survey indicate that concentrations of most metals were linked to subtle natural variation in physical sediment characteristics across the survey area (Gardline, 2016a).

Given the above, it is anticipated that whilst the concentration of some metals within the 2018 Columbus survey area could be elevated above OSPAR BCs. However, most metals are expected to be below UKOOA (2001) 95th percentile values with limited potential for toxicological effects on seabed communities. In addition, metal concentrations are likely to be linked to natural variation in physical sediment characteristics across the survey area.

3.4 Water

3.4.1 Oceanography

Waves

Waves are the result of the action of wind on the surface of the sea and their size depends upon the distance or fetch over which the wind can operate. The height of a wave is the distance from the crest to trough but as the waves at any one time are not of equal size, the significant wave height is taken and corresponds approximately to the mean height of the highest third of the waves. The wave period is the (mean) time between two wave crests, called the zero up-crossing period and is given in seconds. The wave climate of the area provides information on the physical energy acting on structures and dictates the structural design requirements.

The average wave height in the central North Sea follows a gradient decreasing from the northern area of the Fladen/Witch Ground to the southern area of the Dogger Bank. The average annual mean significant wave height in the vicinity of the proposed Columbus Development ranges between 2.11 m and 2.40 m (Marine Scotland, 2018). Significant wave heights in the vicinity of the proposed Columbus Development exceed 4.0 m for only 10% of the year (Table 3.5). However, there is considerable seasonal variation with waves in excess of 4 m recorded for up to 32% of the time in autumn and winter, but only up to 5% of the time in summer (Martin and Wainwright, 1998).

Table 3.5. Yearly Significant Wave Heights in the Vicinity of the Proposed Columbus Development (BODC, 1998)

10% Exceedance	25% Exceedance	50% Exceedance	75% Exceedance
4.0 m	3.0 m	2.0 m	1.5 m

Tides and Water Circulation

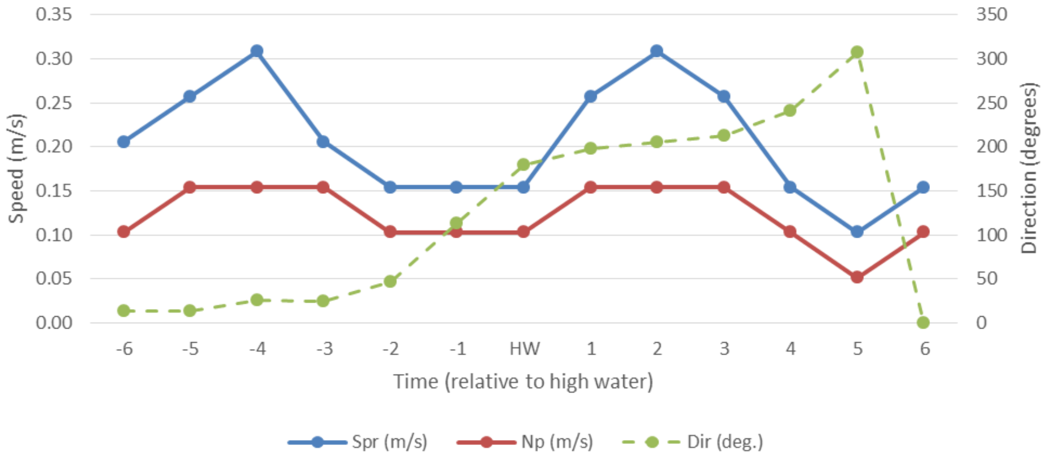
The general circulation of near-surface water masses in the North Sea is cyclonic, mostly driven by the ingression of Atlantic surface water in the western inlets of the northern North Sea. As a result, residual water currents near the sea surface tend to move in a south-easterly direction along the coast towards the English Channel.

Water in the central North Sea circulates in a broadly anti-clockwise direction, entering between the Orkneys and the Shetland Islands and to the east of the Shetlands. The predominant current in the region is an inflow of vertically well-mixed coastal and Atlantic water known as the Fair Isle Current or the Dooley Current. This flows around the north of Orkney and then heads south until reaching the

100 m depth contour of the Fladen Ground where it changes to an easterly flow, thus producing an anticlockwise gyre in the northern North Sea (North Sea Task Force, 1993; Martin and Wainwright, 1998). The effect of this counter current in the Columbus Development area pushes the near-surface water movement towards an easterly direction. However, occasional strong south easterly winds can push the near surface current in the opposite direction (BODC, 1998). Generally in the non-coastal regions of the North Sea, winds are strong and variable, capable of deriving from almost any direction, which can have profound temporal influences on the near-surface current direction.

Tides in the central North Sea are predominately semi-diurnal and tidal waters offshore in this area flood southwards and ebb northwards. Tidal currents are moderate in this region, with maximum tidal rates in the vicinity of the proposed Columbus Development of 0.31 and 0.15 m per second (ms^{-1}) for spring and neap tides respectively in an approximately north-south direction (Figure 3.5). Residual spring current is 0.02 ms^{-1} in the direction of bearing 005 (Hydrographer of the Navy, 2011).

Figure 3.5. Tidal Current Speed & Direction at 57°10’ N, 2°22’ E (Tidal Diamond E, Admiralty Chart 2182B, Hydrographer of the Navy, 2011)



3.4.2 Physical Characteristics

Information from the National Marine Plan Interactive (NMPi) Map (Marine Scotland, 2018) indicates that the annual mean surface temperature within the area is around 9.6°C, whilst the annual mean seabed temperature are about 6.9°C.

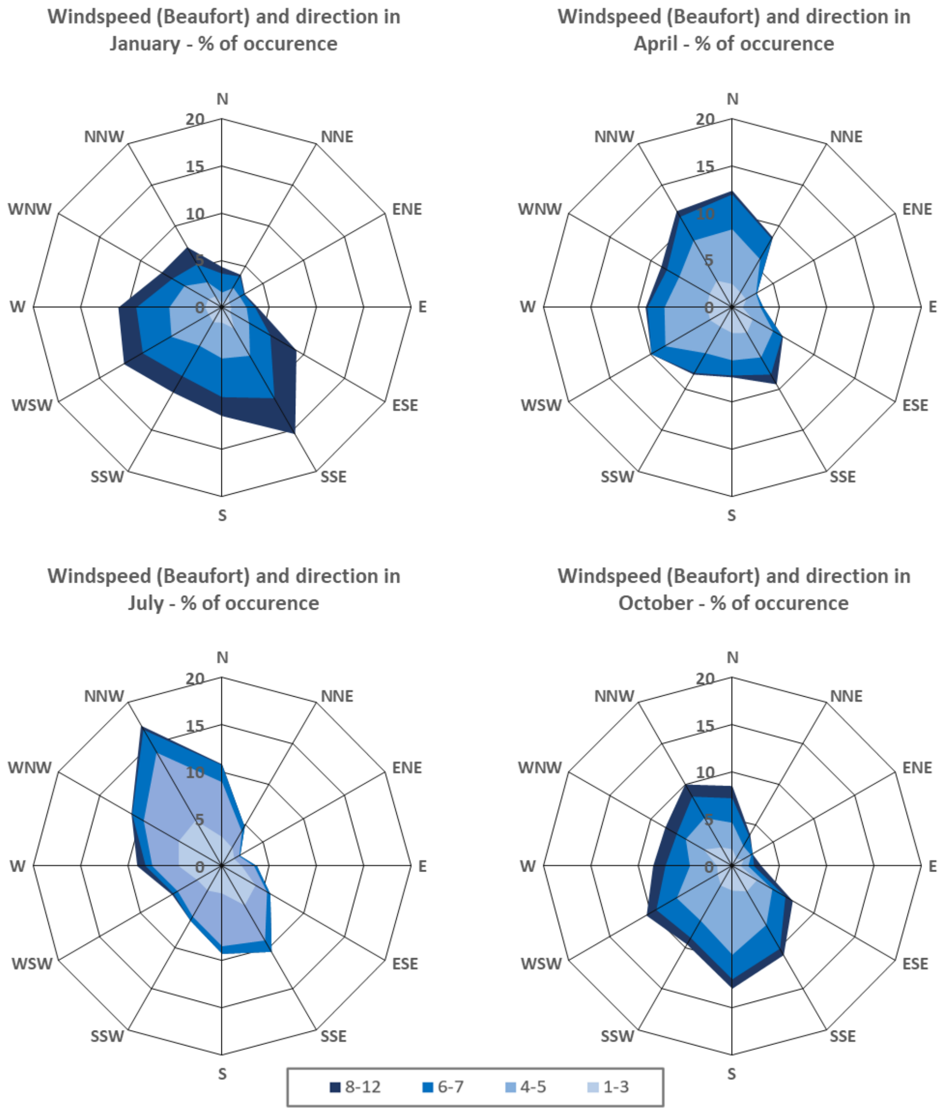
In addition, annual mean surface and near-bed salinity within the area is 35 parts per thousand (ppt) (Marine Scotland, 2018).

3.5 Wind

Prevailing wind directions in the area are variable throughout the year, but winds deriving from a southerly direction are most frequent (Figure 3.6). During the winter, south-easterly and south-westerly winds are most common, and during the early summer, northern winds become more frequent. From July to September, however, north-westerly winds are most common, returning to winds more commonly derived from the south in October.

Winds over the North Sea are subject to great variability due to the numerous mobile depressions that regularly cross the area and the topography of the east coasts of the UK, which introduce many local variations in wind conditions. Winds are capable of deriving from almost any direction in the North Sea, however, winds from the south and southwest are generally the most common in most areas. The windiest time of the year in the North Sea is winter. In the central North Sea in the waters to the east of Scotland, the wind force offshore may exceed force 7 up to as much as 12 to 16 days in every month during the winter period. The calmest period of the year is from May to August, where winds in the central North Sea reach or exceed force 7 approximately 4 to 5 days per month (Hydrographer of the Navy, 1995). Given the distance from the shoreline, coastal topography will have no influence on the wind conditions experienced at the Columbus Development, and it is highly likely that observed wind conditions will be in-line with the general pattern of wind conditions for the area as observed over the last few decades.

Figure 3.6. Wind Roses for the Area 58.0N – 59.9N, 0.0E – 1.9E (Korevaar, 1990)



3.6 Flora and Fauna

3.6.1 Plankton

Plankton forms a fundamental link in the food chain and consists of organisms that drift with the ocean currents and can be divided into phytoplankton (plants) and zooplankton (animals).

Plankton is vulnerable to discharges to the sea and accidental chemical or hydrocarbon spills. The composition of plankton communities at any time is variable and depends upon the circulation of water into and around the North Sea, the time of year and nutrient availability. Plankton abundance is strongly influenced by several factors such as; depth, tidal mixing, temperature stratification, nutrient concentrations and the location of oceanographic fronts. Species distribution is directly influenced by temperature, salinity, water inflow and the presence of local benthic (bottom dwelling) communities.

The plankton community of this area of the central North Sea is influenced by the inflow of nutrient rich Atlantic water which sustains phytoplankton blooms for longer than in some other areas of the North Sea. Phytoplankton production increases during spring between mid-March and mid-April, reaching a peak or 'bloom' in May, often followed by a smaller peak in autumn. The concentrations of organisms in these blooms can be very high, with dinoflagellates being the most successful due to the deep, cool stratification of waters (Leterme *et al*., 2006) and a coincident elevated level of primary productivity. These blooms are important in sustaining a period of elevated biological productivity throughout marine food chains during the spring months and also to a lesser extent during autumn.

The phytoplankton community in Scottish waters, including those in the vicinity of the proposed Columbus Development, is typical of those found in northern latitudes (Baxter *et al*., 2011). The phytoplankton community is dominated by the dinoflagellate genus *Ceratium* (*C. fusus, C. furca, C. lineatum*), with diatoms such as *Thalassiosira* spp. and *Chaetoceros* spp. also abundant. However, there has been a sharp decline in dinoflagellates in the North Sea over the last decade, due largely to a dramatically reduced abundances of *Neoceratium* spp., although there have been signs of a recovery in recent years (Edwards *et al.*, 2014).

Zooplankton is a primary food source for fish, seabirds and whales, such as humpback, right and fin whales (Reid *et al*., 2003; DECC, 2009). The zooplankton community is dominated by copepods, with *Calanus* species having the highest abundance, although other groups such as *Paracalanus* and *Pseudocalanus* are also abundant. Dominant copepods, species in the North Sea area *C. finmarchicus* and *C. helgolanidcus*, both of which provide a major food source for many fish species. Larval stages of many benthic organisms also form an important part of the zooplankton assemblage, particularly echinoderm, decapod and coelenterate larvae (Johns, 2004).

Studies indicate that zooplankton appear to be the most vulnerable group to toxic effects of discharges such as produced water, whereas the phytoplankton and fish larvae tend to be more robust to any direct effects (GESAMP, 1993). While some studies have found oil to be lethal and decrease photosynthesis in phytoplankton, other sources have found low concentrations of hydrocarbon spills actually stimulate phytoplankton growth (Sloan, 1999). Moreover, planktonic organisms are generally short lived and recovery following a, pollution induced, population reduction is usually rapid. Natural seasonality is also important as the plankton comprises different types and quantities of organisms at different times of the year.

Any measurable effects on the plankton from the proposed operations are therefore likely to be hard to detect against natural temporal and spatial variability in the plankton communities.

3.6.2 Seabed Communities

The benthos refers to the animals (and plants where light levels are sufficient) that live on or within the seabed. Animal communities are divided at a basic level into infauna and epifauna. Infauna consists mainly of animals that burrow into the sediment or form tubes in it, generally representing the larger component of benthic communities. Those species which live on, as opposed to in, the seabed including those attached to rocks or other animals are known as epifauna. Activities that result in physical or chemical disruption of the seabed, such as the deposition of discharged drill cuttings, can have a direct effect on the benthic fauna communities in the vicinity of an operation.

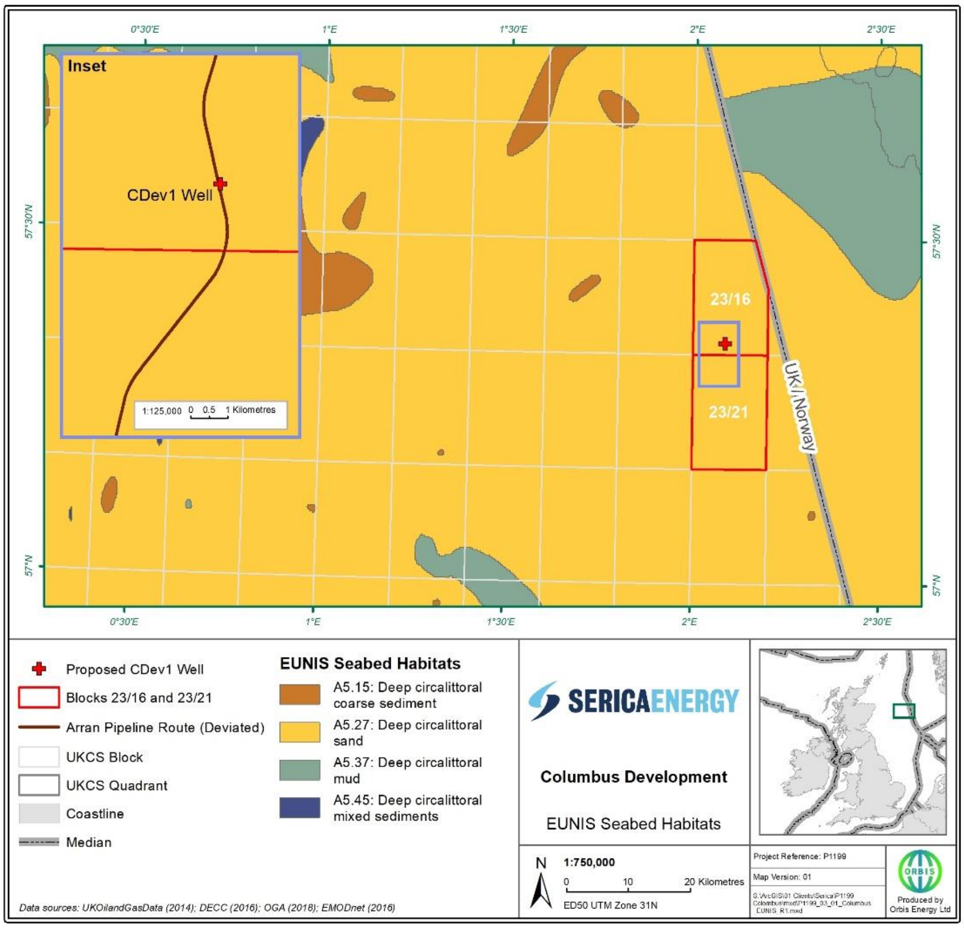
Historical surveys of the North Sea show that the benthic fauna is characterised by thermal stability over time (Glémarec, 1973), water depth and seabed granulometry (Künitzer *et al*., 1992). The seabed community (benthos) in the vicinity of the development area is characteristic of wider areas of the central North Sea with a 'finer' sediment type and water depth of approximately 80 to 90 m. The surface layer of the seabed sediments within this part of the central North Sea are predominantly comprised of fine sands. The benthic infaunal communities resident in uncontaminated sediments of this type are dominated by the polychaete worms with species such as *Levensenia gracilis* and *Lumbrineris gracilis* and the amphipod crustacean *Eriopisa elongate* being typical for the area (Eleftheriou and Basford, 1989).

EUSeaMap Seabed Habitat Project Data

The EUSeaMap Seabed Habitats Project (EMODnet, 2016) has mapped and classified seabed sediment types in UK waters according to the European Nature Information System (EUNIS) classification. The system identifies keystone species which have been identified as occurring within certain environmental conditions (e.g. water depth, temperature, sediment type etc.). This allows for the inference of community composition based on seabed type and mapping and identification of benthic biotopes.

The A5.27 (deep circalittoral sand) is the only EUNIS seabed habitat identified within the vicinity of the proposed Columbus Development (Figure 3.7). Communities of EUNIS habitat A5.27 are typically dominated by a diverse range of polychaetes, amphipods, bivalves and echinoderms (EEA, 2018). This EUNIS habitat type is also classified under the Marine Habitat Classification for Britain and Ireland as 'offshore circalittoral sand' and is given the code SS.SSa.Osa (EEA, 2018).

Figure 3.7. EUNIS Seabed Habitats in the Vicinity of the Proposed Columbus Development



Columbus Site Specific Data

As previously mentioned, of the surveys undertaken in the Columbus area, stations ENV14, ENV15A, ENV17A to ENV19 and ENV21A of the 2015 Gardline survey, stations ENV1 to ENV3 of the 2010 Gardline (route) survey and stations ENV1 to ENV3 of the Gardline 2008 survey lie in closest proximity to the proposed CDev-1 well location and the proposed deviated section of the Arran pipeline route (refer to Figure 3.1). As such, the preceding sub-sections will focus on the results of these stations.

Given the stability of the benthic environment in 80-90 m of water depth and the general homogeneity of the seabed sediments in this part of the central North Sea, it is considered that these surveys are recent enough to provide an accurate assessment of the environmental conditions in this area.

Seabed Imagery Observations

The 2015 Gardline survey noted that the epifaunal density observed was noticeably higher around boulders and areas of probable MDAC (located approximately 16 km to the north west of the proposed CDev-1 well), and otherwise low in areas of sand. Visible epifauna included (Gardline, 2016a):

- **Annelida**: Polychaeta, Serpulidae and *Ditrupa* sp;
- **Arthropoda**: hermit crab (*Pagurus bernhardus*), Caridea, Galatheidae, Lithodidae, Balanomorpha, king crab (*Lithodes maja*) and harbour crab (*Liocarcinus depurator*);
- **Mollusca:** Scaphopoda, Bivalvia, Buccinidae, Gastropoda sp., Cardiidae, Nudibranchia, *Mytilidae* and Pectinidae)
- **Echinodermata**: Asteroidea, Echinoidea, edible sea urchin (*Echinus esculentus*), Camarodonta, Holothuroidea, Amphiuridae, Cidaroidea and Ophiuroidea);
- **Bryozoa**: Flustridae, *Reteporella* sp.;
- **Chordata**: Actinopterygii, European hake (*Merluccius merluccius*), vommon dab (*Limanda limanda*), Myxinidae, starry ray/ thorny skate (*Amblyraja radiata*), pogge (*Agonus cataphractus*), long rough dab (*Hippoglossoides platessoides*), Gadiformes, Sebastidae, Gobiidae, Pleuronectiformes and Cottidae;
- **Cnidaria**: Hormathiidae, dead man's fingers (*Alcyonium digitatum*), Plumose anemone (*Metridium senile*), dahlia anemone (*Urticina feline*), sea anemone (*Hormathia digitata*), deeplet sea anemone (*Bolocera tuediae*), phosphorescent sea pen (*Pennatula phosphorea*), Actiniaria, Pennatulacea;
- **Other:** Hydrozoa (*Hydractinia echinata*), Echiura, Nemertea and Porifera (Demospongiae).

Of the species listed above, starry ray/thorny skate is listed on the IUCN Red List as 'vulnerable' (IUCN, 2018). One individual was observed at station ENV13 of the 2015 Gardline survey (Gardline, 2016a). In addition, individuals belonging to the genus Sebastidae were observed at station ENV36, however, it was not possible to identify conclusively whether the specimens were IUCN Red List species (such as *Sebastes mentella*, listed as endangered) or a more common non-listed species (Gardline, 2016a).

Macrofaunal Analysis

Taxonomic Grouping

Table 3.6 presents a summary of the macrofaunal analysis for the 2008 and 2010 (route) Gardline surveys. Note, equivalent information was not available for the 2015 Gardline survey.

Taxonomic analysis of grab samples taken during the 2008, 2010 (route) and 2015 Gardline surveys found the most abundant taxa to be annelida (polychaeta) (46%, 44% and 33-62%, respectively). The next most abundant taxonomic group was arthropoda in the 2008 Gardline survey and 2010 Gardline (route) survey (23% and 25%, respectively) (Gardline, 2008; 2010b). For the 2015 Gardline survey, mollusca ranked second at most stations across the northern part of the surveyed area, exceptions being at stations ENV11, ENV14, ENV13, ENV7 and ENV8, where arthropoda were ranked second (Gardline, 2016a). For the remainder of the route, arthropoda generally maintained second rank. It was noted that, arthropoda maintained second rank by the clearest margins where coarser sediment was observed on the SSS and / or during grab sample analysis (Gardline, 2016a).

In terms of abundance (the number of individuals), annelida were also the most dominant taxonomic group in the 2008, 2010 (route) and 2015 Gardline surveys (67%, 60% and 55-85%, respectively). The next most abundant taxonomic group was mollusca in the 2008 Gardline survey (16%) and Echinodermata in the 2010 Gardline (route) survey (26%) (Gardline, 2008; 2010b). For the 2015 Gardline survey, the second and third most abundant major taxonomic group was interchangeable between mollusca and arthropoda, with echinodermata taking this rank position at station ENV24 and ENV41 (Gardline, 2016a).

It is worth noting that, the 2008, 2010 (route) and 2015 Gardline surveys recorded a large proportion of single and low abundance species. This suggests that the community found in each survey area has been subject to relatively little recent contamination or disturbance (Gardline, 2008; 2010b; 2016a).

Table 3.6. Summary of Taxonomic Groups for the 2008 and 2010 (Route) Gardline Surveys (Gardline, 2008; 2010b)

Taxonomic Group	Individuals		Taxa	
	Abundance	Proportional Contribution %	Abundance	Proportional Contribution %
2008 Gardline (Adult only dataset[N1])				
Annelida (Polychaeta)	3,593	67	76	46
Arthropoda (Crustacea)	294	5	38	23
Mollusca	864	16	31	19
Echinodermata	184	3	8	5
Others	415	8	14	8
Totals	**5,350**	**100**	**167**	**100**
2010 Gardline (Route) (Full Dataset [N2])				
Annelida (Polychaeta)	3,039	60	44	38
Arthropoda (Crustacea)	322	6	29	25
Mollusca	260	5	28	24
Echinodermata	1,307	26	9	8
Others	171	3	7	6
Totals	**5,099**	**100**	**117**	**100**

Notes

[N1] Adult only dataset – used to avoid skewing the results with the abundant but largely ephemeral juveniles (Gardline, 2016a).

[N2] Full dataset - juveniles were insufficiently influential in the faunal community structure (Gardline, 2010b).

Species Ranking

Species ranking is a measure of the overall dominance pattern in a given sampling area, which may be achieved by ranking the top species per station according to abundance, giving a rank score of ten to the most abundant species, decreasing to one for the tenth most abundant species, and summing these scores for all stations to provide and overall dominance score for each species (Eleftheriou and Basford, 1989). The results for the species ranking procedure for the 2008, 2010 (route) and 2015 Gardline surveys are presented in Table 3.6.

Overall, polychaeta dominated the taxon found in all of the surveys, with the presence and dominance of polychaeta *Paramphinome jeffreysii* and *Galathowenia oculata* consistent across all three surveys. However, the other taxon among the top 10 ranking for each survey vary.

The polychaeta *Paramphinome jeffreysii*, was the top ranking taxon in the 2008 and 2015 Gardline surveys and came sixth in the 2010 Gardline (route) survey. In terms of abundance, this species came second in the 2008 Gardline survey, sixth in the 2010 Gardline (route) survey and first in the 2015 Gardline survey (refer to Table 3.6). *Paramphinome jeffreysii* is one of the most commonly encountered polychaete in the North Sea and is typical of deep sea (>50 m), muddy and sandy bottom habitats throughout the North-East Atlantic region (Pearson *et al*., 1996; Rees *et al*., 2007). Abundances of *Paramphinome jeffreysii* are reported to have increased especially in the central North Sea (Rees *et al*., 2007). This polychaete is known to be highly tolerant of hydrocarbon contamination (Olsgard and Gray, 1995; Hiscock *et al*., 2005) and intolerant of elevated heavy metal concentrations such as copper (Rygg, 1985). A study by Kingston *et al*. (1995) identified that *Paramphinome jeffreysii* obtained maximum abundance at contaminated sites following the Braer oil spill.

The polychaete *Galathowenia oculata* was the top ranking taxon in the 2010 Gardline (route) survey and came second and third in the 2008 and 2015 Gardline surveys, respectively. In terms of abundance, this species came first in the 2008 and 2010 (route) Gardline surveys and third in the 2015 Gardline survey (refer to Table 3.6). *Galathowenia oculata* is normally found within sandy muds or muddy sand (Hiscock *et al*., 2005), the latter being the predominant sediment type within the survey area. Given the high abundance of this species in the survey area it is unlikely that there is any significant contamination due to hydrocarbons (Gardline, 2010b).

Other taxon that could also be considered as biological indicators include the arthropoda *Harpinia antennaria* (intolerant of hydrocarbons contamination and physical disturbance) and the polychaete *Lagis koreni* (intolerant of physical disturbance) (Hiscock *et al*., 2005). The 2010 Gardline (route) survey report concluded that the presence of these species within the community was reflective of the background concentrations of hydrocarbons and metals within the survey area, and suggests there has been little physical disturbance (Gardline, 2010b).

The 2008 Gardline survey report concluded that, on the whole, taxa appeared to be typical of fine and muddy sand North Sea sediments that had not been subject to recent or elevated levels of contamination (Hiscock *et al*., 2005; Hayward and Ryland, 1995; MARLIN, 2009).

Table 3.7. Species Ranking for Surveys in the Columbus Area (Gardline, 2008; 2010b; 2016a)

Rank		Species/Taxon	Total Rank Score	Fidelity	Total Abundance
Score	Abundance				
2008 Gardline Survey (Adult only dataset[N1])					
1	2	*Paramphinome jeffreysii*	58.0	0.97	1,641
2	1	*Galathowenia oculata*	53.0	0.98	973
3	3	*Philine sp.*	37.0	0.77	327
4	4	*Pholoe inornata*	25.0	0.60	185
5	6	*Owenia fusformis*	23.5	0.65	118
6	7	*Polycarpa fibrosa*	20.0	0.67	114
6	9	*Acanthocardia sp.*	14.0	0.58	92
8	5	*Ampharete falcata*	12.0	0.67	133
9	8	*Phoronis*	11.5	0.96	93
10	13	*Phtisica marina*	10.0	1.67	65
2010 Gardline (Route) Survey (Full Dataset [N2])					
1	1	*Galathowenia oculata*	50.0	1.00	1,945
2	5	Asteroidea indet. juv.	36.0	0.80	329
3	4	*Lagis koreni* (inc. juv.)	35.0	0.88	340

Rank		Species/Taxon	Total Rank Score	Fidelity	Total Abundance
Score	Abundance				
4	3	Ophiuroidea indet. juv.	35.0	1.00	372
5	2	Echinoidea indet. juv.	35.0	1.17	561
6	6	*Paramphinome jeffreysii*	26.0	1.04	294
7	7	*Harpinia antennaria*	22.0	1.08	174
8	8	*Phoronis muelleri*	15.0	0.97	116
9	9	Polynoidae indet. juv.	8.0	0.75	78
10	11	*Pholoe balthica*	4.0	0.70	46
2015 Gardline Survey (Adult only Dataset N1)					
1	1	*Paramphinome jeffreysii*	327	0.99	5,776
2	2	*Spiophanes bombyx*	287	0.97	2,846
3	3	*Galathowenia oculata agg.*	194	0.73	1,108
4	4	*Scoloplos (Scoloplos) armiger*	168	0.73	618
5	5	*Pholoe assimilis*	97	0.49	525
6	6	*Eudorellopsis deformis*	90	0.55	399
7	7	*Ophiocten affinis*	71	0.54	347
8	9	*Amphiura filiformis*	63	0.64	295
9	8	*Owenia borealis*	56	0.85	300
10	11	*Amphictene auricoma*	53	1.61	252

Notes

Cells are coloured to indicate the taxonomic division the taxon belong: Mollusca, Annelida, Echinodermata, Arthropoda and other.

N1 Adult only dataset – used to avoid skewing the results with the abundant but largely ephemeral juveniles (Gardline, 2016a).

N2 Full dataset - juveniles were insufficiently influential in the faunal community structure (Gardline, 2010b).

Ocean Quahog (*Arctica islandica)*

The ocean quahog (*Arctica islandica*) is listed as threatened and/or declining species by OSPAR (2018), as a species feature of conservation importance, and may form a PMF and be included within MPA criteria (SNH, 2014) under the Marine and Coastal Access Act (2009). The nomination of ocean quahog for inclusion on the OSPAR list was with reference to decline and sensitivity, primarily due to significant changes in distribution and density over the last century (OSPAR, 2009).

A low number of ocean quahog were found in the grab samples taken at a number stations during the 2007, 2008 and 2015 Gardline surveys. During the 2015 Gardline survey a total of 24 individual ocean quahogs were recorded across fifteen stations within the surveyed area (refer to Table 3.8; Gardline, 2016a). Of these 24 individuals the majority were juvenile, with only two adult specimens. In addition, 47 individual ocean quahog juveniles were found during both the 2008 Gardline survey across all six stations (Gardline, 2008) and the 2007 Gardline survey across nine of the 10 stations (Gardline, 2007).

Table 3.8. Number of Ocean Quahog (*Arctica islandica*) Recorded during the Surveys in the Columbus Area (Gardline, 2007; 2008; 2016a)

Survey	Sampling Station[N1] and the Number of *Arctica islandica* Recorded				
2015 Gardline Survey	ENV4 – 1 ENV7 – 1 ENV28 – 1 ENV20 – 1	ENV16 – 1 ENV12 – 1 ENV13 – 1 ENV15A – 2	ENV17A – 1 ENV22A – 3 ENV23 – 3 ENV25 – 1	ENV26 – 3 ENV42 – 2 ENV40 - 2	**Total = 24**
2008 Gardline Survey	ENV1 – 11 ENV2 – 3 ENV3 – 2 ENV4 – 5	ENV5 – 2 ENV6 – 24			**Total = 47**
2007 Gardline Survey	ENV1 – 1 ENV2 – 4 ENV3 – 3 ENV4 - 5	ENV5 – 1 ENV6 – 12 ENV7 – 7 ENV8 - 12	ENV10 - 2		**Total = 47**

Notes

[N1] The location of the survey stations is presented in Figure 3.1.

Ocean quahog filter food from passing currents and can use a shovel-like foot to bury into the sediment. To escape predators, they can burrow deep into the sediment and live for long periods of time without food or oxygen. Ocean quahog are an important food source for several species of fish including cod. Although they are not specific to one type of habitat, sands and gravels are the ocean quahogs' preferred habitat. The main threat to ocean quahog is disturbance of the seabed, most often from bottom fishing activities, but licensed activities, such as oil, gas and aggregate extraction, can also directly and indirectly affect this species (JNCC, 2017c).

Given the proximity of the 2015, 2008 and 2007 Gardline survey stations which recorded ocean quahog (refer to Table 3.8 and Figure 3.1) to the proposed Columbus Development, , it is considered likely that this species will also be present in the grab samples collected during the 2018 survey. It should be noted, however, that ocean quahog is commonly found within the North Sea (Oil and Gas UK, 2010) and when compared with other areas, the abundance of ocean quahog in the proposed Columbus Development area is relatively low. For example, particularly high densities have been reported from the North Sea Fladen Grounds, dominated by juveniles with 28,600 individuals per 100 per square m (Witbaard and Bergman, 2003).

<u>Habitats of Conservation Importance</u>

As noted in Section 3.3, the 2016 Gardline survey found evidence from the seabed imagery and geophysical data of protected/sensitive habitats within the Arran North Site. At stations ENV35 and ENV36, probable MDAC structures were observed. MDAC structures can form potentially sensitive habitats or features and are protected under Annex I of the EC Habitats Directive 92/43/EEC as submarine structures made by leaking gas (Gardline, 2015b). However, these stations are located approximately 16 km to the north west of the proposed CDev-1 well location.

Apart from the presence of probable MDAC structures, no further habitats of conservation importance were identified in the seabed imagery data or observed in the seabed sampling of the 2006, 2007, 2008, 2010 (route or site) or 2015 Gardline surveys, as listed under Annex I of the Habitats Directive (1992), as implemented by the Offshore Marine Conservation (Natural Habitats, &c.) Regulations (2007 (as amended)) and as endorsed by the Marine and Coastal Access Act (2009); as PMF in Scottish offshore waters (Joint Nature Conservation Committee, 2012), under the Marine and Coastal Access Act (2009); as habitats on the OSPAR (2008) list of threatened and/or declining species and habitats. This will be verified by the proposed 2018 Columbus site and route survey.

Conclusions

The 2008 Gardline survey report concluded that both univariate and multivariate analysis showed some degree of variability in the faunal community and that physico-chemical attributes of the sediment appeared to subtly influence the community (Gardline, 2008). Overall, the range of taxa was diverse and characteristic of fine muddy North Sea sediments, suggesting an absence of any recent anthropogenic disturbance gradient (Gardline, 2008).

The 2010 Gardline (route) survey report concluded that the faunal community in the survey area was relatively abundant and diverse, despite some dominance by the polychaete *Galathowenia oculata*. Multivariate analyses indicated that there was no significant difference between the faunal communities sampled at each station, and that they were uniformly spread with little evidence of patchiness. Ultimately it is likely that the community was free from any discernible anthropogenic impact (Gardline, 2010b).

The 2015 Gardline survey report concluded that the macrofaunal dataset suggested that the faunal community within the surveyed area was diverse and moderately evenly distributed with no strongly dominant taxa other than the polychaeta *Paramphinome jeffreysii* (Gardline, 2016a). Any significant variation in the macrofaunal community was predominantly associated with changes in sediment particle size, together with less weathered hydrocarbons. Multivariate analysis suggested that the variation in the macrofaunal community was linked to variation in sediment particle size and its co-variants. Overall this indicated primarily natural variation throughout the surveyed area (Gardline, 2016a).

In addition, the 2015 Gardline survey report identified the gravelly stations (i.e. ENV11) to correspond with EUNIS habitat A5.15 (deep circalittoral coarse sediment) or A5.45 (deep circalittoral mixed sediment) and the majority of the remaining stations correspond with EUNIS habitat A5.27 (deep circalittoral sand). This strongly agrees with the EUNIS habitat map presented in Figure 3.7.

Given the above, it is anticipated that the macrofaunal community within the 2018 Columbus survey area is likely to be diverse and to show some spatial variability. However, this is expected to be in line with natural variability (i.e. the physico-chemical attributes of the sediments) rather than as a consequence of anthropogenic disturbance or contamination. In addition, the predominant habitat type across the survey area is expected to be EUNIS habitat A5.27 (deep circalittoral sand).

3.6.3 Fish

Species diversity within the fish community is not as great in the central and northern North Sea as in the southern North Sea (DECC, 2016). The fish community between depths of 50 and 100 m in the central North Sea (i.e. within the depth bounds of the Columbus Development area) is expected to be characterised by dab (*Limanda limanda*) and long rough dab (*Hippoglossoides platessoides*) (DECC, 2016).

Although the distribution of adult fish populations is highly fluid, analysis of recent fisheries landing and effort data suggests that adult populations of the pelagic species (living in open water) herring (*Clupea harengus*) and the demersal species (living at or close to the seabed) plaice (*Pleuronectes platessa*), lemon sole (*Microstomus kitt*), haddock (*Melanogrammus aeglefinus*), witch (*Glyptocephalus cynoglossus*), cod (*Gadus morhua*), monks/anglers (Lophiidae), saithe (*Pollachius virens*) and whiting (*Merlangius merlangus*) are relatively abundant in this area (Marine Scotland, 2017a).

Spawning and Nursery Grounds

The Centre for Environment, Fisheries and Aquaculture Science (CEFAS) has published data on spawning and nursery grounds for selected fish species around the UK (Coull *et al.,* 1998; Ellis *et al.,* 2012). Data is based on historic and more recent surveys to identify key spawning and nursery habitats for certain species of interest. Spawning and nursery grounds are mapped according to International Council for the Exploration of the Seas (ICES) statistical rectangles. The proposed Columbus Development lies within ICES Rectangle 43F2.

Fish species reported to use the proposed Columbus Development area as spawning grounds include cod, lemon sole, mackerel (*Scomber scombrus*), Norway Pout (*Trisopterus esmarkii*), plaice and sandeels (*Ammodytes* spp.) (Coull *et al.,* 1998; Ellis *et al.,* 2012; Table 3.9; Figure 3.8 and Figure 3.9).

A number of fish species, including Norway pout, have pelagic eggs and/or larvae (i.e. they release large numbers of eggs directly into the water column; DTI, 2001; Nash *et al.,* 2012; FishBase, 2017). The spawning grounds of these species can cover extensive areas (DECC, 2016). While other fish species, including sandeels, have a dependency on specific substrata for spawning.

Sandeel eggs are demersal and are laid in sticky clumps on clean, sandy sediments therefore hatching success and recruitment can be affected by activities that disturb seabed sediments. This habitat dependence, along with a tendency to remain in the same area, makes the species vulnerable to site disturbance.

Sandeels are considered an important component of marine food webs providing food for marine predators such as seabirds, mammals and other fish (Furness, 1990; 2002; Lancaster *et al.,* 2014). They generally occur in water depths of between 20 and 100 m (Reay, 1970). Of the five species of sandeels occurring in the North Sea, the lesser sandeel (*Ammodytes marinus*) is the most abundant species comprising over 90% of sandeel fishery catches (JNCC and SNH, 2014).

Sandeels are burrowing species that spend the majority of their time in sandy sediments (Lancaster *et al*., 2014). The distribution of sandeels is primarily dictated by the availability of suitable substrates for settlement and burrowing; gravel or coarse sand with a low silt-clay fraction (Wright *et al*., 2000). They are reported to be rare in sediments where the proportion of silt (particle size < 0.63µm) is greater than 4%, and absent where silt concentration is greater than 10% (Wright *et al*., 2000; Holland *et al*., 2005). In addition, the lesser sandeel requires very specific sediment, favouring substratum with a high proportion of medium and coarse sand (between 0.25mm and 2mm) and low silt content (Holland *et al*., 2005).

The Columbus Development lies within the optimal water depth range for sandeels (85 to 87 m below LAT). However, the results of the particle size analysis undertaken on the sediment samples collected during the 2007, 2008, 2010 (route and site) and 2015 Gardline surveys found all stations to have a fines content >4% (refer to Section 3.3.3). In addition, all but six of the 25 stations within 5 km of the proposed CDev-1 well location and deviated section of the Arran pipeline route have a fines content >10% (Gardline, 2007; 2008; 2010b; 2016a). Exceptions were stations ENV1, ENV4 and ENV9 from the 2007 Gardline survey, ENV3 from the 2008 Gardline survey and ENV14 and ENV21A from the 2015 Gardline survey. As such, it is considered unlikely that the Columbus Development area is suitable sandeel habitat. However, it should be noted that other factors (such as salinity conditions, zooplankton densities, etc.) have been reported to play an important role in sandeel abundance (Kooij *et al*., 2008).

In addition to spawning grounds, the waters of the Columbus Development area also act as a nursery area for anglerfish (monkfish; *Lophius piscatorius*), blue whiting (*Micromesistius poutassou*), cod, European hake (*Merluccius merluccius*), haddock, herring, horse mackerel (*Trachurus trachurus*), ling (*Molva molva*), mackerel, Norway pout, plaice (*Pleuronectes platessa*), sandeel, spotted ray (*Raja montagui*), spurdog (*Squalus acanthias*) and whiting (Coull *et al*., 1998 and Ellis *et al*., 2012; Table 3.9; Figure 3.8 and Figure 3.9). Therefore juveniles of these species are likely to be present following hatching.

Of the species that may be present within the vicinity of the proposed Columbus Development area, the majority are considered to be demersal species, i.e. species that spend most of their time at or near the seabed. These species include anglerfish, cod, European hake, haddock, lemon sole, ling, Norway pout, plaice, sandeels, spurdog, spotted ray and whiting (FishBase, 2017). However species such as spurdog and Norway pout can also be regarded as benthopelagic species that move into mid-water periodically, and have been known to predate upon midwater species (DTI, 2001; FishBase, 2017). In addition, sandeels remain buried in sandy sediments during the night and hunt for prey in mid-water during daylight hours and are therefore not a wholly demersal species (W*i*nslade, 1974 cited in DTI, 2001). Other species such as blue whiting, herring, horse mackerel and mackerel are considered to be pelagic species i.e. species that spend most of their time in open water, away from the seabed (DECC, 2016; FishBase, 2017).

Although many of the species that may utilise the waters surrounding the proposed Columbus Development area as spawning and / or nursery grounds are fairly widespread throughout the region, a number of these species are listed as PMFs in Scottish waters. These include the anglerfish (monkfish), blue whiting, cod, herring, horse mackerel, ling, mackerel, Norway pout, lesser sandeels (*Ammodytes marinus* offshore), spurdog (also known as the spiny dogfish) and whiting (SNH, 2014; Tyler-Walters *et al*., 2016). Lesser sandeel are also listed as an MPA search feature in Scottish waters (Tyler-Walters *et al*., 2012). This species is designated as a NC MPA search feature to aid in its conservation, focus research and assist in marine planning due to its importance as commercial fishery target species (Marine Scotland, 2017b).

Of note is that cod, spotted ray and spurdog are on the OSPAR List of Threatened and / or Declining Species and Habitats. In addition, cod and spurdog are also listed as Vulnerable on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species and should therefore be considered as priorities for protection (IUCN, 2018; OSPAR, 2018). The spotted ray is ranked as being of Least Concern on the IUCN Red List (IUCN, 2018).

Table 3.9. Fish Spawning and Nursery Species within the Proposed Columbus Development Area (Coull *et al*., 1998; Ellis *et al*., 2012)

Species	J	F	M	A	M	J	J	A	S	O	N	D
Anglerfish (monkfish) [N1]			N	N	N	N	N	N				
Blue whiting						N	N	N				
Cod			N	N	N	N						
European hake			N	N	N	N	N	N				
Haddock				N	N	N	N					
Herring										N	N	
Horse mackerel[N2]					N	N	N	N	N	N		
Lemon sole												
Ling				N	N	N	N					
Mackerel							N	N	N	N		
Norway pout			N	N	N	N						
Plaice		N	N	N	N							
Sandeel	N	N	N	N								
Spotted ray						N	N	N	N	N		
Spurdog[N3]	N	N	N	N	N	N	N	N	N	N	N	N
Whiting				N	N	N	N	N				

Key

Spawning | Peak Spawning | N Nursery

Notes

The red box indicates the proposed window for the operations.

[N1] Insufficient data available on spawning grounds

[N2] Horse mackerel appear to be widespread and with no spatially discrete nursery grounds (Ellis *et al*., 2012).

[N3] Viviparous species (gravid females can be found all year) (Ellis *et al*., 2012)

Figure 3.8. Fish Spawning and Nursery Areas in the Proximity of the Proposed Columbus Development (1 of 2)

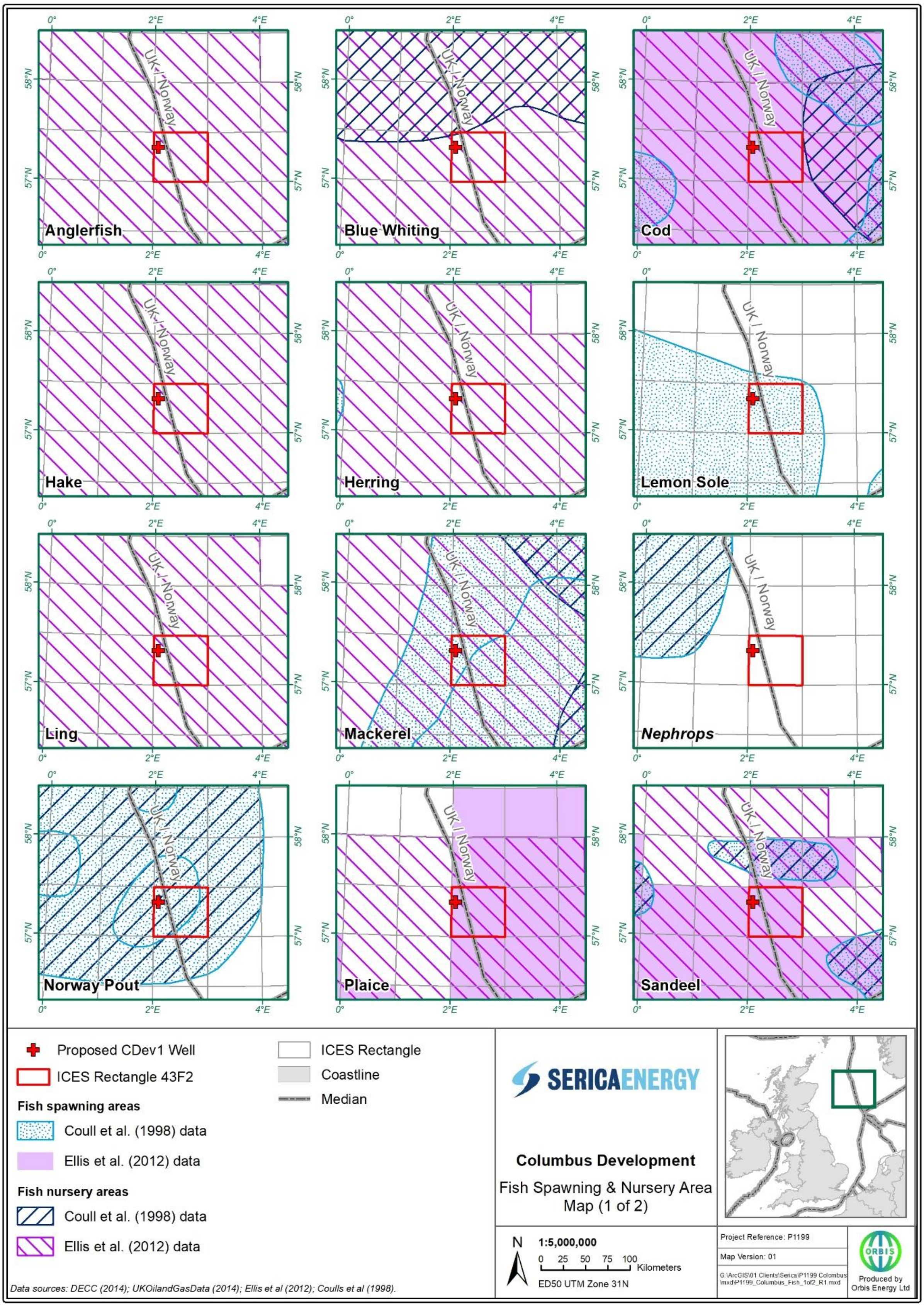
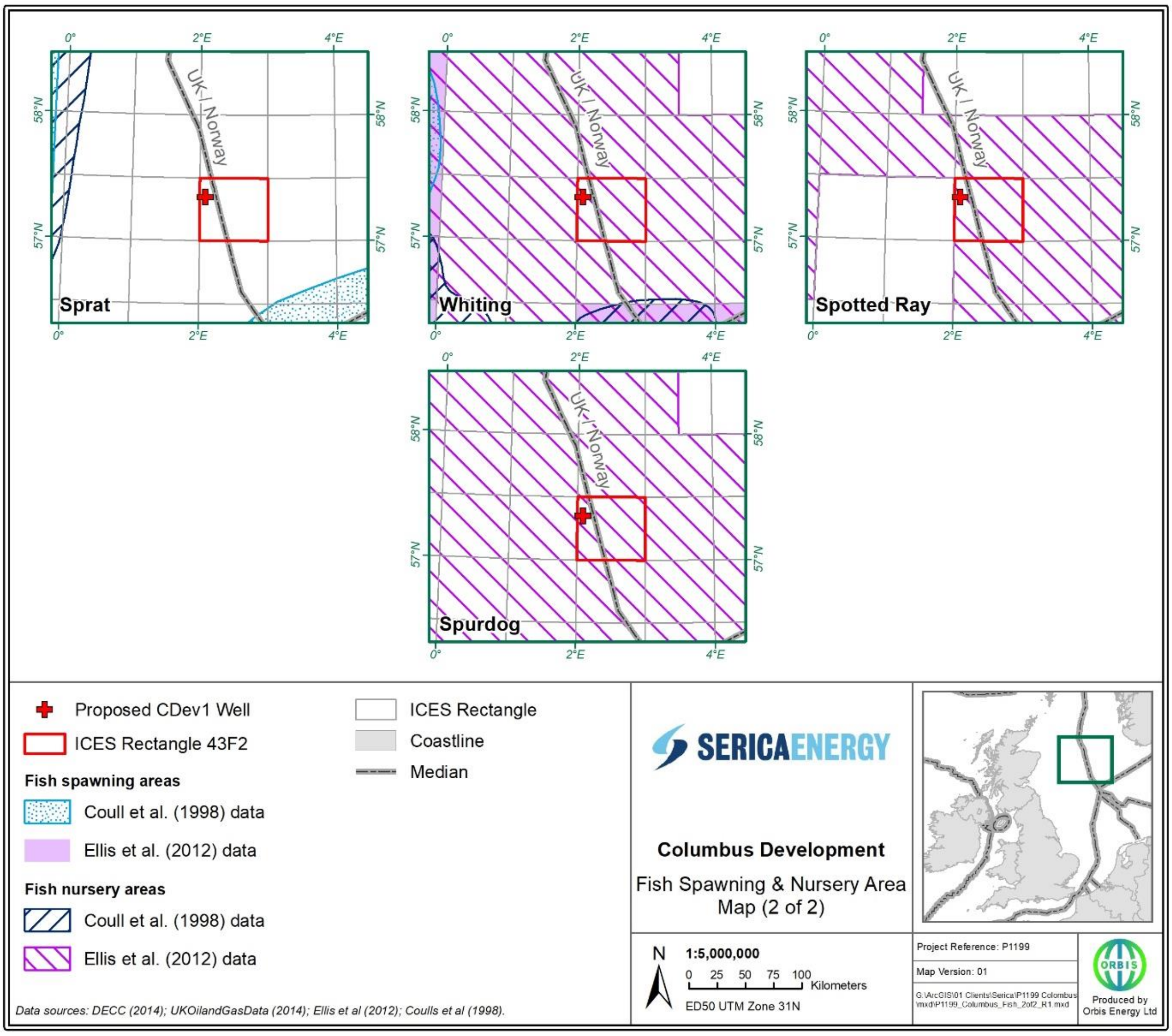


Figure 3.9. Fish Spawning and Nursery Areas in the Proximity of the Proposed Columbus Development (2 of 2)



0 Group Fish Species

In addition to the mapping of spawning and nursery grounds of key commercial fish species, more recent spatial modelling of the probability of the occurrence of aggregations of fish in the first year of their life (termed 0 group fish species) and/or larval stages has been undertaken. This has provisionally identified the spatial distribution of sensitive life stages of commercial fish species (in line with Coull *et al*., 1998 and Ellis *et al*., 2012) that could be affected by oil and gas operations (Aires *et al*., 2014). 0 group fish are considered to be most sensitive to physical damage from oil and gas operations (e.g. through seismic surveying and piling). In general, the juvenile stages of many commercial fish species remain within coastal areas for a year or two before moving offshore (DTI, 2004) and therefore juveniles are less likely to utilise the offshore waters in the vicinity of the proposed Columbus Development area as a significant habitat.

Based on spatial modelling of 0 group fish, the area in the vicinity of the proposed Columbus Development area is not considered to be of high importance to juvenile fish species in their first year of development (Figure 3.10 and Figure 3.11). Of the species mapped, there is a low to moderate probability of 0 group aggregations of anglerfish, European hake, haddock, Norway pout and whiting in the vicinity of the proposed Columbus Development area (Figure 3.10 and Figure 3.11). It is important to note, however, that the specific locations of these sites of fish sensitivity are dynamic and may shrink or expand or move over time as maps are updated (Aires *et al*., 2014).

Figure 3.10. Probability of 0 Group Fish Aggregations in the Vicinity of the Columbus Development Area (1 of 2)

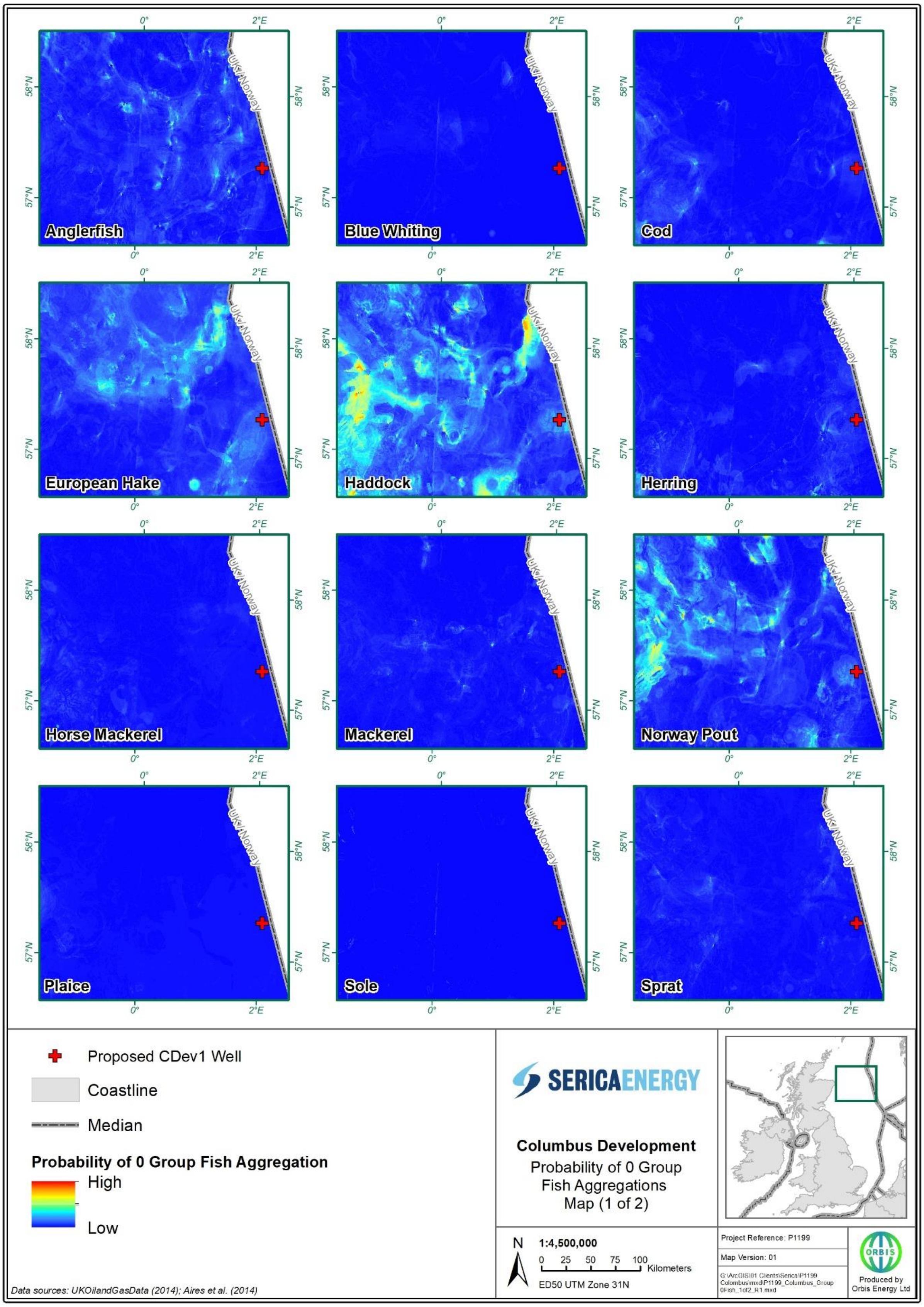
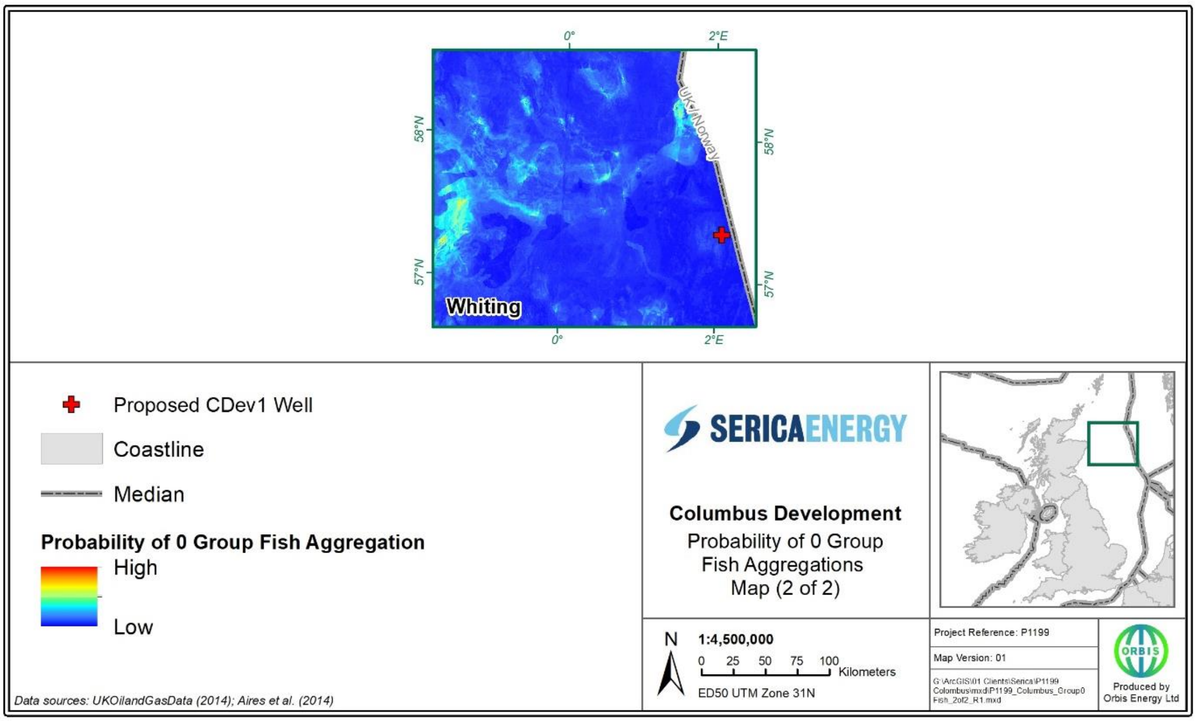


Figure 3.11. Probability of 0 Group Fish Aggregations in the Vicinity of the Columbus Development Area (2 of 2)



Elasmobranchs

Elasmobranchs encompasses species of sharks, skates and rays. These species differ from other fish by having a skeletal structure made out of cartilage as opposed to bone. They typically have a slow growth rate and low fecundity, leaving their populations vulnerable to over-fishing, habitat degradation and pollution events however, their distribution is wide throughout the world's oceans (Baxter *et al*., 2011).

Surveys of the distribution of elasmobranchs in UK waters were undertaken by Ellis *et al.* in 2004 and have also been reviewed by Baxter *et al.* (2011). Species which have been recorded in the central and northern North Sea at various times throughout the year and may therefore be present in the vicinity of the proposed Columbus Development area, are listed in Table 3.10 (Ellis *et al.,* 2004; Baxter *et al.,* 2011).

A number of the species listed in Table 3.10 are also PMFs including; the basking shark, common skate, sandy ray and spurdog (spiny dogfish) (SNH, 2014). In addition, the basking shark and common skate are also listed as MPA search features whereby MPA designation should seek to protect these features (Marine Scotland, 2017b).

Table 3.10. List of Elasmobranch Species Likely to be found in the Vicinity of the Proposed Columbus Development (Ellis *et al.,* 2004; Baxter *et al*., 2011; IUCN, 2018)

Common Name	Latin Name	Depth Range (m)	IUCN Status[1]
Spurdog / Spiny dogfish	*Squalus acanthias*	15-528	Vulnerable
Blackmouthed catshark	*Galeus melastomus*	106-433	Least Concern
Tope shark	*Galeorhinus galeus*	17-200	Vulnerable
Starry smooth hound	*Mustelus asterias*	10-199	Least Concern
Thorny skate / Starry ray	*Amblyraja radiata*	18-1400	Vulnerable
Common skate	*Dipturus batis*	84 -271	Critically Endangered

Common Name	Latin Name	Depth Range (m)	IUCN Status[1]
Black skate / Norwegian skate	*Dipturus nidarosiensis*	111-1000	Near Threatened
Sandy ray	*Leucoraja circularis*	108-432	Endangered
Shagreen skate	*Leucoraja fullonica*	90-424	Vulnerable
Cuckoo ray	*Leucoraja naevus*	12-290	Least Concern
Rabbitfish	*Chimaera monstrosa*	50-1000	Near Threatened
Basking shark	*Cetorhinus maximus*	0-750	Vulnerable
Blue shark	*Prionace glauca*	0-600	Near Threatened

[1] Status as of May 2018.

Information relating to the distribution of basking sharks on the Scottish continental shelf is limited. Basking sharks appear to be most regularly recorded in coastal areas of the UK with seasonally persistent tidal fronts. They are mainly recorded in surface waters from April to September, when mostly immature females are seen. In late summer, basking sharks are thought to disperse offshore but their winter distribution remains unknown, but is thought to be in deep water (DTI, 2003). Research (Sims *et al*., 2003) suggests that they make extensive migrations both vertically and horizontally to locate high concentrations of plankton that will often be associated with fronts, and that they principally migrate north to south during the winter months along the continental shelf of Europe (Sims *et al*., 2003; 2005). Therefore, basking sharks may be present in the proposed Columbus Development area.

3.6.4 Seabirds

Seabirds found in offshore areas around the UK include members of several families, most notably petrels, shearwaters, gannets, gulls, skuas and auks. Seabird presence and abundance is often used as an indicator for assessing the state of the marine environment as their populations and distribution varies with changes in prey abundance, weather, predation and pollution (Baxter *et al*., 2011).

Offshore Seabirds

Seabird abundance tends to decrease with increasing distance from shore, and their distribution becomes increasing patchy in relation to a number of oceanographic features. The availability and distribution of prey, however, is considered to be the most important factor driving seabird distribution and abundance. The various seabird families also differ in the total amount of time they spend at sea, the distances they travel and how they behave when at sea, both during and outside the breeding season. Table 3.11 summarises the at-sea distribution of the main seabird species found in the Northern North Sea area (Regional Sea 1), the region within which the proposed Columbus Development is located (DECC, 2016).

In 2012, Thaxter *et al*. published a review of representative breeding season foraging ranges for different seabird species. The Columbus Development area lies approximately 230 km off the Scottish coast and is therefore potentially within the breeding season foraging ranges of fulmar (*Fulmarus glacialis*), Manx shearwater (*Puffinus puffin*) and gannet (*Morus bassanus*) (Thaxter *et al*., 2012).

Note that there are no bird species identified as PMFs in Scottish waters as they are protected under the EU Birds Directive (SNH, 2014; Tyler-Waters *et al*., 2016). However, the black guillemot (*Cepphus grylle*) is listed as a NC MPA search feature in Scottish waters thereby encouraging the designation of MPAs to protect this species (Tyler-Walters *et al*., 2012). Unlike other auk species, the black guillemot is typically found feeding in inshore waters and rarely disperses from its breeding areas, even in winter (DECC, 2016). As such, it is unlikely to be found in the vicinity of the proposed Columbus Development area.

Table 3.11. Summary of Seabird Distribution at Sea on the Northern North Sea Area (Regional Sea 1) (Tasker and Pienkowski, 1987; Skov *et al.,* 1995, Furness, 2015 cited in DECC, 2016)

Months	Presence and Distribution of Seabirds
January	**Guillemot** and **razorbill** are abundant in the Moray Firth and close to the coasts of eastern Scotland and northern England. Guillemots return to Shetland waters. **Herring and great black-backed gulls** most frequently seen in the Moray Firth and off the eastern coast of Britain. **Glaucous gulls** reach an annual peak in the northern North Sea. Although commonest off Shetland, **fulmars** are present in high numbers, in most offshore areas of the northern and central North Sea, with spring migration in January in most years. Breeding birds can attend nest sites from early winter, but as this species can forage vast distances, nest attendance during this time may be sporadic.
February	Main concentrations of **guillemots** present in Moray Firth and Firth of Forth, birds also around the southern half of Shetland. Important numbers present off most of Scottish coast. **Puffins** present in large numbers and widely distributed in northern North Sea. Adult **gannets** returning, with the areas off south east Scotland and north-east England important at this time. Spring migration of **Manx shearwater** (Feb-Mar).
March	**Guillemots** and **puffins** return to the vicinity of their colonies. Main concentrations of **kittiwakes** in northern North Sea, off Orkney and Shetland, and more **gannets** return. Highest densities of **fulmar** present off main breeding areas, but many also present in central North Sea. **Herring** and **great black-backed gulls** from Norway return north-eastwards. **Gulls** remaining in area are breeding birds and the Moray Firth remains important.
April	Breeding season for some seabirds begins at the end of the month. Many birds returning to colonies and pre-breeding feeding, both close to colonies and further offshore. **Kittiwakes** remain widely distributed particularly in north near main breeding areas. Large numbers of **gannets** found near colonies. Many immature gannets attend at colonies during summer (for shorter times than breeding adults). **Great skuas** return to breeding grounds in Shetland. **Terns** return in greatest numbers.
May	Start of breeding season for most seabirds, birds away from colonies likely to be immature. Areas including Shetland, Caithness, Aberdeenshire, Firth of Forth and Farne Islands, the most important for **auk** species. Birds still forage at distances further from the colonies than during chick rearing. **Manx shearwater**, **storm petrels** and **Arctic skua** start arriving back in the northern North Sea.
June	Peak of breeding season. Majority of seabirds in coastal areas. Majority of the **guillemots** in Shetland & Moray Firth, with important concentrations also found further south. Most breeding **guillemots** do not feed further than 30 km from their breeding site. At end of month, guillemot chicks start to leave colonies and disperse into northern North Sea. Breeding **razorbills** feed closer to shore than **guillemots**. Some adult **gannets** forage great distances from breeding sites, with many staying much closer, with immatures still present. **Kittiwakes** forage in similar areas as **guillemots**, **razorbill** and **puffin**. Breeding **Arctic** and **great skua** feed close to colonies.
July	The nesting season for many species of seabird ends in late June/early July, and adult and juvenile birds start to move south to wintering grounds or move to areas where they form moulting flocks. The area of the Shetland Basin, over some of the banks of the central North Sea and off the Moray Firth and Aberdeenshire coasts support large concentrations of birds than at any other time of the year. Birds widely dispersed so many areas of the North Sea hold vulnerable populations.

Months	Presence and Distribution of Seabirds
August	The highest number of auks occurs off east coast of Scotland and northern England. **Black guillemots** moult at this time and are found at specific moult sites concentrated in sheltered inshore waters around Shetland. **Puffins** disperse rapidly from colonies. Young **gannets** start to leave and are flightless for a short period with areas close to colonies containing vulnerable concentrations. Autumn migration of **Manx shearwater**.
September	Distribution of **auks** spreads outwards into North Sea. Inshore areas off the east coast of Scotland and north-east England remain important for birds, but the width of the area away from the coast is greater than in August. The sea off the Scottish and north-east English coast between Moray Firth and Barmade Bank of importance to **guillemot**. Largest concentrations of **razorbills** found off Moray Firth (and the inner area of the Firth also important for **Manx shearwaters**) and east of the Forth and Tay, these areas are also important for **puffins**. **Great skuas** become widespread in North Sea as they leave their breeding sites and move south. Gr**eat black-backed gulls** move across the North Sea from Norway and found off east coast of England. **Fulmars** numerous and widespread across most of northern and central North Sea. Peak autumn migration of **gannet**.
October	Southward shift in **guillemot** and **razorbill** populations, however the inshore band off Scotland and northern England still hold the largest numbers. **Puffins** found in offshore areas, with areas in central North Sea holding the most birds. **Kittiwake** distribution moves south and large numbers of birds found off the Moray Firth. Small numbers of **little auks** arrive in northern North Sea. **Fulmars** remain common throughout most of the northern North Sea.
November	Areas off eastern coast of Britain remain important for **guillemots** and **razorbills**. The east coast of Scotland holds relatively few birds compared to other times of the year, with the exception of the Firth of Forth and its approaches. Flocks of **kittiwake** found around fishing fleets in the Fladen Ground and several winter visitors become more common in northern North Sea: an obvious change is the arrival of **gulls** in offshore waters, with **herring gulls** from Norway moving south-west across the North Sea to areas including the Fladen Ground.
December	Large numbers of **guillemots** close to coasts, with the most important area being the southern shore of the Moray Firth. **Puffins** present in central North Sea, off the north-east and east coasts of England and Scotland. **Fulmars** commonest in northern North Sea.

Seabird Sensitivity to Surface Oiling

Seabirds are vulnerable to accidental releases of hydrocarbons. The vulnerability of bird species to oil pollution is dependent on a number of factors and varies considerably throughout the year.

The Seabird Oil Sensitivity Index (SOSI) (Webb *et al*., 2016) combines seabird data collected between 1995 and 2015 and individual seabird species sensitivity index values to create a single measure of seabird sensitivity to oil pollution. The SOSI score for each UKCS Block can be ranked into sensitivity categories, from 1 (extremely high sensitivity) to 5 (low sensitivity). An assessment of the median SOSI scores in the vicinity of the proposed Columbus Development area varies from low to high throughout the year (Webb *et al*., 2016), with low sensitivity recorded throughout the year within UKCS Blocks 23/16 and 23/21 (Table 3.12 and Figure 3.12). It should be noted that data was unavailable for August and November and scores for March, May, October and December were acquired using indirect assessment of the data, as per the JNCC guidance (Webb *et al.,* 2016).

Table 3.12. Assessment of Seabird Oil Sensitivity Index (SOSI) Scores for UKCS Blocks of the Vicinity of the Proposed Columbus Development Area and the Surrounding UKCS Blocks (Webb *et al.*, 2016)

UKCS Blocks	J	F	M	A	M	J	J	A	S	O	N	D
22/15	5	5	5	N	5	5	5	5	5	5	N	5
23/11	5	5	5	N	5	5	5	5	5	5	N	5
23/12	5	5	N	N	N	5	5	5	5	N	N	N
22/20	5	5	5	N	5	5	5	5	5	5	N	5
23/16	**5**	**5**	**5**	**N**	**5**	**5**	**5**	**5**	**5**	**5**	**N**	**5**
23/17	5	5	5	N	5	5	5	5	5	5	N	5
22/25	5	5	5	5	5	5	5	5	5	5	N	5
23/21	**5**	**5**	**5**	**N**	**5**	**5**	**5**	**5**	**5**	**5**	**N**	**5**
23/22	5	5	5	N	5	5	5	5	5	5	N	5
22/30	5	5	5	5	5	5	5	5	5	5	N	5
23/26	5	5	5	N	5	5	5	5	3	3	N	5
23/27	5	5	5	N	5	5	5	5	5	5	N	5

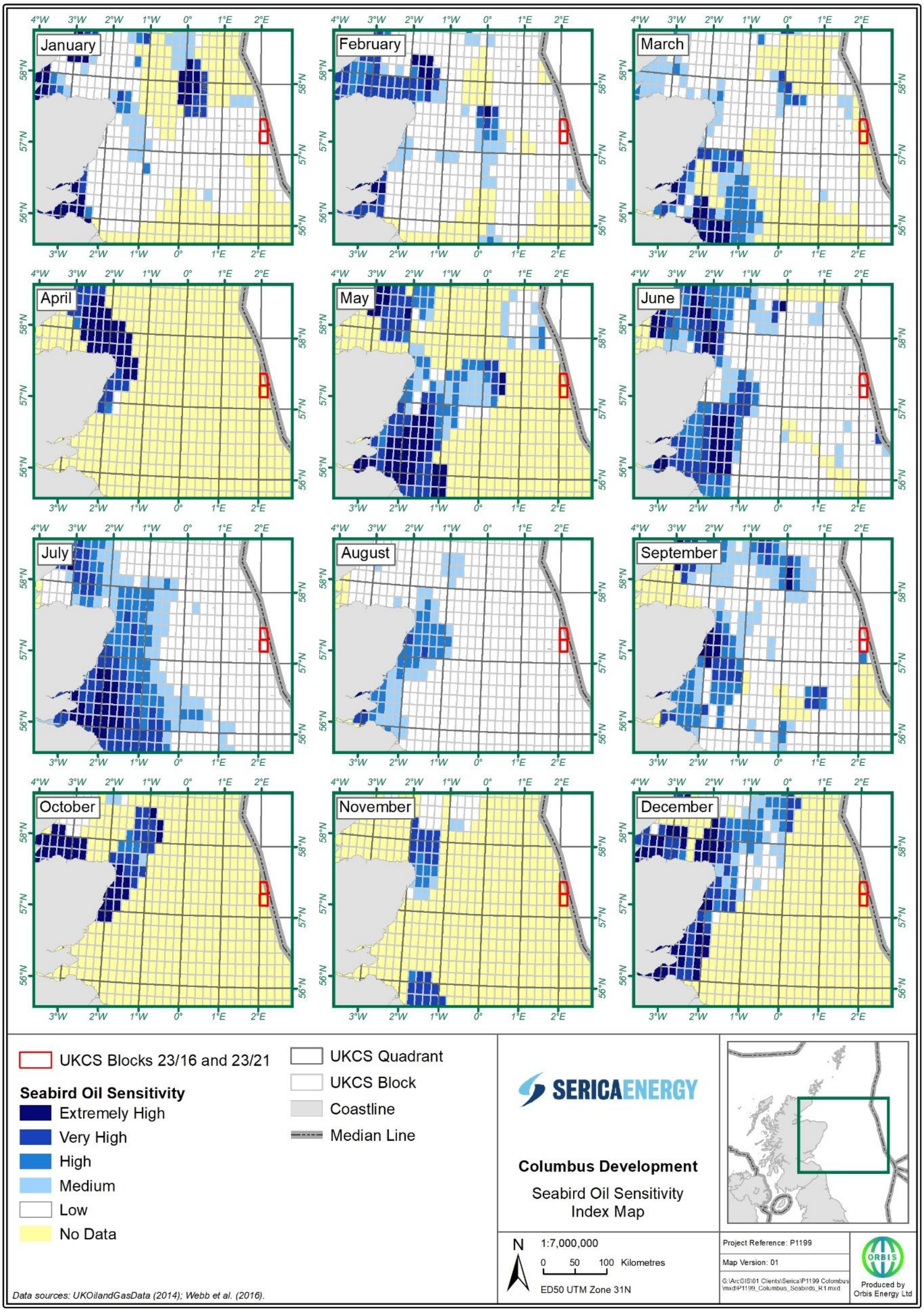
Notes

Key to SOSI Sensitivity: Extremely High: 1, Very High: 2, Moderate: 3, Low: 2, Very Low: 5, No data: N.

SOSI sensitivity category in red and underlined indicates an indirect assessment of SOSI scores, in light of coverage gaps.

Row in **bold** indicates the blocks within which the proposed Columbus Development infrastructure and the proposed deviated section of the Arran pipeline route are located.

Figure 3.12. Seabird Oil Sensitivity Index (Median) Scores in the Vicinity of the Proposed Columbus Development Area (Webb *et al.*, 2016)



Breeding Seabirds

Numerous seabird colonies are located along the adjacent coast of the Moray Firth. The Moray Firth SAC lies approximately 350 km from the proposed Columbus Development. The colonies are concentrated between Lybster and Helmsdale (in the Cromarty Firth) around Peterhead and at Inverbervie. The largest colonies, supporting high numbers of kittiwake, guillemot and razorbill are located at Fowlsheugh, Troup Head and West Gotten (Sturr Ruadh) (Barne *et al*., 1996).

Many of these colonies are internationally important, supporting numbers of seabirds at more than one percent of the total population of the species in the European Union. Other colonies are of national importance, supporting numbers more than one percent of the total British populations.

As a consequence, many of these coastal areas have been designated as sites of international importance for their wintering waterfowl populations. Designations specifically for the protection of birds include Ramsar sites and Special Protection Areas (SPAs). Many other designations such as National Nature Reserves (NNRs) and Sites of Special Scientific Interest (SSSIs) have also been selected wholly or partly for their migrant and wintering waterfowl interest.

The key factors affecting breeding numbers and success of key species are food availability (generally fish and other marine species), weather conditions, predation and pollution (SNH, 2016).

The UK Seabird Monitoring Programme has been monitoring coastal seabird breeding numbers and breeding success for a number of species since 1986 (SNH, 2016). In general, the mean breeding numbers and breeding success of seabirds in Scotland has been declining since 1986 (SNH, 2016).

Out of the 12 species assessed for breeding numbers, the most notable species affected is the Artic skua (declined by 76 %). While no species show an overall increase in the indicator, the numbers of common guillemot, common tern, Arctic tern and Sandwich tern have shown a slight increase from 2011 to 2015 (SNH, 2016).

Breeding success varied amongst the 12 species assessed. In 2015, it was higher than the long-term (1986 to 2014) average for six species: Arctic skua; black-legged kittiwake; common tern; common guillemot; northern gannet; and Sandwich tern. Three species had breeding success lower than the long-term average: herring gull; little tern; and northern fulmar. Three species had breeding success in 2015 around the long-term average: Arctic tern; Atlantic puffin; and great skua (SNH, 2016). In addition, a recent survey of northern gannet (Murray *et al*., 2015), has shown a large increase in their breeding numbers. This increase was accredited to good breeding success and improved survival of immature and adult birds which led to an expansion in their range. However, due to the distance from the coast (approximately 230 km from the proposed CDev-1 well), of the 12 species studied only fulmar and gannet are likely to be present in the vicinity of the proposed Columbus Development area during the breeding season (Thaxter *et al*., 2012).

3.6.5 Marine Mammals

Cetaceans

Twenty three species of cetacean have been recorded in Scottish waters over the last 25 years. Of these, only 11 species are thought to be residents or are regularly sighted and the rest are presumed to be migrants or vagrant individuals. The central and northern North Sea has a moderate to high diversity and density of cetaceans (DECC, 2016).

Cetaceans are protected under Annex IV of the Council Directive 92/43/EEC (also known as the Habitats Directive). In addition, cetacean species are all listed as PMFs in Scottish waters (SNH, 2014) and the minke whale (*Balaenoptera acutorostrata*), Risso's dolphin (*Grampus griseus*) and white-beaked dolphin (*Lagenorhynchus albirostris*) are also listed as MPA search features in Scottish waters (Marine Scotland, 2017b), however, all of these species are regarded as being of Least Concern in terms of their population threats (IUCN, 2018).

Harbour porpoises (*Phocoena phocoena*) are frequently sighted throughout the central North Sea, in both coastal and offshore waters. While sighted throughout the year, peak numbers are generally recorded in the summer months from June to October (DECC, 2016). White-beaked dolphins are also commonly found within the central North Sea. As with harbour porpoise they are present year round, although sightings are more frequent from July to October (DECC, 2016). Atlantic white-sided dolphins (*Lagenorhynchus acutus*) appear to be seasonally present and are most frequently sighted in the central North Sea over 10 km from the coast from June to September (Reid *et al*., 2003).

During the summer months (July to October), minke whales are well distributed (both coastally and offshore) throughout the central North Sea, particularly in the west. They are frequently sighted in small numbers off the coast of Scotland (DECC, 2009).

Other species which may be present within the central North Sea, although sightings are rare, include killer whales (*Orcinus orca*) and common dolphins (*Delphinus delphis*). Killer whales are reported in most months of the year, with sightings most frequent between April and September (DECC, 2016) while common dolphins have been observed sporadically in offshore areas during July and August. Pilot whales (*Globicephala melas*) are also infrequently sighted in inshore areas in the summer (Reid *et al*., 2003).

The Moray Firth and the coast of eastern Scotland is home to the only resident population of bottlenose dolphins (*Tursiops truncatus*) in the North Sea. Dolphins are seen year round in the Moray Firth and off Aberdeenshire; in the latter area the rate of sightings is highest in March to May (Hammond *et al*., 2004).

The UK Statutory Nature Conservation Bodies (SNCBs) have recently defined Management Units (MUs) for six cetacean species (harbour porpoise, common dolphin, bottlenose dolphin, white-beaked dolphin, white-sided dolphin and minke whale) in UK waters in order to provide an understanding of the geographical range and abundance of marine mammal populations, and subpopulations to aid conservation and management purposes. The MUs within which the proposed Columbus Development is located, along with the corresponding abundance of animals within these units, are listed in Table 3.13 below.

Table 3.13. Management Units for Cetaceans in the Vicinity of the Proposed Columbus Development (IAMMWG, 2015)

Species	Management Unit	Abundance of Animals	95% Confidence Interval	Density [N1]
Bottlenose dolphin	Greater North Sea (Total area: 639,886 km^2)	0	-	-
Harbour porpoise	North Sea (Total area: 678,206 km^2)	227,298	176,360-292,948	0.335
Risso's dolphin [N2]	Marine Atlantic [N3]	-	-	-
Common dolphin	Celtic and Greater North Seas (Total area: 1,560,875 km^2)	56,556	33,014-96,920	0.036
Minke whale		23,528	13,989-39,572	0.015
White-beaked dolphin		15,895	9,107-27,743	0.010
White-sided dolphin		69,293	34,339-139,828	0.044

Notes

[N1] Density was calculated using the total area of the MU and the abundance of animals within that MU.

[N2] There is no current abundance estimate available for Risso's dolphin (IAMMWG, 2015).

[N3] 'Marine Atlantic' Management Unit comprises all UK waters and extends to the seaward boundary used by the EC for Habitats Directive reporting (IAMMWG, 2015).

The relative abundance and density of cetaceans in the vicinity of the proposed Columbus Development can also be derived from data obtained during the Small Cetacean Abundance of the North Sea (SCANS-III) aerial and ship-based surveys. This project identified the abundance and density of cetacean species within predefined sectors of the North Sea and North-East Atlantic. The proposed Columbus

Development area is situated within the SCANS-III block Q which was surveyed by air (Hammond *et al*., 2017). The results indicate that the density of the two cetacean species recorded in the vicinity of the proposed Columbus Development is lower than the total surveyed area (Hammond *et al*., 2017). Of note is that, the density of minke whale is an order of magnitude less than the total surveyed area (Hammond *et al*., 2017). The results from this programme for block Q are summarised in Table 3.14.

Table 3.14. Cetacean Abundance and Density Recorded in SCANS-III Aerial Survey Block Q (Hammond *et al.*, 2017)

Species	SCANS-III Block Q		Total (Aerial Survey Blocks)	
	Abundance	Density N1	Abundance	Density N1
Bottlenose dolphin	-	-	19,201	0.016
Harbour porpoise	16,569	0.333	424,245	0.351
Minke whale	348	0.007	13,101	0.011
White-beaked dolphin	-	-	36,287	0.030
White-sided dolphin	-	-	2,187	0.002

Notes

N1 Density is the number of animals per km^2

It should be noted, however, that the SCANS-III survey area encompasses a relatively large geographical area and, as such, is unlikely to accurately reflect the abundance and densities of cetaceans which may be present within the vicinity of the proposed Columbus Development area. Data taken from the JNCC Atlas of Cetacean Distribution in north-west European Waters, as summarised in Table 3.15 below, has therefore been used to give a more localised indication (based on sightings within ICES Rectangle 43F2 and the surrounding ICES Rectangles) of seasonal distribution of cetaceans. It can be seen from this that the most frequently sighted cetaceans throughout the year are harbour porpoise, minke whale, Risso's dolphin, white-beaked dolphin and white-sided dolphin. Furthermore, cetacean sightings across all species are most common in July (Reid *et al*., 2003).

Table 3.15. Cetaceans Sightings within the Vicinity of the Proposed Columbus Development (ICES Rectangle 43F2 and the surrounding ICES Rectangles) (Reid *et al.*, 2003)

Species	J	F	M	A	M	J	J	A	S	O	N	D
Harbour porpoise												
Minke whale												
Risso's dolphin												
White-beaked dolphin												
White-sided dolphin												

Key (Number of individuals per hour of sightings effort)

High (>100)	Medium (10 - 100)	Low (10 - 0.01)	Very Low (0 – 0.01)	No sightings

Seals

Two species of seals; grey seal (*Halichoerus grypus*) and the harbour (or common) seal (*Phoca vitulina*) are found around the Scottish coast and inshore waters.

Grey and harbour seals are both listed under Annex II of the EU Habitats Directive, requiring the designation of Special Areas of Conservation (SACs) in order to protect these species. In addition, harbour and grey seals are protected under the Conservation of Seals Act 1970 (DTI, 2004 and both the harbour and grey seal are listed as PMF to aid in their conservation in Scottish waters (SNH, 2014).

Grey Seals

Approximately 88% of the UK population breeds in Scotland, largely in the Hebrides and Orkney. Major colonies are also present on Shetland and along the east coast of Scotland including the Isle of May and Fast Castle. Breeding takes place in the autumn between September and November. Pup production has continued to increase exponentially at colonies in the North Sea; elsewhere, it is stable or increasing (DECC, 2016).

Most of the grey seal population will be on land for several weeks from October to December during the pupping and breeding season, and again in February and March during the annual moult. Densities at sea are likely to be lower during this period than at other times of the year. They also haul-out and rest throughout the year between foraging trips to sea (DECC, 2016). Studies have shown some mature seals to return year after year to particular breeding sites and foraging season haul-outs (Pomeroy *et al*. 2000; Vincent *et al*. 2005).

Grey seal foraging destinations at sea are typically localised areas characterized by a gravel/sand seabed sediment, which is the preferred burrowing habitat of their primary prey, sandeels. The distance from a haul-out site of a typical foraging trip indicates that the ecological impact of seal predation may be greater coastally than further offshore (DECC, 2016). They are generalist feeders, foraging mainly on the sea bed at depths up to 100 m, although likely capable to feed at all depths found across the continental shelf (SCOS, 2014).

Grey seal foraging movements are on two geographical scales: long and distant trips from one haul-out site to another; and local repeated trips to discrete foraging areas (McConnell *et al*. 1999). Foraging areas can be up to 100 km offshore and connected to haul-out sites by prominent high-usage corridors (Jones *et al*., 2015). As illustrated in Figure 3.13 the distribution of grey seals in the vicinity of the Columbus Development area is therefore generally very low (less than one individual per 25 km^2) (Russel *et al*., 2017).

Harbour Seal

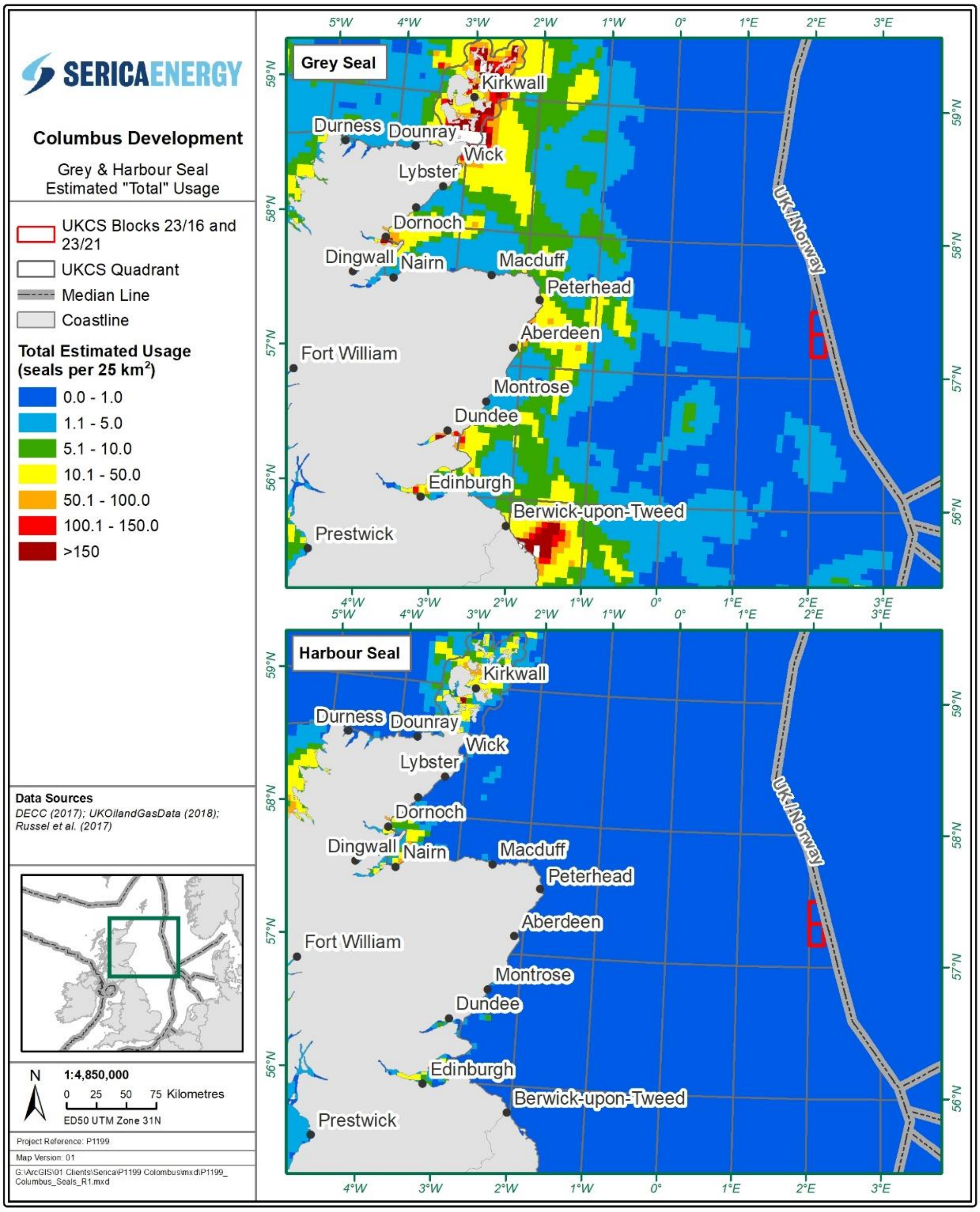
Harbour seals around the UK belong to a European sub-species (*P. vitulina vitulina*) which mainly occur in UK, Icelandic, Norwegian, Swedish, Danish, German and Dutch waters; at the latest count in 2013 approximately 30% of the world population of this sub-species occurs in the UK (DECC, 2016). Approximately 79% of the UK harbour seal population occurs in Scotland, with 16% in England and 5% in Northern Ireland (SCOS, 2017). Overall, the UK harbour seal population has increased since the late 2000s, contrasting with rapid declines along the east coast of Scotland (52%) (SCOS, 2017).

Harbour seals are widely distributed around most of the coasts of North Scotland, Shetland and Orkney and along the Moray Firth and the east coast of Scotland. There are many important haul-out and breeding sites on these coastlines, several of which contain internationally important numbers; seals are abundant throughout coastal waters surrounding these sites (DECC, 2016). Harbour seal haul-out along the coast adjacent to the proposed Columbus Development area include Moray Firth, Firth of Tay and Firth of Forth (DECC, 2016).

The harbour seal is the smaller of the two species of pinniped that breed in Britain and is also an important predator in this area of the North Sea. Their diet is composed of a wide variety of prey and varies seasonally and from region to region. In the North Sea, harbour seals haul out on tidally exposed areas of rock, sandbanks or mud. Pupping occurs on land from June to July, while the moult is centred on August and extends into September. Therefore, from June to September harbour seals are ashore more often than at other times of the year (DECC, 2016).

Models of marine usage by harbour seals show foraging areas off much of the east coast of Scotland, with hotspots of activity east of Shetland, northeast of Orkney, in the Moray Firth and north of St Andrews marine, usage in these areas is among the highest in UK waters (Jones *et al*., 2015). In general, the harbour seal tends to forage within 40 – 50 km of its haul-out sites (SCOS, 2014). This is confirmed by Figure 3.13 which shows that the harbour seal utilisation of waters surrounding the proposed Columbus Development area is very low (less than one individual per 25 km^2) (Russel *et al*., 2017).

Figure 3.13. Estimated Grey and Harbour Seal Total Usage (at sea and hauled out) around the Proposed Columbus Development Area (Russel *et al.*, 2017)



Management Units

The UK SNCBs have also defined MUs for grey and harbour seals in inshore UK waters in order to provide an understanding of the geographical range and abundance of their populations, and subpopulations to aid conservation and management purposes. Each species possesses a number of MUs depending on its spatial distribution, habitat use and environmental pressures. The proposed Columbus Development area is not located within a MU for seals as these are specific to inshore waters (IAMMWG, 2013). However, it is noted that the seaward extent of these MUs is illustrative and not definitive as seals will cross MU boundaries on a regular basis. Table 3.16 therefore lists the MUs for seals, along with the corresponding abundance of animals within these units, which are adjacent to the proposed Columbus Development area.

Table 3.16. Management Units for Seals Adjacent to the Proposed Columbus Development Area (IAMMWG, 2013)

Species	Management Unit [N1]	Seal Count	Estimated Population Size [N1]	Survey Year
Harbour Seal	East Coast	315	-	2007, 2011
Grey Seal	East Coast	2,045	6,800	2007, 2011

Notes

[N1] An independent population estimate for grey seals was calculated using counts obtained during the 2007 and 2008 summer surveys (Lonergan *et al.*, 2010). Please note, these estimates were not available for harbour seals.

3.6.6 Marine Reptiles

Only the leatherback turtle (*Dermochely coriacea*) is considered to be a regular member of the British marine fauna (Gaywood, 1997; Godley *et al*., 1998) and is reported annually in the North Sea. The species exhibits physiological adaptations unique among reptiles that allows it to function in temperate waters such as the North Sea. All other turtle species are believed to reach UK waters only when displaced from their normal range by adverse currents or other unknown circumstances.

Densities of the leatherback turtle in the North Sea, however, are very low, due to the limiting physiological barrier presented by the cold water temperatures. Individuals found any further north in even colder waters such as Iceland and Norway are considered to be very rare exceptions (JNCC, 2007).

3.7 Marine Protected Areas

A network of well-managed Marine Protected Areas (MPAs) is being established to meet UK objectives as well as the European Marine Strategy Framework Directive (MSFD), Convention on Biological Diversity and the requirements of the OSPAR Convention to deliver an ecologically coherent MPA network in the North East Atlantic. Approximately 23% of UK waters fall within existing MPAs (JNCC, 2017a). In Scottish waters the main types of MPAs are:

- **Special Areas of Conservation (SACs)** (also known as European Sites of Community Importance; SCIs) - designated for habitats and species listed under the EU Habitats Directive. These include three marine habitat types (shallow sandbanks, reefs and submarine structures made by leaking gases) and four marine species (grey seal, harbour seal, bottlenose dolphin and harbour porpoise) (JNCC, 2017a). In the UK there are 105 SACs with marine components (JNCC, 2017a);
- **Special Protection Areas (SPAs)** - designated to protect birds under the EU Wild Birds Directive. The Directive requires conservation efforts to be made across the sea and land area. In the UK 106 SPAs with marine components have been designated, including four wholly marine SPAs (JNCC, 2017a);
- **Scottish Nature Conservation (NC) MPAs** - these sites have been established under the Marine (Scotland) Act and the Marine and Coastal Access Act. To date, 30 NC MPAs have been designated in Scottish waters (JNCC, 2017c). Of these, 17 fall under the Marine (Scotland) Act 2010 within Scottish territorial waters, and 13 in offshore waters under the Marine and Coastal Access Act (2009). These sites are intended to protect rare, representative and productive species and habitats.

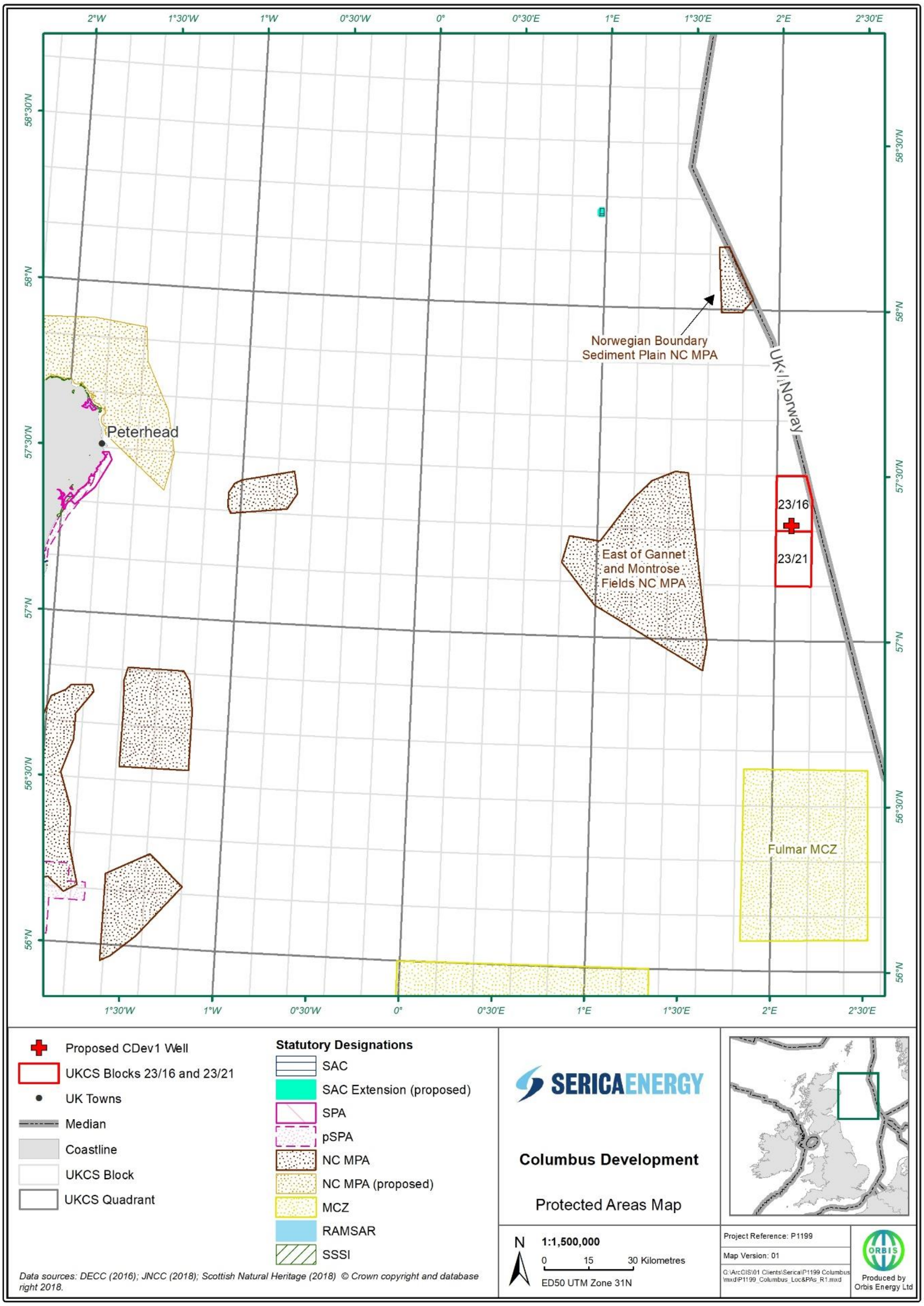
Together SACs and SPAs form the European Natura 2000 network. Other international designations such as Ramsar Wetlands of International Importance (hereafter referred to as Ramsar sites), and national designations such as Sites of Special Scientific Interest (SSSIs) also form part of the UK MPA network through their protection of marine, coastal terrestrial and geological features (JNCC, 2017a). OSPAR MPAs encompass existing MPAs designated under existing legislation and Conventions including SACs, SPAs and NC MPAs (JNCC, 2017a).

Figure 3.14 illustrates the MPAs currently designated within the waters surrounding the proposed Columbus Development area.

The closest MPA to the proposed Columbus Development area is the East of Gannet and Montrose Fields NC MPA, located approximately 33 km to the west of the proposed CDev-1 well. The site, a relatively shallow sediment plain, has been designated for ocean quahog (*Arctica islandica*) aggregations which are considered to be threatened and/or declining across the north-east Atlantic by the OSPAR Commission. The MPA has also been designated for the presence of offshore deep sea mud. This mud provides an important habitat for many species of worms and mollusc, which in turn are important sources of prey for fish species (JNCC, 2017b).

The nearest protected coastal sites to the proposed Columbus field development are located on the adjacent coastline, approximately 230 km to the west.

Figure 3.14. Protected Areas in the Vicinity of the Proposed Columbus Development Area



3.8 Human Populations

3.8.1 Commercial Fishing

Development operations can potentially interfere with commercial fishing activities through the physical exclusion of the fishing vessels from the immediate area around the site (Safety Exclusion Zone) and through increasing the hazard of snagging fishing gear on structures proud of the seabed.

The North Sea is one of the world's most important fishing grounds and major UK and international fishing fleets operate in this area of the central North Sea, including vessels from Scotland, England, Denmark and Norway. The main fishing ports along the coast are at Aberdeen, Peterhead, Lerwick, and Fraserburgh (DECC, 2016). The proposed CDev-1 well lies within ICES rectangle 43F2; landings and fishing effort data for this ICES Rectangle for UK vessels over 10 m in length are available from Marine Scotland for 2012 to 2016 (Marine Scotland, 2017a). Where fewer than five ≥10 m vessels undertook activity, fishing activity is identified but the data is disclosive so it is not available.

Fishing Effort

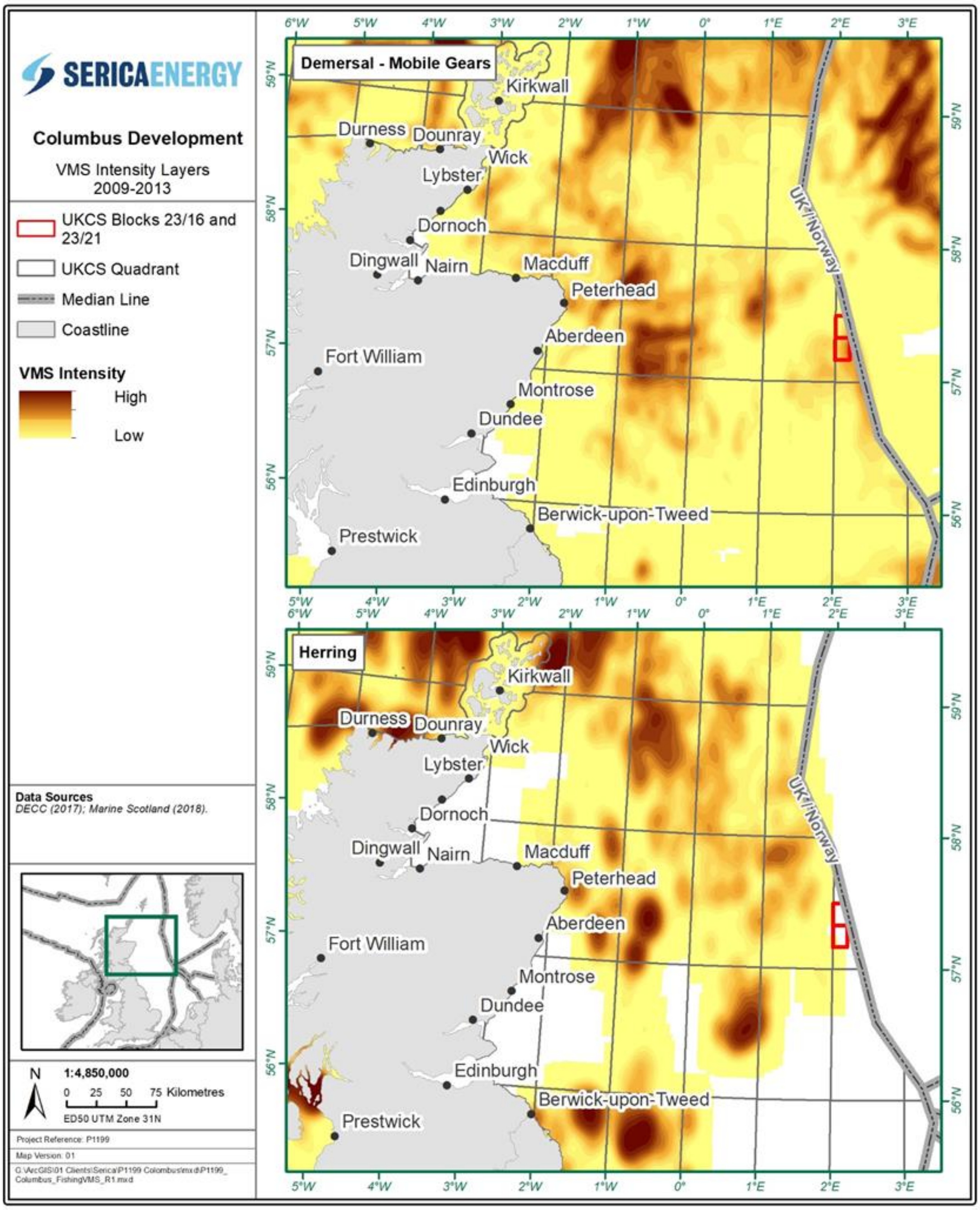
Between 2012 and 2016 the mean annual fishing effort, by UK vessels over 10 m in length, in the vicinity of the proposed CDev-1 well was recorded at 23 days in ICES rectangle 43F2. The highest annual fishing effort was recorded in 2013 at 32 days and the lowest annual fishing effort was recorded in 2016 where fewer than five vessels fished in this rectangle during the course of the year (Marine Scotland, 2017a). Average monthly fishing effort between 2012 and 2016 indicates that the fishing season occurs between March and August, with some level of fishing activity recorded each year in July (Marine Scotland, 2017a).

For the same period, 2012-2016, fishing effort in ICES rectangle 43F2 came exclusively from gear falling into the category trawls (100%) (Marine Scotland, 2017a).

An analysis of fishing activity has also been undertaken by Kafas *et al.* (2012) using the Vessel Monitoring System (VMS) (Marine Scotland, 2018). The VMS provides information on the locations and identity of all UK fishing vessels greater than 15 m in length from 2009 to 2013. Fishing activity data from the VMS were combined with landings data to identify spatial patterns of fishing intensity. It is important to note that the data does not provide an absolute quantitative representation of the amount of fishing in an area, but can be used to qualitatively describe relative fishing intensity.

Moderate levels of demersal mobile gear fishing occurs in UKCS Blocks 23/16 and 23/21, alongside low levels of herring fishing activity (Figure 3.15). No activity from the following targeted fisheries was recorded in the vicinity of proposed CDev-1 well for vessels ≥ 15 m in length: demersal – static gears, lobster, mackerel, *Nethrops* – static gears, *Nethrops* – (mobile gears) and crab (Kafas *et al.*, 2012; Marine Scotland, 2018). In the northern and central North Sea, the majority of fishing activity for vessels ≥ 15 m in length is concentrated in the north, with the highest fishing intensity recorded offshore of the Shetland Islands (Kafas *et al.*, 2012).

Figure 3.15. VMS Intensity Layers by Targeted Fishery in the Period 2009-2013 (Kafas *et al.*, 2012; Marine Scotland, 2018)



Fish Landings

Commercially important pelagic species for the northern and central North Sea include sprat (*Sprattus sprattus*) and herring, which are abundant in the summer and autumn (Barne *et al.*, 1996). Commercially important and exploited demersal species include whiting, saithe and Norway pout, which are found in deep offshore waters. Other important demersal species found in the area include cod, which is widely distributed in the region in summer, and haddock, which are abundant in summer and autumn (CEFAS, 2001b; DECC, 2016). The central North Sea is also an important area for sandeel fisheries (DECC, 2016).

Various shellfish species are also exploited in the region, including deep-water prawn (*Pandalus borealis),* scallops (*Pecten maximus*) and *Nephrops*.

Aquaculture sites and protected areas for shellfish are typically situated in coastal waters and as such, there are none located in the vicinity of the proposed CDev-1 well location.

Between 2012 and 2016, fish landings (by weight) from ICES Rectangle 43F2 were predominantly comprised of pelagic species (64%), followed by demersal fish (36%). However, the large amount of pelagic species landed is almost entirely accounted for by an annual landing of herring of 178 tonnes in 2012 (Marine Scotland, 2017a). Apart from this isolated year, pelagic species make up very little of the catches from the area. By comparison, landings of mollusc and crustacean species from the area are very low.

The dominant species landed (by weight) include herring, plaice, lemon sole and haddock (Figure 3.16). Other species caught in ICES rectangle 43F2 include witch, cod, monkfish / anglerfish, saithe, whiting and turbot (*Psetta maxima*) (Marine Scotland, 2017a).

In terms of revenue generated, herring was the greatest component to the fishery between 2012 and 2016 with an average value of landings worth £48,729.62 (Figure 3.17) (Marine Scotland, 2017a). This is despite the fact that many of the demersal species caught, such as lemon sole and haddock have a higher value per tonne compared to herring.

Landings by UK vessels over 10 m in length primarily occurred during late spring and summer, in tandem with fishing efforts, peaking in June and July (Marine Scotland, 2017a).

Figure 3.16. Average Landings by Species (Weight) for all UK Vessels (ICES Rectangle 43F2) from 2012-2016 (Marine Scotland, 2017a)

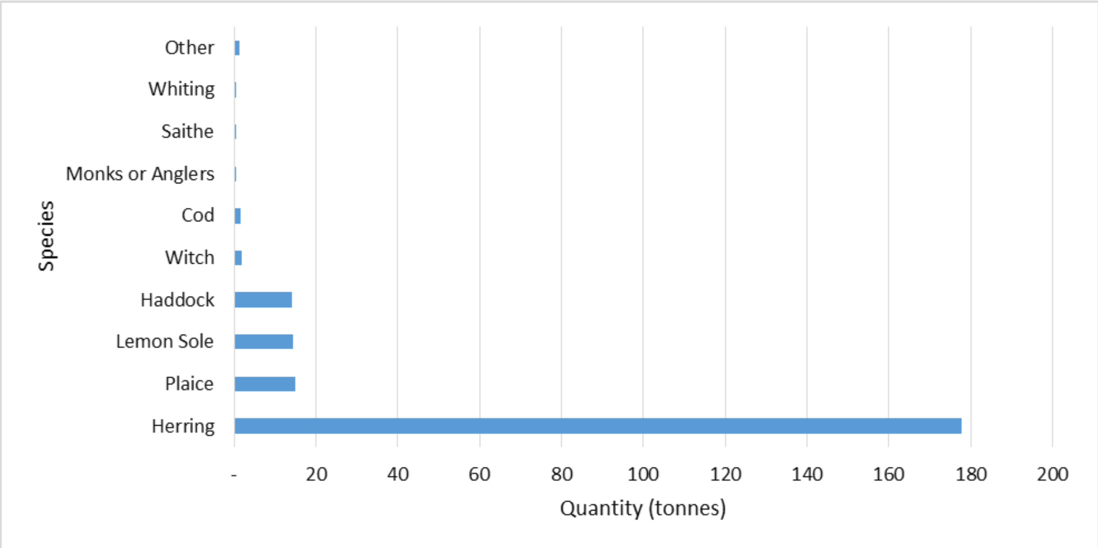
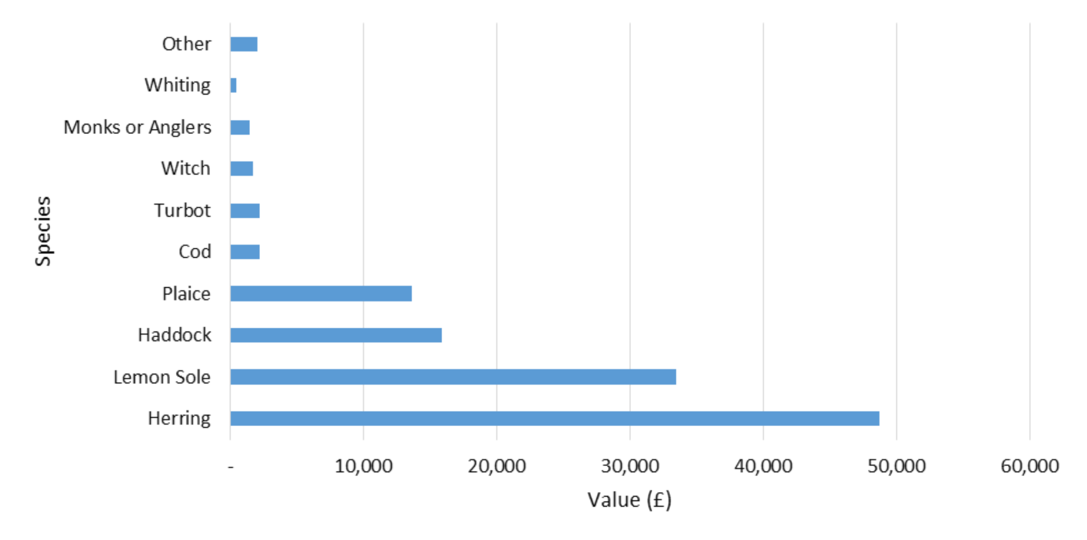


Figure 3.17. Average Landings by Species (Value) for all UK Vessels (ICES Rectangle 43F2) from 2012-2016 (Marine Scotland, 2017a)



3.8.2 Shipping and Ports

Due to its deep water anchorage, which is unique to the north-east of Scotland, the Cromarty Firth is home to the ports of Cromarty, Invergordon and Nigg and is the main area of coastal industrial development in the region. Other important ports on the north coast of Grampian are Fraserburgh, Macduff, Buckie, Burghead, Peterhead and Aberdeen (Barne et al., 1996).

The North Sea is home to a high number of shipping routes, with traffic generated by vessels trading between ports at either side of the North Sea and the Baltic (DECC, 2016). Oil and Gas in the North Sea also contributes to general vessel traffic by way of support vessels. The average weekly vessel density in the vicinity of the proposed CDev-1 well is approximately between 0.1 and 10.2 vessels (MMO, 2014).

A survey of shipping routes within 10 nautical miles (nm) (19 km) of a previous well location (referred to as 'Columbus South', 57° 20' 52.672" N, 2° 5' 24.799" E) approximately 300 m south east south of the proposed CDev-1 well was conducted by Anatec Ltd. in 2006 using Anatec's ShipRoutes software. The survey identified a total of 16 routes trafficked by an estimated 889 vessels per annum (Table 3.17 and Figure 3.18), which corresponds to an average of approximately 2 to 3 vessels per day, passing within 10 nautical miles (Anatec, 2006).

The closest routes found are routes 1-6, which pass within 2 nautical miles of Columbus South. Details of these routes are described below:

- Route No. 1 is used by an estimated 35 vessels per year between Bomlafjorden and Tees. This route passes the location to the Southeast at a mean distance of 0.3 nm;
- Route No. 2 is used by an estimated 15 vessels per year between Forth and Egersund. These cargo vessels pass the location to the Northwest at a mean distance of 0.3 nm;
- Route No. 3 is used by an estimated 60 vessels per year between Aberdeen and Kattegat (Baltic). This route passes the location to the North at a mean distance of 0.6 nm;
- Route No. 4 is used by an estimated 225 vessels per year between Humber and Norway/Russia. This route passes the location to the East at a mean distance of 1.4 nm;
- Route No. 5 is used by an estimated 45 cargo vessels per year between Norway and Humber. This route passes the location to the West at a mean distance of 1.4 nm;
- Route No. 6 is used by an estimated 1 vessels per year between Boknafjorden and Tyne. This cargo vessel passes the location to the Southeast at a mean distance of 1.7 nm.

A breakdown of the passing vessels by type and size can been seen in Figure 3.19 and Figure 3.20, respectively. This shows that the majority of vessels passing in the vicinity of CDev-1 are cargo vessels

(71%), with the most common mass category being 1,500-5,000 Dead Weight Tons (DWT) (Anatec, 2006).

The 2006 Anatec survey suggests that the overall shipping density in the vicinity of the Columbus Development is low. An up to date collision risk assessment and shipping density study will be undertaken prior to the drilling phases of the Columbus Development which will be used to support the planned operations.

Table 3.17. Routes Identified Passing Within 10 nm (Approximately 19 km) of the Columbus South Well Location (Anatec, 2006)

Route No.	Description	CPA (nm)	Bearing (°)	Ships Per Year
1	Bomlafjorden-Tees*	0.3	123	35
2	Forth-Egersund	0.3	333	15
3	Aberdeen-Kattegat*	0.6	354	60
4	Humber-N Norway / Russia	1.4	105	225
5	Storfjorden-Humber*	1.4	294	45
6	Boknafjorden-Tyne b	1.7	134	1
7	Aberdeen-Lomond*	3.2	177	94
8	Iceland-Hamburg	3.9	233	30
9	Aberdeen-Mungo*	4.0	304	44
10	Montrose-Norway S	5.4	168	15
11	Humber-Storfjorden*	5.6	105	20
12	N Norway / Russia-Humber	6.3	281	190
13	Sognefjorden-Humber	6.5	108	50
14	Aberdeen-Norway S	8.0	352	30
15	Egersund-Tay	9.1	337	10
16	Norway S-Tay	9.2	164	25
				889

Notes
* Where two or more routes have identical Closest Point of Approach (CPA) and bearing, they have been grouped together. In this case, the description lists the sub-route with the most ships per year.

Figure 3.18 Shipping Route Positions Within 10 nm (Approximately 19 km) of the Columbus South Well Location (Anatec, 2006)

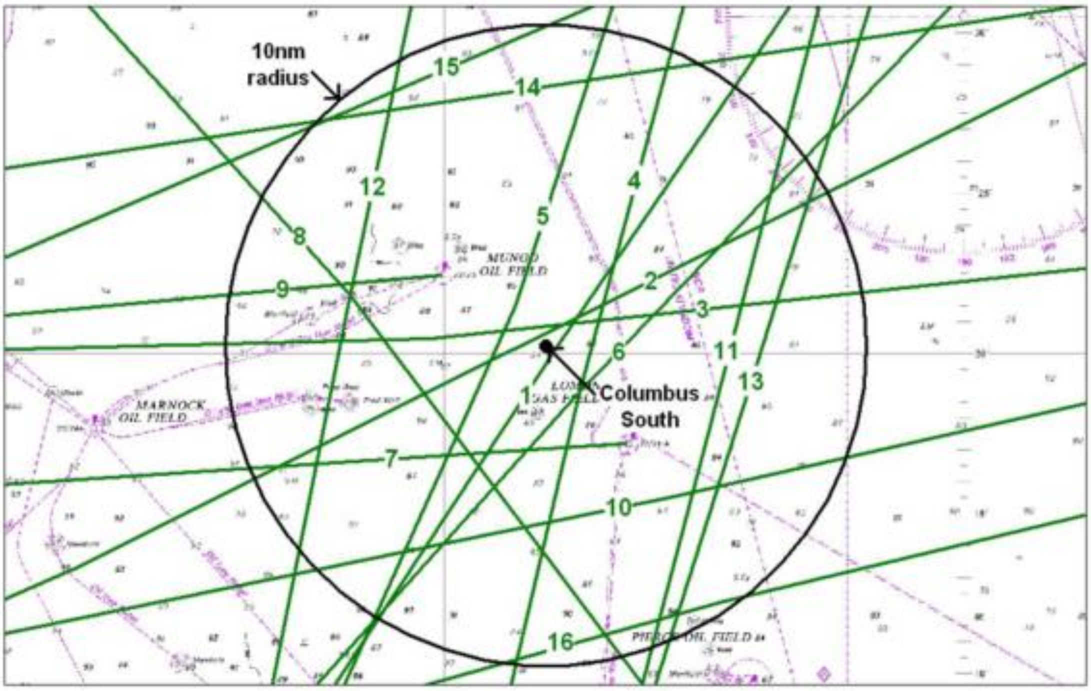


Figure 3.19 Type Distribution of Vessels Passing Within 10 nm (Approximately 19 km) of the Columbus South Well Location (Anatec, 2006)

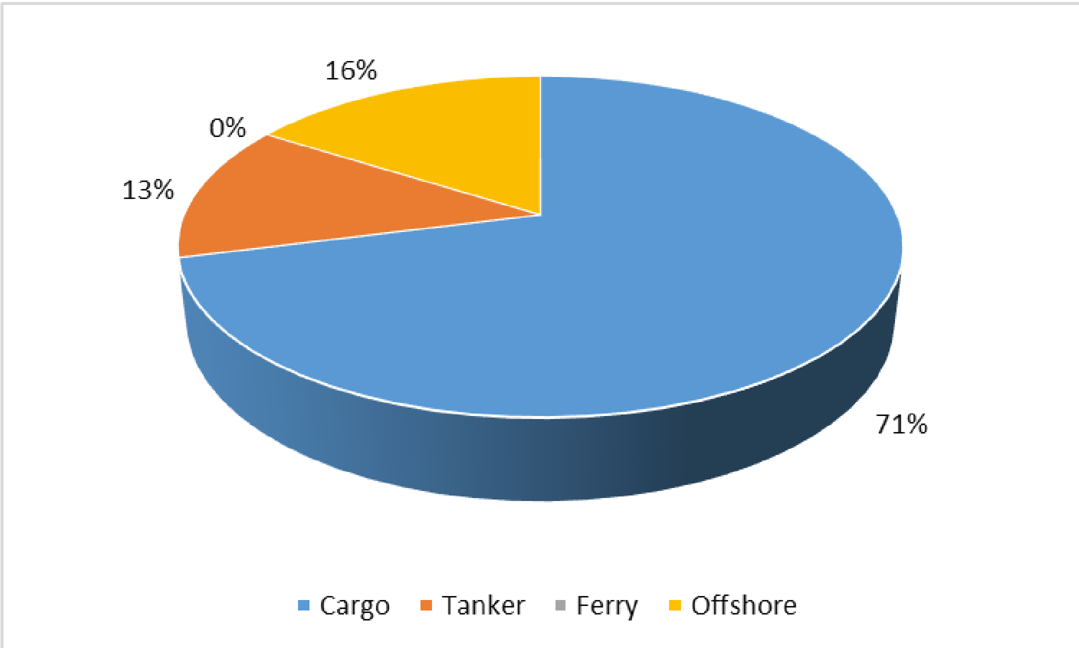
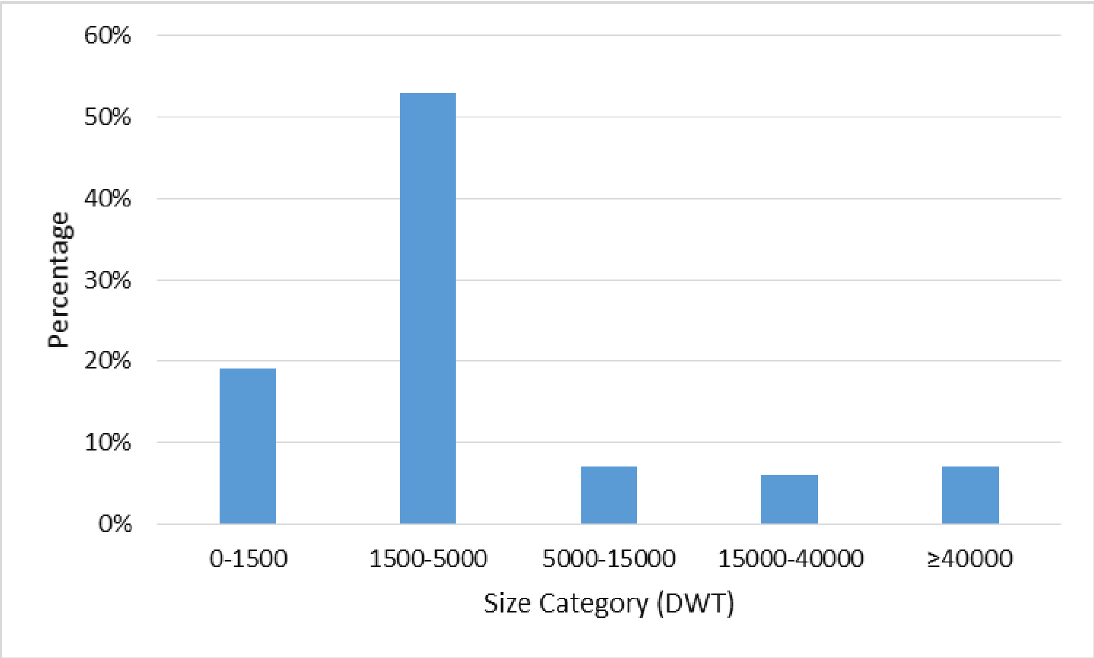


Figure 3.20. Size Distribution (Mass in DWT) of Vessels Passing Within 10 nm (Approximately 19 km) of the CDev-1 Well Location (Anatec, 2006)



3.8.3 Military Activity

There are no charted or known areas of military activity within the vicinity of the proposed Columbus Development area (Baxter *et al.*, 2011; DECC, 2016). The nearest military practice and exercise area for the Airforce is located approximately 67 km west of the proposed CDev-1 well location (DECC, 2016). Similarly, there are no charted submarine exercise areas in the vicinity of the proposed Columbus Development area (Baxter *et al.*, 2011).

3.8.4 Pipelines, Wells and Submarine Cables

Oil and gas activity is relatively high in the vicinity of the proposed Columbus Development (Figure 3.21).

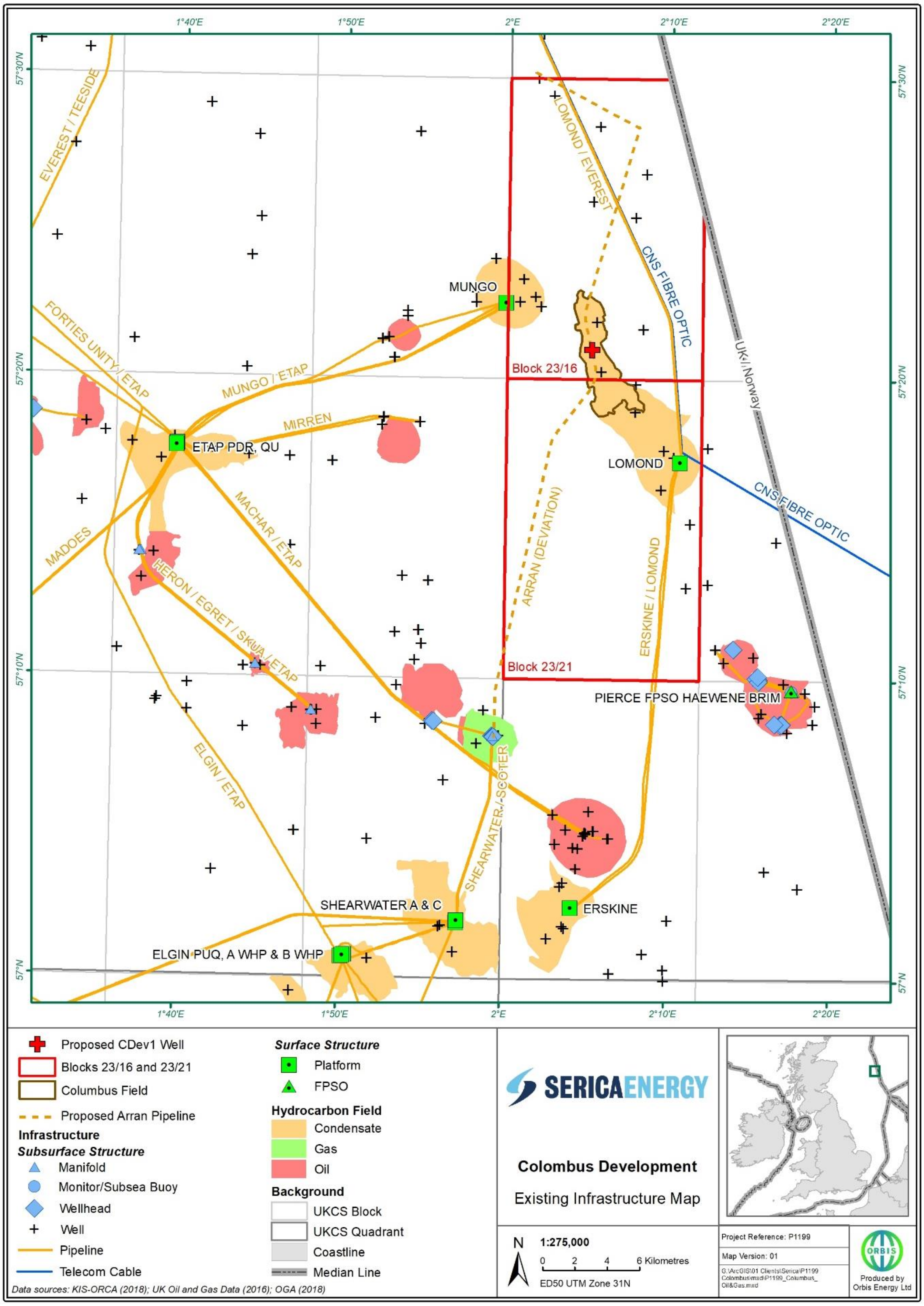
The Columbus Field was discovered in 2006 by well 23/16f-11 and subsequently appraised by four wells 23/16f-12, 23/16f-12z, 23/21a-7x and 23/21a-7z.

The nearest offshore infrastructure to the proposed CDev-1 well is the Mungo Platform (Operator: BP) located approximately 6.1 km to the northwest. In addition, the Lomond platform (Operator: Chrysaor) is located approximately 8.8 km south east of the proposed CDev-1 well.

A number of pipelines traverse the area including the 'active' Lomond to CATS Riser Platform condensate pipeline PL781 (Operator: Chrysaor), 'active' Lomond to Everest (CATS Riser) gas pipeline PL780 (Operator: Chrysaor), 'active' Erskine to Lomond oil pipeline PL1257A (Operator: Chevron) and the 'not in use' Erskine to Lomond gas pipeline PL1257 (Operator: Chevron) as illustrated in Figure 3.21 (UK Oil and Gas Data, 2018).

The active 'CNS Fibre Optic' telecom cable (Operator: BP) passes through the central North Sea, running from Aberdeen on the Scottish mainland to the ULA platform (KIS-ORCA, 2018). The telecom cable runs through Blocks 23/16 and 23/21 and is located approximately 5.0 km to the east of the proposed CDev-1 well.

Figure 3.21. Oil and Gas Infrastructure and Submarine Cables in the vicinity of the proposed CDev-1 Well location



3.8.5 Dredging and Dumping Activity

There are no licensed dredging or charted dumping areas within the vicinity of the proposed CDev-1, and at present there are no licences for marine aggregates extraction in Scotland, although the possibility for marine aggregates to be extracted is mentioned in the Scottish National Marine Plan.

3.8.6 Wind Farms

Currently there are no offshore wind farms operating, consented or proposed in this area of the central North Sea.

3.8.7 Archaeology

There are no charted wrecks located in the vicinity of the proposed Columbus Development (Hydrographer of the Navy, 2003; Marine Scotland, 2018).

There are a number of non-charted wrecks within Blocks 23/16 and 23/21, the closest of which is an unnamed potential obstruction located 5.2 km south of the proposed CDev-1 well (Marine Scotland, 2018). No wrecks or features of archaeological interest were found during the 2010 Gardline surveys (Gardline, 2010a; 2010b) or the 2015 Gardline (Gardline, 2016a) and none were noted in the preliminary findings of the 2018 Gardline surveys (Gardline, 2018a; 2018b).

3.8.8 Tourism and Leisure

No tourism and leisure activities are identified as occurring within the boundaries of the proposed Columbus Development due to its distance from the shore (230 km to the nearest coastline in Aberdeenshire, Scotland). In general, tourism and leisure activities are focussed along the coastline and nearshore waters of north east Scotland.

3.9 Key Environmental Sensitivities

Key sensitivities relevant to the proposed Columbus Development are summarised in Table 3.18 below, along with their seasonality.

Table 3.18. Seasonal Environmental Sensitivities

Component	Abundance / Activity	J	F	M	A	M	J	J	A	S	O	N	D
Plankton	Plankton	Low	Low	Moderate	Moderate	High / Peak	Moderate	Low	Low	Low	High / Peak	Low	Low
Benthic Fauna	Benthic communities	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Fish [N1]	No. of species spawning in any one month	4	4	3	3	2	2	2	2	1	0	1	2
	No. of species with nursery grounds in any one month	2	3	7	10	10	11	10	8	4	5	2	1
Seabirds [N2]	Block 23/16	5	5	5	N	5	5	5	5	5	5	N	5
	Block 23/21	5	5	5	N	5	5	5	5	5	5	N	5
Cetaceans [N3]	Harbour porpoise						Low	Low		Low	Low		
	Minke whale	Low	Low	Low	Low	Low	Low	Low	Very low			Low	Low
	Risso's dolphin							Low					
	White-beaked dolphin					Low	Low	Low	Low	Low	Low	Moderate	
	White-sided dolphin							Low		Low			
Pinnipeds [N4]	Harbour seals at sea	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low
	Grey seals at sea	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low
Resource Users	Fishing (ICES Rectangle 43F2) [N5]	Low	Low	Moderate	Moderate	Moderate	High / Peak	High / Peak	Moderate	Moderate	Low	Low	Low
	Shipping	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
	Military activity												
	Existing oil & gas activity [6]	High / Peak	High / Peak	High / Peak	High / Peak	High / Peak	High / Peak	High / Peak	High / Peak	High / Peak	High / Peak	High / Peak	High / Peak
Protected Areas	Marine protected areas												

KEY

High / Peak	Moderate	Low	Very low	No Activity

Notes

[N1] Data from Coull *et al*. (*1998*); Ellis *et al*. (*2012*).

[N2] High Sensitivity: 1, Low Sensitivity: 5. SOSI sensitivity category in red and underlined indicates an indirect assessment of SOSI scores, in light of coverage gaps (Webb *et al*., 2016).

[N3] Data compiled from Reid *et al.* (2003).

[N4] Data from Russel *et al.* (2017).

[N5] Data compiled from Marine Scotland (2017a).

[N6] Data from UK Oil and Gas Data (2018).

4 Assessment Methodology

4.1 Overview

The EIA process which has been followed for the Columbus Development project is illustrated in Figure 4.1. The process commences with the identification of potential project issues (or aspects) that could impact the environment or other users of that environment. Once identified these aspects are assessed to determine the significance of the potential impact so that, where necessary, measures can be taken to remove or reduce such impacts through design or operational measures (mitigation). The impact that is predicted to remain once mitigation measures have been designed into the intended activity is referred to as the residual impact. Further detail on the methodology used is provided below.

Figure 4.1: Impact Assessment Process

4.2 Aspects and Impacts

The ISO (International Organization for Standardization) Standard for Environmental Management Systems, ISO 14001, defines an **environmental aspect** as:

'An element of an organization's activities, products, or services that can interact with the environment.'

Environmental aspects may be planned or unplanned. Planned environmental aspects are those that are guaranteed to occur over the course of the proposed operations and include single, intermittent and continuous events. Unplanned environmental aspects are those arising from abnormal activities or from hazardous or emergency situations.

An environmental impact may result from any of the identified environmental aspects. ISO 14001 defines an **environmental impact** as:

'Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services.'

Impacts may be adverse (i.e. have a detrimental or negative effect to an environmental resource or receptor) or positive (i.e. have an advantageous or positive effect to an environmental resource or receptor).

Cumulative impacts (i.e. impacts that result from incremental changes caused by other past, present or reasonably foreseeable activities or projects in the local area, in combination with the proposed development) and transboundary impacts (i.e. impacts experienced in one country as a result of activities in another) are also considered.

4.3 Environmental Issues Identification

Environmental issues associated with the proposed Columbus Development were initially identified by the EIA team and subsequently reviewed by members of the Serica field development team. The key objectives of this process were to:

- Identify potential environmental aspects associated with the proposed drilling and completion, installation, hook-up and commissioning, production and maintenance operations;
- Determine the consequences associated with each aspect and hence the significance of the potential impact;
- Consider if existing or planned safeguards are adequate to prevent or mitigate the aspect;
- Propose recommendations to eliminate, prevent, control or mitigate the aspect where existing safeguards were considered insufficient.

The findings from this process provided a focus for the remainder of the EIA process.

4.4 Evaluation of Significance

ISO 14001 defines a **significant environmental aspect** as:

'An environmental aspect that has or can have a significant environmental impact.'

For the Columbus Development project, the significance of potential impacts has been determined using the following oil and gas industry standard risk assessment approach:

Risk** = **Likelihood of Occurrence (Frequency / Probability)** x **Magnitude of Impact (Consequence)

The likelihood of occurrence is rated from 'A' (one off / remote) to 'D' (continuous / very likely) as defined in Table 4.1. The magnitude of impact is rated from negligible (1) to severe (5), or can be positive, as defined in Table 4.2.

A risk assessment matrix, defined in Table 4.3, has been used to determine the overall significance of the potential risk. For the purposes of this assessment, impacts ranked as Medium or High risk are considered to be significant.

It should be noted, however, that the evaluation of significance is inherently subjective; based on the professional judgement of the EIA team, informed by regulatory standards, good industry practices and the views of stakeholders. Where uncertainty affects the assessment of impacts, a conservative (i.e. reasonable worst case) approach has been used.

When determining the significance of potential impacts, it has been assumed that some mitigation measures (termed Standard Operating Procedures) are implemented as standard practice for UKCS E&P activities to comply with regulatory requirements, such as the establishment of a 500 m safety zone around the MODU. The Standard Operating Procedures applicable to the Columbus Development project are detailed in Appendix C.

Table 4.1: Likelihood of Occurrence (Frequency / Probability)

Likelihood	Planned Event (Frequency)	Unplanned Event (Probability)
A	**One Off** A single occurrence over the lifetime of the project lasting for a period of minutes or hours.	**Remote** Event is extremely unlikely to occur during the project given the industry best practises and procedures that are in place
B	**Intermittent** An occasional, intermittent event lasting for a period of hours.	**Possible** Event has occurred in a minority of similar projects, but is unlikely to occur during the project
C	**Regular** A single event lasting for a period of days or weeks or a series of frequent events each lasting a period of hours, days or weeks.	**Likely** Event could easily occur during the project
D	**Continuous** A continuous event over the lifetime of the project	**Very Likely** Event is almost certain to occur during the project

Table 4.2: Definition of Consequence Categories

Consequence Category[1]	Environmental Receptors	Social Receptors / Company Reputation
5 Severe	Severe, widespread (extending over an area of >100 km^2), long term or potentially irreversible, effects on the ecosystem at an international level. Severe, long term deterioration of air and / or water quality and / or changes / reduction in biodiversity abundance or distribution.	Severe and potentially irreparable damage to archaeological, cultural or natural resources of national and international importance. Intervention by national and international governmental bodies. Extensive worldwide media interest and public community outrage.
4 Major	Major, widespread (extending over a wide area of up to 100 km^2), medium to long term effects on the ecosystem at a national level. Major, medium to long term deterioration of air and / or water quality and / or change / reduction in biodiversity abundance or distribution.	Major damage with medium to long term loss of archaeological, cultural or natural resources of national. Possible Intervention by national governmental bodies. Extensive national media interest and public concern.
3 Moderate	Moderate effects on the ecosystem at a regional level, leading to observable and measurable changes within an area of less 10 km^2. Moderate, medium term deterioration of air and / or water quality and / or change / reduction in biodiversity abundance or distribution.	Moderate damage to archaeological, cultural or natural resources of regional importance. Regional/local public concerns at the community or broad interest-group level.

Consequence Category[1]	Environmental Receptors	Social Receptors / Company Reputation
2 Minor	Limited effects on the ecosystem at a local level, leading to observable and measurable changes within an area of less 1 km^2. Minor, short term deterioration of air and / or water quality and / or change / reduction in biodiversity abundance or distribution.	Limited damage to archaeological, cultural or natural resources of local importance. Issues may affect individual people or stakeholders at the local level. Limited public awareness and concern.
1 Negligible	Insignificant effects on the ecosystem, unlikely to be observable or measurable above small random changes due to ambient environmental conditions.	Has no discernible effect on archaeological, cultural or natural resources. No noticeable stakeholder concern or public interest.
0 Positive	An enhancement of an ecosystem.	An enhancement in the availability or quality of a resource. Of benefit to stakeholders.

[1] Where magnitude appears to fall within different consequence categories, the higher category is selected to provide a worst-case scenario for the purposes of assessment.

Table 4.3: Risk Assessment Matrix

			Likelihood			
			A	B	C	D
			One off / Remote	Intermittent / Possible	Regular / Likely	Continuous / Very Likely
Consequence	5	Severe				
	4	Major				
	3	Moderate				
	2	Minor				
	1	Negligible				
	0	Positive				

Overall Significance (Risk to Environment) Definitions:

High	**Considered to be a highly significant risk:** the level of risk is unacceptable. Additional mitigation measures are required to move the risk to lower risk categories.
Medium	**Considered to be a significant risk:** the level of risk is considered to be within applicable standards, however, it is best practice to demonstrate that these impacts have been reduced to a level that is as low as reasonably practicable (ALARP).
Low	**Not considered to be a significant risk:** the level of risk is considered to be broadly acceptable, although commitment to continuous improvement in environmental performance is still required.
Positive	**Positive impact:** to be encouraged and enhanced, if possible.

4.5 Mitigation Measures and Residual Impacts

Where potentially significant impacts (i.e. those ranked as being of medium or high risk in Table 4.3) are identified, mitigation measures must be considered. The intention is that such measures should remove, reduce or manage the impacts to a point where the significance of the resulting residual impact is at an acceptable level. Significance is then reassessed to determine the residual effect.

For impacts that are deemed not significant (i.e. low risk or positive in Table 4.3), there is no requirement to adopt specific mitigation. These impacts are usually managed through good industry practice and operational plans and procedures.

All the mitigation measures and commitments made by Serica, as identified in this ES, have been listed within the Commitments Register (Table 11.1) in Section 11. Section 11 also provides details on how these measures will be managed as the project progresses.

4.6 Assessment Results

The results of the impact assessment process for the proposed Columbus Development project are summarised in the Environmental Aspects Registers in Appendix C.

Environmental aspects of the Columbus Development project which are not considered to be significant have been scoped out from detailed assessment in this ES, whereas those identified as having potentially significant impacts (i.e. impacts ranked as high or medium risks to the environment) are discussed in detail within the following sections of the ES:

- Physical Presence (Section 5);
- Seabed Disturbance (Section 6);
- Noise (Section 7);
- Atmospheric Emissions (Section 8);
- Marine Discharges (Section 9);
- Accidental Releases (Section 10).

Where relevant, potential transboundary and cumulative impacts have also been discussed in these sections.

5 Physical Presence

5.1 Introduction

Key aspects of the Columbus Development, which have a potential to interfere with other sea users in the area, include the presence of the MODU during the proposed drilling operations, subsea infrastructure (i.e. deviated section of the pipeline and umbilical, Xmas tree structure and CTIS and the tie-in spools), designated exclusion zone and increased vessel activity, particularly during installation and commissioning operations.

The marine environment within which the Columbus Development is located is utilised by a number of other sea users, primarily commercial fishing and shipping.

Fishing effort in the vicinity of the Columbus Development is considered to be variable with low effort in winter, moderate effort from March to May and August to September and high effort in June and July. The area is utilised by both the UK and international fishing fleets (refer to Section 3.8.1; Marine Scotland, 2017b). Fishing activity in the Columbus Development area is dominated by trawls (Marine Scotland, 2017b). VMS data indicates that the Columbus Development area is within an area of moderate intensity of demersal mobile gear fishing alongside low levels of herring fishing activity (Kafas *et al.*, 2012; Marine Scotland, 2018). The dominant species landed (by weight) in the vicinity of the Columbus Development area include herring, plaice, lemon sole and haddock (Marine Scotland, 2017b).

Commercial shipping activity within the vicinity of the Columbus Development is considered to be low (Anatec, 2006). The majority of vessels passing within 18.5 kilometres (10 nautical miles) of the proposed Columbus Development are cargo vessels, followed by offshore support vessels and tankers (Anatec, 2006) (refer to Section 3.8.2).

5.2 Aspects with Potentially Significant Impacts

As identified in the Environmental Aspects Registers in Appendix C, the physical presence of the following aspects associated with the Columbus Development have been identified as having potentially significant impacts on other sea users:

- MODU and its associated anchor spread (if semi-submersible MODU is used) and 500 m exclusion zone during the drilling phase;
- Vessels during the installation and commissioning phase;
- Subsea Xmas tree structure, CTIS, protection material and the associated 500 m exclusion zone once in place;
- Seabed berms if formed during trenching of the pipeline and umbilical.

The potential impacts from these aspects on other sea users (namely fishing and shipping) are discussed below.

5.3 Assessment of Impacts on Other Sea Users

5.3.1 At the Sea Surface

The presence of the MODU and other working vessels at the surface can pose a navigation hazard to other users of the sea and the presence of the 500 m exclusion zone will preclude vessel activity at the surface.

The drilling phase will involve the use of either a semi-submersible MODU or a Heavy Duty Jack-Up (HDJU), which will be on location at Columbus for a period of around 79 days. While the MODU is on location, a 500 m safety exclusion zone will be in place. This equates to an area of 0.8 square kilometres at the sea surface that will be unavailable to other sea users.

Although the 500 m safety zone around the MODU will be temporary, Serica will apply for a 500 m safety exclusion zone to cover the Xmas tree structure and CTIS, from the point when the MODU moves off location, which will then be in place throughout the life of the Columbus Development. Therefore, an area of 0.8 square kilometres at the sea surface will be unavailable to other users of the sea for the life of the Columbus Development.

Shipping vessels may have to re-route around the Columbus 500 m safety exclusion zone and could therefore be displaced. This could lead to extended passage times and have knock-on effects on the users of other nearby shipping routes in the area. However, the density of shipping traffic in the area is relatively low (refer to Section 3.8.2, Anatec, 2006).

It is expected that large vessels would need to pass around 3.7 km (2 nautical miles) from the Columbus Development location and smaller vessel would need to pass around 2.8 km (1.5 nautical miles) from the Columbus Development location. A survey of shipping routes of a previous well location (approximately 300 m south east south of the CDev-1 well) using the ShipRoutes data identified several shipping routes potentially passing within 3.7 km (2 nautical miles) (refer to Section 3.8.2, *Anatec, 2006*). As such, vessels regularly using these shipping routes would need to re-route in order to achieve a safe distance, however it is anticipated that there is ample sea room to perform these actions with minimal effect on navigation.

Given the above the impact to shipping from the Columbus Development throughout the field life is considered to be **medium** (the likelihood is continuous and the consequence is minor).

Fishing vessels will also be displaced from the 500 m exclusion zone. However, actively fishing vessels will be excluded from a greater cumulative area, due to the presence of the seabed infrastructure; this has therefore been discussed in Section 5.3.2.

It is anticipated that pipeline and umbilical installation vessels will be on location between Q2 and Q3 2020 and the DSV will be on location during Q2 2021. While these vessels may pose a navigation hazard to other users of the sea, unlike the MODU they will be mobile and therefore able to actively avoid collisions with other vessels.

5.3.2 Below the Sea Surface

The physical presence of seabed infrastructure and the mooring system of a semi-submersible MODU (if this is the selected rig type) is not considered to have a significant impact on commercial shipping activity as shipping vessels will not be interacting with the seabed; however, it will pose a snagging hazard to fishing gears in the area. Snagged gears can pose a hazard to the safety of the vessel and crew and, if unsnagging is not possible, a loss of fishing gear and catch. There is also a risk of cumulative damage to the subsea infrastructure itself and weakening of any stabilisation material if repeated contact is made with fishing gears.

If a semi-submersible MODU is used during the drilling phase, the anchors of the MODU will extend outside of the 500 m exclusion zone (each anchor chain is anticipated to be 2,500 m in length) and will therefore represent a snagging hazard to fishing vessels. In addition, the deployment of anchors means that there is the potential for the formation of anchor mounds. As a result, fishing vessels, particularly benthic trawlers and those with pelagic mobile gear, are likely to be displaced from the area beyond the 500 m exclusion zone when the MODU is on location. It should be noted, however, that previous surveys in the area have shown that fine sand dominates the area (refer to Section 3.3.3), therefore the creation of significant anchor mounds is considered unlikely.

Based on a worst case assumption, it is assumed that fishing vessels may avoid a radius of up to 2.5 km from the MODU location, equating to an area of 19.625 square kilometres. This is a conservative figure as it assumes loss of access to a radius equal to the length of the anchors chain around the semi-submersible MODU, which is unlikely to be the case. For example, pelagic fishing vessels are more capable of operating close to the mooring system, as their fishing gear is suspended in the water column.

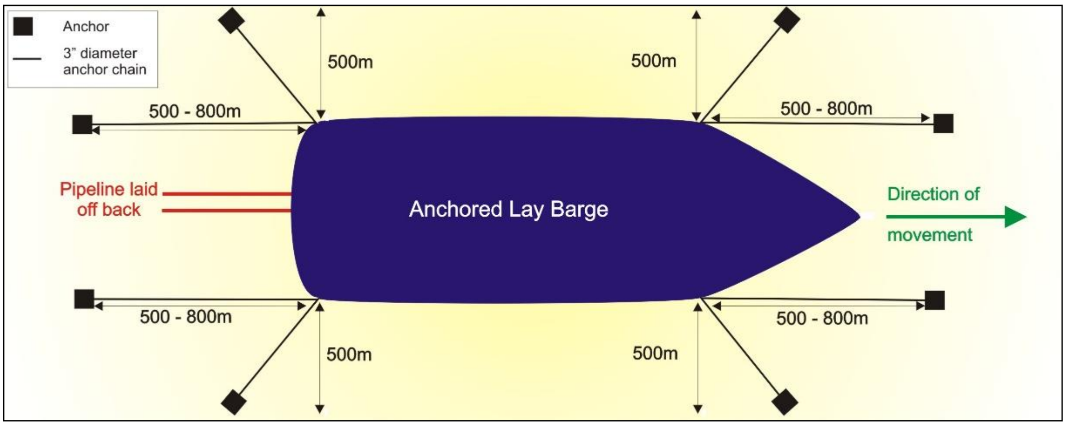
Given the above and the fact the fishing activity is variable in the locality of the proposed Columbus Development location, with peak fishing activity in June and July, the risk to fishing from the MODU anchors and associated 500 m exclusion zone during the drilling phase is considered to be **medium** (the likelihood is regular and the consequence is moderate).

Once the MODU moves off location, fishing will be displaced from a smaller area throughout the life of the Columbus Development, which corresponds to 500 m exclusion zone (0.8 square kilometres) in place around the Columbus Xmas tree structure and CTIS. As such, the longer term risk is fishing is considered to be **medium** (the likelihood is continuous and the consequence is minor).

During activities associated with the installation of the deviated section of the Arran pipeline and umbilical, scheduled to occur between Q2 and Q3 2020 and last up to seven days, fishing activity will be temporarily displaced from the working corridors of the deviated section, with the area remaining unavailable to commercial fisheries until the production pipeline and umbilical are trenched and backfilled (in relation to the pipeline only) and protective stabilisation material has been laid where required (refer to Section 2.8). The maximum footprint of the pipeline and umbilical corridors of the deviated section is expected to be approximately 0.2295 square kilometres; assuming Dynamic Positioning (DP) vessels are used, the length of the deviated section is 7,650m and that the width of the working corridor is 30 m. To limit the area impacted, pipeline working corridors will be minimised as far as possible.

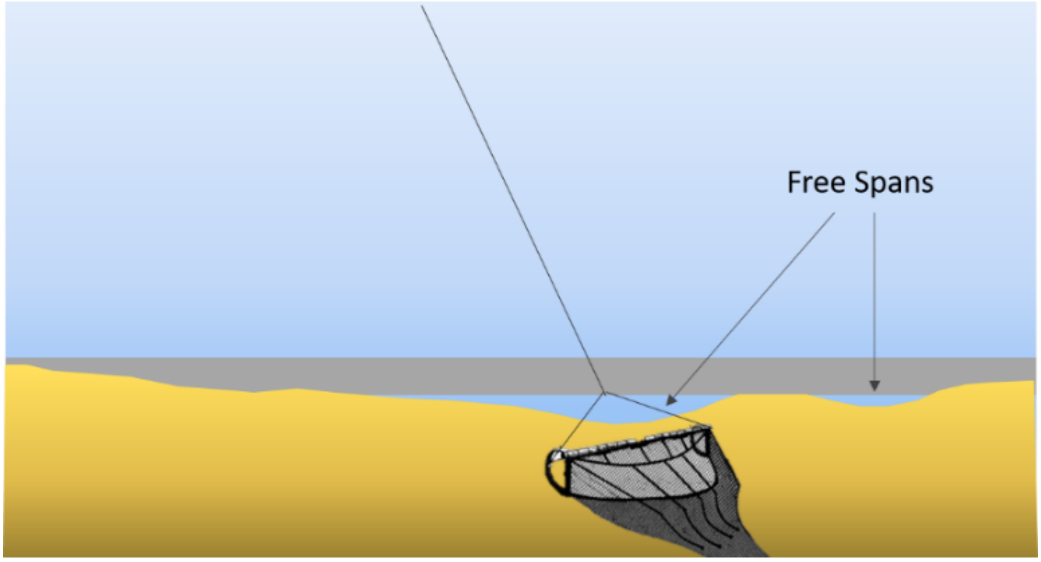
The majority of pipelay vessels make use of DP systems. However, the potential remains that a pipelay vessel which uses anchors for station keeping may be utilised, which would result in fishing vessels being displaced from a large area. A typical spread from an anchored lay barge vessel is illustrated in Figure 5.1, although the exact layout will be dependent on wind, wave and current conditions and operational requirements. The vessel would carry 12 anchors, which would be deployed up to 1 km from the hull of the vessel. This may displace the fishing vessels from an area of up to 3.14 square kilometres around the construction vessel. It is estimated that a total area of approximately 15.3 square kilometres, based upon a 2 km by 7.65 km rectangle centred on the pipeline route, will be temporarily unavailable to commercial fishermen when the pipelay vessel operates over the deviated section of the pipeline. The use of an anchor barge would require a pre-lay anchor corridor to be surveyed as the anchors can be up to 1,000 m either side of the vessel which would be out with the surveyed route corridor width of 540 m (270 m either side of the route centre line).

Figure 5.1. Anchor Spread from a Typical Anchored Lay Barge



Once the Columbus infrastructure is in place, the presence of the Xmas tree structure and CTIS which will sit proud of the seabed by 5.5 m and 4.5 m, respectively, will also pose a potential snagging risk. To reduce this risk, the Xmas tree and CTIS will have integral fishing friendly structures (FFSs) and a 500 m exclusion zone will be in place around the infrastructure. Where the pipeline and umbilical transition from their respective trenches at the CTIS within the 500 m exclusion zones, exposed sections will be protected with mattresses. Out-with the 500 m exclusion zones, spot rock-dumping may be used to protect against upheaval buckling along the deviated section of the Arran pipeline. Where rock is used it will have a 1:3 gradient in order to be overtrawlable. The use of stabilisation material will ensure the integrity of the Columbus infrastructure at the seabed, prevent damage in the event of contact with fishing gears, and prevent the development of free spans (as shown in Figure 5.2) from upheaval buckling, which could both pose a greater snagging hazard, particularly to mobile demersal fishing gears.

Figure 5.2. Example Flowline Free Spans on Unprotected Flowline and Potential Snagging Hazard



Fishing vessels may therefore avoid the Columbus Development area in order to reduce the risk of interactions with seabed infrastructure, which may lead to a loss of fishing grounds resulting in an economic impact on local fisheries that normally operate in the area. However, the spatial extent of the Columbus Development area is relatively small in comparison with the wider area available to the fishing vessels.

Given the above, the risk to fishing from the long term physical presence of the subsea Xmas tree structure and CTIS, pipeline, umbilical and subsea protection material is considered to be **medium** (the likelihood is continuous and the consequence is minor).

In addition, when the pipeline and umbilical are trenched, the plough used to create the trench will displace sediment (generally fine sand; Gardline, 2016a) on the seabed forming seabed berms along the length of the trenches. Overtrawling of seabed berms by fishing vessels can result in sediment being retained in the net, with potential damage to the nets, equipment and catch, and potential risks to the safety of the fishing vessel and persons on board. As such, the presence of spoil berms if left on the seabed, may lead to the displacement of fishing vessels from the area. It is assumed, as a very conservative estimate, that an area of around 0.2295 square kilometres would be impacted for the deviated section of the pipeline and umbilical (assuming the width of the corridor including the pipeline trench, umbilical trench and spoil berms is of the order of 30 m). In addition, if anchored construction vessels are used there is the potential for the formation of anchor mounds. However, as noted above, surveys have shown that fine sand are present in the area, therefore the creation of seabed berms or anchor mounds is considered unlikely. In addition, as the pipeline will be mechanically backfilled the extent of any seabed berms remaining on the seabed will be minimised. Nevertheless, if berms or anchor mounds were to remain on the seabed once the pipeline and umbilical had been installed, the risk to fishing is considered to be **medium** (the likelihood is continuous and the consequence is minor).

5.4 Mitigation Measures

5.4.1 Standard Operating Measures

The assessment of impacts detailed above has assumed that the following standard operation measures will be implemented during the life of the proposed Columbus Development:

- An up to date collision risk assessment and shipping density study will be undertaken prior to the drilling phase of the project which will be used to support the planned operations;
- Consent to Locate will be in place for the MODU under Part 4A of the Energy Act 2008;
- 500 m safety exclusion zone will be designated around the MODU and a dedicated ERRV will be present during drilling operations to monitor movements of other vessels in the area and prevent them entering the exclusion zone;

- Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, Kingfisher, NAVTEX / NAVAREA warnings and fisheries notices;
- Subsea infrastructure will be marked as hazards on admiralty charts and entered into the Fishsafe system so that it may be avoided by fishing vessels.

5.4.2 Additional Mitigation Measures

In order to remove, reduce or manage the potentially significant impacts identified in Section 5.3 above, Serica proposes to implement the following additional mitigation measures during the various lifecycle stages of the project:

- Early consultation and ongoing engagement with other sea-users (stakeholders);
- Appointment of an onshore Fisheries Liaison Officer (FLO) to maintain good communication with local fisheries and co-ordinate activities throughout the drilling phase, installation and commissioning phase;
- During installation and commissioning, the number of vessels and length of time they are required on site will be reduced as far as practicable through careful planning of the installation activities;
- Pipeline working corridors will be minimised, as far as possible;
- The deviated section of the pipeline will be trenched and mechanically backfilled. Where the burial depth is not achieved, exposed sections outside the exclusion zone will be protected using rock placement, which will be deposited at a gradient designed to allow fishing gear to pass without snagging;
- All seabed infrastructure will be designed to be fishing friendly and a 500 m safety exclusion zone will be applied for around the Xmas tree and CTIS, which will be clearly marked on navigation charts;
- A post-development survey will be conducted, and any anchor scars, spud can depressions and trench berms that are considered to pose a snagging risk will be flattened using a chain mat;
- With the exception of areas of spot rock-dump, all protection material will be contained within safety exclusion zones;
- Pipeline and umbilical may be installed in the same trench. This will be considered in future design work.

5.5 Residual Impacts

Given the proposed mitigation measures detailed in Section 5.4, there are unlikely to be any significant adverse residual impacts to shipping and fishing as a result of the physical presence of the Columbus Development.

Commercial shipping activity in the vicinity of the Columbus Development is considered to be low (Anatec, 2006), and there is adequate sea room available for vessels to increase their passing distance should they think it necessary. The risk of a collision between vessels will be minimised by implementing measures, including marking exclusion zones on appropriate Admiralty and navigation charts, to help ensure other sea users are aware of the Columbus Development. In addition, standard communication and notification measures will be in place to ensure that all vessels operating in the area are aware of the activities taking place, particularly during the installation and commissioning phase (refer to Section 5.4). The risk to shipping is also only temporary, as once installed all the Columbus Development infrastructure is subsea.

The total area lost to fishing during the life of Columbus Development is summarised in Table 5.1. It is emphasised that the only long-term exclusion from the area will be as a result of the 500 m exclusion zone around the Xmas tree structure and CTIS. To put this in context, the exclusion zone would be located in ICES Rectangle 43F2 and the average area of an ICES Rectangle is 3,224 square kilometres

(Marine Scotland, 2017b), and as such fishing vessels would only be excluded from approximately 0.02 % of the ICES Rectangle.

Table 5.1. Estimated Fishing Exclusion Areas Related to the Columbus Development

Aspect	Approximate Area (km^2)	Duration
MODU 500 m exclusion zone and anchor spread	19.625	79 days
Installation activities for deviated section of the pipeline and umbilical	0.2295 (or 15.3 if anchored pipelay vessel is used)	Temporary
Xmas tree structure and CTIS 500 m exclusion zone	0.8	Life of field

The pipeline trench will be mechanically backfilled to minimise any impact to fishing as much as possible. Although the creation of seabed berms is considered unlikely, if they are identified during post-lay surveys and are considered to pose a snagging risk, they will be flattened using a chain mat. This would thereby reduce the risk of seabed berms to fishing to **low**. All other risks to fishing and shipping from the physical presence of the Columbus Development during the drilling and installation and commissioning phases are considered to remain **medium**, but the risks have been minimised as much as possible and are therefore not considered to be significant.

5.6 Transboundary Impacts

Given the distance to the nearest transboundary line; the UK/Norwegian median line around 8 kilometres to the east-north-east of the proposed Columbus Development, it is very unlikely that the physical presence of the Development and associated vessels would lead to transboundary impacts. Any areas excluded from use by other sea users (e.g. shipping and fishing) will be restricted to within close proximity to the Columbus Development area and will not extend across the UK/Norwegian median line. In advance of offshore activities occurring, Serica will ensure that international fishing organisations, with known vessels working within the area of the Columbus Development, are informed of the proposed works via appropriate fishing notifications.

5.7 Cumulative Impacts

Loss of access to other sea users for the life of the Columbus Development will be restricted to an area totalling 0.8 square kilometres around the CTIS and Xmas tree structure. There may also be some additional displacement of fishing vessels from the area of the MODU anchor spread, if a semi-submersible MODU is used, which (conservatively) equates to around 19.625 square kilometres and during installation and commissioning activities, up to 15.3 square kilometres if an anchored pipelay barge is used, with these displacements being temporary (refer to Table 5.1). These displacements have the potential to have a cumulative effect with the loss of access generated by the activities associated with the Arran Field Development project (i.e. drilling, subsea facilities installation and commissioning and Shearwater modification). However, in comparison to the total sea area accessible in this area of the central North Sea this direct loss is considered to be very small. As such, significant cumulative loss of access to other sea users is considered unlikely. There may be some cumulative increase in snagging risk in the vicinity of the Development as Columbus lies in close proximity to a number of currently producing and future oil and gas fields (refer to Section 3.8.4); however, given the mitigation measures proposed, no significant cumulative impacts are anticipated.

6 Seabed Disturbance

6.1 Introduction

Disturbance to the seabed can have wide ranging effects, including decline in water quality due to increased turbidity, smothering of organisms and habitats, the loss of habitat attributed to change in substrate characteristics (i.e. from a soft to hard substratum type), toxicity effects from chemical components, pollution to the seabed sediments and water column and potential decrease in local oxygen levels due to the presence of increased organic components. These changes can have direct effects on marine fauna, or indirect effects by habitat degradation or avoidance and loss or redistribution of prey.

A number of site surveys have previously been conducted in the vicinity of the Columbus Development area as detailed in Section 3. In May 2018, Serica undertook a habitat assessment and EBS within a 3 km by 3 km survey area centred on the proposed CDev-1 well location (site survey) and along a 8 km route corridor centred on the deviated section of the Arran pipeline (route survey). At the time of writing this ES, the results of the 2018 habitat assessment and EBS were not available. However, given the stability of the benthic environment in 80-90 m of water depth and the general homogeneity of the seabed sediments in this part of the central North Sea, it is considered that the historic survey data allows a good understanding of the surrounding area upon which to undertake the EIA.

6.2 Aspects with Potentially Significant Impacts

As shown in the Environmental Aspects Registers in Appendix C, the following aspects associated with the Columbus Development have been identified as having potentially significant impacts to the seabed:

- MODU anchoring or spud can placement (depending on final rig selected);
- Discharge of drill cuttings, muds and cement;
- Trenching, pipelay and backfill activities during the installation of the deviated section of the pipeline and umbilical (including stabilisation material and pipelay vessel anchors);
- Installation and long term presence of Xmas tree, CTIS and associated protective stabilisation material;

The potentially significant impacts of these aspects on the seabed, in particular, seabed sediments and seabed communities are discussed in detail below.

6.3 Estimating the Scale of Seabed Disturbance

6.3.1 MODU Anchoring / Spud Can

The proposed CDev-1 well will be drilled using either a semi-submersible MODU of a Heavy Duty Jack-Up (HDJU).

If selected, the semi-submersible rig will be moored using 8 anchors. The maximum anchor spread radius will be 2,500 m, of which approximately 1,000 m of the anchor line is estimated to lie on the seabed. An area of seabed where each anchor is placed will be compressed as the anchors sink into the seabed. Consequently, the placement of the anchors will cause localised direct damage to the habitats and species at the point of placement, whilst the movement of the associated lines as they sweep back and forth across the seabed will affect the benthos for the duration they remain in position. It is assumed that a 10 m wide corridor will be disturbed per anchor chain. The total area of seabed disturbed from anchoring of the MODU is therefore estimated to be 0.08 square kilometres.

If the HDJU is selected this will use spud cans to remain on location. Typically, three or four spud cans will be used, each with a footprint of approximately 380 m^2, which will impact an area of up to 1,520 m^2 (0.00152 square kilometre).

In terms of seabed impacts the anchored rig and anchor lines in conjunction is the worst case option and has therefore been included in the seabed impact calculations below.

6.3.2 Discharge of Drill Cuttings, Muds and Cement

As described in Section 2.7, the Columbus Development well will be drilled in sections, with each section decreasing in diameter towards the reservoir section. A 36 inch-diameter top-hole section will be drilled, into which a 30 inch-diameter conductor pipe will be cemented. A 26 inch section will then be drilled through the conductor and a 20 inch-diameter steel casing will be installed and cemented into place. Following this, the wellhead and blowout preventer (BOP) will be installed, and a marine riser (a conduit from lengths of steel pipe) will connect the wellhead and BOP to the MODU. The riser will also allow drilling mud to be returned for treatment on the MODU and to be cycled repeatedly through the well. A 17½ inch section will then be drilled through the conductor and a 13⅜ inch-diameter steel casing will be installed and cemented into place, followed by the drilling of a 12¼ inch section and the installation of a 9⅝ inch-diameter casing. Finally, the 8½ inch wellbore section will be drilled through the reservoir and a 7 inch-diameter liner will be installed in place.

The two top-hole sections will be drilled with WBM. As the riser will not yet be installed, the seawater and associated cuttings and drill fluids, will be discharged to the seabed and deposited around the wellbore. In the bottom three sections, LTOBM will be circulated through the well. Cuttings contaminated with LTOBM will be returned to the MODU and skipped and shipped to shore for onshore processing and disposal at a licenced treatment and landfill site (refer to Table 2.7 in Section 2.7.3).

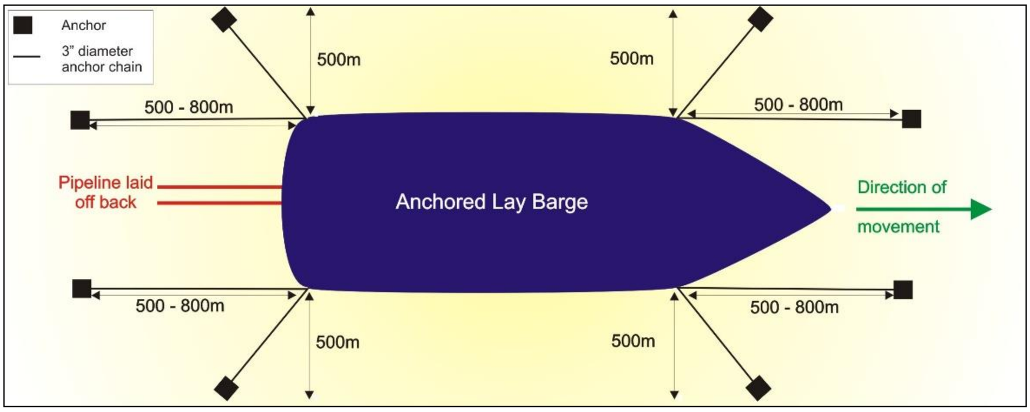
The WBM cuttings discharged directly onto the seabed from the two top well sections will form a pile in the immediate vicinity of the Columbus drilling location. As detailed in Section 3.3.2, the location of the suspended 23/16f-12 well, completed in November 2007 and located approximately 1.73 km to the north northeast of the proposed CDev-1 well, was observed during the 2008 Gardline survey nine month after the drilling operations had been completed. It was noted that the wellhead was surrounded by an area of drilling mud and cuttings of >350 m by 200 m. Conservatively, it is assumed for this assessment that the cuttings discharged during the drilling of the CDev-1 well will cover a similar area around the wellhead, disturbing an area of approximately 70,000 square metres.

6.3.3 Pipeline and Umbilical Installation

During trenching, pipelay and backfill activities of the deviated section of the Arran pipeline and umbilical, it is estimated that approximately 0.2295 square kilometres (229,500 square metres) of seabed will be disturbed. This assumes that disturbance of the deviated section will occur within a 30 m working corridor, centred on the pipeline / umbilical, which could be laid in separate trenches for a distance of 7,650 meters (refer to Section 2.8.4).

Additional areas of seabed may also be disturbed if anchored vessels are used during installation of the pipeline / umbilical, rather than DP vessels. A typical lay barge will move forward by winching itself within the array of anchors and simultaneously moving some of the anchors forward (Figure 6.1).

Figure 6.1: Anchor Spread from a Typical Anchored Lay Barge



The vessel would carry 12 anchors, which would be deployed up to 1 km from the hull of the vessel. The vessel would then pull itself along by winching in the forward anchor chains. At regular intervals, anchors would need to be recovered and redeployed by anchor handling vessels. The vessel is able to pull itself approximately 500 m per anchor deployment, and therefore over the total length of the deviated section of the pipeline of 7.65 km, approximately 16 full redeployments would be required, equalling 192 individual anchor placements. Each anchor contact with the seabed will be approximately 5 m by 8 m, or 40 m^2, which multiplied by the number of anchor placements required gives a total direct impact area of 7,680 m^2.

6.3.4 Installation of the Xmas Tree and CTIS

There will be a small loss (around 153 square metres) of available seabed once the Xmas tree, protected by a FFS measuring 9.5 m (length) by 9 m (width); and the CTIS, protected by an integral FFS measuring 9 m (length) by 7.5 m (width), are installed.

6.3.5 Seabed Infrastructure Protection Material

As detailed in Section 2.8.5, spot rock-dumping will be required along certain points of the pipeline route to protect against upheaval buckling. The umbilical will not require any rock placement provided it is suitably trenched below mean seabed level.

Concrete mattresses, assumed to be 6 m (length) by 3 m (width), will be required between the Xmas tree and the CTIS and from the CTIS to the buried pipeline / umbilical section.

In total, it is estimated that approximately 8,611 square metres of seabed will be disturbed by the placement of seabed infrastructure protection material (refer to Section 2.8.5).

6.3.6 Estimated Total Seabed Disturbance Area

The total area of seabed disturbed from the Columbus Development is summarised in Table 6.1.

Table 6.1: The Estimated Extent of Disturbed Seabed from Development of the Columbus Field

Aspect	Assumptions	Estimated Area of Seabed Disturbance	
		m^2	km^2
MODU Anchoring	• 8 anchors with 2.5 km anchor chains, each abrading an area of seabed assumed to be 1,000 m; • Disturbance corridor width approx. 10 m.	80,000	0.08
Discharge of WBM drill cuttings, muds and cement	• One well; • WBM cuttings discharged from both the 36 and 26 inch sections, directly to the seabed.	70,000	0.07
Installation of pipeline and umbilical (including pipelay vessel anchoring)	• 192 pipelay vessel anchor (5 m x 8 m) placements (if DP vessel not used) will disturb an area of 7,680 m^2; • Pipeline and umbilical: total approx. 7,650 m in length, with a disturbance corridor of 30 m.	237,180	0.2372
Installation of Xmas tree and CTIS	• Xmas tree and Xmas tree system protected by a FFS; measuring 9.5 m by 9 m (impact area: approx. 82.8 m^2); • CTIS and integral FFS with dimensions 9 m by 7.5 m (impact area: approx. 67.5 m^2).	153	0.0001

Aspect	Assumptions	Estimated Area of Seabed Disturbance	
		m^2	km^2
Subsea Infrastructure Protection	• Rock (6,583 tonnes for the deviated section of the pipeline)[1] and 120 mattresses (6 m x 3 m) will be used for subsea infrastructure protection.	8,611	0.009
	Total:	395,944	0.3963

[1] Based on the length of the deviated section of the pipeline (i.e. 7,650m), with 50,000 tonnes for the upheaval buckling mitigation used along the whole Arran to Shearwater pipeline;

6.4 Assessment of Impacts

6.4.1 Discharge of Drill Cuttings, Muds and Cement

The risk of contamination to seabed sediments from drilling of the CDev-1 well is considered to be **medium** (the likelihood is regular and the consequence is low). The main components of WBM are naturally occurring products (e.g. Ba and bentonite clay), to which may be added various products to ensure the mud has suitable properties. The mud components are generally low risk and many chemical components are labelled as PLONOR (or Pose Little or No Risk to the marine environment). A full Chemical Hazard Assessment and Risk Management (CHARM) analysis assessment of the proposed chemicals to be used and discharged, as required under the Offshore Chemicals Regulations 2002, will be undertaken during the permitting process prior to drilling of the Development well CDev-1. Any contamination to the seabed sediments which does occur is likely to be confined within an area of 0.0962 square kilometre, corresponding to the area of seabed impacted by the cuttings piles formed around the drill centre.

The effects on seabed fauna from the deposition of WBM cuttings and fine solids are usually subtle or undetectable, although the presence of drilling material at the seabed close to the drilling location (less than 500 m) is often detectable chemically. Considerable data has been gathered from the North Sea and other production areas, indicating that localised physical effects are the dominant mechanism of ecological disturbance, where WBM cuttings, muds and cements are discharged (DECC, 2011).

A comprehensive desk study of the composition, environmental fates and biological effect of WBM cuttings and muds was prepared on behalf of the Petroleum Environmental Research Forum (PERF) and American Petroleum Institute by Neff (2005). The review, covering more than 200 publications and reports, concludes that effects of WBM cuttings piles on bottom living biological communities are caused mainly by burial and low sediment oxygen concentrations resulting from organic enrichment. Toxic effects, when they occur, are probably caused by sulphide and ammonia by-products of organic enrichment (DECC, 2011).

The effects on seabed fauna due to increased turbidity in the water column following the discharge of WBM drill cuttings, muds and cements are also anticipated to be very local and transitory. Studies of the discharge of WBM into the water column in areas where currents are weak have found dilutions of 500 to 1,000 times within 1 to 3 m of discharge (Ray and Meek, 1980). Rapid dilution is therefore expected and it is unlikely that any discharge will be noticeable above the existing background turbidity.

It is anticipated that the macrofaunal community within the Columbus Development area is likely to be diverse and to show some spatial variability (refer to Section 3.6.2). However, this is expected to be in line with natural variability (i.e. the physico-chemical attributes of the sediments) rather than as a consequence of anthropogenic disturbance or contamination. In addition, the predominant habitat type across the survey area is expected to be EUNIS habitat A5.27 (deep circalittoral sand).

It is considered likely that ocean quahog will be present in the grab samples collected during the 2018 survey (refer to Section 3.6.2). The ocean quahog is of conservation importance due to its slow growth, late age of reaching reproductive maturity and vulnerability to disturbance (JNCC, 2015). Data taken from the Feature Activity Sensitivity Tool (FEAST) indicates that the ocean quahog is highly sensitive to the introduction of on-synthetic compound contamination (including heavy metals, hydrocarbons and produced water), changes in substratum (i.e. habitat loss), changes in siltation, physical abrasion from activities (such as dredging and trawling) and changes in temperature (Marine Scotland, 2013). As such, there is a possibility that ocean quahog could be impacted by the discharge of WBM cuttings, muds and cement, but only in an area limited to 0.0962 square kilometre from the drill centre location. Ocean quahog is, however, commonly found within the North Sea (Oil & Gas UK, 2010) and when compared with other areas, the abundance of ocean quahog previously recorded in the vicinity of the Columbus Development area is relatively low (refer to Section 3.6.2).

Any impacts are to seabed communities from the discharge of WBM cuttings, WBM and cement are anticipated to be temporary and it is envisaged that communities will begin to recover once development drilling activities have ceased. Recolonisation of the impacted area can take place in a number of ways, including mobile species moving in from the edges of the area (immigration), usually more effective for the larger epifaunal species, juvenile recruitment from the plankton or from burrowing species digging back to the surface. In a series of large scale field experiments Dernie *et al*. (*2003*) investigated the response to physical disturbance of marine benthic communities within a variety of sediment types (clean sand, silty sand, muddy sand and mud). Of the four sediment types investigated, the communities typical of silty sands and mud had the most rapid recovery rate following disturbance. Further evidence of recovery of seabed communities following drilling can be seen from the research work undertaken by AUMS (1987). A benthic environmental survey was undertaken in 1987 at three single well sites in the central North Sea (at depths of 102 m, 120 m and 130 m respectively). The wells had been drilled five years prior to the survey using a WBM and a total of approximately 800 tonnes of cuttings had been deposited on the seabed at each location. The results of the survey indicated that, with the exception of a slightly elevated barium concentration, levels of sediment metals and hydrocarbons were similar to background concentrations. The analysis of the benthic fauna indicated that, even at sites closest to the Xmas tree, full recovery of the impacted sediments had taken place. These well sites were revisited by Oil and Gas UK (formerly UKOOA) in 2005 with analysis of the sediment samples showing that the area had recovered to be consistent with background conditions (Hartley Anderson Ltd, 2005).

In addition, field studies in the United States of America have shown that recovery of benthic communities impacted with water based drilling discharges is likely to be very rapid (i.e. within a few months) (Neff, 1982).

Given the above, the risk to seabed communities from the discharge of WBM cuttings, WBM and cement is considered to be **medium** (the likelihood is regular and the consequence is minor).

6.4.2 MODU / Vessel Anchoring

The indirect effects of anchoring include the resuspension of sediments, and subsequent smothering, and abrasion which are likely to occur over a wider area as sediments are re-suspended and transported away from the immediate vicinity of the Columbus Development.

The placement of the anchors and anchor chain from both the MODU and any anchored vessels used during the installation phase of the Columbus Development would smother any organisms under them, but also potentially disturb sediments and suspend them in the water column. The area impacted is however relatively small (refer to Section 6.3.6) and the estimated recovery periods for anchor scarring and scraping from cables / anchor chains are expected to be relatively rapid (within one to five years) (DECC, 2016).

The sediments within the Columbus Development area are expected to comprise silty sand with intermittent areas of clay outcrop with gravel, shells and cobbles (refer to Section 3.3.3). The predominant habitat type across the survey area is expected to be EUNIS habitat A5.27 (deep circalittoral sand) and the epifauna is expected to include similar species to those encountered during the 2015 Gardline survey (Gardline, 2016a), with polychaeta (Serpulidae and *Ditrupa* sp) being the dominant species (refer to Section 3.6.2).

Species' vulnerability to the effects of smothering and physical disturbance is variable and dependent on the individuals' mobility, physiology and ecology. However, as the sediments at the Columbus Development are classed as silty sand, the impact of smothering on seabed communities is expected to be less than on those species found in a hard or gravely location. This is due to the organisms already have a tolerance for organic matter and increased turbidity. These species are also more likely to be mobile and are therefore able to move away from smothering impacts, unlike sessile species which have no choice. However, many sessile species are filter or suspension feeders which may benefit from some degree of sedimentation as it may make some organic material available that had been previously buried. Whilst the increase in suspended particulates may benefit some species, other more delicate species are adversely affected by smothering (Hartnoll, 1998) which can damage feeding apparatus and the abrasion can also damage soft-bodied organisms.

There is also a possibility that anchoring of the MODU or pipelay vessel could disturb the contaminated sediments generated by the previous appraisal drilling campaigns. The 23/16f-12 well is located approximately 1.73 km to the north northeast of the proposed CDev-1 well and 700 m to the east northeast of the proposed deviated section of the Arran pipeline route. The 23/16f-11 well is located approximately 1.48 km to the south southeast of the proposed CDev-1 well and 380 m to the east of the proposed deviated section of the Arran pipeline route. As noted in Section 3.3.3, elevated concentrations of Ba and other metals were encountered during the Gardline 2008 and 2010 surveys in close proximity to the 23/16f-11 and 23/16f-12 wells. However, given the time that has lapsed since these surveys were conducted and, based on AUMS (1987), it is expected that the concentration of Ba and other metals are now likely to be closer to background levels.

Given the above, the risk to seabed communities from MODU and vessel anchoring is considered to be **medium** (the likelihood is regular and the consequence is minor).

6.4.3 Installation of Subsea Infrastructure & Protection Material

During pipeline and umbilical installation activities it is likely that a proportion of the sediments will become suspended in the bottom few metres of the water column. Sediments should drop out of suspension, however, some of the finer mud and silts may remain in the water column for some time and could be transported away from the immediate area of impact on the prevailing currents. The relatively low seabed current speeds in the deeper waters of the central North Sea, however, would tend to suggest that settlement of suspended material will occur in the vicinity of operations with limited further field sediment transport occurring. This also indicates that any smothering effects on seabed fauna associated with pipeline and umbilical installation activities will be localised.

The impact to benthic communities from the installation of the deviated section of the pipeline and umbilical will be almost entirely physical, (i.e. disturbance and smothering of an area of 0.2295 square kilometres) and, given that the sediments will not have been contaminated, it is anticipated that seabed communities will begin to recover as soon as the trenches have been backfilled.

Although recovery times for soft sediment faunal communities, such as those found within the Columbus Development area, are difficult to predict, van Dalfsen *et al.* (2000) showed that the recovery of benthic communities following sand extraction at sites in the North Sea off the coasts of Denmark and the Netherlands occurred within two to four years. The effects on the benthic community appeared to be related to the physical impact on the sea floor, with small-scale disturbances in seabed morphology and sediment composition resulting in relatively short-term and localised effects. *Rees et al*. (1992) also showed that newly deposited sediment (at dredged material disposal sites) was rapidly colonised by opportunistic macrofauna.

Further, 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 (the impact width of which is similar to a pipeline trench) could occur within about 100 days. In this sort of impact, it was assumed that recolonisation was through immigration into the disturbed area rather than from settlement or reproduction within the area. It was also noted that whilst the recovery rate of small bodied taxa, such as the polychaetes, which tend to dominate the data set, could be accurately predicted, sandy sediment communities often contain one or two long lived and therefore vulnerable species, the recovery of which is far harder to predict.

In a series of large scale field experiments Dernie *et al.,* (2003) investigated the response to physical disturbance of marine benthic communities within a variety of sediment types (clean sand, silty sand, muddy sand and mud). Of the four sediment types investigated, the communities from clean sands (such as those prevalent along the pipeline route) had the most rapid recovery rate following disturbance and mud the slowest.

The use of mattress protection and rock dumping, required at certain places to ensure the integrity of the facilities, are likely to disturb the mobile benthic fauna and smother the fixed flora and fauna directly beneath it. In addition to a temporary increase in turbidity as sediments become suspended, the area beneath the rock and mattresses will become unavailable for recolonisation by soft sediment inhabiting infauna, and over time a new rocky substrate habitat would become established. Taxa likely to colonise such a hard substrate could include sea anemones, tunicates, sponges, squat lobsters, sessile tube-dwelling polychaetes such as *Sabella* spp. (fanworms) and encrusting organisms such as bryozoans. It should be noted, however, that the materials to be deposited have no toxic component and their presence will only lead to a local modification of the seabed. As such, both direct and secondary impacts of rock dumping and mattressing on the benthic communities will be limited to a small local area, approximately 0.009 square kilometres.

The installation of seabed infrastructure (i.e. the Xmas tree and CTIS), will also result in potential smothering, change in habitat type (from soft to hard substratum) and exclusion from the area due to loss of available sediment during the life of the Columbus Development. The Xmas tree, CTIS and associated FFS will cover an area of 153 square metres.

As noted above, one species of conservation importance, the ocean quahog, is expected to be present within the proposed Columbus Development area (refer to Section 3.6.2). The ocean quahog is highly sensitive to physical pressures as outlined in Table 6.2, based on the Marine Evidence based Sensitivity Assessment (MarESA) approach, and therefore could be adversely impacted by the proposed installation activities and long term presence of the Columbus subsea infrastructure. It should be noted, however, that ocean quahog is commonly found within the North Sea (Oil & Gas UK, 2010) and when compared with other areas, the abundance of ocean quahog in the proposed Columbus Development area is expected to be relatively low.

Table 6.2: Ocean Quahog (*A. islandica*) Sensitivity Assessment (MarLIN, 2018)[1]

Physical Pressure	Resistance	Resilience	Sensitivity
Physical change (to another seabed type)	None Q: H, A: H, C: H	Very Low Q: H, A: H, C: H	High Q: H, A: H, C: H
Physical change (to another sediment type)	Low Q: L, A: NR, C: NR	Very Low Q: H, A: H, C: H	High Q: L, A: L, C: L
Habitat structure changes – removal of substratum (extraction)	None Q: H, A: H, C:M	Very Low Q: H, A: H, C: H	High Q: H, A: H, C: H
Abrasion / disturbance of the surface of the substratum or seabed	Low Q: H, A: H, C: M	Very Low Q: H, A: M, C: M	High Q: H, A: M, C: M
Penetration or disturbance of the substratum subsurface	Low Q: H, A: H, C: M	Very Low Q: H, A: M, C: M	High Q: H, A: M, C: M

Note 1: Key to Confidence Assessment:

- Q: Quality of evidence (information sources), A: Applicability of evidence, C: Degree of concordance (agreement between studies), H: High, M: Medium, L: Low, NR: Not Recorded

Given the above, the risk to seabed communities from pipeline and umbilical installation activities is considered to be **medium** (the likelihood is regular and the consequence is minor). The risk to seabed communities from the more long term presence of the Xmas tree, CTIS and subsea protection material is also considered to be **medium** (the likelihood is continuous and the consequence is minor).

6.5 Mitigation Measures

6.5.1 Standard Operating Measures

The assessment of impacts detailed above has assumed that the following standard operation measures will be implemented during the life of the proposed Columbus Development:

- A full Chemical Hazard Assessment and Risk Management (CHARM) assessment of the proposed chemicals to be used and discharged, as required under the Offshore Chemicals Regulations 2002 (as amended), will be undertaken during the permitting process prior to drilling operations commencing;
- Deposits Consents will be obtained prior to use of stabilisation / protection material;
- The amount of deposited material used will be minimised, as far as possible, whilst still achieving the required level of stabilisation / protection.

6.5.2 Additional Mitigation Measures

In order to remove, reduce or manage the potentially significant impacts identified in Section 6.4 above, Serica proposes to implement the following additional mitigation measures during the various lifecycle stages of the project:

- A detailed anchor pattern for the use of a semi-submersible drill rig or a spud can location assessment for the use of a HDJU will be developed prior to mobilisation;
- As part of chemical selection and assessment process, less hazardous alternatives will be sought in preference for any chemicals identified to be high risk (e.g. those with substitution warnings);
- WBM will be mixed offshore to ensure that only what is required is used;
- A rig audit will be conducted to ensure that the rig is in compliance with all relevant guidelines and legislation;
- If an anchored pipelay vessel is used, the pipeline site survey data will be reviewed to determine if placement will affect any existing environmentally sensitive features or hazards;
- The appropriate number of anchors and length of anchor chains will be used to maintain stability and integrity;
- Working corridors will be minimised, as far as possible;
- The pipeline and umbilical may be installed in the same trench; this will be considered in future design work;
- Stabilisation material will be constrained to areas where trenching alone does not sufficiently protect the deviated section of the pipeline;
- The volumes and locations of rock and mattresses used will be refined during Detailed Design to reduce the footprint on the seabed to the extent practicable;
- The spread of rock placement will be restricted through the use of a fall pipe system held a few metres above the seabed to accurately place rock material.

6.6 Residual Impacts

Given the proposed mitigation measures detailed in Section 6.5, there are unlikely to be any significant adverse residual impacts to seabed sediments or seabed communities as a result of disturbance to the seabed during the life of the Columbus Development.

The maximum total area of seabed that will be directly impacted by the Columbus Development is estimated at around 0.4 square kilometres (refer to Table 6.1). This is a relatively small area in comparison to seabed available across the central North Sea, with similar water depths, sediment types and benthic communities. In addition, much of the area impacted by the Columbus Development (around 97 %) will be disturbed as a result of cutting and mud discharges, MODU anchoring activities or use of spud cans and pipeline and umbilical installation activities. These are temporary operations and it is expected that recovery of affected areas of seabed will be relatively rapid once associated operations have ceased.

7 Noise and Vibration

7.1 Introduction

Underwater noise has the potential to disturb, or cause injury to, a number of species in the marine environment. This section discusses the potentially significant environmental impacts on sensitive marine fauna (specifically marine mammals and fish) that may arise from noise generated throughout the life of the proposed Columbus Development. It also considers whether the Columbus Development has the potential to affect a European Protected Species (EPS).

Marine life, including marine mammals, fish and some species of invertebrates, have developed a range of complex mechanisms for both emitting and detecting underwater noise signals that allow them to communicate, avoid predators and other perceived dangers, locate food and mates, and to navigate (Richardson *et al*., 1995; DOSITS, 2017). Sounds are particularly important for intra-species communication as they can convey significant amounts of information quickly and over great distances (DOSITS, 2017). As such, many marine species are vulnerable to anthropogenic noises that may disrupt their ability to perceive their surrounding environment.

As discussed in Section 3.6.5, species of cetacean likely to be present in the Columbus Development area include common dolphin, harbour porpoise, killer whale, minke whale, Risso's dolphin, white-beaked dolphin and white-sided dolphin, however, with the exception of white-beaked dolphin, these have only been sighted in low or very low frequencies within the immediate vicinity of the proposed development itself (Reid *et al.,* 2003). Although both harbour and grey seals are widely found in the coastal water around Scotland they generally tend to remain within 50 km and 100 km respectively, of their onshore haul-out sites and therefore are likely to be only infrequent visitors to the Columbus Development area.

As discussed in Section 3.6.3, fish species likely to be present in the development area include anglerfish (monkfish), blue whiting, cod, European hake, haddock, herring, horse mackerel, lemon sole, ling, mackerel, Norway pout, plaice, sandeel, spotted ray, spurdog and whiting (Coull *et al*., 1998 and Ellis *et al*.,2012). Other species targeted by commercial fisheries in this area include saithe and witch (Marine Scotland, 2017b).

For the Columbus Development activities, the majority of underwater noise will be generated during the drilling, installation, hook-up and commissioning phases of the project, with notable sources of underwater noise produced during piling activities and from movements of large construction vessels. Noise sources associated with the different phases of the Columbus Development with the greatest potential for impact on marine fauna (specifically fish and marine mammals) are identified in Section 7.2.2 and discussed further in Sections 7.2.3 and 7.2.4.

7.2 Assessment of Impacts

7.2.1 Underwater Noise Transmission

Sound manifests itself as pressure (i.e. a force acting over a given area). It is expressed in terms of 'sound pressure levels' (SPL), which use a logarithmic scale of the ratio of the measured pressure to a reference pressure (expressed as decibels relative to one micro-Pascal (dB re 1 µPa)).

This noise assessment uses the model proposed by Richardson *et al*. (1995), which assumes spherical spreading, to calculate the propagation of underwater sound. Refer to Appendix E for further information.

7.2.2 Noise Sources with Potentially Significant Impacts

As shown in the Environmental Aspects Registers, in Appendix C, noise generated from the following sources has been identified as resulting in potentially significant impact on fish and marine mammals:

- MODU and support vessels during the drilling phase;
- Vessels during the installation, hook-up and commissioning phase; and

- Piling operations to install the subsea CTIS during the installation, hook-up and commissioning phase.

The worst-case noise levels associated which each of these sources is summarised in Table 7.1 and discussed below. For the purpose of this assessment, to assess the worst-case noise levels, it has been assumed that a semi-submersible MODU will be used as this is generally louder than a jack-up MODU (refer to Table 7.1).

Table 7.1. Worst-Case Noise Levels associated with the Columbus Development (taken from: Richardson *et al.,* 1995; Wyatt, 2008; Genesis, 2011)

Project Phase	Noise Source	Sound Type [1]	Frequency Range (kHz)	Sound Pressure Level (dB re 1µPa.m)
Drilling Operations	Jack-up MODU	Non-pulse	0.01 – 10	127
	Semi-submersible MODU	Non-pulse	0.01 – 10	170
	Support vessels [2]	Non-pulse	0.01 – 20	190
Installation, Hook-Up and Commissioning	Vessels [2]	Non-pulse	0.01 – 20	190
	Piling	Multiple pulse	0.1 – 1	194

[1] Underwater sound has been categorised by Southall *et al.* (2007) as single pulse, multiple pulse and non-pulsed.
[2] DP thrusters generate greater noise levels (up to 190 dB re 1µPa.m) therefore this has been assumed as a worst-case for all vessels (with the exception of the MODU).

Vessels

High levels of non-pulse noise will be generated from a number of different vessels that will be operating at the Columbus Development; however, their presence will largely be intermittent throughout the life of the field.

As a worst case, it has been assumed that the majority of installation, hook-up and commissioning activities for Columbus will use DP vessels which produce more noise than anchored vessels due to the continual use of their thrusters in order to maintain their position (Wyatt, 2008). High noise levels may also be expected from short-term activities such as the use of anchor tugs, with noise levels in the vicinity of 170 dB re 1µPa.m (decibels relative to one micro-Pascal referred to 1 metre), and pipelay and DSV with noise levels in the vicinity of 190 dB re 1µPa.m (Wyatt, 2008; Genesis, 2011).

Noise produced during drilling activities is primarily generated as the drill bit penetrates the seabed, and from power generation and process equipment on board the MODU. However, the noise generated by on board equipment tends to be of low frequency (Genesis, 2011), meaning that it will also attenuate less and will travel further from its source, but is likely to be lower in intensity than the noise levels from physical drilling activity. The semi-submersible MODU will be anchored in place, thereby minimising the requirements for DP thrusters. Noise levels associated with a typical semi-submersible MODU may be up to 170 dB re 1µPa.m (Richardson *et al*., 1995), although other studies have recorded slightly lower levels at 154 dB re 1µPa.m (measured from the SEDCO 708 semi-submersible MODU in water depths of 114 m) (Greene, 1986 cited in Genesis, 2011).

As a worst-case, it is assumed that a noise level of 190 dB re 1µPa.m (Genesis, 2011; Richardson *et al.,* 1995) is applicable for all vessels operating during the drilling operations and installation, hook-up and commissioning phases.

Piling Operations

Piling is classified as multiple pulse noise (Southall *et al*., 2007). Underwater noise generated from piling can extend across a range of frequencies from 10 hertz (Hz) to 120 kilohertz (kHz) depending on the piling method used, the diameter of the piles and the seabed being penetrated (McHugh *et al.,* 2005). The majority of piling impulses however emit noise in the low frequency range below 500 Hz

(Genesis, 2011; DOSITS, 2017). Piling transmits noise through the water column as well as through the seabed as the pile penetrates the seabed.

The following equation provides a conservative estimate of the source level of piling noise where *D* is the pile diameter in metres:

SPL = (24.3 * D) + 179 (Nedwell *et al.*, 2005)

Of note, is that existing equations used to estimate noise generated from piling are largely based on a small number of *in-situ* measurements and have not been fully validated.

For the Columbus Development the CTIS will be overboarded and held in place by four piles to ensure its structural integrity on the seabed. Each pile will measure approximately 0.6 m in diameter and therefore, noise levels associated with installation of the CTIS are estimated to be in the region of 194 dB re 1µPa.m. It is anticipated that piling operations could take place during Q2 2021 and last for a duration of up to two days.

7.2.3 Potential Impacts on Fish

Sounds produced by fish are predominantly related to reproduction or conveying territorial aggression or predation (DOSITS, 2017). As such, many fish species have developed sensory mechanisms for detecting, locating and interpreting underwater sounds. Hearing ability is highly variable between fish species. Species with a connection between the inner ear and the swimbladder, a gas-filled organ primarily used for buoyancy, are more sensitive to sound (Hawkins, 1993; Moyle and Cech, 2004; Popper, 2012). Fish may tentatively be separated into (Popper *et al.*, 2014):

- Category I - Fish with no swim bladder, or other gas volume, such as flatfish, mackerel and sharks, skates and rays (Myrberg, 2001). These fish only detect particle motion not sound pressure;
- Category II - Fish with a swim bladder, or other gas volume, but where the organ is not involved in hearing. These fish are susceptible to barotrauma (injury caused by increased air or water pressure) but only detect particle motion not sound pressure;
- Category III - Fish with a swim bladder, or other gas volume, where the organ is also involved in hearing, such as herring and relatives (Hawkins, 1993; Popper et al., 2014; DOSITS, 2017). These species are susceptible to barotrauma and detect both sound pressure and particle motion.

As discussed in Section 3.6.3, the fish community in the vicinity of the Columbus Development is dominated by demersal species such as monkfish (anglerfish), cod, witch, haddock and whiting (DECC, 2016; Marine Scotland, 2017b). Many demersal species have a small or reduced swim bladder or a swim bladder that is not in close proximity, or mechanically connected to the ears (DOSITS, 2017) and would therefore be classified as Category II fish. These species therefore tend to have relatively poor auditory sensitivity, and generally cannot hear sounds at frequencies above 1 kHz (DOSITS, 2017).

Thresholds for Injury and Disturbance to Fish

Potential effects on fish from intense noise sources, such as those from piling, range from behavioural changes including fish moving away from an area or ceasing feeding, to physiological changes such as temporary hearing loss, tissue damage or even death (DOSITS, 2017). Fish species vary in their response to sound in many ways, such that a guideline for a behavioural response can never fit all fish (Popper *et al.*, 2014). However, peak SPL (SPL_{peak}) injury thresholds have been proposed for Category I fish (> 213 dB re 1µPa) and Category II and III fish (>207 dB re 1µPa) (Popper *et al.*, 2014).

Physiological damage to fish eggs and larvae is also of particular concern, since unlike adult fish they are unable to move away from a noise source and are therefore at greater risk of mortality (Turnpenny and Nedwell, 1994). Popper *et al.*, (2014) proposed SPL_{peak} injury thresholds for fish eggs and larvae (>207 dB re 1µPa) for noise produced by seismic airguns. However, the threshold proposed by Turnpenny and Nedwell, (1994) of 180 dB re 1µPa is more conservative and has been used in this assessment. It is also noted that the impact on juvenile fish will be greater than for adults of the same species. In the absence of an injury threshold for juvenile fish, the Turnpenny and Nedwell (1994) threshold for fish eggs and larvae (180 dB re 1µPa) has been used in this assessment.

Noise Modelling Results

As discussed in Section 7.2.2, the loudest noise will occur during the piling operations to install the subsea CTIS and from vessels operating with DP thrusters. However, based on the injury thresholds proposed for fish (Popper *et al*., 2014), modelling has shown that the worst-case noise levels for either piling operations or vessel use are unlikely to exceed the injury thresholds for adult fish at any distance from the noise source (refer to Table 7.2). However, fish eggs and larvae (and juvenile fish) may suffer injury within 6 m and 4 m, respectively, of the noise source (refer Table 7.2 and Appendix E for graphical model output from noise propagation model).

Table 7.2. Sound Pressure Level Thresholds for Injury to Fish

Fish	Injury Threshold (SPL; dB re 1µPa)	Radius of Impact for Piling Operations [N1]	Radius of Impact for Vessel Use [N1]
Category I fish [N2]	> 213 dB	0	0
Category II and III fish [N2]	> 207 dB	0	0
Fish eggs and larvae (and juvenile fish) [N3]	> 180 dB	6 m	4 m

Notes

[N1] The radius of impact has been calculated based on the sound propagation results, as illustrated in Appendix E.

[N2] Threshold from Popper *et al*. (2014).

[N3] Threshold from Turnpenny and Nedwell (1994).

As most noise produced by fish is related to reproduction, many fish are more receptive and therefore more sensitive to introduced noise during reproductive periods and spawning events. The waters surrounding the Columbus field development have been identified as spawning and nursery grounds for a number of fish species (refer to Section 3.6.3). In addition, disturbance to fish during key lifecycle events may have greater impacts at a population level as it could deter individuals away from crucial habitats. This would be of greater significance where species demonstrate a strong preference for a particular habitat or niche. Species such as sandeels demonstrate such a preference. Sandeels only lay their eggs in clean sandy sediments and are therefore vulnerable to any disturbances to their preferred habitat. Sandeels are a commercially important fish species and an important prey resource such that periods of poor recruitment can have knock-on effects on seabird populations, which rely on sandeels as prey during the nesting period (Frederisken *et al.,* 2006; Lancaster *et al*., 2014).

As piling will be undertaken at the seabed, it will be in close proximity to potential sandeel spawning grounds (according to Coull *et al*., 1998; Ellis *et al*., 2012). Fish egg and larvae damage could occur at distances of around 6 m from the piling activity and as the proposed window for piling (April – June) overlaps with the nursery period for sandeels (January - April), sandeel spawning and recruitment could be adversely affected by the proposed piling operations. However, as discussed in Section 3.6.3, the seabed sediments in the vicinity of the Columbus Development are expected to have a greater proportion of fines than in preferred by sandeels (<4%; Wright *et al*., 2000; Holland *et al*., 2005). Therefore, while sandeels and sandeel spawning grounds may be present, the Columbus Development area is unlikely to offer prime habitat for this species and is considered to represent only a small proportion of the spawning and nursery grounds available for the fish species in the North Sea (refer to Section 3.6.3).

Juvenile and larval fish, in their first year of life (termed 0 group fish) are also very sensitive to anthropogenic noise (Aires *et al*., 2014). Mapping and modelling of 0 group fish distribution does not, however, identify the Columbus Development area as being a significant habitat for fish in their first year of life (refer to Section 3.6.3).

Given the above, the risk to fish from noise associated with the Columbus Development activities is considered to be as follows:

- Non-pulse noise generated from the MODU and support vessels during the drilling operations is of **medium** risk (the likelihood is regular and consequence is minor);
- Non-pulse noise generated from the vessels during the installation, hook-up and commissioning phase is of **medium** risk (the likelihood is regular and consequence is minor); and
- Multi-pulse noise generated from the piling operations to install the subsea CTIS during the installation, hook-up and commissioning phase is of **medium** risk (the likelihood is intermittent and consequence is moderate).

Additional mitigation measures have therefore been proposed in Section 7.3 in order to manage the potentially significant impacts.

7.2.4 Potential Impact on Marine Mammals

Marine mammals rely on sound to communicate, protect themselves, locate prey, navigate and understand their general surroundings and maintain social structures within groups of individuals (DOSITS, 2017).

Characteristics of Hearing Sensitivities

Not all marine mammal species have equal hearing capabilities, in terms of absolute hearing sensitivity and the frequency band of hearing (NOAA, 2016) and, consequently, vulnerability to impact from underwater noise differs between species.

Table 7.3 presents the marine mammal species that have been sighted within the proposed Columbus field development area (refer to Section 3.6.5) by their functional hearing group and associate estimated hearing range, as classified by Southall *et al*. (2007) and NOAA (2016). It can be seen that the hearing ability of many species may overlap with noise generated from the proposed operations.

Table 7.3. Functional Marine Mammal Hearing Groups That May Be Present Within the Columbus Development Area

Hearing Group	Estimated Hearing Range		Species Represented in the Columbus Development Area [N1]
	Southall *et al.* (2007)	NOAA (2016)	
Low-frequency cetaceans	7 Hz – 22 kHz	7 Hz – 35 kHz	Minke whale
Mid-frequency cetaceans	150 Hz – 160 kHz	150 Hz – 160 kHz	Common dolphin, Killer whale, Risso's dolphin, White-beaked dolphin, White-sided dolphin
High-frequency cetaceans	200 Hz – 180 kHz	275 Hz -160 kHz	Harbour porpoise
Pinnipeds in water	75 Hz to 75 kHz	-	Harbour seal, Grey seal
Phocid pinnipeds [N2] (underwater)	-	50 Hz – 86 kHz	

Notes
[N1] refer to Section 3.6.5
[N2] Earless or true seals.

Thresholds for Injury and Disturbance to Marine Mammals

There are two metrics that can be used to assess the impact of noise on marine mammals: sound exposure level (SEL) and sound pressure level (SPL) (Southall *et al.*, 2007). SEL is based on the assumption that sounds of equivalent energy will have similar effects on the auditory systems of exposed individuals, even if they differ in SPL, duration and / or temporal exposure (Genesis, 2011).

However, SPL provides a peak noise level and is therefore a more conservative threshold for which to assess the potential impact from anthropogenic noise. Measurements of SPL have therefore been used to assess the impacts from underwater noise on marine mammals.

In the immediate vicinity of a high sound level source, noise can have a severe effect causing a permanent threshold shift (PTS) in hearing, leading to hearing loss and ultimately with increasing exposure, to physical injuries which may be fatal. However, at greater distances from a source the noise decreases and the potential effects are diminished (Nedwell *et al.*, 2005; Nedwell and Edwards, 2004), possibly causing the onset of a temporary shift in hearing thresholds (Temporary Threshold Shift (TTS)-onset).

According to Southall *et al.* (2007), the injury SPL threshold for mid-, high- and low-frequency cetaceans for all noise types (single, multiple and non-pulsed noise) is 230 dB re 1µPa. However, in 2016, the America scientific agency, the National Oceanic and Atmospheric Administration (NOAA), published 'Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing' which reports lower PTS onset thresholds than Southall *et al*. (2007) for impulse noise (refer to Table 7.5). As the NOAA (2016) report represents more up-to-date thinking by many of the Southall *et al*. (2007) authors these thresholds will be used in this assessment going forwards. It should be noted that NOAA (2016) only has SPL levels for impulsive noise sources, therefore these thresholds have been used for all types of noise sources in the proposed survey.

Table 7.4. NOAA (2016) Injury (PTS Onset) Thresholds (Impulsive Noise)

Hearing Group	PTS-Onset Level (SPL_{peak}; dB re 1µPa)
Low-frequency cetaceans	219 dB
Mid-frequency cetaceans	230 dB
High-frequency cetaceans	202 dB

Southall *et al*. (2007) undertook a review of the impacts of underwater noise on marine mammals and used this to define criteria for predicting the onset of behavioural response in marine mammals with different hearing characteristics when subjected to different types of noise. Southall *et al*. (2007) proposed a behavioural response severity scaling system which ranks from a zero for 'no response' to a nine for 'outright panic, flight, stampede, attack of conspecifics or stranding events'.

Non-trivial disturbance, as defined in regulation 39(1A)(a) of the Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (as amended) and hereafter referred to as 'significant behavioural change', is interpreted for the purposes of this EIA as the sustained or chronic disruption of behaviour, scoring five or more in the Southall *et al*. (2007) behavioural response severity scale, that could impair reproduction or survival (Southall *et al*., 2007; JNCC, 2010a).

Table 7.5 presents the conservative SPL thresholds for significant behavioural response in marine mammals that are used in this assessment.

Table 7.5. Significant Behavioural Change (TTS-Onset) Sound Pressure Level Thresholds for Marine Mammals

Functional Hearing Group	TTS-Onset (SPL; dB re 1µPa) Threshold [N1]	
	Multi-Pulse Noise	Non-Pulse Noise
Low-frequency cetaceans	>145 dB (BRS = 6-7)	>120 dB (BRS = 6-7)
Mid-frequency cetaceans	>150 dB (BRS = 6)	>145 dB (BRS = 5-8)
High-frequency cetaceans [N2]	>125 dB (BRS = 6)	>125 dB (BRS = 6)
Pinnipeds in water	>180 dB (BRS = 6)	>105 dB (BRS = 6)

Notes
BRS = Behavioural Response Severity.

N1 Significant behavioural change thresholds are based on observed behavioural responses scored as 5/6 on the severity scale in Southall *et al*. (2007).

N2 No behavioural response thresholds for high-frequency cetaceans to multi-pulse noise are put forward by Southall *et al*. (2007). However, it is acknowledged that some multi-pulse noise sources may produce characteristics of non-pulse noise, particularly with distance from the source. As such, in the absence of defined thresholds, a conservative estimate of 125 dB re 1µPa (as per non-pulse noise) has been used for the assessment of behavioural effects that may be elicited in high-frequency cetaceans in response to multi-pulse noise.

Noise Modelling Results

Of the noise sources identified for the proposed activities associated with the Columbus Development (refer to Table 7.1), none are expected to exceed the NOAA (2016) injury thresholds (refer to Table 7.4).

In contrast, worse-case noise levels generated by the use of vessels (190 dB re 1 µPa 1 m) and piling operations (194 dB re 1 µPa 1 m) exceed the Southall et al. (2007) criteria for significant behavioural changes in marine mammals (refer to Table 7.6 and Appendix E for graphical output from noise propagation model).

Table 7.6. Sound Pressure Level Thresholds for Significant Behavioural Change (TTS-Onset) and Potential Impact Ranges for Piling Operations (multi-pulse noise) and Vessel Use (non-pulse noise)

Function Hearing Group	Piling Operations		Vessel Use	
	TTS-Onset Level (SPL; dB re 1µPa)	Impact Range N1	TTS-Onset Level (SPL; dB re 1µPa)	Impact Range N1
Low-frequency cetaceans	> 145 dB	299 m	> 120 dB	3,500 m
Mid-frequency cetaceans	> 150 dB	168 m	> 145 dB	189 m
High-frequency cetaceans	> 125 dB	3,000 m	> 125 dB	2,000 m
Phocid pinnipeds (underwater)	> 180 dB	6 m	> 105 dB	20,000 m

Notes

N1 The impact range has been calculated based on the sound propagation results, as illustrated in Appendix E.

Approximate densities of marine mammals likely to be found in the Columbus Development area have been used to estimate the number of animals of each species potentially experiencing likely significant behavioural changes from piling operation and vessel use (Table 7.7). Where possible, the density of cetaceans in the area has been estimated from the SCANS III survey data (Hammond *et al*., 2017; refer to Table 3.14 in Section 3.6.5). SCANS III survey data is not available for common dolphin, white-beaked dolphin and white-sided dolphin, therefore, the MU data for the Celtic and Greater North Seas (IAMMWG, 2015; refer to Table 3.13 in Section 3.6.5) has been used to calculate the density of these species instead. The estimated density of harbour seal and grey seal and has been calculated using data from Russel *et al*. (2017) (refer to Section 3.6.5). Of note is that abundance estimate data is not available for killer whale or Risso's dolphin therefore these species have not been included in Table 7.7.

Table 7.7. Estimated Number of Animals Potentially Experiencing Significant Behavioural Changes (TTS-Onset) from Piling Operations and Vessel Use during the Columbus Field Development Activities

Species	Estimated Density in Area (animals / km^2)	Estimated Number of Animals that may Experience TTS-Onset N4	
		Piling Operations	Vessel Use
Harbour porpoise N1,N5	0.333	10	5
Minke whale N1,N5	0.007	<1	<1
Common dolphin N2,N5	0.036	<1	<1
White-beaked dolphin N2,N5	0.010	<1	<1
White-sided dolphin N2,N5	0.044	<1	<1

Species	Estimated Density in Area (animals / km²)	Estimated Number of Animals that may Experience TTS-Onset N4	
		Piling Operations	Vessel Use
Harbour seal N3	0.04	<1	51
Grey seal N3	0.04	<1	51

Notes

N1 Source: Hammond *et al*. (2017) – SCANS-III block Q. It should be noted that block Q covers an area of 49,746 km², which is significantly larger than that covered by the proposed development;

N2 Source: Management Unit data for the Celtic and Greater North Seas (IAMMWG, 2015) (refer to Table 3.14 in Section 3.6.5). It should be noted that this Management Unit covers an area of 1,560,875 km², which is significantly larger than that covered by the proposed development;

N3 Source: Russel *et al*. (2017);

N4 Calculation method based on Southall *et al*. (2007) as recommended by JNCC (2010a), using Southall *et al*. (2007) thresholds for behavioural response (TTS);

N5 Indicates species that are European Protected Species (EPS).

Piling Operations

Noise levels from piling activities could elicit significant behavioural responses for all cetaceans at varying distances from the noise source. Mid-frequency cetaceans (e.g. white-beaked dolphin and killer whale) could elicit significant behavioural responses with 0.17 km of the source, low-frequency cetaceans (e.g. minke whale) within 0.3 km and high-frequency cetaceans (e.g. harbour porpoise) within 3 km. In addition, piling activities could cause behavioural responses in pinnipeds in water (e.g. grey and harbour seals) within a distance of around 6 m from the source, although it should be noted that the at-sea distribution of seals in the vicinity of the proposed Columbus development area is generally very low.

The above results are broadly consistent with other reviews of the zone of impact of piling activities on marine mammals conducted in the North Sea (e.g. Bailey *et al*., 2010; Thomsen *et al*., 2006). Behavioural responses in cetaceans are extensive and highly variable but could include changes in swimming and diving behaviour, changes in vocalisations, avoidance of the sound / area, startle responses and aggressive behaviour (e.g. tail / flipper slapping, jaw clapping and teeth gnashing) (Southall *et al*., 2007).

Piling noise is generally broad-band in its frequency range (refer to Table 7.1); however, the greatest energy from piling is emitted at low frequencies (<1 kHz), which is within the hearing range of most cetaceans (Thomsen *et al*., 2006) that tend to dominate the marine mammal assemblage in the area. It is important to note that although behavioural responses could be elicited out to considerable distances from the noise source in high-frequency cetaceans, their hearing ability is poorer at lower frequencies and they are therefore less sensitive to impacts from low-frequency noise.

Studies of the effects of piling activity have noted a decrease in vocalisations in certain species (Thomsen *et al*., 2006). In the vicinity of wind farm piling activity Tougaard *et al.* (2003 in Thomsen *et al*., 2006) reported that acoustic activity of harbour porpoises decreased after each pile strike event (either by them leaving the area or ceasing vocalisations), but subsequently returned to baseline conditions after approximately three to four hours. Porpoises also exhibited more directional swimming patterns following pile strikes. Although it should be noted that acoustic deterrent devices were used prior to piling, in order to deter marine mammals from the area (Thomsen *et al*., 2006).

The duration of piling operations for the Columbus field development will be relatively short in comparison to the lifecycle of the marine mammal receptors (approximately two days of piling). The current proposed window for the installation of the subsea CTIS is Q4 2020 to Q2 2021 (April – September). During this window, cetacean species likely to be present include harbour porpoise, killer whale, minke whale and white-beaked dolphin (Reid *et al*., 2003; DECC, 2016; refer to Section 3.6.5).

Given the above; the risk to marine mammals from noise generated by the proposed piling operations is considered to be **medium** (the likelihood is intermittent and the consequence is moderate).

Vessel Use

As shown in Table 7.6, noise levels from vessel use could elicit significant behavioural responses in low-frequency cetaceans (e.g. minke whale), mid-frequency cetaceans (e.g. white-beaked dolphin and killer whale) and high-frequency cetaceans (e.g. harbour porpoise) within distances of around 3.5 km, 0.19 km and 2 km, respectively, from the source. In addition, vessel operations could cause behavioural responses in phocid pinnipeds (underwater; e.g. grey and harbour seals) within a distance of around 20 km from the source.

Research has shown that marine mammals are typically more tolerant of fixed location noise sources, as opposed to moving sources (Southall *et al*., 2007), which may be perceived as an approaching threat. However, the majority of vessels working in the Columbus Development area are likely to be large and slow moving, meaning that cetaceans in the area are unlikely to be startled by the approaching vessel.

It should also be noted that this assessment conservatively assumes a worst-case noise level for all vessels. In reality noise levels generated will vary according to the vessel type and the activity that a vessel is undertaking (working, in transit etc.). Therefore it is anticipated that the actual noise levels generated by the majority of vessels involved in the development of the Columbus field will be lower than the worst-case level assumed in this assessment.

Given the above, the risk to marine mammals from noise generated by vessels during both the drilling operations and the installation, hook-up and commissioning phase is considered to be **medium** (the likelihood is regular and the consequence is minor).

7.2.5 European Protected Species Risk Assessment

European Protected Species are those that are listed on Annex IV of the EU Habitats Directive, which is transposed into UK law through The Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (as amended) (OMR) (from 12 – 200 nautical miles). In UK waters, these consist of all species of cetacean, marine turtles and the Atlantic sturgeon (JNCC, 2010a). It is an offence under the OMR to deliberately disturb, injure or kill a species designated as a European Protected Species. Non-trivial disturbance, as defined in regulation 39(1A)(a) of the OMR is interpreted as sustained or chronic disruption of behaviour scoring five or more on the Southall *et al*. (2007) BRS scale (JNCC, 2010a). Conversely, less severe reactions could constitute disturbance under the Regulations if there is chronic disruption of behaviour. This could happen for certain activities that expose the same animals to noise for many weeks, months, or years (JNCC, 2010a).

The results of the noise assessment indicate that the worst-case noise levels generated by piling operations and vessel use will not exceed the injury thresholds of cetaceans. However, these worst-case noise levels could elicit significant behavioural changes in cetaceans (Table 7.6). With the exception of harbour porpoise, Table 7.7 indicates that for the majority of cetacean species up to one individual is likely to experience significant behavioural changes as a result of the proposed piling operations and vessel use during the development of the Columbus field.

Based on their density, compared to other species (Table 7.7), harbour porpoise is the most likely EPS to be displaced by noise generated during the development of the Columbus field. It has been predicted that significant behavioural changes could be experienced by up to 10 harbour porpoise due to the proposed piling operations and up to five harbour porpoise due to vessel use during the development of the Columbus field (Table 7.7). However, to put these figures into perspective, the estimated abundance of harbour porpoise in SCANS III block Q in the North Sea is 16,569 and this block covers a wider area (49,746 km^2) than the proposed Columbus development (Hammond *et al.*, 2017). In addition, as a general rule, animals do not hear equally well at all frequencies within their hearing range. It is likely that underwater noise levels from the piling operations may have attenuated from peak levels before the best auditory frequency range of harbour porpoises is reached.

The central and northern North Sea has a moderate to high diversity and density of cetaceans (DECC, 2016). Data from the Cetaceans Atlas has indicated that around the proposed Columbus field development itself (within ICES Rectangle 43F2 and the eight surrounding rectangles) sightings of cetaceans are low for most species with the exception of white-beaked dolphin which reaches medium in November and minke whales which is very low in August (Reid *et al*., 2003). Although there are a number of species that may be present year-round, these are likely to be highly dispersed and wide-ranging.

The likelihood of an offence being committed under the OMR is highly dependent on the temporal characteristics of the activity (JNCC, 2010a). A disturbance offence is more likely where an activity causes persistent (sustained and chronic) noise in an area for long periods of time. For most cetacean populations in the UK, disturbance in terms of the OMR is unlikely to result from single, short-term operations such as the driving of small-diameter piles (JNCC, 2010a).

For the proposed Columbus Development, pile-driving operations will be restricted to the installation of the manifold with up to two days of hammering. Activities such as this are likely to result in temporary sporadic disturbance, which on its own is not likely to impair the ability of an animal to survive or reproduce nor result in significant effects on the local abundance or distribution (JNCC, 2010a).

Vessels used during the development of the Columbus field are likely to be large and slow moving, meaning that cetaceans in the area are unlikely to be startled by the approaching vessel. In addition, vessel use will be intermittent. As such, it is considered unlikely that the proposed piling operations or use of vessels would constitute an offence under the OMR. However, in order to minimise the risk of disturbance to EPSs, mitigation measures have been proposed in Section 7.3.

7.3 Proposed Mitigation Measures

7.3.1 Standard Mitigation Measures

The assessment of impacts detailed above has assumed that the following standard operation measures will be implemented during the life of the proposed Columbus Development:

- Use the minimum diameter piles necessary to achieve structural integrity;
- Follow JNCC (2010b) protocol for minimising the risk of injury to marine mammals from piling noise (August 2010), e.g. soft-start of pile driver, use of MMOs.

7.3.2 Additional Mitigation Measures

In order to remove, reduce or manage the potentially significant impacts identified in Section 7.2 above, Serica proposes to implement the following additional mitigation measures during the various lifecycle stages of the project:

- Where possible, piling operations will be timed to avoid periods of high sensitivity for marine mammals and fish.

7.4 Residual Impacts

Most underwater noise will be generated during drilling operations and installation, hook-up and commissioning phases of the project, with notable sources of noise produced during the pile driving activities and from vessels using DP thrusters. However, given the temporary nature of these activities and the mitigation measures that will be implemented, no significant negative impacts are anticipated.

In conclusion, the residual risk to fish and marine mammals from noise associated with the Columbus Development is considered to be medium, but not significant given the mitigation measures that will be in place. It is also considered unlikely that the proposed operations will constitute an offence under the OMR.

7.5 Transboundary Impacts

The Columbus field development area is located approximately 8 km to the west southwest of the UK/Norway median line. Given the predicted impact ranges (refer to Table 7.6) only phocid pinnipeds (underwater; grey and harbour seals) would be expected to experience transboundary impacts. However, they are considered to be infrequent visitors to the Columbus Development due to the distance from shore (230 km). As such, given the distance involved, any impacts to fish and marine mammals are not considered to be significant.

7.6 Cumulative Impacts

Given the extent to which marine mammals may exhibit significant behavioural changes during both the piling driving activities and vessel use (i.e. within 20 km from the source) it is possible that marine mammals could experience cumulative effects if noise from other anthropogenic sources (e.g. other oil and gas development activity or military exercises) were ongoing at the same time. However, given the temporary nature of these activities and the mitigation measures that will be in place, significant cumulative impacts are not expected.

8 Atmospheric Emissions

8.1 Introduction

The Columbus Development will generate a number of atmospheric emissions during the drilling, installation and commissioning and production phases. The major sources of emissions to atmosphere from the Columbus Development will be the combustion of hydrocarbons for power generation by the MODU, vessels and aircraft. The combustion of hydrocarbons will result in emissions to atmosphere of carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4) and oxides of nitrogen (NOx) Volatile Organic Compounds (VOCs) and sulphur (SOx), with small amounts of nitrous oxide (N_2O) also being released.

8.2 Aspects with Potentially Significant Impacts

As shown in the Environmental Aspects Registers in Appendix C, atmospheric emissions of the following aspects associated with the Columbus Development have been identified as having potentially significant impacts on air quality:

- Atmospheric emissions generated at the Columbus Field during drilling, installation and commissioning activities from:
  - Power generation for MODU, support and installation vessels;
  - Flaring of the CDev-1 well during well clean-up and testing;
- Atmospheric emissions generated at Shearwater during production and maintenance activities from:
  - Additional fuel use at Shearwater during operation of the field;
  - Temporary increases in flaring as a result of Columbus production coming online and from unplanned shut down and start-up.

Emissions from the drilling, installation and commissioning activities have been quantified, where relevant, in Sections 2.7.7 and 2.8.7. Emissions from the Shearwater platform associated with production of the Columbus field have been quantified, where relevant, in Sections 2.9.2. The potential impacts of these emissions on the atmosphere, at both a local scale (air pollution) and wider scale (climate change), have been discussed below.

Local, regional and transboundary issues include the potential generation of acid rain from nitrogen and sulphur oxides (NOX and SOX) released from combustion, and the human health impacts of ground level nitrogen dioxide (NO_2), sulphur dioxide (SO_2), both of which will be released from combustion and ozone (O_3), generated via the action of sunlight on NOX and volatile organic compounds (VOCs). On a global scale, anthropogenic sources of greenhouses gases (particularly CO_2, but also CH4 and NOX) are implicated in amplifying the natural greenhouse effect resulting in climate change.

8.3 Background

Atmospheric emissions from the UKCS are recorded annually and presented in an annual report (OGUK, 2017).

Production increased by almost 16 % between 2014 and 2016, when over the same period, CO_2 emissions from the UKCS oil & gas sector saw a 4 % increase. 2016 maintained the longer-term trend of falling CO_2 emissions on the UKCS with a minor decrease from 13.2 million tonnes to 13.1 million tonnes. 74 % of CO_2 emissions (9.7 million tonnes) in 2016 were generated from fuel consumed by combustion equipment to provide electrical power and drive compressors for gas export.

CH_4 emissions from UKCS operations fell from 41,200 tonnes in 2015 to 40,800 tonnes in 2016. VOC emissions were also down 16 % to just over 31,000 tonnes.

NO_x SO_2 and CO emissions all saw minor increases. This is likely due to increased combustion to meet demand from installations with growing levels of production (OGUK, 2017).

8.4 Assessment of Impacts

The potential environmental effects from gaseous emissions from the Columbus Development can be broadly summarised as follows:

- **Climate change:** anthropogenic sources of greenhouses gases (particularly CO_2, but also CH_4 and NOx) are implicated in amplifying the natural greenhouse effect resulting in climate change (IPCC, 2013). The potential effects of emissions of greenhouse gases are therefore global in scale; however, emissions from offshore oil and gas production only form a small proportion of the UK's total greenhouse gas emissions (just over 3 % in 2016) (OGUK, 2017).
- **Acidification:** atmospheric acid gases, including SO_2 and NOx, react with water vapour forming acids, to increase the acidity of clouds and rain which can result in vegetation damage, acidification of surface waters and land, and damage to buildings and infrastructure. The potential effects of emissions of acid gases are therefore considered to be most important at a regional scale. In addition, emissions of CO_2 can also be absorbed into the oceans, which can lead to a reduction in the pH of the water column due to the formation of carbonic acid (H_2CO_3), making seawater slightly more acidic and altering the chemistry of the water column (Caldeira & Wickett, 2003; Secretariat of the Convention on Biological Diversity, 2014). The full extent of impacts of ocean acidification are not fully understood, but may affect photosynthesis and growth and reproduction in a number of marine organisms (UKOA, 2010).
- **Ground level ozone formation:** inputs of contaminants such as NOx and VOCs can contribute to the formation of local tropospheric ozone and photochemical smog, resulting in a reduction in local air quality, which in turn can result in effects on human health.

8.4.1 Atmospheric Emissions Generated at the Columbus Field During Drilling, Installation and Commissioning Activities

In order to put the CO_2 emissions from the Columbus Development in context, Table 8.1 summarises the worst-case amount of CO_2, that could be generated by each aspect involving the combustion of hydrocarbons, in comparison with the total annual CO_2 emissions generated offshore from the UKCS in 2016; recorded at 13.1 million tonnes (this in turn is around 3 % of the total CO_2 emissions produced from all sectors in the UK in 2016, estimated at 378.9 million tonnes; BEIS, 2018b). It can be seen from this that the predicted emissions associated with the drilling, installation and commissioning activities of the Columbus Development would represent a very small percentage of the total annual CO_2 emissions on the UKCS. It should also be noted, that the drilling and installation and commissioning activities are temporary events.

Table 8.1: Estimated Worst-Case CO_2 Emissions from the Columbus Drilling, Installation and Commissioning Activities

Aspect	CO_2 Emissions Emitted from the Columbus Development (tonnes) [1]	Percentage of Offshore UKCS Annual Total CO_2 [2]	Percentage of UK Annual Total CO_2 [3]
Diesel use by MODU and Support vessels [4]	11,912	0.09 %	0.0031 %
CDev-1 well flaring [4]	5,600	0.04 %	0.0015 %
Diesel use by vessels during installation and commissioning [5]	2,070	0.02 %	0.0006 %
Totals	**19,582**	**0.15%**	**0.005 %**

[1] Emission factors from DECC (*2008*).
[2] Annual Total Offshore UKCS CO_2 emissions were recorded at 13,1 million tonnes in 2016 (*OGUK, 2017*).
[3] Annual Total UK CO_2 emissions were 378.9 million tonnes in 2016 (*BEIS, 2018b*).
[4] See Table 2.9 (Section 2.7.6) – Based on 3,454 tonnes of diesel used and 2,000 tonnes of gas flared during well testing and clean-up.
[5] See Table 2.15 (Section 2.8.7) – Based on 647 tonnes of diesel used

It can be seen from Table 8.1 that the proposed drilling activities will have the highest CO_2 emissions of any project phase of the Columbus Development. However, all activities from the Columbus Development represent a very small contribution to both the offshore UKCS annual total (0.15 %) and the UK annual total (0.005 %). Therefore, given the small volumes of CO_2 emitted and the fact that these operations are not ongoing, it is concluded that atmospheric emissions generated from the Columbus Development activities will not have a significant impact to CO_2 levels, with any impacts being highly localised.

Global Warming Potential of Atmospheric Emissions

Global Warming Potential (GWP) represents how much a given mass of a chemical contributes to climate change over a given time period compared to the same mass of CO_2. The GWP of CO_2 is defined as 1.0 (US EPA, 2016). For example, the 100-year GWP of CH_4 is 25 (IPCC, 2007), which means that if the same mass of methane and CO_2 were introduced into the atmosphere, methane will trap 25 times more heat than CO_2 over the next 100 years.

Using the GWP factors from the International Panel on Climate Change (IPCC) Fourth Assessment Report, Table 8.2 calculates the equivalent mass of CO_2 required to achieve the same GWP as the total predicted emissions of N_2O and CH_4 generated from power generation during drilling, installation and commissioning at the Columbus Development. This shows that the worst-case predicted annual emissions of CO_2, N_2O and CH_4 from power generation have a combined GWP equivalent to 22,187 tonnes of CO_2. Which is equal to 0.005 % of the total tonnes of CO_2 equivalent greenhouse gas emissions emitted in the UK from all sectors during 2016 (467.9 million tonnes; *BEIS, 2018b*).

It should be borne in mind that the emissions estimated are worst-case values for the purpose of planning and actual annual emissions are likely to be lower, given that the values in Table 8.2 account for the maximum diesel fuel usage.

Table 8.2: The Global Warming Potential (GWP) for the Atmospheric Emissions Associated with the Drilling, Installation and Commissioning of the Columbus Development

Gas	Total Predicted Emissions (tonnes)	GWP[1] Factor	Equivalent Mass of CO_2 to Achieve the Same GWP (tonnes)
Drilling, Installation and Commissioning (total emissions)			
CO_2	19,582	1	19,582
N_2O	1.12	298	345
CH_4	90.8	25	2,270
		Total	**22,187**

[1] Emissions are converted into CO_2-equivalents based on 100-year GWP (GWP_{100}), in the IPCC Fourth Assessment Report (*IPCC, 2007*). Please note GWPs are only available for CO_2, N_2O and CH_4

Local Air Quality

The emissions generated by the combustion of hydrocarbons for power generation during the Columbus Development could potentially have a negative impact on local air quality.

Atmospheric pollutants such as NOx, VOCs and particulates can contribute to the formation of low level ozone and photochemical smog. However, the open and dynamic metocean environment in the central North Sea should help disperse emissions quickly and prevent accumulations which could result in a reduction of local air quality.

A simple dispersion model has been used to predict the atmospheric concentration of NOx and VOCs with increasing distance from the Columbus Development, for the predicted worst-case daily fuel consumption rates during both the drilling and installation and commissioning phases of the Columbus Development (Table 8.3). The model assumes spherical spreading of atmospheric gases, under calm atmospheric conditions (refer to Appendix F).

Table 8.3: Predicted Atmospheric Concentrations of NOx and VOCs Emitted (in micrograms per cubic metre) Spreading Out from Columbus Development during Worst-Case Daily Activities

Project Phase	1 km	2 km	5 km	10 km	20 km	50 km
Drilling Activities [2]						
NOx [1]	0.066	0.047	0.016	0.006	0.002	0.001
VOCs [1]	0.002	0.002	0.001	0.000	0.000	0.000
Installation and Commissioning Activities [3]						
NOx [1]	0.063	0.045	0.015	0.006	0.002	0.001
VOCs [1]	0.002	0.002	0.001	0.000	0.000	0.000

[1] Emission factors used from EEMS Atmospheric Emissions Calculations (*DECC, 2008*).
[2] Worst-case daily emissions, refer to Section 2.7.7.
[3] Worst-case daily emissions refer to Section 2.8.7.

It should be noted, that the worst case daily emissions are unlikely to be released instantaneously and therefore the actual concentration of NOx and VOCs at source at any point in time is likely to be lower than that modelled.

It can be seen from Table 8.3 that even at 1 km from the emission source, the NOx concentrations are already significantly below the 30 micrograms per cubic metre UK limit for protection of vegetation and ecosystems (DEFRA, 2018). Although no UK limits on VOC concentrations as a group are available, the UK limit (human health) for benzene is 5 micrograms per cubic metre (DEFRA, 2018). As seen in Table 8.3, the concentration of VOC is well below this value at 1 km from source.

Although these emissions will cause a short-term deterioration of local air-quality within a few metres of the point of the discharge, the exposed and high wind energy environment of the central North Sea will promote the rapid dispersion of these emissions. In addition, there is a general lack of sensitive environmental receptors in the area and the nearest coastline to the Development is 230 km away.

In conclusion, no significant impacts are expected to air quality from the combustion of hydrocarbons during the drilling, installation and commissioning phases of the Columbus Development. It is unlikely that concentrations of the emitted gases will contribute to either acidification or ground level ozone formation.

However, the atmospheric emissions from the drilling, installation and commissioning activities of the Columbus Development will contribute to the global emissions of greenhouse gases, namely CO_2, N_2O and CH_4. Conversely, as discussed in the text above, this will form a very small percentage of the UK total (0.0005 %) of emitted greenhouse gas from all sectors. Therefore, given the above and the mitigation measures proposed (Section 8.5) atmospheric emissions the combustion of hydrocarbons for power generation from the Columbus Development, will not pose a significant impact to climate change.

Given the above, the risk posed by atmospheric emissions from flaring of the CDev-1 well during well clean-up and testing and from power generation for MODU, support and installation vessels during drilling, installation and commissioning is considered to be **medium** (the likelihood is regular and the consequence is minor).

8.4.2 Atmospheric Emissions Generated at Shearwater During Production and Maintenance Activities

Atmospheric emissions during the Columbus production phase will arise at the Shearwater platform from the power generation required for the Columbus field production, which will be a proportion of the total power generation at Shearwater, and from the flaring of the Columbus gas, which will be a proportion of the gas flared at Shearwater during unplanned shut down and start-up.

Based on the production profile and the information in Section 2.9.2, Table 2.18, the maximum yearly estimate of CO_2 will be 140,849 tonnes in year 13 of production (i.e. 2033). The total estimate of CO_2 produced from the combustion of fuel gas and the flaring of gas over 16 years is 1,320,450 tonnes.

Global Warming Potential of Atmospheric Emissions

Table 8.4 below calculates the equivalent mass of CO_2 required to achieve the same GWP as the total predicted emissions of N_2O and CH_4 generated from power generation at Shearwater relating to the processing of the Columbus fluids. This shows that the worst-case predicted annual emissions of CO_2, N_2O and CH_4 from power generation and flaring have a combined GWP equivalent of 1,447,824 tonnes of CO_2 over 16 years. This is equal to 0.31 % of the total tonnes of CO_2 equivalent greenhouse gas emissions emitted in the UK from all sectors during 2016 (467.9 million tonnes; *BEIS, 2018b*).

Table 8.4: Global Warming Potential (GWP) for the Atmospheric Emissions Associated with the Production of the Columbus Development over 16 years

Gas	Total Predicted Emissions (tonnes)	GWP[1] Factor	Equivalent Mass of CO_2 to Achieve the Same GWP (tonnes)
Total emissions over 16 years			
CO_2	1,320,450[2]	1	1,320,450
N_2O	37.6[2]	298	11,205
CH_4	4,641.86[2]	25	116,047
		Total	**1,447,702**

[1] Emissions are converted into CO_2-equivalents based on 100-year GWP (GWP_{100}), in the IPCC Fourth Assessment Report (*IPCC, 2007*). Please note GWPs are only available for CO_2, N_2O and CH_4.
[2] Based on P10 forecast.

It should be borne in mind that the emissions estimated are worst-case values for the purpose of planning and will be emitted over 16 years based on the P10 production profile. The actual annual emissions are likely to be lower, given that the values in Table 8.4 account for maximum production levels.

Table 8.5 below considers operational year 13 only, which represents the maximum yearly atmospheric emission production. This shows that the worst-case predicted annual emissions of CO_2, N_2O and CH_4 from power generation and flaring associated with the Columbus field have a combined GWP equivalent to 154,423 tonnes of CO_2 during year 13 (2033). This is equal to 0.03 % of the total tonnes of CO_2 equivalent greenhouse gas emissions emitted in the UK from all sectors during 2016 (467.9 million tonnes; *BEIS, 2018b*).

Table 8.5: Global Warming Potential (GWP) for the Atmospheric Emissions Associated with the Production of the Columbus Development in year 13 i.e. 2021

Gas	Total Predicted Emissions (tonnes)	GWP[1] Factor	Equivalent Mass of CO_2 to Achieve the Same GWP (tonnes)
Total emissions in Year 13			
CO_2	140,849[2]	1	140,849
N_2O	4.01[2]	298	1,195
CH_4	495.14[2]	25	12,379
		Total	**154,423**

[1] Emissions are converted into CO_2-equivalents based on 100-year GWP (GWP_{100}), in the IPCC Fourth Assessment Report (*IPCC, 2007*). Please note GWPs are only available for CO_2, N_2O and CH_4.
[2] Based on P10 forecast.

Given the above, although it recognised that the Columbus Development will emit greenhouse gas emissions over the life of the field, it is considered that the development's contribution to global warming will be negligible in relation to those from the wider offshore industry and outputs at a national or international level.

To compare this with the total atmospheric emissions generated at the Shearwater platform, the combined GWP equivalent of Columbus during year 13 of production would equal approximately 42% of the CO_2 equivalent emissions generated from the Shearwater platform in 2016 (369,000 tonnes; *Shell, 2017*).

Table 8.6 represents the forecasted yearly GWP for the atmospheric emissions associated with the production of all fields at the Shearwater platform, including Shearwater, Fran, Arran and Columbus. This shows that, even though the GWP associated with Columbus increases significantly from 2029, as detailed in Section 2.9.2, the total GWP from Shearwater progressively decreases as Fram, Shearwater and Arran production diminishes or stops. Forecasted GWP for the Shearwater platform in Year 16 (151,848 tonnes of CO_{2e}) is less than half of the forecasted GWP for the Shearwater platform in Year one (305,139 Tonnes of CO_{2e}).

Table 8.6: Yearly Forecasted Global Warming Potential (GWP) for the Atmospheric Emissions Associated with the Production of all Fields Tied to the Shearwater Platform

Year	Yearly GWP for the Atmospheric Emissions Associated with the Production of the Fields Tied to the Shearwater Platform (Tonnes of CO_{2e})				
	Columbus[1]	Arran[1]	Shearwater	Fram	Total
2021	26,950	78,842	172,632	26,716	**305,139**
2022	39,524	89,468	178,911	33,121	**341,024**
2023	43,145	81,713	139,723	31,743	**296,324**
2024	54,450	79,385	78,692	38,828	**251,355**
2025	62,232	72,301	51,355	43,387	**229,275**
2026	43,630	61,674	81,308	40,116	**226,727**
2027	44,812	54,633	95,928	21,612	**216,983**
2028	54,785	51,692	97,433	0	**203,910**
2029	112,281	75,957	0	0	**188,238**
2030	110,873	80,871	0	0	**191,744**
2031	93,432	108,641	0	0	**202,073**
2032	149,417	16,285	0	0	**165,701**
2033	154,423	0	0	0	**154,423**
2034	153,551	0	0	0	**153,551**
2035	152,349	0	0	0	**152,349**
2036	151,848	0	0	0	**151,848**

[1] Based on P10 forecast.

Local Air Quality

The emissions generated by the combustion of fuel gas for power generation during the operation of the Columbus field could also potentially have a negative impact on local air quality. Atmospheric pollutants such as NOx, VOCs and particulates can contribute to the formation of low level ozone and photochemical smog.

The existing combustion equipment on Shearwater includes gas turbines for main power generation and compressor drive and diesel engines for air compression, emergency power and for driving fire pumps (refer to Section 2.9.2). There will be an incremental power demand from bringing the Columbus production online against the current requirement at Shearwater. However, given that the production and power demand from the other fields connected to the Shearwater platform is reducing over the year, it is anticipated that there will be significantly more power capacity available onboard the Shearwater platform when Columbus comes online than there is at present. No new power generation facilities will be required and the quantity of atmospheric emissions from power generation equipment should be less, or in the worst case equal, to the quantity of atmospheric emissions generated at Shearwater at present. Therefore, although these emissions will cause a short-term deterioration of local air-quality within a few metres of the point of the discharge, the exposed and high wind energy environment of the central North Sea will promote the rapid dispersion of these emissions. In addition, there is a general lack of sensitive environmental receptors in the area and the nearest coastline is located 230 km away.

In conclusion, no significant impacts to air quality are expected from the combustion of fuel gas for power generation or flaring during production of the Columbus field. It is unlikely that concentrations of the emitted gases will contribute to either acidification or ground level ozone formation.

The risk posed by atmospheric emissions from the combustion of fuel gas for power generation or flaring at the Shearwater platform associated with the Columbus field is therefore considered to be **medium** (the likelihood is continuous for power generation and regular for flaring and the consequence is minor).

8.5 Mitigation Measures

8.5.1 Standard Operating Measures

The assessment of impacts detailed above has assumed that the following standard operation measures will be implemented during the life of the proposed Columbus Development:

- Use of fuel oil with a sulphur content of no more than 0.1% in accordance with MARPOL and UK regulatory requirements;
- Vessels and contractors will have UK/International Air Pollution Prevention (UKAPP/IAPP) Certificates;
- All combustion equipment will have a maintenance programme and will be tested regularly;
- Power required for the Columbus subsea facilities will be covered by the existing power generation capacities on the Shearwater platform;
- The Columbus Development will utilise the existing flaring facilities on the Shearwater platform during production.

8.5.2 Additional Mitigation Measures

In order to remove, reduce or manage the potentially significant impacts identified in Section 8.2 above, Serica proposes to implement the following additional mitigation measures during the various lifecycle stages of the project:

- As part of the contractor selection processes, MODU and vessel contractors will be required to demonstrate that they have control processes in place to minimise environmental impacts (i.e. maintain equipment) through review of International Marine Contractors Association (IMCA) / Offshore Vessel Inspection Database (OVID) inspections;
- During well testing and clean-up, high combustion efficiency burners will be used and the volume flared will be kept to a practical minimum;
- Operating procedures will be in place in order to reduce flaring at Shearwater during maintenance operations, process upset conditions, system depressurisation and start-up.

8.6 Residual Impacts

Emissions associated with the Columbus Development are expected to represent only a small proportion of emissions typically arising from oil and gas production on the UKCS.

The risk to air quality from planned atmospheric emissions from the Columbus Development are considered to remain **medium**, but the risks have been minimised as much as possible and are therefore not considered to be significant.

In conclusion, given the proposed mitigation measures detailed in Section 8.5, there are unlikely to be any significant adverse residual impacts to air quality as a result of the Columbus Development. The emissions generated will also only make a very small contribution to global warming gas emissions and potential acidification.

8.7 Transboundary Impacts

The UK/Norway median line is located approximately 8 km to the north east of the proposed Columbus Development. Atmospheric dispersion modelling has predicted that there will be no significant impacts on air quality in Norwegian waters as the result of the Columbus Development operations.

8.8 Cumulative Impacts

The Columbus Development also lies within an area of fairly high producing oil and gas activity (refer to Section 3.8.4), with the closest producing surface infrastructure being the Mungo Platform, approximately 6 km northwest of the proposed Columbus Development. Therefore, during drilling, installation and commissioning activities there could be potential for cumulative impacts from atmospheric emissions over this period. However, as the activities are temporary in nature, these will not have a lasting effect on air quality or long term greenhouse gas emissions. Any cumulative impacts are therefore not considered to be significant.

9 Marine Discharges

9.1 Introduction

Serica is committed to minimising discharges into the marine environment from its operations, as far as possible. This section assesses the potentially significant impacts that may arise from planned operational discharges associated with the proposed Columbus Development and the measures that will be employed to ensure discharges are minimised, as far as practicable.

Planned operational discharges to sea will occur during the drilling, installation, commissioning and production phases of the Columbus Development. If not managed correctly, these discharges could result in wide ranging environmental impacts on the water column, including a decline in water quality, changes in water chemistry (such as pH and temperature), toxicity effects from chemical components and hydrocarbons, a decrease in local oxygen levels due to the presence of increased organic nutrients and subsequent bacterial or algal growth that leads to the depletion of nutrients. These changes can have direct effects on marine flora and fauna, or indirect effects such as habitat degradation or avoidance and tainting or loss or redistribution of prey.

9.2 Aspects with Potentially Significant Impacts

As shown in the Environmental Aspects Registers in Appendix C, marine discharges of the following aspects associated with the Columbus Development have been identified as having potentially significant impacts on water quality, sediments, seabed communities, plankton, fish and seabirds:

- Discharge of WBM drill cuttings, muds and cement during the drilling phase;
- The incremental increase in produced water discharges at the Shearwater platform during the operational phase.

The discharge of WBM drill cuttings, muds and cement has been assessed in detail in Section 6 and will not be discussed further in this section. In addition, the marine discharges associated with the installation and commissioning of the Arran – Shearwater pipeline have been assessed in the Arran ES. The deviation of the Arran – Shearwater pipeline to accommodate the Columbus Development will not impact of the conclusions of the Arran ES which were that the residual impact of discharges to sea by the Arran Development during installation and commissioning will be negligible and therefore not significant. As such, only the impacts from the discharge of produced water are assessed below.

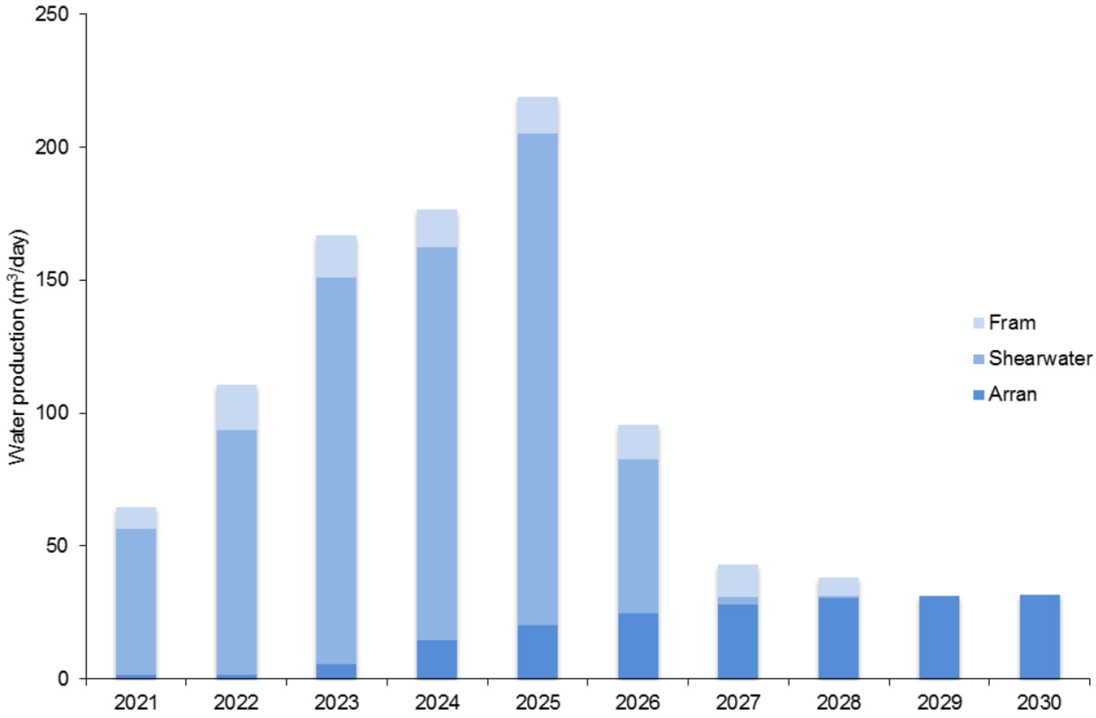
9.3 Assessment of Impacts

9.3.1 Discharge of Produced Water

For the Columbus Development, it is planned that all produced water will be treated and discharged at the Shearwater platform via existing facilities. It would not be economically viable to drill a water injection well specifically for Columbus. In addition, the Shearwater facilities operate within existing consent limits and have sufficient capacity to cope with the additional produced water from the Columbus Development as noted below. As such, this is considered to be the Best Available Technology (BAT).

A new produced water treatment package was installed and commissioned on Shearwater in 2016. This has a total maximum capacity of 699.6 m^3 per day (4,400 barrels per day). It should be noted that in addition to Dana planning to bring the Arran field online and route production through Shearwater, Shell intend to bring the Fram field online and also route production through Shearwater. As such, Shearwater could process production from four fields; Shearwater, Arran, Fram and Columbus. The combined daily rates of produced water estimated from Shearwater, Fram and Arran are expected to stay below 250 m^3 per day, peaking in 2025 (Figure 9.1). With the additional produced water from Columbus, estimated to be an average of 43.6 m^3 per day (refer to Section 2.9.4), the total produced water from all four developments will be well within the maximum capacity of the Shearwater produced water treatment package.

Figure 9.1. Predicted Daily Produced Water Rates from Shearwater, Arran and Fram (Dana, 2018)



Details of the produced water system are given in Section 2.9.4. It is estimated that up to an additional 0.48 tonnes of hydrocarbons could be discharged to sea each year at the Shearwater platform, once the Columbus field comes online. This is a worst-case estimate, based on both the maximum monthly average discharge limit of 30 mg/l and the peak produced water production (P10 case). However, produced water is expected to reduce after the first eight years of the field's life.

Table 9.1 shows the worst-case maximum annually quantity of produced water and oil that could be produced by the Columbus development, and subsequently discharged from Shearwater, compared to the total annual oil discharge for the UKCS.

Table 9.1. Estimated Worst-Case Annual Produced Water and Oil Discharged from the Columbus Development Compared to the Total Annual UKCS Produced Water and Oil discharges for 2016

Scenario	Total Annual Produced Water Discharged (m^3)	Total Annual Weight of oil discharged (tonnes)
Columbus Development Worst-case Produced Water	15,899	0.48 N1
Total Produced Water Discharged for the UKCS in 2016 (OGUK, 2017)	155,000,000	2,000
Columbus Development Discharge as a % of UKCS Total	**0.01%**	**0.02%**

Notes

N1 Based on an average annual oil in water concentration of 30 mg/l.

Discharges from the Columbus Development would not represent a significant increase in produced water or oil in water discharges in the UKCS, representing only 0.01% of the UKCS total for produced water and less than 0.02% for oil.

The composition and characteristics of naturally-occurring chemical substances in produced water are closely coupled to the geological characteristics of each reservoir. The composition of produced water is complex and can comprise several thousand compounds that vary in concentration between wells and over the lifetime of a well. Dispersed oil, aromatic hydrocarbons and alkylphenols (APs) and heavy metals are of particular environmental concern (Neff *et al.,* 2011).

Polycyclic Aromatic Hydrocarbons (PAHs) can have mutagenic, carcinogenic and teratogenic properties, but at the concentrations found in the receiving environment, many marine organisms including fish and invertebrates have the ability to metabolise and detoxify PAHs (Stein, undated; Tuvikene, 1995; Rust *et al.,* 2004). In the laboratory, high molecular weight APs can be shown to exhibit endocrine disruption potential, however these experiments were conducted using much higher concentrations than would be present in pre-treated produced water discharge. This explains the difficulty to establish a clear connection between the exposure of produced water and biological effects (OGP, 2005). The lower molecular weight PAHs are less toxic to aquatic organisms than higher molecular weight PAHs. This is in part linked to the ability of compounds to accumulate in tissue. Accumulation of PAHs increases with increasing molecular weight however, as the size of the molecules increases, they become less able to pass through cell membranes. In addition to this, as PAHs have high volatility and degradability, it means that they pose little threat to marine organisms.

Upon discharge to sea, the produced water will also be rapidly diluted. Both field measurements and dispersion modelling studies of the fate of produced water differ in specific details, but all predict a rapid initial dilution of discharges by a 30- to 100-fold factor within tens of metres of the discharge point (Neff, 2002). Moreover, given the water depths (around 91 m) and wind speeds encountered at the Shearwater platform, high rates of dilution and mixing are expected.

The persistence of the produced water in the marine environment is also a factor in assessing the impacts. Biodegradation is the major decomposition pathway for organic compounds in the aquatic environment and it occurs both in the water column and in sediments. Biodegradation experiments performed with produced water from the North Sea indicated that many of the medium molecular weight aromatic hydrocarbons and phenols (that are typical components of produced water) are biodegraded by indigenous micro-organisms in seawater (Neff, 2002), although, some higher molecular weight organic compounds, including heterocyclic compounds may be less readily biodegradable and remain in the plume for a longer time (Neff, 2002). However, given that the Columbus reservoir is a gas condensate reservoir, it is not expected that any oil would persist for long periods.

Experiments conducted in Norway in mature oilfields showed that the concentrations of hydrocarbons and APs that are likely give rise to biological effects only occurred within 500 m of the major discharge source (OGP, 2005). Therefore, any biological impacts from produced water discharges at the Shearwater platform are likely to be contained within 500 m of the discharge.

APs found in produced water can affect a number of reproductive parameters in fish (Bakke *et al.,* 2013). However, a risk assessment by Beyer *et al*. (2011) concluded that the environmental exposure of fish to APs from produced water is most probably too low to induce endocrine disruption to an extent that causes significant effects on the reproduction of fish stocks. This assessment takes into account that produced water discharges offshore are rapidly diluted, which reduces the risk of population effects, and is supported by results from the monitoring of caged fish exposed to produced water offshore (Brooks *et al.*, 2009).

Phytoplankton and zooplankton populations and most fish species have a much wider distribution than the documented produced water impact zones (Bakke *et al.,* 2013). Hence, for a significant impact to occur either harmful exposure to produced water has to be sufficiently wide scale or the population influence from locally affected individuals has to be large enough. None of these are likely as the communities of these taxa are widely distributed in the North Sea. It is also inherently difficult to make reliable extrapolation to the population level since effects on individuals may be masked by other factors acting on populations (e.g. distribution patterns, seasonality and species interaction) (Bakke *et al.,* 2013). In support of this, studies from both Neff *et al*. (2006) and Durell *et al*. (2006) came to the same conclusion regarding the risk from PAHs in produced water to the wider pelagic ecosystem in the North Sea. The impact of produced water discharge on plankton has not been widely studied and therefore conclusions from this cannot be supported. However, given the rapid turnover times, growth and proliferation of phytoplankton and zooplankton, the effects from produced water are not expected to be significant.

Oil sheens on the sea surface have the potential to impact seabirds. As noted above, a new produced water treatment package was installed and commissioned on Shearwater in 2016. This package operates within the approved limit of a maximum monthly average of oil (dispersed) in water content of 30 mg/l or less and therefore the discharge of produced water is unlikely to result in a visible oil sheen on the sea surface. In addition, seabird sensitivity to surface oiling within the vicinity of the Shearwater platform (UKCS Block 22/30) is low throughout the year (refer to Section 3.6.4), therefore any potential impacts to seabirds are not expected to be significant.

Given the above, the risk from produced water to water quality, plankton, fish and seabirds is considered to be **medium** (the likelihood is continuous and the consequence is minor).

9.4 Mitigation Measures

The assessment of impacts detailed above has assumed that the following standard operation measures will be implemented during the life of the proposed Columbus Development:

- The Columbus Development will utilise the existing produced water treatment system on the Shearwater platform;
- Any discharge of produced water will be treated to meet oil-in-water limits of less than 30 mg/l;
- Discharge stream will be monitored and sampled in accordance with the approved Shearwater OPPC permit.

9.5 Residual Impacts

Discharges of produced water can contain potentially harmful concentrations of oil and other chemicals, however a number of studies have shown that any potential impacts will be limited to the local area in the immediate vicinity of the source. In addition to this, the produced water concentrations and discharge rates stated above are a worst-case estimate, based on the peak produced water production from the Columbus field.

The residual risks to water quality, plankton, fish and seabirds from the incremental increase in produced water discharges at the Shearwater platform as a result of the Columbus development are considered to remain **medium**, but are not deemed to be significant.

9.6 Transboundary Impacts

Given the distance to the nearest transboundary line; the UK/Norwegian median line around 26 km to the east of the Shearwater Platform (where the produced is discharged), it is very unlikely that the incremental increase in produced water discharges at the Shearwater platform would lead to transboundary impacts, as it is anticipated that discharges will be diluted rapidly within close proximity (i.e. within 500 m) to their release location.

9.7 Cumulative Impacts

The closest producing surface infrastructure to the Shearwater platform is Erskine, located approximately 7.13 km to the east northeast. Given this distance and the fact that any produced water discharged is likely to be rapidly diluted within close proximity to the release location, no cumulative impacts are expected.

10 Accidental Releases

10.1 Introduction

This section identifies the potential risk of a major hydrocarbon spill occurring from the Columbus Development, the potentially significant environmental and socio-economic effects that could occur in the event of a spill and details the control and mitigation measures Serica proposes to implement to both reduce the risk and limit the potential impacts.

All offshore activities associated with the Columbus Development will carry a potential risk of hydrocarbon pollution to sea. However, hydrocarbon spills from normal oil and gas operations are uncommon and can be effectively mitigated against.

In planning its activities, a primary focus of Serica is to ensure that all practicable measures are taken to prevent the occurrence of accidental events and, should they occur, mitigate their effects. The risk of an accidental release occurring from the Columbus Development will be minimised through the implementation of physical barriers such as downhole safety valves, maintenance to minimise leaks, and the development and implementation of handling and operational procedures and training. Measures to respond to a spill from the MODU or the Columbus subsea facilities once operational will be covered in approved oil pollution and emergency plans, which will be prepared in advance of drilling operations commencing offshore.

10.2 Aspects with Potentially Significant Impacts

As shown in the Environmental Aspects Registers in Appendix C, accidental releases of the following aspects associated with the Columbus Development have been identified as having potentially significant impacts on the marine environment:

- Loss of containment from the MODU due to a collision or other major event;
- Well blowout during drilling, installation and commissioning and production operations (releasing large quantities of hydrocarbons);
- Loss of integrity from the Columbus tie-in spool during production operations.

The likelihood of these scenarios occurring and their fate and effects in the marine environment are discussed in the proceeding sections. Note the loss of inventory from the proposed Arran to Shearwater pipeline has been assessed in Dana's Arran Project ES (Dana, 2018).

10.3 Likelihood of Accidental Hydrocarbon Releases

10.3.1 Loss of containment from the MODU

Potential spills from a MODU may be caused by mechanical failure, operational failure or human error. Data from the Health and Safety Executive (HSE, 2007) on accident statistics for floating offshore units engaged in the oil and gas activities on the UKCS, estimates that there were 228 spill events on MODUs between 1990 and 2005, giving an occurrence frequency of 0.232 per unit per year.

An accidental release from a MODU may arise from a collision with another vessel. The Ship/Platform Collision Incident Database (2001), contains details of 557 collision incidents recorded between 1975 and 2001. Of these, 549 (98.6%) were assessed as being collisions between an installation (fixed or floating) and an 'attendant vessel' and the remainder with a 'passing vessel' (HSE, 2006). Table 10.1 presents a summary of the mean incident frequencies of all reported incidents and those where the installation required repair (moderate or severe damage category incidents, which could result in an oil spill) by all vessel types ('attendant' and 'passing' vessels) (HSE, 2003).

Table 10.1. Mean Incident Frequencies of All Reported Incidents and Moderate or Severe Damage Category Incidents (All Vessel Types) (HSE, 2003)

Installation / Rig Type	All reported incidents / year	Incidents resulting in moderate or severe damage / year
All Installations	0.0987	0.0152
Fixed Installations	0.0630	0.0095
Semi-submersibles	0.2379	0.0487
Jack-ups	0.1413	0.0054

The likelihood of a worst-case accidental release from the MODU as a result of a vessel collision whilst it is on location at Columbus is therefore considered to be **remote**.

10.3.2 Well Blowout

A blowout is an uncontrolled flow of oil or natural gas (or a mixture of the two), which comes about following a failure in the pressure control systems. Data indicates that blowouts most frequently occur when drilling into a shallow gas pocket or whilst drilling a deep gas well. If the flow does not stem itself or by the pumping of cement to 'kill' the well, it may require intervention (e.g. the deployment of a capping device or relief well drilling) to bring it back under control.

Data available on blowout frequencies globally is poor and cannot be reliably compared or assessed. Data for the North Sea (UK, Dutch and Norwegian sectors) indicates that oil wells that undergo completion operations have a blowout frequency of 8.4 x 10^{-5} (i.e. one blowout in every 11,905 well completion operations) (Scandpower, 2011 cited in Petroleumstilsynet, 2012).

The likelihood of a well blowout occurring during the Columbus Development operations is therefore considered to be **remote**.

10.3.3 Subsea Infrastructure

Accidental releases of hydrocarbons or chemicals from subsea infrastructure are most likely to occur as a result of structural failures of equipment (i.e. corrosion). Releases due to impact damage are considered rare.

Historic data for the period between 2001 and 2012, records a total of 183 loss of containment events from pipelines and umbilicals on the UKCS (PARLOC, 2012). The average loss of containment frequency (i.e. how many spills per km of pipeline) and rupture frequencies for pipelines during this period is detailed in Table 10.2.

Table 10.2. Estimated Pipeline Loss of Containment and Rupture Frequencies (2001 -2012) (PARLOC, 2012)

Pipeline Type	Average Loss of Containment Frequency (per km-year)	Rupture[N1] Frequency (per km-year)
Flexible Flowline (all diameters and length)	5.47 x 10^{-3}	9.8 x 10^{-4}
Flexible Risers (all diameters)	5.89 x 10^{-3}	(no data)
Steel pipelines (all diameters and length)	4.23 x 10^{-04}	4.0 x 10^{-05}
Steel Risers (all diameters)	1.64 x 10^{-03}	(no data)
Control Umbilicals (all lengths)	1.0 x 10^{-3}	(no data)

Notes

[N1] Line ruptures are generally assumed to have a hole diameter equal to the pipeline's nominal diameter (PARLOC, 2012).

Worst-case release scenarios would involve the loss of containment of the entire inventory of the pipeline; however these types of events are rare. Data from the Worldwide Offshore Accident Database (WOAD) for the period from 1970 to 2007 indicates that worldwide there have only been two major accidents resulting in the total loss of inventory from a pipeline (OGP, 2010).

The likelihood of a loss of inventory from the Columbus tie-in spool during production operations is therefore considered to be **remote**.

10.4 Fate of Hydrocarbons in the Marine Environment

In order to gain an understanding of the behaviour of a hydrocarbon release from the Columbus Development, oil spill modelling using the RPS ASA OILMAP modelling package (Version 7.1.5.0) has been undertaken.

The following 'worst-case' release scenario has been modelled:

- **Scenario 1: blowout at the Columbus CDev-1 well with a cumulative release of 95,400 m^3 of 47.6° API condensate after 60 days with a release rate 1,590 m^3/day.**

This represents the worst-case blowout scenario for the Columbus Development in terms of both the volume of condensate which would be released and the duration of the spill (i.e. it assumes a relief well would need to be drilled to bring the well back under control). This scenario was modelled as a subsurface release for 60 days. The total model simulation time was 70 days; a further 10 days after the time required to complete the relief well.

The loss of condensate from the Columbus tie-in spool during production operations (maximum inventory estimated to be 0.7 m^3, based on a tie-in pipeline diameter of 6" and a length of 36 metres) and the loss of diesel from a vessel/MODU (maximum inventory estimated to be 2,820 m^3, based on typical semi-submersible drilling rig) attending the Columbus Development location during any phase of operations have not been modelled for the purposes of the EIA, as the condensate released from the blowout scenario is considered worst-case (95,400 m^3).

The type of modelling undertaken was stochastic (i.e. the model was run using actual wind and current data collected over a period of time to establish a statistical picture of the probability of surface oiling and shoreline beaching) and, in order to take into account seasonal changes, all four seasons were modelled: winter (December to February), spring (March to May), summer (June to August) and autumn (September to November).

A summary of the spill modelling results is provided in Table 10.3, although it is important to note that this assumes no response is mobilised. Full details of the model input parameters and the output, including figures showing plots of minimal arrival times, probability of surface oiling and potential beaching locations, are provided in Appendix G.

Table 10.3. Summary of Columbus Development Worst-Case Spill Modelling Results

Scenario	Hydrocarbon	Volume Released	Summary of Fate of Spill (refer to Appendix G for further details)
1: Well Blowout	Columbus Condensate (47.6° API)	95,400 m^3	• There is a very low probability that the spill could beach on the east coast of the Shetland Islands (up to 6%), Aberdeenshire (up to 5%) and the Highlands region (up to 1%), with the shortest arrival time to shore being 596 hours (over 24 days). The greatest volume beached is 227.1 m^3 in winter; • There is 100% probability that the spill could cross the UK/Norway median line at the surface during all seasons, with shortest arrival time after 6 hours in autumn; • There is a very low probability (up to 8%) of the spill crossing the Norway/Denmark median line at the surface during winter, spring and autumn, with the shortest arrival time to shore being 129 hours (over 5 days); • There is a low probability (up to 17%) that shoreline oiling could occur on international coastlines (Norway, Denmark and Germany) with Norway most at risk; • There is the potential for a number of marine and coastal protected areas to be subject to surface and/or coastal oiling; • Fates analysis of the worst-case trajectory run (regarding amount of shoreline oiling) revealed that after 70 days very little condensate (8.46%) remained on the sea surface with the majority (84%) having evaporated, with only a small amount (0.2%) on shorelines. The remainder was either decayed (10.5%) or entrained (5.2%) in the water column.

10.5 Environmental and Socio-Economic Effects of a Spill

The effects of an oil spill will depend on a variety of factors including the quantity and type of oil spilled, and how it interacts with the marine environment, but can include (ITOPF, 2014):

- **Physical smothering of organisms**: this is caused by oils with a high viscosity (i.e. heavy oils). Smothering will affect an organism's physical ability to continue critical functions such as respiration, feeding and thermoregulation;
- **Chemical toxicity**: this is characteristic of lighter chemical components which are more bioavailable (i.e. absorbed into organs, tissues and cells), and can have sub-lethal or lethal toxic effects;
- **Ecological changes**: this is caused by the loss of key organisms with a specific function in an ecological community. They can be replaced by different species undertaking similar functions in which case the implications for the ecosystem as a whole may not be severe. However, more detrimental is the niche in the community being replaced with organisms performing completely different functions thereby altering the ecosystem dynamics; and
- **Indirect effects**: loss of shelter or habitat through oiling or clean-up operations.

In addition, economic losses can be experienced by industries and individuals dependent on offshore or coastal resources. Usually, the tourism and commercial fisheries sectors are where the greatest impacts are felt. Other industries that can be affected include industry that relies on seawater for normal operations, mariculture, shipyards, ports and harbours (ITOPF, 2014).

It should be noted that many species are exposed to fluctuating environmental conditions (including pollution resulting from an oil spill) and therefore have a degree of intrinsic tolerance to environmental stressors, including pollution. However, acute events, (such as oils spills) can reduce the resilience of individuals and communities.

Given the open water and dynamic hydrographic regime within the proposed Columbus Development area, it is anticipated that hydrocarbons will disperse rapidly and will be naturally degraded. This has been demonstrated by the oil spill modelling, summarised in Section 10.4 and presented in Appendix G. Effects of oiling may be more acute in coastal and shallow waters as the amount of oil is dispersed within a smaller area. However, in exposed high-energy coastal environments, the dilution capacity, e.g. due to tidal flushing, may be sufficient to keep oil concentrations below harmful levels.

A summary of the potentially significant impacts to environmental and socio-economic receptors in the vicinity of the Columbus Development is provided in the proceeding sections.

10.5.1 Effects on Plankton

Plankton play a key role in marine and aquatic food webs. Changes in the plankton community can have knock-on effects on fauna feeding at higher trophic levels, such as fish, birds and cetaceans.

Phytoplankton and zooplankton occupy the upper layers of the water column are therefore more likely to be exposed to spilt hydrocarbons which tend to surface as they are less dense than water (ITOPF, 2011a). Phytoplankton and zooplankton may be exposed to toxic water-soluble components from spills. Studies have shown growth inhibition in phytoplankton at hydrocarbon concentrations of 100,000 parts per billion. Conversely, lower levels of hydrocarbons, around 100 parts per billion, have been found to stimulate growth (Harrison *et al*., 1986). There is evidence that some zooplankton (particularly copepods) can sense and actively avoid oiled areas, therefore reducing potential contact with oil (Seuront, 2010). In general, plankton communities have been found to be highly resilient to the effects of spilt hydrocarbons (Abbriano *et al*., 2011) and their high turnover rate and reproduction is sufficient to make up for any losses of eggs and larval stages that may be lost through mortality in the vicinity of a spill (ITOPF, 2011a).

Given the above, the potential impact to plankton in the event of a worse case spill from the Columbus location is not considered to be significant. Consequently, the potential for knock-on effects on fauna feeding at high trophic levels is also not considered to be significant.

10.5.2 Effects on Benthos

Benthic species may be sensitive to deposition of oil associated with sedimentation, or following chemical dispersion. The proportion of a surface spill that is deposited to the seabed might be expected to increase as a result of high turbulence and suspended solids concentrations in the water column, both associated with storm conditions in shallow water. Most studies on the effects of oil on benthic communities have focused on near shore areas and the impacts of beached oil. Studies of seabed infauna following the Braer spill (Kingston *et al*., 1995), which occurred under such conditions, found no significant changes in benthic community structure which could be related to the areas of seabed affected by the spill. Although, this may have been because Braer oil was of low toxicity, or because the sampling programme was carried out too soon after the spill to enable the full effects of its impact to be detected. However, further sampling 10 years after the spill indicated a substantial decline in sediment hydrocarbon concentrations (DECC, 2016).

Therefore, the greatest impact to marine fauna is likely to be found near-shore, where sedentary benthic species may be smothered by oil or directly exposed to toxic components over extended periods of time. Impacts of oil on sedentary benthic species in shallow waters may be more acute, as they are unable to move away from a spill. In addition, where light refined products or light crude oils have become dispersed into shallow water leading to high concentrations of the toxic components of oil, mortality of benthic fauna has occurred (ITOPF, 2011a). However, much of the intertidal flora and fauna on the shore are inherently robust as they must be physiologically and behaviourally adapted to periods of exposure and immersion, and subsequent fluctuations in temperature, salinity, winds and exposure during the tidal cycle (ITOPF, 2011a). This was observed following the Exxon Valdez spill, which found that intertidal plants and animals were generally resistant to acute toxicity of heavy oil, sometimes surviving three to four months of exposure, with long-term monitoring indicating that intertidal impacts from the spill, whether by oil or treatment, were not evident within three to four years (Shigenaka, 2014).

Given the above, coupled with the results of the oil spill modelling which show that the hydrocarbons are likely to readily disperse and evaporate, the potential impact to benthos in the event of a worst-case spill from the Columbus location is not expected to be significant.

10.5.3 Effects on Fish and Shellfish

Fish (including eggs and larvae) may be affected by spilt oil in a number of ways; their gills may be contaminated with oil, planktivorous or piscivorous fish may consume contaminated prey and larvae or eggs may be susceptible to certain toxic and volatile components of oil (Neff, 1990). Free swimming adult fish however, tend to be less susceptible to the effects of an oil spill as they can detect it and move away from the affected area (ITOPF, 2011a). In addition, many fish species have developed systems which can metabolise and excrete aromatic hydrocarbons (a key component of crude oil) and therefore most fish do not tend to accumulate high concentrations of petroleum hydrocarbons, even in heavily oil-contaminated environments (Neff, 1990).

Juvenile fish and larvae are susceptible to the toxic effects of hydrocarbons that may cause larval mortality depending on the type of oil and the exposure time (Abbriano *et al*., 2011). Oil spills can result in high mortality, as well as genetic mutations, in fish eggs and larvae which are relatively immobile and are therefore more likely to be exposed to a spill for a longer period of time. Studies have shown that fish tainting from oil exposure can occur at oil concentrations from 0.01-1 milligrams per litre (GESAMP, 1993).

There are a number of fish spawning and nursery grounds with the vicinity of the Columbus Development (Section 3.6.3). However, many these species have a widespread distribution and their spawning and nursery grounds are not restricted to this area of the North Sea.

Fish are generally considered to be at greatest risk from contamination when the water depth is very shallow. In the open waters around the proposed Columbus Development, where the water depth is around 85 m, there is a relatively low likelihood that contaminant concentrations will be high enough to affect fish populations (DECC, 2016).

Many shellfish species have limited mobility. Filter feeding bivalve molluscs, may accumulate hydrocarbons from sediments, food and water. Bivalve molluscs are less able to metabolise oil and may accumulate more and retain them for longer than other taxa (Neff, 1990) with a potential for accumulation further up the food chain. Many mobile benthic species, such as crustaceans, have well-developed systems which can metabolise and excrete such compounds (Lee, 1981) which are therefore less likely to accumulate in their tissues. This was the case following the 1996 Sea Empress oil spill in South Wales, where concentrations of hydrocarbons were higher in molluscs than in crustaceans (Edwards and White, 1999). However, fates analysis of the worst-case trajectory run predicts that the majority of the Columbus condensate would evaporate.

The potential impact to fish and shellfish in the event of a worst-case spill from the Columbus location is therefore not expected to be significant.

10.5.4 Effects on Seabirds

The effects of oil on seabirds has been widely studied and includes both immediate chronic impacts which can kill birds or longer-term, sub-lethal, impacts that could affect individuals and populations over many years (e.g. Camphuysen *et al*., 2005; Perez, *et al*., 2009). Seabird species that raft together or spend a significant amount of time on the sea surface (such as auks) are particularly vulnerable to oil spills. A small spill during the breeding season or moulting season, when they cannot fly or where large populations of seabirds have congregated, can prove more harmful than a larger spill at a different area or time of year. Oiling of plumage can result in mortality due to hypothermia, loss of buoyancy and potentially drowning, as well as indirectly by reducing the bird's ability to take off and fly thereby potentially hindering their search for food or escape from predators (ITOPF, 2011a). A seabirds' instinctive response to oiling is to clean itself by preening and ultimately ingesting oil from its plumage. Seabirds may also be indirectly affected through the ingestion of contaminated prey.

Seabird vulnerability within the vicinity of the Columbus Development area is recorded as low throughout the year (refer to Section 3.6.4; Webb *et al*., 2016) and offshore bird numbers in this area of the central North Sea are comparably lower than in nearshore waters, such as those around the north east coast of Scotland which hold vulnerable concentrations of seabirds all year round (DECC, 2016). The greatest risk to seabirds would therefore be in the event that a spill from the Columbus location reaches the coast. However, modelling results indicate that the probability of the worst-case blowout incident beaching on the UK coastline is very low; up to 6% on the east coast of the Shetland Islands. As such, impacts to seabirds are not expected to be significant.

10.5.5 Effects on Marine Mammals

Marine mammals are generally less affected by spills of oil as they can detect and move away from oiled areas (Abbriano *et al*., 2011). Unlike fish or seabirds, oil is unlikely to adhere to or permeate through the skin of marine mammals where it could accumulate in tissues and have toxicity effects (Neff, 1990). Additionally, marine mammals do not drink large volumes of water, therefore accumulation of oil via this route is unlikely (Neff, 1990). Baleen whales (such as the minke whale) however, frequently filter feed on the water's surface, and therefore would be more likely to ingest oil as they target their prey (Neff, 1990). Marine mammals may also be exposed to toxic volatile fractions as they surface to breathe. In general, cetacean abundance in this area of the North Sea is relatively high and a number of species have been recorded in the vicinity of the Columbus Development location at various times throughout the year (refer to Section 3.6.5). It is worth noting, however, that cetacean sightings before and after the Sea Empress oil spill (harbour porpoise and bottlenose dolphin) in South Wales suggested no change in the frequency or distribution of their occurrence (Edwards and White, 1999).

Seals rely on their fur to regulate their body temperature which may be hindered if fur becomes matted with oil and may subsequently suffer from hypo- or hyperthermia. Individuals may also be at risk of ingesting oil when cleaning themselves (ITOPF, 2011a). The at-sea distribution of seals in the vicinity of the Columbus Development area is generally low (refer to Section 3.6.5). Seals utilising coastal waters, particularly those at haul-out and breeding sites would be most at risk; however, modelling indicates that the probability of hydrocarbons beaching on the Shetland Islands or the east coast of Scotland is very low.

Given the above, the potential impact to marine mammals in the event of a worst-case spill from the Columbus location is not expected to be significant.

10.5.6 Effects on Marine Protected Areas

It can be seen from the oil spill modelling (refer to Section 10.4 and Appendix G) that a worst-case subsea blowout at the Columbus location has the potential to hit eight offshore marine protected areas (with surface oiling at a minimum thickness 0.3µm) and the potential to hit 20 coastal marine protected areas (with shoreline oiling at a minimum thickness 1.0µm), albeit the probability of this occurring is very low.

The offshore marine protected areas in the vicinity of the proposed Columbus Development location are at the greatest risk (more than 10% probability) from surface oiling. However, all but one of these sites are designated for subsea features. As hydrocarbons associated with the Columbus Development are light and tend to have very high evaporation rates (84% evaporated after 70 days for the worst-case trajectory run), no potentially significant environmental effects are predicted at these sites. The remaining site; the Southern Trench NC MPA, is of importance for minke whale, but as discussed in Section 10.5.5 impacts to marine mammals are also not expected to be significant.

A number of sites on the coast of the Shetland Islands and the mainland Scotland, which are of importance for features including seabirds, harbour seal, Atlantic salmon and freshwater pearl mussel, also have the potential to be subject to surface oiling in the event of a worst-case blowout incident. It is therefore possible that seabirds using these sites could be impacted, although given the high evaporation rates (84% evaporated after 70 days for the worst-case trajectory run) and the fact that only a very small percentage of the condensate is predicted to remain on the sea surface, this is considered to be unlikely. The Columbus condensate has a low wax and asphaltene content and is therefore unlikely to persist in the marine environment. Potential impacts to coastal marine protected areas are therefore also not anticipated to be significant, give the extremely low probability of beaching (up to 6%).

10.5.7 Effects on Shoreline Habitats

It can be seen from the oil spill modelling results, as summarised in Section 10.4, that a worst-case blowout incident from the Columbus location has the potential to beach on the Shetland Islands, Aberdeenshire and the Highlands of Scotland. However, the maximum probability of beaching is very low, up to 6%, with the greatest volume of beached condensate across all coastlines recorded at 227.1 m^3. In addition, exposed rocky shores, such as those found around much of the Shetland Islands, Aberdeenshire and the Highlands have demonstrated a high recoverability to pollution events due to their ability to self-clean with the aid of strong tidal effects (IPIECA, 1995). As such, the potential impact to shoreline habitats in the event of a worst-case spill from the Columbus location is not expected to be significant.

10.5.8 Socio-economic Effects

Major oil spills can have a serious impact on commercial fishing activities through physical contamination of fish, oiling of fishing boats and gear and loss of access to fishing grounds as well as market confidence (ITOPF, 2011b). Overall commercial fishing activity within the vicinity of the Columbus Development area is considered to be low, with effort generally highest between March and August (Marine Scotland, 2017a). Key species targeted include herring, plaice, lemon sole and haddock (refer to Section 3.8.1) (Marine Scotland, 2017a; Kafas *et al*., 2012).

Given the area that could be affected in the event of a worst-case oil spill scenario from the Columbus Development location, commercial fishing activities could be impacted in the short- to medium-term. However, as previously discussed, free-swimming adult fish can detect oil and move away from the affected area (ITOPF, 2011a). In addition, the oil concentration in the water column offshore tends to rapidly decline after a spill. Only rarely do concentrations reach levels sufficient to cause mortality or significant harm, and such instances are usually confined to the area near to the source of a spill (ITOPF, 2011b).

In coastal areas there can be high economic costs associated with oil spills, due to the clean-up operations involved, as well as financial losses to industry sectors that rely on clean seawater and clean coastal areas, such as the tourism industry (ITOPF, 2011c). Oil spill modelling has demonstrated that a worst-case blowout incident from the Columbus Development location has the potential to beach on the UK shoreline. However, given that the maximum probability of beaching is very low, up to 6%, with the greatest volume of beached condensate across all coastlines recorded at 227.1 m^3, impacts to coastal areas are not anticipated to be significant.

10.6 Mitigation Measures

10.6.1 Spill Prevention Measures

Serica has systems and procedures in place to ensure environmental risks are identified and minimised. This includes an Operations Management System (OMS; as described in Section 11), a process to identify and assess operational risks to the environment and ensure appropriate measures are in place to eliminate and/or mitigate them, systems to manage inspection and maintenance of equipment and systems to ensure all personnel are trained and competent to undertake their assigned duties.

Robust contractor selection process will be in place for engineering and fabrication contracts and MODU and vessel contractors will be required to demonstrate that they have control processes in place to minimise environmental impacts. Training, competency and maintenance of safety and environmentally critical equipment all play vital roles in ensuring the risks of pollution are as low as reasonably practicable. For the Columbus Development, Serica will ensure that the minimum exercise requirements as stipulated in Appendix C of the BEIS Guidance Notes for Preparing Oil Pollution Emergency Plans for Offshore Oil and Gas Installations and Relevant Oil Handling Facilities (October 2017) are met.

Approved OPEPs will be in place, which will be prepared in advance of activities commencing offshore and will detail the spill prevention measures, response procedures and resources available in the event of a spill. All vessels, will also have a Shipboard Oil Pollution Emergency Plan (SOPEP) onboard.

It is Serica's policy that the Columbus facilities will be designed and operations will be conducted in such a manner as to minimise the risk of hydrocarbon and chemical pollution. Onshore design reviews, risk assessments and operations planning are used to identify potential risks and to ensure that, where possible, risks are minimised at the design stage. Where residual risks remain, mitigation procedures will be put in place to prevent accidental spills as summarised in Table 10.4.

Table 10.4. Spill Prevention Measures

Source	Spill Prevention Measures
A loss of chemicals, fuel or utility hydrocarbons during bunkering and general operations on the MODU/vessels	• OPEP will be in place. • Liquid storage areas and areas that might be contaminated with oil are segregated from other deck areas. • Permanent drip trays will be located under process plant, pumps and vessels (on grated decks). • Bunding or additional containment will be provided around plated areas beneath equipment with significant hydrocarbon inventories. • Chemicals will be stored in bunded areas where any spillages can be routed to the closed drainage system. • Chemical, utility and fuel storage tanks will be equipped with alarm systems and procedure will be in place to minimise and prevent overfilling these storage tanks. • Small spill kits will be on board the MODU / vessels to clean up deck spills and prevent spilt hydrocarbons and chemicals from reaching the sea. • Non-return valves will be installed on transfer hoses and hoses to be tested and inspected as a part of a regular maintenance programme. • Bunkering procedures will be put in place to include measures such as transfer operations to be supervised at all times from both the supply vessel and MODU. • Crews will be adequately trained, supervised and regular exercises held to contain and clean-up deck spills. • Routine equipment maintenance programme will be in place with specific emphasis on environmentally critical equipment. • Effective management of chemicals to endeavour to reduce the volumes required and therefore the frequency of bunkering. • Use of floating hoses. • Where feasible, bunkering operations will be undertaken in daylight and in good weather conditions. • A rig audit will be conducted to the ensure rig is in compliance with all relevant guidelines and legislation. The audit will also cover oil spill response, procedural controls, bunkering and storage arrangements. • Tool box talks will highlight the importance of minimising the risk of spills occurring. • Monitoring of ROV operations. • Maintenance and inspection procedures in place for ROV including hydraulic hoses. • Knowledge of subsurface infrastructure and therefore potential snagging hazards in the area.
Loss of containment on MODU due to collision or other major event	• A vessel traffic survey will be undertaken for the area closer to the proposed start of drilling as part of the standard permitting process, together with a collision risk assessment. • Consent to Locate will be in place for the MODU under Part 4A of the Energy Act 2008. • 500 m safety exclusion zone will be designated around the MODU.

Source	Spill Prevention Measures
	• Dedicated ERRV present during drilling to monitor movements of other vessels in the area and prevent them entering the exclusion zone. • Notifications made to 'regular runners' and local fisheries organisations via Kingfisher, Notices to Mariners, NAVTEX / NAVAREA warnings and fisheries notices. • OPEP and other Emergency Plans will be in place. • Early consultation and ongoing engagement with other sea-users (stakeholders); • Appointment of an onshore FLO to maintain good communication with local fisheries and co-ordinate activities throughout the drilling phase.
Well blowout (releasing large quantities of hydrocarbons)	• Undertake shallow gas survey prior to drilling. • Environmentally critical elements related to drilling operations will be identified, and a suitable maintenance and testing schedule applied to each. • Well design and construction reviewed by an independent well examiner. • Weighted drilling fluids will provide the primary barrier and the well will be carefully controlled and monitored. The secondary barrier will be the BOP which will be regularly maintained and tested. • Simultaneous operations (SIMOPs) will be actively identified and managed. • Emergency response plans and equipment will be in place. Crews will be adequately experienced and trained in well control techniques. Emergency drills will be held regularly. • OPEP will be in place. • Ongoing verification of well operations by an independent body. • Pressure instrumentation and isolation of subsea systems. • Isolation valves will be included on the subsea Xmas tree and all safety critical subsea valves will be ROV or diver operable. • Review spill mitigation measures of all contractors as part of the contractor selection process. • In the event of a spill incident, rapidly act to stem the flow of hydrocarbons from the well through the necessary shutdown procedures. Mobilise Tier 2 and 3 spill response resources to contain and respond to a spill incident offshore. • If suitable, relief well drilling would be considered to the stem the flow.
Loss of integrity from the Columbus Tie-in Spool	• Tie-in spool is protected from corrosion through a combination of a protective coating and cathodic protection system and a margin for corrosion is built into the design. • Tie-in spool will be pressure tested to above the planned operating pressure. • Tie-in spool will be protected from physical damage by fishing gear or anchors by mattresses. • Pressure and temperature routine monitoring will be undertaken. Automatic and manual shutdown systems will be in place. • Regular ROV inspection will be undertaken.

10.6.2 Oil Spill Response Strategy

With respect to accidental spills, the greatest importance lies with preventing their occurrence in the first instance. However, in the unlikely event of a spill incident occurring during any lifecycle phase of the proposed Columbus Development, a suitable response strategy must be in place to manage and control a spill. This will include response options to respond to a spill and source control options to stop the spill in the event of an uncontrolled release.

Based on a review of data within Oil and Gas UK's Oil Spill Response Effectiveness in UK Waters Guidelines (April 2015), the response options available to Serica for the Columbus Development, given the type of condensate which would be released (ITOPF non-persistent Group 1) and the location of the development in the Northern North Sea geographical region, are depicted in Figure 10.1. It can be seen from this that the following two strategies could be used in the event of an accidental release of condensate from the Columbus Development:

1. Natural Dispersion: the natural processes by which the crude reacts to when in the environment;
2. Monitor and Evaluate: monitoring the fate of the oil and quantifying the size of the slick.

Due to the nature of these options there is no limit on their effectiveness or availability throughout the year (OGUK, 2015b). These response options (natural dispersion and monitor and evaluate) are also considered viable for an accidental release of diesel.

Response options will be reviewed and further defined during preparation of the OPEPs required to be in place for the proposed Columbus Development, and approved by the regulator, in advance of activities commencing offshore. Serica will also ensure that a contract is in place with an established oil spill response contractor, who would be able to provide the full range of response equipment and personnel necessary to respond to a worst-case spill incident from the Columbus Development.

Figure 10.1. Response Options for ITOPF Non-Persistent Group 1 Oils in the Northern North Sea Geographic Region (OGUK, 2015b)

	Aerial Dispersant	In-situ Burn	Monitor & Evaluate	Natural Dispersion
Wind Speed	N/A Aerial dispersant is not an option for Non-Persistent Group 1 oil as it will naturally disperse	N/A In-situ burning is not an option for Non-Persistent Group 1 oil as it will naturally disperse	**Between 0 kts & 45 kts**	**All wind speeds**
Visibility			Does not affect Response	Does not affect Response
Precipitation			Does not affect Response	Does not affect Response
Temperature			Does not affect Response	Does not affect Response
Tidal State			Does not affect Response	Does not affect Response
Current Speed			Does not affect Response	Does not affect Response
Ice & Debris			N/A in UK Climate	N/A in UK Climate
Daylight			**Available 24 hrs**	Does not affect Response
Wave Height			Does not affect Response	**All wave heights**

	Contain and Recover	Shoreline Response	Vessel Dispersant
Wind Speed Visibility Precipitation Temperature Tidal State Current Speed Ice & Debris Daylight Wave Height	N/A Containment and recovery is not an option for Non-Persistent Group 1 oil as it will naturally disperse	N/A Shoreline response is not an option for Non-Persistent Group 1 oil as it is unlikely to make landfall.	N/A Vessel dispersant is not an option for Non-Persistent Group 1 oil as it will naturally disperse

10.6.3 Source Control

While in no way analogous to Columbus, the BP Macondo Field Deepwater Horizon incident in the Gulf of Mexico in 2010 has demonstrated that in some extreme cases a relief well may be required to stem an uncontrolled flow of hydrocarbons, if no other suitable alternatives were available.

As the proposed CDev-1 well is not a high pressure/high temperature well and is not being drilled in deep water, it is not anticipated that a specialist drilling rig configuration would be required and a standard HDJU or semi-submersible drilling rig would be suitable to drill a relief well.

It is anticipated that it would take 60 days to drill a relief well for the proposed Columbus CDev-1 well (this has been used to inform the worst-case oil spill scenarios). Relief well timings will be further defined during preparation of the OPEP for the drilling phase.

10.7 Residual Impacts

Analysis of long-term data, over the last 30 years, highlights a shift towards ever smaller spill volumes and a reduction in the number of spill reports per year. The latest OGUK Environmental Report, published in December 2017, notes that the average size of reported accidental oil releases has varied each year from between 0.10 tonnes and 2.11 tonnes since 2010, but is affected by the low frequency, high mass releases. In 2016, the average mass of oil released per occurrence was 0.4 tonnes, lower than the average of 0.6 tonnes for 2010-16 (OGUK, 2017). Based on this historical data and taking into account the spill prevention measures that will be in place, the most probable accidental releases from the Columbus Development will be small in volume, with the majority anticipated to be less than 1 tonne. It is considered unlikely that a major event, such as a blowout, would occur, particularly given the measures that will be in place to reduce the probability of a failure of well control.

The consequences of an accidental release will vary depending on the quantity and type of oil spilt, the wind speed and direction and sea state and the sensitivity of receptors depending on the time of year.

Impacts from small spills are likely to be within the immediate vicinity of the release location. The Columbus condensate and diesel are both light oils and, as indicated by the fates analysis of the worst-case trajectory run for the well blow out scenario (refer to Appendix G), it is predicted that if accidentally released into the marine environment they would rapidly break up by wind and wave action and evaporate. As such, the overall risk to the marine environmental from an accidental release of hydrocarbons from the Columbus location is considered to be ALARP (as low as reasonably proacticable) and not significant.

In all instances, in the event of a spill, Serica will ensure that an appropriate oil spill response is implemented to minimise the impact to the marine environment as far as practicable and immediate attempts will be made on site to stem the release.

10.8 Assessment of Potential Major Environmental Incidents

In accordance with requirements of both the EIA Regulations and The Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations 2015 (SCR 2015), the major accident hazard scenarios that would result in the worst case release of hydrocarbons need to be identified for the Columbus Development and an assessment made of the potential for, and environmental consequences of, a Major Environmental Incident (MEI).

Under SCR 2015, a major accident is defined as:

"(a) an event involving a fire, explosion, loss of well control or the release of a dangerous substance causing, or with a significant potential to cause, death or serious personal injury to persons on the installation or engaged in an activity on or in connection with it;

(b) an event involving major damage to the structure of the installation or plant affixed to it or any loss in the stability of the installation causing, or with a significant potential to cause, death or serious personal injury to persons on the installation or engaged in an activity on or in connection with it;

(c) the failure of life support systems for diving operations in connection with the installation, the detachment of a diving bell used for such operations or the trapping of a diver in a diving bell or other subsea chamber used for such operations;

(d) any other event arising from a work activity involving death or serious personal injury to five or more persons on the installation or engaged in an activity on or in connection with it; or

(e) any major environmental incident resulting from any event referred to in paragraph (a), (b) or (d)."

The risk assessment undertaken as part of the planning process for the proposed CDev-1 well has identified a well blow out incident, releasing large quantities of hydrocarbons, as having the potential to result in a Major Environmental Incident (MEI).

The loss of containment from the MODU due to a collision or other event is not considered to have the potential to result in a MEI due to the significantly smaller quantities of hydrocarbons that could be released into the marine environment and the light, volatile nature of marine diesel which would lead it to evaporate quickly. Once a MODU has been contracted to drill the proposed CDev-1 well, the MODU's Safety Case will be reviewed to confirm if any additional MAH scenarios are applicable.

As discussed in Section 10.4, a well blow out incident was modelled for the proposed CDev-1 well assuming a cumulative release of 95,400 m^3 of 47.6° API condensate after 60 days (with a release rate 1,590 m^3/day). The potential environmental and socio-economic impacts associated with the worst-case spill scenario have been assessed in Section 10.5 above. This concluded that the residual risk to the marine environment from accidental hydrocarbon releases is considered to be **low** (and ALARP).

A MEI is defined as an incident which results, or is likely to result, in significant adverse effects on the environment in accordance with Directive 2004/35/EC of the European Parliament and the of the Council on environmental liability with regard to the prevention and remedying of environmental damage ('the Environmental Liability Directive'). Under Directive 2004/35/EC, "environmental damage" means *"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."*

Offshore marine protected areas that may be subject to surface oiling include five NC MPAs designated for sandeels, minke whale, ocean quahog and/or subsea habitats, two SACs designated for Annex I listed habitats submarine structures made by leaking gases and one MCZ designated for ocean quahog and broad-scale habitat types (refer to the Appendix G for further details). However, as the Columbus condensate is highly volatile and is expected to naturally evaporate (fates analysis indicates that 84% of the spill had evaporated after 70 days for the worst-case trajectory run) it is not predicted that these marine protected areas will be significantly impacted. As such, even if relevant species or habitats were affected as a result of a well blow-out, the damage is unlikely to be significant in terms of the conservation status of the relevant species or habitat in relation to their natural distribution.

The MEI provisions also apply to transitional and coastal waters covered by provisions under Directive 2000/60/EC, the Water Framework Directive, or marine waters covered by provisions under Directive 2008/56/EC, the Marine Strategy Framework Directive. However, it is not considered that the well blow-out scenario would result in damage that would significantly adversely affect the ecological, chemical and/or quantitative status and/or ecological potential, as defined in Directive 2000/60/EC, or the environmental status of marine waters as defined in Directive 2008/56/EC.

It is, therefore, considered that a major accident relating to the Columbus Development operations would not result in a MEI.

10.9 Transboundary Impacts

The oil spill modelling results show that there is a very high probability that a worst-case release of condensate from the Columbus CDev-1 well location would cross the UK / Norway median line in all seasons, with shortest arrival time after 6 hours in autumn. There is a very low probability (up to 8% in winter, spring and autumn) that the spill would also cross the median line between Norway and Denmark. Beaching could occur on the Norwegian, Danish and German coastlines, but the probability of this is low (up to 17 %).

In the event of an oil spill entering Norwegian waters it may be necessary to implement the NORBRIT Agreement (the Norway-UK Joint Contingency Plan). The NORBRIT Agreement sets out command and control procedures for pollution incidents likely to affect both parties, as well as channels of communication and resources available. The Agreement is largely oriented towards major spills; however, it is not confined to such events and will apply as necessary to any spills within the NORBRIT regions, which are of sufficient severity to warrant joint action. The NORBRIT Agreement becomes operational when agreement to the request for its implementation is reached. Responsibility for implementing joint action rests with the Action Co-ordinating Authority (ACA) of the country on whose side of the median line a spill originated.

The Bonn Agreement may also be activated. This is the main counter-pollution agreement that influences an offshore response for a spill that may cross into international waters for the countries bordering the North Sea and English Channel. This includes Belgium, France, Germany, Ireland, the Netherlands, Norway, Sweden, Denmark and the UK.

Given that the Columbus condensate and diesel are likely to readily disperse and evaporate no significant transboundary impacts are predicted.

10.10 Cumulative Impacts

The probability of a major spill occurring is extremely low, limiting the potential for cumulative oil spill impacts from the Columbus Development with other existing oil and gas installations. All nearby installations will also have approved OPEPs in place outlining the response measures to be implemented in the event of a spill.

11 Environmental Management

11.1 Introduction

The identification and control of environmental impacts associated with all Serica's activities forms an integral part of managing the business. Potential impacts are identified during the planning stages of all operations, and the risks evaluated and managed through an integrated Operations Management System (OMS). This system provides the structured management framework within which environmental impacts are identified, assessed, controlled, and monitored.

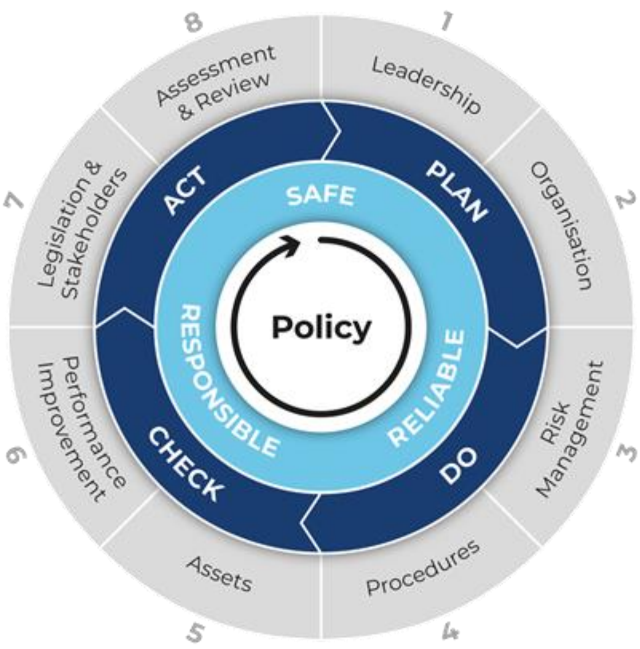
As the offshore licensee, Serica is responsible for the Columbus Development during all lifecycle phases of the project. Serica is also planning to be the appointed well operator, subject to approval by the OGA under The Offshore Petroleum Licensing (Offshore Safety Directive) Regulations 2015, managing the development drilling and well completion operations, as well as any future well intervention (maintenance) and subsequent well abandonment operations. As part of the Columbus Development, Serica will interact with Dana Petroleum (E&P) Limited (Dana), operator of the Arran to Shearwater pipeline, and Shell UK Limited (Shell), operator of the Shearwater host platform (refer to Section 2.3).

The remainder of this section describes the main components of the Serica OMS, how it will be integrated with the Management Systems of other entities and explains how the impacts identified within this ES will be managed throughout the development of the Columbus Field.

11.2 Environmental Management System

Serica Energy (UK) Limited (Serica) is a subsidiary of Serica Energy plc, a British-based independent upstream oil and gas company (refer to Section 1.4). The OMS applies to all subsidiaries of Serica Energy plc and the system aligns with international (e.g. ISO14001, ISO45001) and UK (e.g. HS(G)65) standards for health, safety and environmental management. The Serica OMS establishes the main requirements and provides the framework for managing Health, Safety and Environment (HSE) hazards and risks. The basis for the management system is the concept of "Plan-Do-Check-Act" (PDCA), which provides an interactive process to achieve continual improvement in HSE performance. Serica OMS comprises eight Elements, each of which is aligned to a corresponding segment of the PDCA cycle. The relationship between Serica's HSE Policy Statement, the eight Elements of the OMS and the PDCA cycle is illustrated in Figure 11.1.

Figure 11.1: Serica OMS Overview



The Serica OMS is the mechanism that ensures the company standards are maintained, that the commitments specified in this ES are met and that unforeseen aspects of the proposed Columbus Development are detected. This structured management approach will be used to ensure that the on-going process of identification, assessment and control of environmental risks will continue throughout planning and operations.

Prior to being appointed as well operator, Serica is planning to get the OMS externally verified against the ISO14001 standard by an approved certification body as required by OSPAR Recommendation 2003/5 to Promote the Use and Implementation of Environmental Management Systems by the Offshore Industry.

11.2.1 Environmental Health and Safety Policy

The Serica HSE Policy Statement is provided in Figure 11.2. It is signed and dated by the Chief Executive Officer (CEO) and reviewed at defined intervals, but at least annually, as part of the Management Review process.

The HSE Policy Statement is available on the Serica website, posted in the Serica offices, communicated to all staff and contractors and posted on any worksites under Serica management.

11.2.2 Corporate Major Accident Prevention Policy

Serica recognises that the nature of oil and gas activities may give rise to major accident hazards and that they have obligations to all stakeholders to reduce the risks associated with such hazards to levels as low as is reasonably practicable (ALARP). In order to meet these obligations, Serica has developed a Corporate Major Accident Prevention Policy (CMAPP) which is supported by the OMS. The CMAPP provides demonstration from the Board of Serica of their commitment to major accident prevention.

Figure 11.2: Serica HSE Policy Statement

SERICAENERGY

HEALTH, SAFETY, ENVIRONMENTAL POLICY STATEMENT

It is the policy of Serica Energy to manage all its activities and operations in a responsible manner that:

- Meets the high quality standards we set as part of our business objectives;
- Protects the health and safety of our employees, contractors and public;
- Minimises adverse impact on the environment.

To accomplish this we will:

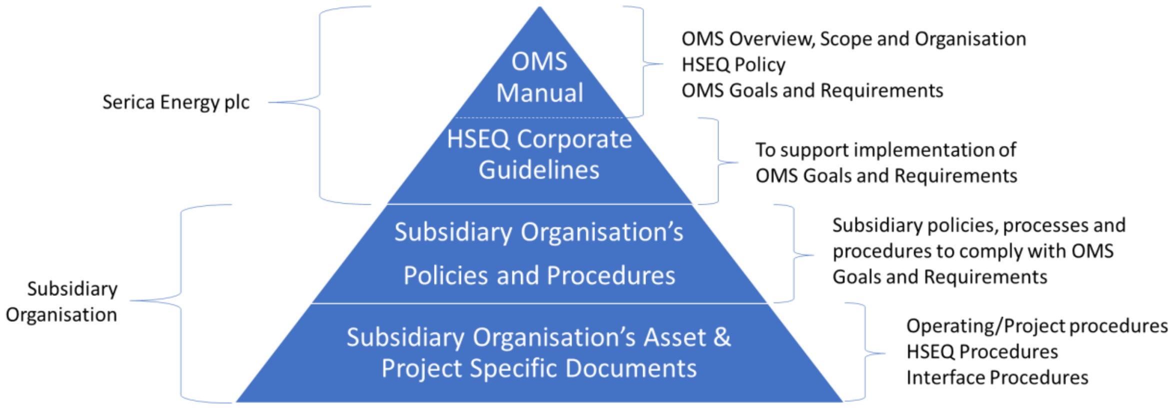
- Ensure that all personnel are aware of their delegated HSE responsibilities and are properly trained to undertake these;
- Ensure that all Company activities are performed to the best of our capabilities;
- Design and manage our activities to prevent pollution, minimise environmental and health impacts and provide work places where safety hazards have been fully assessed and appropriately mitigated;
- As a minimum, comply with all applicable HSE legislation, regulations, other requirements and standards;
- Ensure that environment, health and safety protection command equal prominence with other business considerations in the decision making process;
- Fully consider local community expectations and concerns, cultural heritage, short and long-term benefits and costs and liabilities;
- Investigate the benefits of viable material and process alternatives;
- Strive for continuous improvement in our HSE performance and measure this by setting objectives and targets consistent with the aims of this policy, where applicable.
- Routinely monitor and report HSE performance to the Board of Directors of the Corporation, who will ensure that the necessary resources are provided to support this Policy fully.

Tony Craven Walker
Chairman and CEO
Serica Energy
November 2017

11.2.3 Structure and Process

The structure of the Serica OMS is shown in Figure 12.3.

Figure 12.3: Serica OMS Structure



The OMS structure comprises:

- **OMS Manual:** this provides an overview of the structure, scope and content of the Serica OMS and summarises the roles and responsibilities of management, staff and contractors for effective implementation. The OMS Manual also sets out the goals and requirements for the eight elements of the OMS framework;
- **HSEQ Corporate Guidelines:** these provide guidance on how the OMS goals and requirements can be met.

The lower two tiers of the triangle describe the subsidiary organisation's policies and procedures, and the asset and project specific documents used by these organisations to deliver safe, responsible and reliable operations.

11.2.4 Contractor Selection

Serica will use contractors throughout all lifecycle phases of the Columbus Development. The Serica OMS includes a specific Guideline on contractor selection which defines the requirement to assess HSE capability and performance as an integral part of the contractor selection process. The selection process is dependent on the HSE risks associated with each contract and may include:

- Ensuring an effective HSE management system is in place;
- Reviewing HSE Performance;
- Reviews of regulatory compliance and inspections;
- Ensuring contractors operate an effective competence system;
- Reviewing audit findings and action tracking;
- Maintenance management (where appropriate);
- Review of previous audit reports (certification, internal, external) and outstanding actions;
- Undertaking or commissioning pre-contract health, safety and environmental audits.

11.2.5 Contractor Management

During activities, the systems and procedures of key contractors and suppliers will be applied under the supervision of Serica personnel. These systems and procedures will be the subject of review as part of the contractor selection process (Section 11.2.4) and then monitored during operations to ensure they meet Serica's requirements and expectations, industry best practice and regulatory requirements.

An HSE MS Interface/Bridging Document will also be produced which describes how the various parties will work together in the execution of this project. It will document clear lines of communications and responsibilities between Serica and the contractors throughout the proposed operations, including designation of responsibilities for environmental management and regulatory compliance.

Steps will be taken to ensure that all parties engaged in the Columbus Development understand the potential environmental impacts and commitments as outlined in this ES and the importance of environmental compliance. This will be achieved through meetings prior to the commencement of the proposed development activities and inductions.

11.2.6 Audit, Monitoring and Reporting

Serica will carry out environmental audits and inspections of the drilling rig, installation, maintenance and support vessels prior to and during the proposed Columbus Development activities.

In addition, contractor HSE related performance will be monitored and reviewed by Serica throughout the proposed Columbus Development, with emissions and discharges monitored and reported in accordance with the HSE MS Interface/Bridging Document. All environmental incidents will be subject to joint investigation and dual reporting.

All environmental emissions data recorded during the Columbus Development will be submitted to OPRED via the dedicated Environmental Emissions Monitoring System (EEMS). The reporting of the following data related to the development well will be Serica's responsibility:

- Atmospheric emissions;
- Chemicals;
- Drill fluids;
- OPPC returns;
- Waste.

Reporting of environmental emissions associated with the installation, commissioning ad operation of the Arran to Shearwater pipeline and umbilical, as well as environmental emissions at the Shearwater platform will be the responsibility of Dana and Shell respectively.

11.3 HSE Plan

An HSE plan will be developed for the Columbus Development to summarise how HSE issues will be managed and how the effective implementation of the Serica OMS will be achieved. The objective of this HSE Plan, and the complementary main Subcontractors' HSE plan, is to ensure that the necessary systems and processes are in place to:

- Ensure compliance with relevant statutory provisions as outlined in the Project's Compliance Matrix;
- Design and install facilities which, in addition to meeting all their technical and business goals, will reduce future risks to personnel, the environment and equipment to a level which is tolerable, and ALARP; and
- Execute all phases of the work without significant negative impact on the environment.

Throughout all phases of the Columbus Development project, Serica will ensure that effective, practical and achievable measures which provide for the protection of the environment are in place. To implement the HSE Plan, the following will be undertaken:

- Publicise and communicate Serica HSE Policy Statement and involve all staff, workforce and contractors through participation and consultation, and provide an effective system of communication throughout the Columbus Development;
- Clearly assign responsibility and accountability for the organisation, activities and arrangements to implement the HSE Plans and OMS;
- Ensure that HSE issues are planned and managed with the same priority as other business activities;

- Utilise contractors who have a track record of commitment to recognised HSE standards and who promote industry best practices, and integrate these contractors into the development organisation to ensure effective operations are delivered;
- Report, investigate and address incidents to prevent recurrence;
- Maintain effective systems for monitoring, performance measurement, audit and review; and
- Learn from the active audits and reviews and reactive investigations to strive for continuous improvement in HSE performance.

11.4 Columbus Development ES Commitments

Table 11.1 summaries the mitigation measures and commitments identified within this ES, which are outside of any regulatory or legal requirements.

Serica will ensure these are taken into account and implemented as the Columbus Development progresses through its project and operations phases. Note, statutory regulatory requirements have been excluded as these are mandatory.

Table 11.1: Mitigation Measures and Commitments Register

Ref	Theme	Mitigation Measure / Commitment	ES Section
1	Physical Presence	• An up to date collision risk assessment and shipping density study will be undertaken prior to the drilling phase of the project which will be used to support the planned operations;	Section 5.4
2		• 500 m safety exclusion zone will be designated around the MODU and a dedicated ERRV will be present during drilling operations to monitor movements of other vessels in the area and prevent them entering the exclusion zone;	
3		• Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, Kingfisher, NAVTEX / NAVAREA warnings and fisheries notices;	
4		• Subsea infrastructure will be marked as hazards on admiralty charts and entered into the Fishsafe system so that it may be avoided by fishing vessels;	
5		• Early consultation and ongoing engagement with other sea-users (stakeholders);	
6		• Appointment of an onshore Fisheries Liaison Officer (FLO) to maintain good communication with local fisheries and co-ordinate activities throughout the drilling phase, installation and commissioning phase;	
7		• During installation and commissioning, the number of vessels and length of time they are required on site will be reduced as far as practicable through careful planning of the installation activities;	
8		• Pipeline working corridors will be minimised, as far as possible;	
9		• The deviated section of the pipeline will be trenched and mechanically backfilled. Where the burial depth is not achieved, exposed sections outside the exclusion zone will be protected using rock placement, which will be deposited at a gradient designed to allow fishing gear to pass without snagging;	
10		• All seabed infrastructure will be designed to be fishing friendly and a 500 m safety exclusion zone will be applied for around the Xmas tree and CTIS, which will be clearly marked on navigation charts;	
11		• A post-development survey will be conducted, and any anchor scars, spud can depressions and trench berms that are considered to pose a snagging risk will be flattened using a chain mat;	
12		• With the exception of areas of spot rock-dump, all protection material will be contained within safety exclusion zones;	
13		• Pipeline and umbilical may be installed in the same trench. This will be considered in future design work.	

Ref	Theme	Mitigation Measure / Commitment	ES Section
14	Seabed Disturbance	• A full Chemical Hazard Assessment and Risk Management (CHARM) assessment of the proposed chemicals to be used and discharged, as required under the Offshore Chemicals Regulations 2002 (as amended), will be undertaken during the permitting process prior to drilling operations commencing;	Section 6.5
15		• Deposits Consents will be obtained prior to use of stabilisation / protection material;	
16		• The amount of deposited material used will be minimised, as far as possible, whilst still achieving the required level of stabilisation / protection;	
17		• A detailed anchor pattern for the use of a semi-submersible drill rig or a spud can location assessment for the use of a HDJU will be developed prior to mobilisation;	
18		• As part of chemical selection and assessment process, less hazardous alternatives will be sought in preference for any chemicals identified to be high risk (e.g. those with substitution warnings);	
19		• WBM will be mixed offshore to ensure that only what is required is used;	
20		• A rig audit will be conducted to ensure that the rig is in compliance with all relevant guidelines and legislation ;	
21		• If an anchored pipelay vessel is used, the pipeline site survey data will be reviewed to determine if placement will affect any existing environmentally sensitive features or hazards;	
22		• The appropriate number of anchors and length of anchor chains will be used to maintain stability and integrity;	
23		• Working corridors will be minimised, as far as possible;	
24		• The pipeline and umbilical may be installed in the same trench; this will be considered in future design work;	
25		• Stabilisation material will be constrained to areas where trenching alone does not sufficiently protect the deviated section of the pipeline;	
26		• The volumes and locations of rock and mattresses used will be refined during Detailed Design to reduce the footprint on the seabed to the extent practicable;	
27		• The spread of rock placement will be restricted through the use of a fall pipe system held a few metres above the seabed to accurately place rock material.	

Ref	Theme	Mitigation Measure / Commitment	ES Section
28	Noise	• Use the minimum diameter piles necessary to achieve structural integrity;	Section 7.3
29		• Follow JNCC (2010b) protocol for minimising the risk of injury to marine mammals from piling noise (August 2010), e.g. soft-start of pile driver, use of MMOs;	
30		• Where possible, piling operations will be timed to avoid periods of high sensitivity for marine mammals and fish.	
31	Atmospheric Emissions	• Use of fuel oil with a sulphur content of no more than 0.1% in accordance with MARPOL and UK regulatory requirements;	Section 8.5
32		• Vessels and contractors will have UK/International Air Pollution Prevention (UKAPP/IAPP) Certificates;	
33		• All combustion equipment will have a maintenance programme and will be tested regularly;	
34		• Power required for the Columbus subsea facilities will be covered by the existing power generation capacities on the Shearwater platform;	
35		• The Columbus Development will utilise the existing flaring facilities on the Shearwater platform during production;	
36		• As part of the contractor selection processes, MODU and vessel contractors will be required to demonstrate that they have control processes in place to minimise environmental impacts (i.e. maintain equipment) through review of International Marine Contractors Association (IMCA) / Offshore Vessel Inspection Database (OVID) inspections;	
37		• During well testing and clean-up, high combustion efficiency burners will be used and the volume flared will be kept to a practical minimum;	
38		• Operating procedures will be in place in order to reduce flaring at Shearwater during maintenance operations, process upset conditions, system depressurisation and start-up.	
39	Marine Discharges	• The Columbus Development will utilise the existing produced water treatment system on the Shearwater platform.	Section 9.4
40		• Any discharge of produced water will be treated to meet oil-in-water limits of less than 30 mg/l.	
41		• Discharge stream will be monitored and sampled in accordance with the approved Shearwater OPPC permit.	
42	Accidental Releases	• Liquid storage areas and areas that might be contaminated with oil are segregated from other deck areas.	Section 10.6
43		• Permanent drip trays will be located under process plant, pumps and vessels (on grated decks).	
44		• Bunding or additional containment will be provided around plated areas beneath equipment with significant hydrocarbon inventories.	

Ref	Theme	Mitigation Measure / Commitment	ES Section
45		• Chemicals will be stored in bunded areas where any spillages can be routed to the closed drainage system.	
46		• Chemical, utility and fuel storage tanks will be equipped with alarm systems and procedure will be in place to minimise and prevent spills overfilling these storage tanks.	
47		• Small spill kits will be on board the MODU / vessels to clean up deck spills and prevent spilt hydrocarbons and chemicals from reaching the sea.	
48		• Non-return valves will be installed on transfer hoses and hoses to be tested and inspected as a part of a regular maintenance programme.	
49		• Bunkering procedures will be put in place to include measures such as transfer operations to be supervised at all times from both the supply vessel and MODU.	
50		• Crews will be adequately trained, supervised and regular exercises held to contain and clean-up deck spills.	
51		• Routine equipment maintenance programme will be in place with specific emphasis on environmentally critical equipment.	
52		• Effective management of chemicals to endeavour to reduce the volumes required and therefore the frequency of bunkering.	
53		• Use of floating hoses.	
54		• Where feasible, bunkering operations will be undertaken in daylight and in good weather conditions.	
55		• A rig audit will be conducted to the ensure rig is in compliance with all relevant guidelines and legislation. The audit will also cover oil spill response, procedural controls, bunkering and storage arrangements.	
56		• Tool box talks will highlight the importance of minimising the risk of spills occurring.	
57		• Monitoring of ROV operations.	
58		• Maintenance and inspection procedures in place for ROV including hydraulic hoses.	
59		• Knowledge of subsurface infrastructure and therefore potential snagging hazards in the area.	
60		• A vessel traffic survey will be undertaken for the area closer to the proposed start of drilling as part of the standard permitting process, together with a collision risk assessment.	

Ref	Theme	Mitigation Measure / Commitment	ES Section
61		• Consent to Locate will be in place for the MODU under Part 4A of the Energy Act 2008.	
62		• 500 m safety exclusion zone will be designated around the MODU.	
63		• Dedicated ERRV present during drilling to monitor movements of other vessels in the area and prevent them entering the exclusion zone.	
64		• Notifications made to 'regular runners' and local fisheries organisations via Kingfisher, Notices to Mariners, NAVTEX / NAVAREA warnings and fisheries notices.	
65		• OPEP and other Emergency Plans will be in place.	
66		• Early consultation and ongoing engagement with other sea-users (stakeholders).	
67		• Appointment of an onshore FLO to maintain good communication with local fisheries and co-ordinate activities throughout the drilling phase.	
68		• Undertake shallow gas survey prior to drilling.	
69		• Environmentally critical elements related to drilling operations will be identified, and a suitable maintenance and testing schedule applied to each.	
70		• Well design and construction reviewed by an independent well examiner.	
71		• Weighted drilling fluids will provide the primary barrier and the well will be carefully controlled and monitored. The secondary barrier will be the BOP which will be regularly maintained and tested.	
72		• Simultaneous operations (SIMOPs) will be actively identified and managed.	
73		• Emergency response plans and equipment will be in place. Crews will be adequately experienced and trained in well control techniques. Emergency drills will be held regularly.	
74		• OPEP will be in place.	
75		• Ongoing verification of well operations by an independent body.	
76		• Pressure instrumentation and isolation of subsea systems.	
77		• Isolation valves will be included on the subsea Xmas tree and all safety critical subsea valves will be ROV or diver operable.	

Ref	Theme	Mitigation Measure / Commitment	ES Section
78		• Review spill mitigation measures of all contractors as part of the contractor selection process.	
79		• In the event of a spill incident, rapidly act to stem the flow of hydrocarbons from the well through the necessary shutdown procedures. Mobilise Tier 2 and 3 spill response resources to contain and respond to a spill incident offshore.	
80		• If suitable, relief well drilling would be considered to the stem the flow.	
81		• Tie-in spool is protected from corrosion through a combination of a protective coating and cathodic protection system and a margin for corrosion is built into the design.	
82		• Tie-in spool will be pressure tested to above the planned operating pressure.	
83		• Tie-in spool will be protected from physical damage by fishing gear or anchors by mattresses.	
84		• Pressure and temperature routine monitoring will be undertaken. Automatic and manual shutdown systems will be in place.	
85		• Regular ROV inspection will be undertaken.	

12 Conclusions

12.1 Assessment Process

The EIA process undertaken for the proposed Columbus Development has aimed to identify and assess all potentially significant environmental effects arising from the proposed Development (both from planned and unplanned (accidental) events). Where options are still being investigated, the impact assessment documented in this ES has been based on the worst-case option. Any changes during detailed design will, therefore, only lead to a reduction in the likelihood or severity of environmental impacts.

The scope of the EIA undertaken for the Columbus Development includes:

- Drilling, commissioning and operation of the CDev-1 well;
- Installation, commissioning and operation of the Columbus spool piece and subsea manifold structure designed to tie the CDev-1 well into the Arran to Shearwater pipeline;
- Installation of the deviated section of the proposed Arran to Shearwater pipeline;
- The incremental emissions at the Shearwater platform as a result of processing the Columbus fluids.

The environmental impact of the installation of the remainder of the Arran to Shearwater pipeline, along with the commissioning, operation and maintenance of the entire pipeline, is assessed within Dana's Arran Project ES (Dana, 2018).

The key environmental issues identified during the initial stage of the Columbus Development EIA process as requiring further evaluation included:

- **Physical Presence:** the presence of the proposed Columbus Development in the marine environment, specifically the mooring of the MODU (if a semi-submersible MODU is used) and installation vessels, subsea infrastructure (e.g. deviated section of the Arran to Shearwater pipeline and umbilical, wellheads and tie-in structure), designated exclusion zones and presence of seaberms if formed during trenching activities, has the potential to interfere with other sea users (namely shipping and fishing) in the area.
- **Seabed Disturbance:** activities including MODU anchoring or spud can placement (depending on final rig selected), anchoring of installation vessels, drilling, installation and the protection of the subsea infrastructure, have the potential to adversely impact the seabed and seabed communities within the proposed Columbus Development area through, for example, a decline in water quality due to increased turbidity, smothering of organisms and habitats, the loss of habitat and toxicity effects from chemical components.
- **Noise:** underwater noise generated during the proposed Columbus Development has the potential to disturb, or cause injury to, a number of species in the marine environment, particularly fish and marine mammals. The most notable sources of noise associated with the Columbus Development will be during the piling activities and during installation and commissioning when there is a requirement for vessels to use DP thrusters.
- **Atmospheric Emissions:** major sources of atmospheric emissions from the Columbus Development include power generation for the MODU, support and installation vessels and flaring of the CDev-1 well during well testing and clean-up. In addition, atmospheric emissions will be generated at Shearwater from additional fuel use as a result of processing Columbus fluids, as we as temporary increases in flaring as a result of Columbus production coming online and from unplanned shut down and start-up. Atmospheric emissions have the potential to impact on both natural ecosystems and human health at local, regional and transboundary levels and, from a global perspective, have the potential to contribute to greenhouse gas emissions and climate change.

- **Marine Discharges:** planned operational discharges to sea will occur during all lifecycle phase of the Columbus Development, although the aspects which have the potential to result in significant impacts to the marine environment are limited to discharge of produced water at the Shearwater platform during the production operations.
- **Accidental Releases:** All offshore activities associated with the Columbus Development will carry a potential risk of hydrocarbon pollution to sea. However, hydrocarbon spills from normal oil and gas operations are uncommon and can be effectively mitigated against. In planning its activities, Serica's primary focus is to ensure that all practicable measures are taken to prevent the occurrence of accidental events and, should they occur, mitigate their effects.

Each of these key issues was assessed, as documented in this ES, and their significance (in terms of the potential impact that they present to the environment) determined using a risk assessment approach, whereby:

Risk** = **Likelihood of Occurrence (Frequency / Probability)** x **Magnitude of Impact (Consequence)

The majority of issues were found to be of low risk to the environment (i.e. not significant) and were not considered for further assessment in this ES. Some issues, however, were considered to have the potential for a medium risk to the environment (i.e. potentially significant). For these issues, mitigation measures have been identified to either remove or minimise the potential impacts through operational measures (refer to the detailed mitigation measures defined within each of the impact assessment sections; Sections 5 – 10). A summary of the key residual impacts remaining is provided in Section 12.2.

12.2 Residual Impacts

The key residual impacts from the proposed Columbus Development identified during the EIA process are summarised below. Of note is that all potential impacts from aspects considered to have a medium risk to the environment have been minimised to a level that is as low as reasonably practicable (i.e. in line with industry best practice) and are therefore not considered significant.

- **Physical Presence:** no significant adverse residual impacts to other sea users (shipping, fishing) are predicted as a result of the physical presence of the Columbus Development. The residual risk to the environment is considered to range from **low** to **medium** depending on the aspect. The risk of a collision between vessels will be minimised by implementing measures, including marking safety exclusion zones on appropriate Admiralty and navigation charts and following standard communication and notification measures. The total area that will be lost to fishing to the Columbus Development represents a small proportion of the entire fishing area available in the central North Sea. It is emphasised that the only long-term exclusion from the area will be as a result of the 500 m exclusion zone around the wellhead and tie-in structure; an area of approximately 0.8 square kilometres. To put this in context, the exclusion zone would be located in ICES Rectangle 43F2 the area of which is approximately 3,224 square kilometres, and as such fishing vessels would only be excluded from approximately 0.02 % of the ICES Rectangle.
- **Seabed Disturbance:** no significant adverse residual impacts to seabed sediments or seabed communities are predicted as a result of disturbance to the seabed during the life of the Columbus Development. The residual risk to the marine environment is considered as **medium**. The total area of seabed that will be directly impacted by the Columbus Development is estimated at around 0.4 square kilometres. This is a relatively small area in comparison to seabed available across the central North Sea, with similar water depths, sediment types and benthic communities. In addition, much of the area impacted by the Columbus Development (around 97 %) will be disturbed as a result of cutting and mud discharges, MODU anchoring activities or use of spud cans and pipeline and umbilical installation activities. These are temporary operations and it is expected that recovery of affected areas of seabed will be relatively rapid once associated operations have ceased.
- **Noise:** no significant adverse residual impacts to fish and marine mammals are predicted from noise associated with the Columbus Development operations. The residual risk to the environment is considered to be **medium**. Most underwater noise will be generated during

drilling operations and installation, hook-up and commissioning phases of the project, with notable sources of noise produced during the pile driving activities and from vessels using DP thrusters. However, given the temporary nature of these activities and the mitigation measures that will be implemented, no significant negative impacts are anticipated. It is also considered unlikely that the proposed operations will constitute an offence under the OMR.

- **Atmospheric Emissions:** no significant adverse residual impacts to air quality are predicted from atmospheric emissions generated by the Columbus Development operations. The residual risk to the environment is considered to be **medium**. Emissions associated with the development of the Columbus field are expected to represent only a small proportion of emissions typically arising from oil and gas production on the UKCS. Given the proposed mitigation measures there are unlikely to be any significant adverse residual impacts to air quality as a result of the development of the Columbus field. The emissions generated will also only make a very small contribution to global warming gas emissions and potential acidification.

- **Marine Discharges:** no significant adverse residual impacts to water quality are predicted from planned marine discharges associated with the Columbus Development. The residual risk to the environment is considered to be **medium**. The incremental increase in produced water discharges at the Shearwater platform during the operational phase has the potential to significantly impact the marine environment, as discharges of produced water can contain potentially harmful concentrations of oil and other chemicals. However, a number of studies have shown that any impacts will be limited to the local area in the immediate vicinity of the release location and therefore no significant adverse residual impacts are predicted. In addition to this, the produced water concentrations and discharge rates assessed in the ES are a worst case estimate, based on the peak produced water production which will occur for a short duration over the life of the Columbus field.

- **Accidental Releases:** Impacts from small spills are likely to be within the immediate vicinity of the release location. However, as the UK/Norwegian median line is located approximately 8 km to the east northeast of the proposed Columbus Development, modelling of the worst-case oil spill scenario (a well blow-out) has indicated the potential for a surface slick of condensate to cross the median line. There is a very low probability that a worst case spill could beach on the east coast of the Shetland Islands (up to 6%), Aberdeenshire (up to 5%) and the Highlands region (up to 1%), with the shortest arrival time to shore being 596 hours (over 24 days). Both the Columbus condensate and diesel are light oils and it is predicted that if accidentally released into the marine environment they would rapidly be broken up by wind and wave action and evaporate. The risk of an accidental release occurring from the Columbus Development will be minimised through the implementation of physical barriers such as downhole safety valves, maintenance to minimise leaks, and the development and implementation of handling and operational procedures and training. Measures to respond to a spill from the MODU or the Columbus subsea facilities once operational will be covered in approved oil pollution and emergency plans, which will be prepared in advance of drilling operations commencing offshore. As such, the overall risk to the marine environmental from an accidental release of hydrocarbons from the Columbus Development is considered to be **low** and not significant, even in the event a slick crossed the median line.

12.3 Overall Risk

In summary, it is concluded that the proposed Columbus Development will not result in any significant environmental impacts (including transboundary and cumulative impacts) provided that all identified mitigation measures are implemented. Serica has an established Operations Management System (Section 11), which will help ensure the commitments made within this ES are implemented as the project progresses.

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Appendix A: Legislation and Marine Policy

A.1 Applicable Environmental Legislation

Table A.1 identifies some of the key national and international legislation pertinent to the proposed Columbus Development operations. This is largely focussed on the environmental legislation applicable to the EIA process as described in the Guidance Notes on the Offshore Petroleum Production and Pipelines (Assessment of Environmental Effects) Regulations 1999 (as amended) (DECC, 2011). In addition, Table A.1 describes key legislation that has been identified elsewhere in this ES as being relevant to the proposed Columbus Development.

Table A.1. Key Legislation Pertinent to the Proposed Columbus Development

Legislation	Summary of Requirements	Relevance to Columbus Development
The Petroleum Act 1998	Part I of The Petroleum Act empowers the Secretary of State to grant licences to search for and obtain petroleum. The framework Act also regulates: • Offshore activities (Part II) – requires consent to drill wells through the Well Operations Notification System (WONS); • Submarine pipelines (Part III) – through the Pipeline Works Authorisation for construction and installation of a pipeline, and Deposits Consent for pipeline stabilisation deposits; • The abandonment of offshore installations (decommissioning) (Part IV); and, • Hydrocarbon flaring through the provisions of the Flare Consent. The Act also requires a FDP to be submitted to OGA for approval.	All consents and permits relevant to the proposed Columbus Development will be in place prior to the commencement of operations.
The Offshore Petroleum Production and Pipelines (Assessment of Environmental Effects) Regulations 1999 (as amended)	This legislation transposes into UK law the requirements of the EU Directive on 'The Assessment of the Effects of Certain Public and Private Projects on the Environment' (85/337/EEC) and subsequent amendments. The Directive requires an EIA to be undertaken before consent for a project will be granted. The amendment Regulations (2007) implement EU Directive 2003/35/EC which requires public participation through the submission of an ES. The Offshore Petroleum Production and Pipe-lines (Environmental Impact Assessment and other Miscellaneous Provisions) (Amendment) Regulations 2017, implement European Directive 2014/52/EU. A mandatory ES is required for developments producing >500 tonnes per day of oil, or 500,000 cubic metres per day of gas, and for developments involving pipelines of more than 800 millimetres diameter and 40 kilometres or more in length. Other activities may require an ES depending on the nature of the project and sensitivities.	The project meets the criteria for a mandatory ES as at its peak the Columbus development will produce 0.92 million cubic metres per day of gas and 225 cubic metres per day of condensate. This ES has been produced for submission to Regulators and stakeholders. Public participation will be fulfilled through stakeholder engagement during the statutory public consultation period following the ES submission.

Legislation	Summary of Requirements	Relevance to Columbus Development
The Offshore Chemicals Regulations 2002 (as amended)	All offshore activities that use and discharge chemicals during drilling, well intervention, pipeline and / or production operations, require a Chemical Permit. These permits must detail the chemicals to be used and discharged into the marine environment and undertake a risk assessment, where relevant, within the associated permit.	Chemical use and discharge will be permitted via Chemical Permit SATs (applied for via the online BEIS Energy Portal).
The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended)	Prohibits the discharge of oil to sea other than in accordance with the terms and conditions of a permit. Operators of offshore installations must identify all planned oil discharges to relevant waters and apply for the appropriate permits. Oil Discharge Permits will not be required for those chemicals already covered by the Offshore Chemicals Regulations (2002) as amended (i.e. base oils, lubricants etc.). The 2011 amendment redefined the term 'offshore installation' to encompass all pipelines and the term 'release' to cover all unintentional oil emissions. Intentional emissions are referred to as 'discharges'.	Produced water discharges will be permitted via a variation to the Shearwater Platform's existing OPPC permit. Machinery space drainage water is excluded from these Regulations as it is covered by The Merchant Shipping (Prevention of Oil Pollution) Regulations 1996 (as amended).
The Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation) Regulations 1998 and The Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation Convention) (Amendment) Regulations 2015	These Regulations require that every offshore installation and oil-handling facility must have an approved oil pollution emergency plan (OPEP), setting out arrangements for responding to incidents that cause or may cause a hydrocarbon pollution incident at sea. The OPEP must detail methods to prevent such pollution or reducing or minimising its effect. The 2015 Amendment Regulations implement the EU Offshore Safety Directive (2013/30/EU) (EU OSD)	Approved OPEPs will be in place for all lifecycle phases of the Columbus Development.
The Offshore Installations (Emergency Pollution and Control) (EPC) Regulations 2002	These Regulations give the government powers to intervene in the event of an incident or accident involving an offshore installation where: • There is, or may be a risk of, significant pollution; • An operator is failing or has failed to implement effective control and preventative operations. OPRED's role is to monitor, and if necessary intervene, to protect the environment in the event of a threatened or actual pollution incident in connection with an offshore installation.	Approved OPEPs will be in place for all lifecycle phases of the Columbus Development and will incorporate the requirements of the EPC Regulations.

Legislation	Summary of Requirements	Relevance to Columbus Development
The Offshore Petroleum Licensing (Offshore Safety Directive) Regulations 2015	These Regulations introduce the specific licensing requirements of the EU OSD. The Regulations stipulate that the licensee cannot appoint an installation or well operator without giving written notice to the licensing authority and place a duty on the licensee to ensure that there are adequate provisions to cover any liabilities that may arise from the offshore operations. They also make provision for the licensing authority, in exceptional circumstances (such as the dismissal of an operator), to appoint operators in respect of those licences.	Serica is offshore licensee and will be the appointed well and field operator, approved by the OGA.
OSPAR Recommendation 2003/5 to Promote the Use and Implementation of Environmental Management Systems by the Offshore Industry	All operators of offshore installations on the UKCS are required to have in place an independently verified Environmental Management System (EMS) designed to achieve: the environmental goals of the prevention and elimination of pollution from offshore sources and of the protection and conservation of the maritime area against other adverse effects of offshore activities and to demonstrate continual improvement in environmental performance. OSPAR recognises the ISO 14001 & Eco-Management and Audit Scheme International standards as containing the necessary elements to fulfil these requirements. All operators are also required to provide a public statement of their environmental performance on an annual basis.	Prior to being appointed as well operator, Serica is planning to get the OMS externally verified against the ISO14001 standard and will preferentially select contractors with suitable management systems in place prior to operations. Major contractors will have suitable EMS in place and will comply with the requirements of the Offshore Safety Directive.
OSPAR Decision 98/3 on the disposal of Disused Offshore Installations	This decision prohibits the dumping and leaving wholly or partially in place of disused offshore installations with some exceptions for large structures (derogation cases).	On cessation of production at the field, the Columbus field will be decommissioned in its final state in accordance with the requirements of prevailing UK and international law and following a Comparative Assessment of the decommissioning options and an EIA.
OSPAR Recommendation 2001/1 for the Management of Produced Water from Offshore Installations	This recommendation requires that any plans to construct new offshore installations should endeavour for zero discharges of oil in produced water to sea. The dispersed oil-in-water content of produced water may not exceed a monthly average of 30 milligrams per litre or a maximum of 100 milligrams per litre at any time.	Produced water will be treated to meet regulatory standards stipulated in the Shearwater Platform's existing OPPC permit.
The Energy Act 2008	Part 4A of the Energy Act 2008 administers control for Section 34 of the Coastal Protection Act which requires a permit for the placement of surface and some subsurface structures deemed to pose a navigation risk. It allows OPRED to insist upon the provision of navigational markings that are considered appropriate for the proposed offshore structure or operations.	Consent to Locate permits will be in place for the MODU during drilling operations and for any anchored vessels used during the installation operations.

Legislation	Summary of Requirements	Relevance to Columbus Development
The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)	The Convention was designated to minimise pollution of the seas including dumping of wastes, oil and exhaust pollution. The Convention is made up of six annexes: • Annex I – covers pollution from oil and oily water (transposed into UK legislation through The Merchant Shipping Act 1995 and The Merchant Shipping (Prevention of Oil Pollution) Regulations 1996 (as amended)); • Annex II – covers pollution by noxious liquid substances in bulk (transposed into UK legislation through The Merchant Shipping (Dangerous or Noxious Liquid Substances in Bulk) Regulations 2004); • Annex III – covers pollution by harmful substances carried by sea in packaged form (transposed into UK legislation through The Merchant Shipping Act 1995); • Annex IV – covers pollution through sewage from ships (transposed into UK legislation through The Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008 (as amended)); • Annex V – covers pollution by garbage from ships (transposed into UK legislation through The Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008 (as amended)); • Annex VI – covers prevention of air pollution from ships (transposed into UK legislation by The Merchant Shipping (Prevention of Air Pollution from Ships) Regulations 2008 (as amended)).	The MODU and all other contracted vessels will meet MARPOL requirements throughout all stages of the project. This includes, but is not limited to, adhering to regulations and limits on oily discharges (drainage water, crude oil washing etc.), sewage, garbage, and emissions to air.
The Marine (Scotland) Act 2010	This Act covers inshore and offshore waters and provides a framework to help balance the competing demands on Scotland's seas. It introduces a duty to protect and enhance the marine environment and includes measures to help boost economic investment and growth in areas such as marine renewables. It also sets out a marine planning and licensing regime for offshore activities and measures for improved marine conservation through the designation of Scottish Marine Protected Areas.	The planning system and synergistic use of the marine environment has been taken into account throughout the ES (refer to Table A.2).
The Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (as amended)	These Regulations implement the EU Habitats (92/43/EEC) and Birds Directives (79/409/EEC) and ensure that certain activities that may have an effect on important species and habitats can be managed. The 2010 amendment makes it an offence to deliberately disturb European Protected Species (species listed under Annex IV of the Habitats Directive) in such a way as to be likely to impair their ability to survive, breed, or rear or nurture their young; or, in the case of animals of a hibernating or migratory species, hinder their ability to hibernate, migrate or significantly affect the local distribution or abundance of that species.	The potential impacts on species and habitat of importance have been discussed where relevant in Sections 6, 7 and 10. The potential impacts on European Protected Species have been assessed in Section 7. This has concluded that the Columbus Development is not expected to constitute an offence under this legislation.

Legislation	Summary of Requirements	Relevance to Columbus Development
The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (as amended)	These Regulations require consent for geological surveys related to oil and gas activities. The Regulations also require that the Secretary of State consider whether to undertake a Habitats Regulation Assessment (Appropriate Assessment) (HRA / AA) if the proposed activities are likely to have a significant impact on a relevant Natura 2000 site or feature (Annex I habitats, Annex II or European Protected Species).	Separate consents for future geophysical or geotechnical site surveys will be applied for or relevant notifications submitted, as necessary. These may be required prior to installation activities and may be required for monitoring subsea infrastructure during production. As the proposed development is not expected to have a significant effect on a Natura 2000 site, a HRA / AA is not expected to be required.
Marine Strategy Regulations 2010	These Regulations transpose the EU Marine Strategy Framework Directive 2008/56/EC (MSFD) into UK law. The directive aims to establish minimum requirements for member states to develop strategies aiming to protect the marine ecosystem and to ensure economic activities linked to the marine environment are sustainable. Ensures cooperation within the marine regions (North-East Atlantic, Baltic, Mediterranean and Black Sea) by setting up cross-border programmes. These programmes include actions to meet agreed targets to allow the achievement of 'good environmental status' by 2020. Contributes to the creation of a global network of marine-protected areas and launches a dialogue with countries outside the EU.	The requirements of the MSFD have been considered throughout this ES, and also in relation to Scotland's Marine Plan (refer to Table A.2).

A.2 National Marine Policy

Scotland's National Marine Plan was developed following the implementation of the Marine (Scotland) Act 2010 which fulfils the requirements of EU Directive 2014/89/EU by setting out a framework for marine spatial planning to promote the sustainable use of the marine environment (The Scottish Government, 2015). The key policies contained within the Plan that are relevant to the proposed Columbus Development and how these have been incorporated into the proposed operations are provided in Table A.2 below.

Table A.2. General Policies Contained within Scotland's National Marine Plan that are of Relevance to the Proposed Columbus Development

Policy	Relevance to the Columbus Development
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 the Plan.	The Columbus Development has consider the requirements of Scotland's Marine Plan and will be consistent with the sustainable use of the marine environment. Environmental and socio-economic sensitivities within the project zone of influence will be consider throughout operations.
GEN 2 Economic benefit: Sustainable development and use which provides economic benefit is encouraged when consistent with the objectives and outcomes of the Plan.	The Columbus Development will provide economic and social benefit to the UK and Scotland's oil and gas sector in particular, aiding energy security in the future.
GEN 3 Social benefit: Sustainable development and use which provides social benefits is encouraged when consistent with the objectives of the Plan	
GEN 4 Co-existence: Proposals which enable co-existence 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 the Plan.	Serica undertook a scoping exercise with statutory consultees and other stakeholders prior to the submission of the ES covering the Lomond offtake option in 2011 to ensure that the expectations of concerned parties were incorporated into the project at an early stage. Serica also met with BEIS in May 2018 to discuss the Columbus project. The outcomes of scoping and consultation are detailed in Section 1 and Appendix B of this ES. Continued liaison with other users of the area will be undertaken throughout operations to achieve a synergistic approach to the development of the area.
GEN 5 Climate change: Marine planners and decision makers must act in the way best calculated to mitigate, and adapt to, climate change.	Serica and its contractors are committed to minimising atmospheric emissions where possible. Potential climate change impacts are assessed in Section 8.

Policy	Relevance to the Columbus Development
GEN 9 Natural heritage: Development and use of the marine environments must: a) Comply with legal requirements for protected areas and protected species; b) Not result in significant impact on the national status of PMFs; c) Protect and, where appropriate, enhance the health of the marine area.	The environmental baseline and potential presence of protected species or habitats, including PMFs has been fully characterised through the environmental survey work and desktop study. The ES has undertaken an assessment of the potential impacts of certain aspects on potentially sensitive receptors and has identified, where appropriate, mitigation measures to manage potential impacts.
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.	Where possible, vessels originating from European waters will be preferentially selected, to minimise the possibility of introduction of potentially invasive species. Ballast water exchange will be undertaken offshore. Relevant vessels will have ballast water management systems and procedures in place.
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.	Serica and its contractors will adhere to the Waste Hierarchy Principles and will minimise the generation of waste as a priority. Vessels including the MODU, will have Garbage Management Plans in place in accordance with MARPOL 73/78 which will detail waste handling, storage and disposal procedures to minimise the generation of marine litter.
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 (WFD), MSFD or other related Directives apply.	The MSFD aims to minimise concentrations of contaminants in biota, sediments and water. Legislation such as The Offshore Chemicals Regulations (2002), and enacting legislation, and The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended) are the key legislation that govern the discharges of certain contaminants from oil and gas activities. It is recognised that standards of contaminants are generally only exceeded for legacy chemicals that are toxic, persistent and that will bioaccumulate and in areas close to the sources of historic pollution (DEFRA, 2015). Serica and its contractors will minimise the discharge of contaminants into the marine environment In addition, chemical risk assessment will be undertaken to identify that chemicals will not have significant effects on the marine environment. Note that the WFD applies to inshore waters only and is therefore not applicable to the Columbus Development.

Policy	Relevance to the Columbus Development
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.	The potentially significant environmental impacts on sensitive marine fauna (specifically marine mammals and fish) that may arise from noise generated throughout the life of the proposed Columbus Development is assessed in Section 7 of this ES. To minimise potential impacts on marine fauna, the generation of underwater noise will be minimised where possible and any piling activities in particular will adhere to the JNCC protocol for minimising the risk of injury to marine mammals (JNCC, 2010b).
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.	Serica and its contractors are committed to minimising atmospheric emissions where possible. The sources of atmospheric emissions throughout the project have been identified and quantified in Section 2 based on worst-case assumptions emissions. The potential impacts of atmospheric emissions have been discussed in Section 8 and are expected to disperse rapidly and become diluted with increasing distance from the source.
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.	These policies have been addressed in the EIA process through scoping exercise, the outcome of which is discussed in Section 1 of this ES. In addition, The Offshore Petroleum Production and Pipelines (Assessment of Environmental Effects) Regulations 1999 (as amended) also allows for public participation following the submission of the ES.
GEN 18 Engagement: Early and effective engagement should be undertaken with the general public and all interested stakeholders to facilitate planning and consenting processes.	
GEN 19 Sound evidence: Decision making in the marine environment will be based on sound scientific and socio-economic evidence.	This ES has been based on robust data sources to inform the EIA process, including seven surveys which have been conducted in the area of the Columbus field during the years 2006, 2007, 2008, 2010 and 2015 (refer to Section 3.1).
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 related to the potentially significant aspects have been identified in the impact assessment sections of this ES (Sections 5 – 10).

Table A.3 outlines the marine planning policies for the oil and gas sector (The Scottish Government, 2015). These policies outline how oil and gas activities are expected to develop in the longer term and issues to be addressed to ensure they grown sustainably. Policies for each sector should be read in conjunction with the general policies provided in Table A.2. Key objectives for the offshore oil and gas sector are:

- Maximise the recovery of reserves through a focus on industry-led innovation, enhancing the skills base and supply chain growth;
- An industry which delivers high-level risk management across all its operations and that it is especially vigilant in more testing current and future environments;
- Continued Technical development of enhanced oil recovery and exploration, and the associated seismic activity carried out according to the principles of the BAT and Best Environmental Practice (BEP) approach;
- Where possible, to work with emerging sectors to transfer the experience, skills and knowledge built up in the oil and gas industry to allow other sectors to benefit and reduce their environmental impact.

In addition to the sector-specific policies described in Table A.3, a number of key issues for marine planning have been identified for the oil and gas sector including 'interactions with other users'. Key interactions with oil and gas activities include renewables, carbon capture and storage (CCS) and fishing. Of these interactions, only fishing is of relevance to the proposed Columbus Development due to a lack of suitable conditions and infrastructure for renewables or CCS. The Marine Plan highlights the requirement for an 'exclusion buffer zone' around infrastructure and the resultant exclusion of fishing activity or avoidance of areas due to the presence of seabed obstructions. These potential interactions have been assessed in Section 5 of this ES.

Table A.3. Sector Policies Related to Oil and Gas Developments According to Scotland's National Marine Plan

Marine Planning Policies	Supported Strategic Objectives	Relevance to the Columbus Development
OIL & GAS 1: The Scottish Government will work with OPRED, the OGA 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 BAT and BEP. Consideration will be given to key environmental risks including the impacts of noise, oil and chemical contamination and habitat change.	Economic Social Climate Change – Adaptation Marine Ecosystem	The development concept for Columbus comprises a single subsea production well connected by spool pieces to the Arran to Shearwater subsea pipeline via a tie-in structure, thereby minimising the impact on the environment and other users of the sea. Key environmental risks have been identified in the impact assessment sections of this ES (Sections 5 – 10).
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 processes.	Economic Social	Following cessation of production at Columbus, a comparative assessment and EIA of the decommissioning options for the field will be undertaken to determine the best fate for all infrastructure from a technical, economic, safety and environmental perspective.

Marine Planning Policies	Supported Strategic Objectives	Relevance to the Columbus Development
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.	Economic Marine Ecosystem	The development concept for Columbus comprises a single subsea production well connected by spool pieces to the Arran to Shearwater subsea pipeline via a tie-in structure, thereby minimising the impact on the environment and other users of the sea.
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.	Social Marine Ecosystem	Accidental events that may arise during the Columbus Development have been assessed in Section 10 this ES, along with measures in order prevent their occurrence or to minimise any potentially significant adverse effects.

Appendix B: Columbus Development Consultation Responses

This appendix summarises the responses received during the EIA consultation process carried out as part of the previous Columbus Development ES (BEIS Ref: D/4085/2010) (refer to Section 1.3) and notes where the issues raised have been considered and addressed in this ES.

No.	Organisation	Issues Raised	Comments to Issues Raised	ES Section Reference
1	DECC (comments received on 27th May 2010)	The ES would need to quantify estimated additional produced water volume from the proposed Columbus field development.	The produced water arising from the Columbus field has been quantified in Section 2.9.1, discussed in Section 2.9.4 and assessed in Section 9. Note it is proposed to discharge produced water at the Shearwater platform.	Sections 2.9.1, 2.9.4 & 9
2		The production figures detailed in the ES should reflect those applied for within the FDP.	The production profiles presented in the ES are worst case. At the time of writing the ES, well design work is ongoing and consideration is being given to a well which has a completion that is c. 5,000 ft shorter than the one that has been assessed in the ES. The production profiles presented in the FDP are therefore under review and may decrease compared to the ones presented and assessed in the ES.	Section 2.9.1
3		Within the ES it would be useful to include the pipeline route and host platform options considered and the reasoning behind the chosen pipeline route and host platform.	A concept selection study has been undertaken to determine the optimum development plan for the Columbus field in terms of economics and technical risk/operability, with consideration also given to the potential for health, safety and environmental impacts. The results from this study are presented in Section 2.2.	Section 2.2
4		The proposed ES should address OPPC implications, acknowledge requirement/non-requirement of any new equipment to deal with the increase in production and what impact this will have on power generation. The ES will need to assess increase in atmospheric emissions (CO_2 emissions etc.) due to increase in production.	There will be an incremental power demand at Shearwater from bringing the Columbus production online but no new power generation facilities will be required. There will also be temporary increases in flaring as a result of Columbus production coming online due to initial start-up, planned shut down and start-up and unplanned shut down and start-up. Atmospheric emissions resulting from the process of Columbus fluids at the Shearwater platform are assessed in Section 8.	Sections 2.9 & 8.4.2

No.	Organisation	Issues Raised	Comments to Issues Raised	ES Section Reference
5		The proposed ES should also address any modifications necessary to the relevant topsides.	No additional significant modifications to the Shearwater platform are required in preparation of the tie-in of the Columbus Development.	Section 2.5
6		It is important that a pipeline route / rig site survey be undertaken prior to ES submission, so that results are included in the ES. Surveys should cover the whole impact area of the operations including anchor positions if being used.	A number of site surveys have previously been conducted within the proposed Columbus Development area. The locations of these surveys are displayed in Figure 3.1 in Section 3.1. These surveys are referred to throughout the report where relevant. In addition, Serica has conducted a further habitat assessment and EBS at the proposed location of the CDev-1 well and along the proposed deviated section of the Arran pipeline route in May 2018. At the time of writing this ES, the results of the 2018 survey are not yet available. The reports will be submitted to BEIS and other interested parties as soon as they become available.	Sections 3.1 & 3.3 Appendix D
7		Consideration should be given to existing and new developments in the area, the cumulative impact on the area and the possibility of significant adverse effects from the cumulative effects from installation phase and production must be adequately assessed within the ES.	Cumulative effects on the area from the development are likely to be minimal. These are discussed in the impact assessment sections of the ES.	Sections 5.7, 6.8, 7.6, 8.8, 9.7 & 10.10.
8		The proposed ES should assess the total area of impact due to the subsea installation and pipeline footprint including any rock dumping / mattressing requirements. This should also include proposed trenching/backfilling method.	Methods of pipeline laying, trenching and backfilling, rock dumping requirements and mattress requirements are discussed in Section 2.8. The total subsea installation and pipeline foot print are discussed in Section 5.3.	Sections 2.8 & 5.3
9		The ES would need to address fishing hazard's associated with anchor mounds and proposal to conduct a post drilling (re-entry) survey to confirm anchor mounds are either not present or do not require remediation.	A post-development survey will be conducted, and any anchor scars, spud can depressions and trench berms that are considered to pose a snagging risk will be flattened using a chain mat. It should be noted that fine sand dominates the areas, therefore the creation of significant anchor mounds is unlikely.	Sections 5.3.2 & 5.4.2.

No.	Organisation	Issues Raised	Comments to Issues Raised	ES Section Reference
10		Close proximity of the proposed development to the transboundary median line would need to be taken into account in the ES and Oil Pollution Emergency Plan (OPEP) for drilling and production phase should address this in detail.	Impacts upon Norwegian waters are not considered to be significant and have been assessed where relevant in the impact assessment sections of the ES.	Sections 5.6, 6.7, 7.6, 8.7, 9.6 & 10.9
11		Please ensure that the ES only details project specific commitments.	A summary of project specific commitments is provided in the report.	Section 11.4
12		Decommissioning of sub-sea infrastructure should detail design features including whether the pipelines and umbilical are designed to be removed, if not, providing adequate justification.	Provisions for the decommissioning of subsea infrastructure has been discussed in the ES.	Section 2.10
13		JNCC and Marine Scotland have also been consulted – it is important that Serica take on board any concerns/comments they might have.	See comments 14, 15 and 16 addressed below.	-
14	Marine Scotland (comments received on 21st July 2008)	The most up to date fisheries information should be included in the ES and potential interactions between fishing operations and sub-sea installations identified and proposed ameliorative actions detailed.	The most up-to-date fisheries information has been included in detail, through data supplied by Marine Scotland (2017a) and DECC (2016). Serica propose that all subsea structures outside of the host facility 500 m exclusion zone will be protected with fishing friendly protection structures. Concrete mattresses used for support to exposed pipeline ends will not be overlapped and will be of the tapered edge design to promote overtrawlability. Pipelines will be buried to a depth anticipated to prevent upheaval buckling and will be backfilled to minimise seabed obstructions. This will in turn minimise any amount of rock dumping that may be required for mitigation of upheaval buckling.	Sections 3.8.1, 2.7, 2.8 & 5.4

No.	Organisation	Issues Raised	Comments to Issues Raised	ES Section Reference
15		As there are not vast quantities of seabed information for the site, FRS suggest a slightly heavier emphasis should be placed on the collection of infaunal data, i.e. a more formal seabed community assessment should be conducted rather than using the grab sampling to sea truth the acoustic results.	Since the initial consultation exercise was undertaken, additional environmental baseline surveys (EBSs) have been undertaken in UKCS Blocks 23/16 and 23/21 including a pipeline route survey from Columbus to Lomond in August 2010 (Gardline, 2010a; 2010b) and a pipeline route survey for the Arran pipeline in 2017 (Gardline, 2015a; 2015b; 2016a). These surveys included grab samples and visuals of the seabed. In addition, a further habitat assessment and EBS at the proposed location of the CDev-1 well and along the proposed deviated section of the Arran pipeline route took place May 2018. As such Serica considers that sufficient data has been gathered and analysed to acquire a good understanding of the surrounding area upon which to undertake the EIA.	Sections 3.1.1 & Appendix D
16	JNCC	JNCC indicated no concerns at the present time.	-	-
17	SFF (comments received on 10th September 2008)	Due consideration to be given to the concerns of the fishing industry with regard to snagging of fishing gear on subsea oil and gas infrastructure. Highlighting that lives have been lost due to coming fast on subsea structures in recent years;	The deviated section of the pipeline will be trenched and mechanically backfilled. Where the burial depth is not achieved, exposed sections outside the exclusion zone will be protected using rock placement, which will be deposited at a gradient designed to allow fishing gear to pass without snagging. All seabed infrastructure will be designed to be fishing friendly and a 500 m safety exclusion zone will be applied for around the Xmas tree and CTIS, which will be clearly marked on navigation charts. A post-development survey will be conducted, and any anchor scars, spud can depressions and trench berms that are considered to pose a snagging risk will be flattened using a chain mat. With the exception of areas of spot rock-dump, all protection material will be contained within safety exclusion zones.	Sections 2.7, 2.8 & 5.4
18		Sufficient burial and backfill of pipelines to ensure minimal seabed obstructions and to prevent upheaval buckling;		
19		Use of fishing friendly protection structures on structures located outside of the 500 metre exclusion zones;		
20		Use of tapered edge concrete mattresses to promote overtrawlability of the structures and to prevent damage to subsea oil and gas infrastructure by fishing gear.		

No.	Organisation	Issues Raised	Comments to Issues Raised	ES Section Reference
21	Ministry of Defence	Confirmed that the Ministry of Defence have no safeguarding concerns to the Columbus development.	-	-

Appendix C: Environmental Aspects Register

Key to Significance (Risk to Environment) Ranking:

Positive	Low	Medium	High

Event Type: P = Planned, U = Unplanned/Accidental
Likelihood: 'A' (one off / remote) to 'D' (continuous / very likely) (refer to Table 4.1 in Section 4 of the ES)
Consequence: 1 (negligible) to 5 (severe), or can be positive (refer to Table 4.2 in Section 4 of the ES)

C.1 Drilling Environmental Aspects Register

Drilling Environmental Aspects Register														
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D1. Physical Presence														
D1.1	P	Presence of MODU	Shipping	Potential for navigation hazard Potential for interference with other sea users	• An up to date collision risk assessment and shipping density study will be undertaken prior to the drilling phase of the Development project. • Consent to Locate will be in place for the MODU under Part 4A of the Energy Act 2008.	C	2	M	Y	• Early consultation and ongoing engagement with other sea-users (stakeholders); • Appointment of an onshore FLO to maintain good communication with local fisheries and co-ordinate activities throughout the drilling phase.	C	2	M	Y

Drilling Environmental Aspects Register														
						Impact					Residual Impact			
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Likelihood	Consequence	Risk	Significant (Y/N)	Additional Mitigation Measures	Likelihood	Consequence	Residual Risk	ALARP
			Fishing		• 500m safety exclusion zone will be designated around the MODU. • Dedicated ERRV present to monitor movements of other vessels in the area and prevent them entering the exclusion zone. • Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, Kingfisher, NAVTEX / NAVAREA warnings and fisheries notices.	C	2	M	Y		C	2	M	Y
D1.2	P	Presence of MODU exclusion zone / Semi-submersible MODU anchors	Fishing	Loss of fishing grounds. Economic impact on commercial fisheries	• Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, Kingfisher, NAVTEX / NAVAREA warnings and fisheries notices.	C	3	M	Y	• Early consultation and ongoing engagement with other sea-users (stakeholders); • Appointment of an onshore FLO to maintain good communication with local fisheries and co-ordinate activities throughout the drilling phase.	C	3	M	Y
D1.3	P	Presence of support vessels	Fishing	Potential for navigation hazard. Potential for interference with other sea users	• Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, Kingfisher, NAVTEX / NAVAREA warnings and fisheries notices.	C	1	L	N	• Early consultation and ongoing engagement with other sea-users (stakeholders); • Appointment of an onshore FLO to maintain good communication with local fisheries and co-ordinate activities throughout the drilling phase.	C	1	L	-
			Shipping			C	1	L	N		C	1	L	-

Drilling Environmental Aspects Register																
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D1.4	P	Artificial light on MODU / support vessels	Seabirds	Seabirds are easily disorientated by intense sources of artificial light. In some cases it can result in mortality.	-	B	1	L	N	• No additional mitigation measures proposed.	B	1	L	-
D1.5	U	Dropped objects	Fishing	Potential risk of snagging on fishing gears or anchors	• Dropped objects to sea will be immediately reported and, where possible, objects will be recovered. • Debris will be identified during post-decommissioning surveys. Anything that cannot be recovered will be reported to the relevant authorities to be included on navigation charts.	B	2	L	N	• Lifting procedures in place on the MODU and vessels.	B	2	L	-
D2. Seabed Disturbance														
D2.1	P	MODU anchoring (in case semi-submersible MODU is used) or spud cans (if HDJU is used)	Water Quality	Anchors, anchor chains or spud cans may cause seabed disturbance, disturbance to benthic fauna, and a temporary increase in turbidity during deployment.	-	C	2	M	Y	• Use the appropriate number of anchors and length of anchor chains to maintain stability and integrity. • A detailed anchor pattern for the use of a semi-submersible drill rig or a spud can location assessment for the use of a HDJU will be developed prior to mobilisation.	C	2	M	Y
			Sediments			C	2	M	Y		C	2	M	Y

Drilling Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
			Seabed Communities	Anchors and anchor chains may disturb contaminated sediments generated by previous drilling campaigns.		C	2	M	Y		C	2	M	Y
D2.2	P	Discharge of drill cuttings, muds, and cement	Water Quality	Potential smothering of seabed organisms. Potential loss of seabed habitat. Potential toxicity effects of chemicals. Pollution of the sediments and overlying water column. Increased BOD	• A full Chemical Hazard Assessment and Risk Management (CHARM) assessment of the proposed chemicals to be used and discharged, as required under the Offshore Chemicals Regulations 2002 (as amended), will be undertaken during the permitting process prior to drilling operations commencing.	C	1	L	N	• As part of chemical selection and assessment process, less hazardous alternatives will be sought in preference for any chemicals identified to be high risk (e.g. those with substitution warnings). • WBM will be mixed offshore to ensure that only what is required is used.	C	1	L	N
			Sediments			C	2	M	Y		C	2	M	Y
			Seabed Communities			C	2	M	Y		C	2	M	Y
D2.3	U	Dropped objects	Sediments	Dropped objects may cause seabed disturbance and disturbance to	• Dropped objects to sea will be immediately reported and, where possible, objects will be recovered. • Debris will be identified during post-decommissioning surveys.	B	2	L	N	• Lifting procedures in place on the MODU and vessels.	B	2	L	-

Drilling Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
			Seabed Communities	benthic habitats and communities in the vicinity of the object. Potential loss of seabed habitat.	Anything that cannot be recovered will be reported to the relevant authorities to be included on navigation charts.	B	2	L	N		B	2	L	-
D3. Noise and Vibration														
D3.1	P	Noise from MODU and support vessels	Fish	Potential behavioural disturbance or physiological impacts to sensitive marine fauna	-	C	2	M	Y	• No additional mitigation measures proposed.	C	2	M	Y
			Marine Mammals			C	2	M	Y		C	2	M	Y
D3.2	P	Noise from helicopters	Seabirds	Potential disturbance to seabirds and fish and marine	-	B	2	L	N	• Use of existing fly paths from support locations onshore to minimise disturbance corridor for onshore/coastal species.	B	2	L	-

Drilling Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
			Fish	mammals if noise is transmitted into the water column		B	2	L	N		B	2	L	-
			Marine Mammals			B	2	L	N		B	2	L	-
D4. Atmospheric Emissions														
D4.1	P	Power generation (diesel) on MODU / support vessels: combustion products (CO_2, CO, SO_X, NO_X, etc.)	Air Quality	Minor contribution to global warming, acidification & photochemical smog. Emissions from diesel generation may also contain small particulates which can have health effects if inhaled.	• Use of fuel oil with a sulphur content of no more than 0.1% in accordance with MARPOL and UK regulatory requirements. • Vessels and contractors will have UK/International Air Pollution Prevention (UKAPP/IAPP) Certificates. • All combustion equipment will have a maintenance programme and will be tested regularly.	C	2	M	Y	• As part of the contractor selection processes, MODU and vessel contractors will be required to demonstrate that they have control processes in place to minimise environmental impacts (i.e. maintain equipment) through review of International Marine Contractors Association (IMCA) / Offshore Vessel Inspection Database (OVID) inspections.	C	2	M	Y

Drilling Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D4.2	P	Flaring of the CDev-1 well during well clean-up and testing: combustion products (CO_2, CO, SO_X, NO_X, CH_4 etc.)	Air Quality	Minor contribution to global warming, acidification & photochemical smog. Emissions may also contain small particulates which can have health effects if inhaled.	• Use of fuel oil with a sulphur content of no more than 0.1% in accordance with MARPOL and UK regulatory requirements. • Vessels and contractors will have UK/International Air Pollution Prevention (UKAPP/IAPP) Certificates. • All combustion equipment will have a maintenance programme and will be tested regularly.	C	2	M	Y	• During well testing and clean-up, high combustion efficiency burners will be used and the volume flared will be kept to a practical minimum.	C	2	M	Y
D4.3	P	Dust generation from mud / cement mixing equipment	Air Quality	Small particulates can have health effects if inhaled.	• Working procedure will be in place, to include the use of suitable PPE.	B	2	L	N	• No additional mitigation measures proposed.	B	2	L	-
D4.4	P	Solvents (VOCs) from painting and cleaning	Air Quality	Minor contribution to atmospheric pollution.	• Working procedure will be in place, to include the use of suitable PPE.	B	2	L	N	• No additional mitigation measures proposed.	B	2	L	-
D4.5	U	Leak of gas from a well	Air Quality	Atmospheric pollution associated with the release of unignited or ignited natural gas	• Verification of maintenance programme; • Emergency response plans and equipment will be in place.	B	2	L	N	• No additional mitigation measures proposed.	B	2	L	-

Drilling Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D4.6	U	Use of firefighting equipment	Air Quality	Release of CO_2 which contributes to the pool of greenhouse gases in the atmosphere.	-	B	2	L	N	• Equipment not to be used in exercise scenarios.	B	2	L	-
D5. Marine Discharges															
D5.1	P	Discharge of WBM drill cuttings and muds	Water Quality	Decline in water quality at the discharge point. Potential toxicity impacts of chemicals. Pollution of the water column. Increased BOD	• A full CHARM analysis assessment of the proposed chemicals to be used and discharged, as required under the Offshore Chemicals Regulations 2002 (as amended), will be undertaken during the permitting process prior to drilling operations commencing.	C	1	L	N	• As part of chemical selection and assessment process, less hazardous alternatives will be sought in preference for any chemicals identified to be high risk (e.g. those with substitution warnings). • Cuttings / mud cleaning equipment will ensure optimal cuttings cleaning prior to discharge. • WBM will be mixed offshore to ensure that only what is required is used. • A rig audit will be conducted to ensure that the rig is in compliance with all relevant guidelines and legislation.	C	1	L	-
			Sediments			C	2	M	Y		C	2	M	Y
			Seabed Communities			C	2	M	Y		C	2	M	Y
			Plankton			C	1	L	N		C	1	L	-
			Fish			C	1	L	N		C	1	L	-

Drilling Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D5.2	P	Discharge of cement	Water Quality	Decline in water quality at the discharge point. Potential toxicity impacts of chemicals. Pollution of the water column. Increased BOD	• A full CHARM analysis assessment of the proposed chemicals to be used and discharged, as required under the Offshore Chemicals Regulations 2002 (as amended), will be undertaken during the permitting process prior to drilling operations commencing.	C	1	L	N	• As part of chemical selection and assessment process, less hazardous alternatives will be sought in preference for any chemicals identified to be high risk (e.g. those with substitution warnings).	C	1	L	-
			Sediments			C	2	M	Y		C	2	M	-
			Seabed Communities			C	2	M	Y		C	2	M	-
			Plankton			C	1	L	N		C	1	L	-
			Fish			C	1	L	N		C	1	L	-
D5.3	P	Discharge of completion chemicals	Water Quality	Decline in water quality at the discharge point. Potential toxicity impacts of chemicals. Pollution of the water column. Increased BOD	• A full CHARM analysis assessment of the proposed chemicals to be used and discharged, as required under the Offshore Chemicals Regulations 2002 (as amended), will be undertaken during the permitting process prior to drilling operations commencing.	C	1	L	N	• As part of chemical selection and assessment process, less hazardous alternatives will be sought in preference for any chemicals identified to be high risk (e.g. those with substitution warnings).	C	1	L	-
			Sediments			C	1	L	N		C	1	L	-
			Seabed Communities			C	1	L	N		C	1	L	-
			Plankton			C	1	L	N		C	1	L	-
			Fish			C	1	L	N		C	1	L	-

Drilling Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D5.4	P	Discharge of rig chemicals	Water Quality	Decline in water quality at the discharge point. Potential toxicity impacts of chemicals. Pollution of the water column. Increased BOD	• A full Chemical Hazard Assessment and Risk Management (CHARM) analysis assessment of the proposed chemicals to be used and discharged, as required under the Offshore Chemicals Regulations 2002 (as amended), will be undertaken during the permitting process prior to drilling operations commencing.	C	1	L	N	• As part of chemical selection and assessment process, less hazardous alternatives will be sought in preference for any chemicals identified to be high risk (e.g. those with substitution warnings).	C	1	L	-
			Sediments			C	1	L	N		C	1	L	-
			Seabed Communities			C	1	L	N		C	1	L	-
			Plankton			C	1	L	N		C	1	L	-
			Fish			C	1	L	N		C	1	L	-
D5.5	P	MODU and vessel ballast water exchange	Plankton	Potential for introduction of alien invasive species that can alter the local, and possibly wider ecosystem	• Adherence to IMO and UK guidelines on ballast water discharge.	A	1	L	N	• Consideration shall be given to the previous working locations of vessels during the design contractor selection process to reduce the likelihood of introducing non-native species into the ecosystem; • Pre start-up inspections and audits will ensure that the MODU has suitable systems in place to manage ballast water uptake and discharge.	A	1	L	-
			Fish			A	1	L	N		A	1	L	-

Drilling Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D5.6	P	Discharge of fluids contaminated with LTOBM (during well clean-up)	Water Quality	May cause localised pollution in the water column and have toxicity effects on marine fauna. Fish and marine mammals will avoid contaminated areas, and could potentially reduce their foraging areas	-	B	1	L	N	• Brine to be continuously circulated in the well until suitable for discharge.	B	1	L	-
			Plankton			B	1	L	N		B	1	L	-
			Fish			B	1	L	N		B	1	L	-
			Seabirds			B	1	L	N		B	1	L	-
			Marine Mammals			B	1	L	N		B	1	L	-

Drilling Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D5.7	P	Discharge of grey and black water from MODU and vessels	Water Quality	Decline in local water quality, potential increase in BOD due to bacterial growth and proliferation and may ultimately lead to an increase in opportunistic species. Some marine fauna may avoid contaminated areas.	• Black (sewage) and grey water will be collected, treated to meet the requirements of MARPOL and UK Regulations prior to being discharged to sea.	C	1	L	N	• Good housekeeping standards will be maintained on the MODU and vessels; • A rig audit will be conducted to ensure that the rig is in compliance with all relevant guidelines and legislation.	C	1	L	-
			Plankton			C	1	L	N		C	1	L	-
			Fish			C	1	L	N		C	1	L	-
			Seabirds			C	1	L	N		C	1	L	-
			Marine Mammals			C	1	L	N		C	1	L	-

Drilling Environmental Aspects Register																
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D5.8	P	Release of food waste to sea from MODU and vessels	Water Quality	Decline in local water quality, potential increase in BOD due to bacterial growth and proliferation and may ultimately lead to an increase in opportunistic species. Scavenging seabirds may be attracted to the discharge and may be exposed to other hazards.	• Food waste will be disposed of to meet the requirements of MARPOL and UK Regulations.	C	1	L	N	• Good housekeeping standards will be maintained on the MODU and vessels; • A rig audit will be conducted to ensure that the rig is in compliance with all relevant guidelines and legislation.	C	1	L	-
			Plankton			C	1	L	N		C	1	L	-
			Fish			C	1	L	N		C	1	L	-
			Seabirds			C	1	L	N		C	1	L	-
			Marine Mammals			C	1	L	N		C	1	L	-

Drilling Environmental Aspects Register														
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D5.9	P	Discharge of oily water from machine space drainage on MODU and vessels	Water Quality	May cause localised, short term pollution in the water column potentially impacting marine fauna (e.g. toxicity effects, reduction of foraging areas through avoidance).	• A United Kingdom Oil Pollution Prevention Certificate (UKOPP) or IOPP Certificate for a foreign flagship unit is required. • All discharges will be treated and discharged according to MARPOL and UK Regulations.	B	2	L	N	• Closed drainage system will be in place for areas where there may be oily water streams from equipment. • Good housekeeping standards will be maintained on the MODU and vessels. • A rig audit will be conducted to ensure that the rig is in compliance with all relevant guidelines and legislation.	B	2	L	-
			Plankton			B	2	L	N		B	2	L	-
			Fish			B	2	L	N		B	2	L	-
			Seabirds			B	“	L	N		B	2	L	-
			Marine Mammals			B	2	L	N		B	2	L	-
D5.10	P	Runoff from MODU / vessel decks	Water Quality	Rainwater runoff may contain traces of utility hydrocarbons or chemicals and may have temporary localised impacts on water quality and fauna	• Chemical risk assessment will be undertaken to identify the risk profile of relevant chemicals being used and/or discharged in accordance with the Offshore Chemicals Regulations 2002 (as amended). • Spills kits on board the MODU and vessels to clean-up spills of utilities hydrocarbons or chemicals before they can enter the sea.	B	1	L	N	• As part of chemical selection and assessment process, less hazardous alternatives will be sought in preference for any chemicals identified to be high risk (e.g. those with substitution warnings). • Good housekeeping standards will be maintained on the MODU and vessels. • A rig audit will be conducted to ensure that the rig is in compliance with all relevant guidelines and legislation.	B	1	L	-
			Plankton			B	1	L	N		B	1	L	-
			Fish			B	1	L	N		B	1	L	-

Drilling Environmental Aspects Register														
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D5.11	U	Loss of chemicals during bunkering or general operations	Water Quality	Potential for spills of chemicals which may cause localised toxicity effects on marine fauna and flora and localised pollution of ecosystems.	• Permanent drip trays will be located under process plant, pumps and vessels (on grated decks). • Chemicals will be stored in bunded areas where any spillages can be routed to the closed drainage system. • Small spill kits will be on board the MODU / vessels to clean up deck spills and prevent spilt chemicals reaching the sea. • Bunkering procedures will be put in place to include measures such as, transfer operations to be supervised at all times from the supply vessel and MODU. • Crews will be adequately trained, supervised and regular exercises held to contain and clean-up deck spills. • Routine equipment maintenance programme will be in place with specific emphasis on environmentally critical equipment; • Where feasible, bunkering operations will be kept to good light and weather conditions.	B	2	L	N	• Chemical storage tanks will be equipped with alarm systems and procedure will be in place to minimise and prevent overfilling these storage tanks. • Non-return valves will be installed on transfer hoses and hoses to be tested and inspected as a part of a regular maintenance programme; • Effective management of chemicals to endeavour to reduce the volumes required and therefore the frequency of bunkering. • Use of floating hoses. • A rig audit will be conducted to ensure that the rig is in compliance with all relevant guidelines and legislation. • Tool box talks will highlight the importance of minimising the risk of spills occurring.	B	2	L	-
			Plankton			B	2	L	N		B	2	L	-
			Seabirds			B	2	L	N		B	2	L	-
			Fish			B	2	L	N		B	2	L	-
			Marine Mammals			B	2	L	N		B	2	L	-
			Fishing			B	2	L	N		B	2	L	-

Drilling Environmental Aspects Register														
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D5.12	U	Loss of fuel / utility hydrocarbons during bunkering and general operations	Water Quality	Potential for spills of diesel, LTOBM, base oils and other utility oils which may have toxicity effects on marine fauna and flora and cause localised pollution of ecosystems.	• OPEP will be in place. • Liquid storage areas and areas that might be contaminated with oil are segregated from other deck areas. • Permanent drip trays will be located under process plant, pumps and vessels (on grated decks). • Bunding or additional containment will be provided around plated areas beneath equipment with significant hydrocarbon inventories. • Small spill kits will be on board the MODU / vessels to clean up spilt hydrocarbons deck spills. • Bunkering procedures will be put in place to include measures such as, transfer operations to be supervised at all times from the supply vessel and MODU. • Crews will be adequately trained, supervised and regular exercises held to contain and clean-up deck spills. • Where feasible, bunkering operations will be undertaken in daylight and in good weather conditions.	B	2	L	N	• Utility and fuel storage tanks will be equipped with alarm systems and procedure will be in place to minimise and prevent overfilling these storage tanks. • Non-return valves will be installed on transfer hoses and hoses to be tested and inspected as a part of a regular maintenance programme. • Routine equipment maintenance programme will be in place with specific emphasis on environmentally critical equipment. • Use of floating hoses. • Effective management of fuel / utility hydrocarbons to endeavour to reduce the frequency of bunkering. • A rig audit will be conducted to ensure that the rig is in compliance with all relevant guidelines and legislation. The audit will also cover oil spill response, procedural controls, bunkering and storage arrangements. • Tool box talks will highlight the importance of minimising the risk of spills occurring.	B	2	L	-
			Plankton			B	2	L	N		B	2	L	-
			Seabirds			B	2	L	N		B	2	L	-
			Fish			B	2	L	N		B	2	L	-
			Marine Mammals			B	2	L	N		B	2	L	-
			Fishing			B	2	L	N		B	2	L	-

Drilling Environmental Aspects Register														
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D5.13	U	Loss of containment on MODU due to collision or other major event	Water Quality	Water quality reduced in the vicinity of the spill. Diesel may be dispersed widely in the water column. Toxicity effects on marine fauna, particularly seabirds on the waters' surface, and fish. Fish may become tainted. Fish and marine mammals will avoid contaminated areas, potentially reducing their foraging areas. Loss of biodiversity and revenue.	• Consent to Locate will be in place for the MODU under Part 4A of the Energy Act 2008. • 500m safety exclusion zone will be designated around the MODU. • Dedicated ERRV present during drilling to monitor movements of other vessels in the area and prevent them entering the exclusion zone. • Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, NAVTEX / NAVAREA warnings and fisheries notices. • OPEP and other Emergency Plans will be in place.	A	3	M	Y	• A vessel traffic survey will be undertaken for the area closer to the proposed start of drilling as part of the standard permitting process, together with a collision risk assessment. • Early consultation and ongoing engagement with other sea-users (stakeholders); • Appointment of an onshore FLO to maintain good communication with local fisheries and co-ordinate activities throughout the drilling phase.	A	2	L	-
			Plankton			A	3	M	Y		A	2	L	-
			Sediments			A	3	M	Y		A	2	L	-
			Seabed Communities			A	3	M	Y		A	2	L	-
			Seabirds			A	3	M	Y		A	2	L	-
			Fish			A	3	M	Y		A	2	L	-
			Marine Mammals			A	3	M	Y		A	2	L	-
			Fishing			A	3	M	Y		A	2	L	-
			Shipping			A	3	M	Y		A	2	L	-
			Marine Protected Areas			A	3	M	Y		A	2	L	-

Drilling Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D5.14	U	Loss of containment (hydraulic fluid) from ROV operations	Water Quality	Water quality will be reduced in the vicinity of the release and fluid may be dispersed widely in the water column. Toxicity effects on marine fauna particularly plankton, fish and seabed communities in the vicinity of the subsea release. Fish and marine mammals may avoid contaminated areas, and a spill potentially reduce their foraging areas.	-	B	2	L	N	• Monitoring of ROV operations. • Maintenance and inspection procedures in place for ROV including hydraulic hoses. • Knowledge of subsurface infrastructure and therefore potential snagging hazards in the area.	B	2	L	-
			Plankton			B	2	L	N		B	2	L	-
			Fish			B	2	L	N		B	2	L	-
			Marine Mammals			B	2	L	N		B	2	L	-
			Seabed Communities			B	2	L	N		B	1	L	-

Drilling Environmental Aspects Register														
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D5.15	U	Well blowout during drilling (releasing large quantity of hydrocarbons)	Water Quality	Decline in water quality and toxicity impacts on marine flora (phytoplankton) and fauna. Potential contamination of seabed sediments and toxicity effects on benthic communities. Seabirds, fish and mammals may become physically oiled or may avoid oiled areas. Loss of biodiversity and revenue. Potential shoreline impacts.	• Undertake shallow gas survey prior to drilling. • Environmentally critical elements related to drilling operations will be identified, and a suitable maintenance and testing schedule applied to each. • Well design and construction reviewed by an independent well examiner. • Weighted drilling fluids will provide the primary barrier and the well will be carefully controlled and monitored. The secondary barrier will be the BOP which will be regularly maintained and tested. • Simultaneous operations (SIMOPs) will be actively identified and managed. • Emergency response plans and equipment will be in place. Crews will be adequately experienced and trained in well control techniques. Emergency drills will be held regularly. • OPEP will be in place. • Ongoing verification of well operations by an independent body.	A	3	M	Y	• Review spill mitigation measures of all contractors as part of the contractor selection process. • In the event of a spill incident, rapidly act to stem the flow of hydrocarbons from the well through the necessary shutdown procedures. Mobilise Tier 2 and 3 spill response resources to contain and respond to a spill incident offshore. • If suitable, relief well drilling would be considered to the stem the flow.	A	2	L	-
			Plankton			A	3	M	Y		A	2	L	-
			Sediments			A	3	M	Y		A	2	L	-
			Seabed Communities			A	3	M	Y		A	2	L	-
			Fish			A	3	M	Y		A	2	L	-
			Seabirds			A	3	M	Y		A	2	L	-
			Marine Mammals			A	3	M	Y		A	2	L	-
			Fishing			A	3	M	Y		A	2	L	-
			Shipping			A	3	M	Y		A	2	L	-
			Marine Protected Areas			A	3	M	Y		A	2	L	-
			Tourism & Leisure			A	3	M	Y		A	2	L	-

Drilling Environmental Aspects Register																
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D6. Solid Wastes														
D6.1	P	LTOBM and LTOBM-contaminated cuttings	Land Use	Suitable treatment and disposal facilities required onshore. This may affect future land use options for waste disposal sites. Potential for localised land and air contamination.	• Only licensed and approved onshore handling, treatment and disposal facilities will be used.	B	2	L	N	• Rig and shore base have in place, and are effectively implementing, waste management procedures detailing how wastes will be managed in accordance with the waste hierarchy principles. • Muds will be recycled as far as possible for use in further well sections. • Auditing of waste management contractors to ensure compliance with national and international regulations.	B	2	L	-
			Air Quality			B	2	L	N		B	2	L	-
D6.2	P	Disposal of operational waste to shore	Land Use	Effects of onshore disposal of waste depends on the nature of the waste and disposal site.	• Use of authorised waste contractors.	B	2	L	N	• Rig and shore base have in place, and are effectively implementing, waste management procedures detailing how wastes will be managed in accordance with the waste hierarchy principles. • Appropriate storage facilities on the MODU for segregated wastes.	B	2	L	-

Drilling Environmental Aspects Register															
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						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
			Air Quality	Potential effects on future land use options for waste disposal sites. Potential for localised land and air contamination.		B	2	L	N	• Auditing of waste management contractors to ensure compliance with regulations.	B	2	L	-

C.2 Installation and Commissioning Environmental Aspects Register

Installation and Commissioning Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
IC1. Physical Presence														
IC1.1	P	Presence of CTIS, Xmas tree, deviated section of the pipeline / umbilical and protection material	Fishing	Potential for navigation hazard. Loss of sea area for other users (i.e. loss of access to fishing grounds) Economic impact on commercial fisheries	• Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, NAVTEX / NAVAREA warnings and fisheries notifications. • Subsea infrastructure will be marked as hazards on admiralty charts and entered into the Fishsafe system so that it may be avoided by fishing vessels.	D	2	M	Y	• Early consultation and ongoing engagement with other sea-users (stakeholders). • Appointment of an onshore FLO to maintain good communication with local fishing vessels and co-ordinate activities throughout the installation and commissioning phase. • Deviated section of the pipeline will be trenched and mechanically backfilled. Where the burial depth is not achieved, exposed sections outside the exclusion zone will be protected using rock placement, which will be deposited at a gradient designed to allow fishing gear to pass without snagging. • All seabed infrastructure will be designed to be fishing friendly. • With the exception of areas of spot rock-dump, all protection material, all protection material will be contained within safety exclusion zones. • A 500 m safety exclusion zone will be applied for around the Xmas tree and CTIS, which will be clearly marked on navigation charts.	D	2	M	Y

Installation and Commissioning Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
										• Pipeline and umbilical may be installed in the same trench. This will be considered in future design work.				
IC1.2	P	Presence of Xmas tree and CTIS exclusion zone	Fishing	Loss of fishing grounds. Economic impact on commercial fisheries	• Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, Kingfisher, NAVTEX / NAVAREA warnings and fisheries notices.	D	2	M	Y	• No further mitigation measures proposed.	D	2	M	Y
IC1.3	P	Presence of installation and commissioning vessels (including potential for anchors)	Fishing	Loss of sea area for other users (i.e. loss of access to fishing grounds). Economic impact on commercial fisheries.	• Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, Kingfisher, NAVTEX / NAVAREA warnings and fisheries notifications.	C	2	M	Y	• During installation and commissioning, the number of vessels and length of time they are required on site will be reduced as far as practicable through careful planning of the installation activities; • Early consultation and ongoing engagement with other sea-users (stakeholders). • Appointment of an onshore FLO to maintain good communication with local fishermen and co-ordinate activities throughout the installation and commissioning phase and appointment of an offshore FLO on appropriate installation vessels.	C	2	M	Y
			Shipping			C	2	M	Y		C	2	M	Y

Installation and Commissioning Environmental Aspects Register															
						Impact					Residual Impact				
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Likelihood	Consequence	Risk	Significant (Y/N)	Additional Mitigation Measures	Likelihood	Consequence	Residual Risk	ALARP
IC1.4	P	Presence of seabed berms from trenching operations of the deviated section of the pipeline	Fishing	Berms created during pipeline installation activities may pose a hazard to benthic fishing gears.	-	D	2	M	Y	• A post-Development survey of the anchoring locations and the open umbilical trench will be conducted, and any anchor scars, spud can depressions and trench berms that are considered to pose a snagging risk will be flattened using a chain mat.	D	1	L	Y
IC1.5	U	Presence of installation and commissioning vessels	Marine Mammals	Potential for collision between moving vessels and marine mammals.	• Good operating procedures in place and ensure that vessels generally operate at slow speeds where possible.	C	1	L	N	• No further mitigation measures proposed.	C	1	L	-
IC1.6	U	Dropped objects	Fishing	Potential collision risk or risk of snagging on fishing gears or anchors	• Any dropped objects to be immediately reported and procedures will be in place to recover objects, where possible. • Debris will be identified during post work surveys and anything that cannot be recovered will be reported to the relevant authorities to be included on navigation charts.	B	2	L	N	• No further mitigation measures proposed.	B	2	L	-

Installation and Commissioning Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact: Likelihood	Impact: Consequence	Impact: Risk	Impact: Significant (Y/N)	Additional Mitigation Measures	Residual Impact: Likelihood	Residual Impact: Consequence	Residual Impact: Residual Risk	Residual Impact: ALARP
IC2. Seabed Disturbance														
IC2.1	P	Installation of the deviated section of the pipeline / umbilical– trenching, pipelay and backfill	Water Quality	Disturbance to benthic habitats and fauna. Possible localised increase in water column turbidity and smothering of nearby habitats and species.	-	C	1	L	N	• Minimise working corridors as far as possible. • Pipeline and umbilical may be installed in the same trench. This will be considered in future design work.	C	1	L	Y
			Sediments			C	2	M	Y		C	2	M	Y
			Seabed Communities			C	2	M	Y		C	2	M	Y
IC2.2	P	Installation of Subsea Infrastructure Protection Material	Water Quality	Disturbance to benthic habitats and fauna. Possible localised increase in water column turbidity and smothering of nearby habitats and species during installation. Loss of soft sediment habitat beneath the structures.	• Deposits Consents obtained prior to use of stabilisation / protection material.	D	1	L	N	• Stabilisation material will be constrained to areas where trenching alone does not sufficiently protect the deviated section of the pipeline. • The volumes and locations of rock and mattresses used will be refined during Detailed Design to reduce the footprint on the seabed to the extent practicable. • The spread of rock placement will be restricted through the use of a fall pipe system held a few metres above the seabed to accurately place rock material.	D	1	L	-
			Sediments			D	2	M	Y		D	2	M	Y
			Seabed Communities			D	2	M	Y		D	2	M	Y

Installation and Commissioning Environmental Aspects Register															
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						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
IC2.3	P	Installation of Xmas tree and CTIS	Water Quality	Potential disturbance to benthic habitats and fauna. Possible localised increase in water column turbidity and smothering of nearby habitats and species during installation. Loss of soft sediment habitat beneath the structures.	-	D	1	L	N	• Minimise working areas as far as possible. • No further mitigation measures proposed	D	1	L	Y
			Sediments			D	2	M	Y		D	2	M	Y
			Seabed Communities			D	2	M	Y		D	2	M	Y
IC2.4	P	Anchoring from pipelay vessel when installing the deviated section of the pipeline	Water Quality	Anchors and anchor chains may cause seabed disturbance, disturbance to benthic fauna, and a temporary increase in turbidity during deployment. Anchors and anchor chains may	-	C	2	M	Y	• Use the appropriate number of anchors and length of anchor chains to maintain stability and integrity. • If an anchored pipelay vessel is used, review pipeline site survey data to determine if pipelay vessel anchor placement will affect any existing environmentally sensitive features or hazards.	C	1	M	Y
			Sediments			C	2	M	Y		C	2	M	Y

Installation and Commissioning Environmental Aspects Register

						Impact					Residual Impact			
Ref	**Event Type**	**Aspect**	**Receptor**	**Description of Potential Impact**	**Standard Operating Procedures**	**Likelihood**	**Consequence**	**Risk**	**Significant (Y/N)**	**Additional Mitigation Measures**	**Likelihood**	**Consequence**	**Residual Risk**	**ALARP**
			Seabed Communities	disturb contaminated sediments generated by previous drilling campaigns.		C	2	M	L		C	2	M	Y
IC2.5	U	Dropped objects	Sediments	Dropped objects may caused seabed disturbance and disturbance to benthic habitats and communities in the vicinity of the object. Potential loss of seabed habitat.	• Any dropped objects to be immediately reported and procedures will be in place to recover objects, where possible. • Debris will be identified during post work surveys and anything that cannot be recovered will be reported to the relevant authorities to be included on navigation charts.	B	2	L	N	• No further mitigation measures proposed.	B	2	L	N
			Seabed Communities			B	2	L	N		B	2		N
IC3. Noise and Vibration														
IC3.1	P	Noise (multi-pulse) from piling operations to install CTIS	Fish	Potential behavioural disturbance or physiological impacts to sensitive marine fauna	• Follow JNCC protocol for minimising the risk of injury to marine mammals from piling noise (August 2010), e.g. soft-start of pile driver, use of MMOs.	B	3	M	Y	• Where possible, piling operations will be timed to avoid periods of high sensitivity for marine mammals and fish. • Use the minimum diameter piles necessary to achieve structural integrity.	B	3	M	Y
			Marine Mammals			B	3	M	Y		B	3	M	Y

Installation and Commissioning Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
IC3.2	P	Noise from subsea infrastructure installation (non-piled)	Fish	Potential behavioural disturbance or physiological impacts to sensitive marine fauna from installation of Xmas trees, deviated section of the pipeline / umbilical and stabilisation material.	-	C	1	L	N	• No further mitigation measures proposed.	C	1	L	-
			Marine Mammals			C	1	L	N		C	1	L	-
IC3.3	P	Noise from installation and commissioning vessels	Fish	Potential behavioural disturbance or physiological impacts to sensitive marine fauna	-	C	2	M	Y	• No further mitigation measures proposed.	C	2	M	Y
			Marine Mammals			C	2	M	Y		C	2	M	Y

Installation and Commissioning Environmental Aspects Register														
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
IC4. Atmospheric Emissions														
IC4.1	P	Power generation for installation vessels during installation and commissioning	Air Quality	Use of diesel fuel by power generation equipment will release combustion products which can contribute to the pool of greenhouse gases in the atmosphere (CH_4, CO_2, SO_X and NO_X). Potential for localised smog formation.	• All combustion equipment will have a maintenance programme and will be tested regularly; • Vessels and contractors will have UKAPP/IAPP Certificates. • All combustion equipment will have a maintenance programme and will be tested regularly.	C	2	M	Y	• As part of the contractor selection process, vessel and operations contractors will be required to demonstrate that they have control processes in place to minimise environmental impacts (i.e. maintain equipment, manage fuel consumption and minimise fuel usage wherever possible) through review of International Marine Contractors Association (IMCA) / Offshore Vessel Inspection Database (OVID) inspections.	C	2	M	Y
IC4.2	U	Use of firefighting equipment	Air Quality	Release of CO_2 which contributes to the pool of greenhouse gases in the atmosphere	• Equipment not to be used in exercise scenarios.	B	1	L	N	• No further mitigation measures proposed.	B	1	L	-

Installation and Commissioning Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact: Likelihood	Impact: Consequence	Impact: Risk	Impact: Significant (Y/N)	Additional Mitigation Measures	Residual Impact: Likelihood	Residual Impact: Consequence	Residual Impact: Residual Risk	Residual Impact: ALARP
IC5. Marine Discharges															
IC5.1	P	Installation and commissioning vessels ballast water exchange	Plankton	Potential for introduction of alien invasive species that can alter the local, and possibly wider ecosystem	• Adherence to IMO and UK guidelines on ballast water discharge.	A	1	L	N	• Appropriate ballast water control procedures will be ensured through review of IMCA/OVID inspection reports.	A	1	L	-
			Fish			A	1	L	N		A	1	L	-
IC5.2	P	Discharge of greywater and blackwater from installation and commissioning vessels	Water Quality	Decline in local water quality, potential increase in BOD due to bacterial growth and proliferation and may ultimately lead to an increase in opportunistic species. Some marine fauna may avoid contaminated areas.	• Black (sewage) and grey water will be collected and treated to meet the requirements of the MARPOL Convention prior to being discharged to sea.	C	1	L	N	• Good housekeeping standards will be maintained on the installation and commissioning vessels.	C	1	L	-
			Plankton			C	1	L	N		C	1	L	-
			Fish			C	1	L	N		C	1	L	-
			Seabirds			C	1	L	N		C	1	L	-
			Marine Mammals			C	1	L	N		C	1	L	-
IC5.3	P	Release of food waste to sea from installation and	Water Quality	Decline in local water quality, potential increase in BOD due to bacterial growth and proliferation	• Food waste will be disposed of to meet the requirements of the MARPOL Convention.	C	1	L	N	• Good housekeeping standards will be maintained on the installation and commissioning vessels.	C	1	L	-
			Plankton			C	1	L	N		C	1	L	-

Installation and Commissioning Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
		commissioning vessels	Fish	and may ultimately lead to an increase in opportunistic species. Scavenging seabirds may be attracted to the discharge and may be exposed to other hazards.		C	1	L	N		C	1	L	-
			Seabirds			C	1	L	N		C	1	L	-
			Marine Mammals			C	1	L	N		C	1	L	-
IC5.4	P	Discharge of oily water from machine space drainage on installation and commissioning vessels	Water Quality	May cause localised, short term pollution in the water column potentially impacting marine fauna (e.g. toxicity effects, reduction of foraging areas through avoidance).	• All discharges will be treated and discharged according to MARPOL and UK Regulations. • A UKOPP or IOPP Certificate for a foreign flagship unit is required.	B	2	L	N	• Closed drainage system will be in place for areas where there may be oily water streams from equipment. • Good housekeeping standards will be maintained on the installation and commissioning vessels.	B	2	L	-
			Plankton			B	2	L	N		B	2	L	-
			Seabirds			B	2	L	N		B	2	L	-
			Fish			B	2	L	N		B	2	L	-
			Marine Mammals			B	2	L	N		B	2	L	-
IC5.5	P	Runoff from installation and	Water Quality	Rainwater runoff may contain traces of utility hydrocarbons or	• Chemical risk assessment will be undertaken to identify the risk profile of relevant chemicals being used and/or discharged in	C	1	L	N	• As part of chemical selection and assessment process, less hazardous alternatives will be sought in preference for any chemicals identified to be high	C	1	L	-

Installation and Commissioning Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
		commissioning vessels	Plankton	chemicals and may have temporary localised impacts on water quality and fauna	accordance with the Offshore Chemicals Regulations 2002 (as amended). • Spills kits on board the vessels to clean-up spills of utilities hydrocarbons or chemicals before they can enter the sea.	C	1	L	N	risk (e.g. those with substitution warnings). • Good housekeeping standards will be maintained on the installation and commissioning vessels.	C	1	L	-
			Fish			C	1	L	N		C	1	L	-
IC5.6	U	Loss of chemicals during general operations	Water Quality	Potential for spills of chemicals which may cause localised toxicity effects on marine fauna and flora and localised pollution of ecosystems.	• Permanent drip trays will be located under process plant, pumps and vessels (on grated decks). • Chemicals will be stored in bunded areas where any spillages can be routed to the closed drainage system. • Small spill kits will be on board the vessels to clean up deck spills and prevent spilt chemicals reaching the sea. • Crews will be adequately trained, supervised and regular exercises held to contain and clean-up deck spills.	B	2	L	N	• Chemical storage tanks will be equipped with alarm systems and procedure will be in place to minimise and prevent overfilling these storage tanks. • Tool box talks will highlight the importance of minimising the risk of spills occurring.	B	2	L	-
			Plankton			B	2	L	N		B	2	L	-
			Seabirds			B	2	L	N		B	2	L	-
			Fish			B	2	L	N		B	2	L	-

Installation and Commissioning Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
			Marine Mammals		• Routine equipment maintenance programme will be in place with specific emphasis on environmentally critical equipment.	B	2	L	N		B	2	L	-
			Fishing			B	2	L	N		B	2	L	-
IC5.7	U	Loss of fuel / utility hydrocarbons during general operations	Water Quality	Potential for spills of diesel, base oils and other utility oils which may have toxicity effects on marine fauna and flora and cause localised pollution of ecosystems.	• Liquid storage areas and areas that might be contaminated with oil are segregated from other deck areas. • Permanent drip trays will be located under process plant, pumps and vessels (on grated decks). • Bunding or additional containment will be provided around plated areas beneath equipment with significant hydrocarbon inventories. • Small spill kits will be on board the vessels to clean up spilt hydrocarbons deck spills. • Crews will be adequately trained, supervised and regular exercises held to contain and clean-up deck spills.	B	2	L	N	• Utility and fuel storage tanks will be equipped with alarm systems and procedure will be in place to minimise and prevent overfilling these storage tanks. • Routine equipment maintenance programme will be in place with specific emphasis on environmentally critical equipment.	B	2	L	-
			Plankton			B	2	L	N		B	2	L	-
			Seabirds			B	2	L	N		B	2	L	-
			Fish			B	2	L	N		B	2	L	-
			Marine Mammals			B	2	L	N		B	2	L	-
			Fishing			B	2	L	N		B	2	L	-

Installation and Commissioning Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact: Likelihood	Impact: Consequence	Impact: Risk	Impact: Significant (Y/N)	Additional Mitigation Measures	Residual Impact: Likelihood	Residual Impact: Consequence	Residual Impact: Residual Risk	Residual Impact: ALARP
IC5.8	U	Loss of containment on vessel(s) due to collision or other major event	Water Quality	Water quality will be reduced in the vicinity of the spill and diesel may be dispersed widely in the water column. Toxicity effects on marine fauna particularly seabirds on the waters' surface, and fish. Fish may become tainted. Fish and marine mammals will avoid contaminated areas, and a spill potentially reduce their foraging areas. Loss of biodiversity and revenue.	• Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, NAVTEX / NAVAREA warnings and fisheries notifications. • OPEP and other Emergency Plans will be in place.	A	2	L	N	• No additional mitigation measures proposed.	A	2	L	-
			Plankton			A	2	L	N		A	2	L	-
			Seabirds			A	2	L	N		A	2	L	-
			Fish			A	2	L	N		A	2	L	-
			Marine Mammals			A	2	L	N		A	2	L	-
			Fishing			A	2	L	N		A	2	L	-
			Shipping			A	2	L	N		A	2	L	-
			Marine Protected Areas			A	2	L	N		A	2	L	-

Installation and Commissioning Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
IC5.9	U	Loss of containment (hydraulic fluid) from ROV operations	Water Quality	Water quality will be reduced in the vicinity of the release and fluid may be dispersed widely in the water column. Toxicity effects on marine fauna particularly plankton, fish and seabed communities in the vicinity of the subsea release. Fish and marine mammals may avoid contaminated areas, and a spill potentially reduce their foraging areas.	-	B	2	L	N	• Monitoring of ROV operations. • Knowledge of subsurface infrastructure and therefore potential snagging hazards in the area.	B	2	L	-
			Plankton			B	2	L	N		B	2	L	-
			Fish			B	2	L	N		B	2	L	-
			Marine Mammals			B	2	L	N		B	2	L	-
			Seabed Communities			B	2	L	N		B	2	L	-

Installation and Commissioning Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
D5.10	U	Well blowout during commissioning (releasing large quantity of hydrocarbons)	Water Quality	Decline in water quality and toxicity impacts on marine flora (phytoplankton) and fauna. Potential contamination of seabed sediments and toxicity effects on benthic communities. Seabirds, fish and mammals may become physically oiled or may avoid oiled areas. Loss of biodiversity and revenue. Potential shoreline impacts.	• Simultaneous operations (SIMOPs) will be actively identified and managed. • Emergency response plans and equipment will be in place. Crews will be adequately experienced and trained in well control techniques. Emergency drills will be held regularly. • Pressure instrumentation and isolation of subsea systems. • Isolation valves will be included on the subsea Xmas tree and all safety critical subsea valves will be ROV or diver operable. • OPEP will be in place.	A	3	M	Y	• In the event of a spill incident, rapidly act to stem the flow of hydrocarbons from the well through the necessary shutdown procedures. Mobilise Tier 2 and 3 spill response resources to contain and respond to a spill incident offshore. • If suitable, relief well drilling would be considered to the stem the flow.	A	2	L	-
			Plankton			A	3	M	Y		A	2	L	-
			Sediments			A	3	M	Y		A	2	L	-
			Seabed Communities			A	3	M	Y		A	2	L	-
			Fish			A	3	M	Y		A	2	L	-
			Seabirds			A	3	M	Y		A	2	L	-
			Marine Mammals			A	3	M	Y		A	2	L	-
			Fishing			A	3	M	Y		A	2	L	-
			Shipping			A	3	M	Y		A	2	L	-
			Marine Protected Areas			A	3	M	Y		A	2	L	-
			Tourism & Leisure			A	3	M	Y		A	2	L	-

Installation and Commissioning Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
IC6. Solid Wastes														
IC6.1	P	Disposal of operational waste to shore	Air Quality	Effects of onshore disposal of waste depends on the nature of the waste and disposal site. Potential effects on future land use options for waste disposal sites. Potential for localised land and air contamination.	• Use of authorised waste contractors.	B	2	L	N	• Shore base have in place, and are effectively implementing, waste management procedures detailing how wastes will be managed in accordance with the waste hierarchy principles. • Appropriate storage facilities on the installation and commissioning vessels for segregated wastes.	B	2	L	-
			Land Use			B	2	L	N		B	2	L	-

C.3 Production Operations and Maintenance Environmental Aspects Register

Production Operations and Maintenance Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
P1. Physical Presence															
P1.1	P	Presence of CTIS, Xmas tree, deviated section of the pipeline / umbilical and protection material	Fishing	Potential for navigation hazard. Loss of sea area for other users (i.e. loss of access to fishing grounds) Economic impact on commercial fisheries	• Infrastructure will be marked as hazards on admiralty charts and entered into the Fishsafe system so that it may be avoided by fishing vessels.	D	2	M	Y	• Deviated section of the pipeline will be trenched and mechanically backfilled. Where the burial depth is not achieved, exposed sections outside the exclusion zone will be protected using rock placement. • A 500 m safety exclusion zone will be applied for around the Xmas tree and CTIS, which will be clearly marked on navigation charts. • All seabed infrastructure will be designed to be fishing friendly.	D	2	M	Y
P1.2	P	Presence of Xmas tree and CTIS exclusion zone	Fishing	Loss of fishing grounds. Economic impact on commercial fisheries	-	D	2	M	Y	• A 500 m safety exclusion zone will be applied for around the Xmas tree and CTIS, which will be clearly marked on navigation charts.	D	2	M	Y

<table>
<tr><th colspan="18">Production Operations and Maintenance Environmental Aspects Register</th></tr>
<tr><th rowspan="2">Ref</th><th rowspan="2">Event Type</th><th rowspan="2">Aspect</th><th rowspan="2">Receptor</th><th rowspan="2">Description of Potential Impact</th><th rowspan="2">Standard Operating Procedures</th><th colspan="4">Impact</th><th rowspan="2">Additional Mitigation Measures</th><th colspan="4">Residual Impact</th></tr>
<tr><th>Likelihood</th><th>Consequence</th><th>Risk</th><th>Significant (Y/N)</th><th>Likelihood</th><th>Consequence</th><th>Residual Risk</th><th>ALARP</th></tr>
<tr><td colspan="15">P2. Seabed Disturbance</td></tr>
<tr><td rowspan="2">P2.1</td><td rowspan="2">P</td><td rowspan="2">Subsea infrastructure and stabilisation material</td><td>Sediments</td><td rowspan="2">Placement of stabilisation material will disturb seabed sediments. Loss of soft sediment habitat. Potential subsequent change in benthic community structure as long as the structures are present.</td><td rowspan="2">• Minimise amount of deposited material whilst still achieving the required level of stabilisation / protection.
• Deposits Consents obtained prior to use of stabilisation / protection material.</td><td>D</td><td>2</td><td>M</td><td>Y</td><td rowspan="2">• No further mitigation measures proposed.</td><td>D</td><td>2</td><td>M</td><td>Y</td></tr>
<tr><td>Seabed Communities</td><td>D</td><td>2</td><td>M</td><td>Y</td><td>D</td><td>2</td><td>M</td><td>Y</td></tr>
<tr><td colspan="15">P3. Noise and Vibration</td></tr>
<tr><td rowspan="2">P3.1</td><td rowspan="2">P</td><td rowspan="2">Noise from subsea facilities</td><td>Fish</td><td rowspan="2">Vibrations and noise from high pressure fluids and gas through the deviated section of the pipeline may be transmitted through the water column</td><td rowspan="2">• No standard operating procedures required for noise abatement.</td><td>D</td><td>1</td><td>L</td><td>N</td><td rowspan="2">• No further mitigation measures proposed.</td><td>D</td><td>1</td><td>L</td><td>-</td></tr>
<tr><td>Marine Mammals</td><td>D</td><td>1</td><td>L</td><td>N</td><td>D</td><td>1</td><td>L</td><td>-</td></tr>
</table>

Production Operations and Maintenance Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
P4. Atmospheric Emissions														
P4.1	P	Power generation on Shearwater platform	Air Quality	Use of fuel by power generation equipment will release combustion products which can contribute to the pool of greenhouse gases in the atmosphere (CH_4, CO_2, SO_X and NO_X). Potential for localised smog formation.	• Power required for the Columbus subsea facilities will be covered by the existing power generation capacities on the Shearwater platform. • All combustion equipment will have a maintenance programme and will be tested regularly.	D	2	M	Y	• No further mitigation measures proposed.	D	2	M	Y
P4.2	U	Flaring during production (operational blowdown) at Shearwater platform	Air Quality	Flaring of gases will release combustion products which can contribute to the pool of greenhouse gases in the atmosphere (CH_4, CO_2, SO_X and NO_X). Potential for localised smog formation.	• The Columbus Development will utilise the existing flaring facilities on the Shearwater platform. • All combustion equipment will have a maintenance programme and will be tested regularly.	C	2	M	Y	• Operating procedures will be in place in order to reduce flaring during maintenance operations, process upset conditions, system depressurisation and start-up.	D	2	M	Y

Production Operations and Maintenance Environmental Aspects Register															
						Impact					Residual Impact				
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Likelihood	Consequence	Risk	Significant (Y/N)	Additional Mitigation Measures	Likelihood	Consequence	Residual Risk	ALARP
P4.3	U	Leak of gas from subsea facilities	Air Quality	Atmospheric pollution associated with the release of unignited or ignited natural gas	• Verification of maintenance programme. • Isolation valves will be included on the subsea Xmas tree and all safety critical subsea valves will be ROV or diver operable. • Emergency response plans and equipment will be in place.	B	1	L	N	• No further mitigation measures proposed.	B	1	N	-
P5. Marine Discharges															
P5.1	P	Discharge of produced water (at Shearwater platform)	Water Quality	Decline in local water quality at the discharge point. Toxicity effects of hydrocarbons and chemicals on marine fauna. Fish and marine mammals may avoid contaminated areas. Potential sheen on the waters surface that may impact seabirds.	• Columbus Development will utilise the existing produced water treatment system on the Shearwater platform. • Any discharge of produced water will be treated to meet oil-in-water limits of less than 30 mg/l. • Discharge stream will be monitored and sampled in accordance with the approved Shearwater OPPC permit.	D	2	M	Y	• No further mitigation measures proposed.	D	2	M	Y
			Plankton			D	2	M	Y		D	2	M	Y
			Fish			D	2	M	Y		D	2	M	Y
			Seabirds			D	2	M	Y		D	2	M	Y

Production Operations and Maintenance Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
P5.2	P	Discharge of production chemicals (at Shearwater platform)	Water Quality	Discharged chemicals could have toxicity impacts to marine fauna. Potential localised temporary decline in water quality and increase in BOD.	• A full CHARM analysis assessment of the proposed chemicals to be used and discharged, as required under the Offshore Chemicals Regulations 2002 (as amended), will be undertaken during the permitting process prior to production operations commencing.	D	1	L	N	• As part of chemical selection and assessment process, less hazardous alternatives will be sought in preference for any chemicals identified to be high risk (e.g. those with substitution warnings).	D	1	L	-
			Plankton			D	1	L	N		D	1	L	-
			Fish			D	1	L	N		D	1	L	-
P5.3	P	Subsea controls fluids discharge	Water Quality	Discharged chemicals could have toxicity impacts to marine fauna. Potential localised temporary decline in water quality and increase in BOD.	• A full CHARM analysis assessment of the proposed chemicals to be used and discharged, as required under the Offshore Chemicals Regulations 2002 (as amended), will be undertaken during the permitting process prior to production operations commencing.	B	1	L	N	• Hydraulic fluid will be selected with due consideration to potential environmental impact.	B	1	L	-
			Plankton			B	1	L	N		B	1	L	-
			Seabed Communities			B	1	L	N		B	1	L	-
			Fish			B	1	L	N		B	1	L	-

Production Operations and Maintenance Environmental Aspects Register

Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact: Likelihood	Impact: Consequence	Impact: Risk	Impact: Significant (Y/N)	Additional Mitigation Measures	Residual Impact: Likelihood	Residual Impact: Consequence	Residual Impact: Residual Risk	Residual Impact: ALARP
P5.4	U	Loss of pipeline integrity	Water Quality	Small or large leaks from the deviated section of the pipeline or the tie-in spools may release reservoir hydrocarbons and/or chemicals into the water column. Potential toxicity effects on marine fauna. Potential accumulation in sediments if released at the seabed.	• Tie-in spool is protected from corrosion through a combination of a protective coating and cathodic protection system and a margin for corrosion is built into the design. • Tie-in spool will be pressure tested to above the planned operating pressure. • Tie-in spool will be protected from physical damage by fishing gear or anchors by mattresses. • Pressure and temperature routine monitoring will be undertaken. Automatic and manual shutdown systems will be in place.	A	3	M	Y	• Regular ROV inspection will be undertaken.	A	2	L	-
			Plankton			A	3	M	Y		A	2	L	-
			Sediment			A	3	M	Y		A	2	L	-
			Seabed Communities			A	3	M	Y		A	2	L	-
			Seabirds			A	3	M	Y		A	2	L	-
			Fish			A	3	M	Y		A	2	L	-
			Marine Mammals			A	3	M	Y		A	2	L	-
			Fishing			A	3	M	Y		A	2	L	-

Production Operations and Maintenance Environmental Aspects Register															
Ref	Event Type	Aspect	Receptor	Description of Potential Impact	Standard Operating Procedures	Impact				Additional Mitigation Measures	Residual Impact			
						Likelihood	Consequence	Risk	Significant (Y/N)		Likelihood	Consequence	Residual Risk	ALARP
P5.5	U	Well blowout during production (releasing large quantity of hydrocarbons)	Water Quality	Decline in water quality and toxicity impacts on marine flora (phytoplankton) and fauna. Potential contamination of seabed sediments and toxicity effects on benthic communities. Seabirds, fish and mammals may become physically oiled or may avoid oiled areas. Loss of biodiversity and revenue. Potential shoreline impacts.	• Emergency response plans and equipment will be in place. Crews will be adequately experienced and trained in well control techniques. Emergency drills will be held regularly. • Pressure instrumentation and isolation of subsea systems. • Isolation valves will be included on the subsea Xmas tree and all safety critical subsea valves will be ROV or diver operable. • OPEP will be in place.	A	3	M	Y	• In the event of a spill incident, rapidly act to stem the flow of hydrocarbons from the well through the necessary shutdown procedures. Mobilise Tier 2 and 3 spill response resources to contain and respond to a spill incident offshore. • If suitable, relief well drilling would be considered to the stem the flow.	A	2	L	-
			Plankton			A	3	M	Y		A	2	L	-
			Seabed Communities			A	3	M	Y		A	2	L	-
			Fish			A	3	M	Y		A	2	L	-
			Seabirds			A	3	M	Y		A	2	L	
			Marine Mammals			A	3	M	Y		A	2	L	-
			Fishing			A	3	M	Y		A	2	L	-
			Shipping			A	3	M	Y		A	2	L	-
			Marine Protected Areas			A	3	M	Y		A	2	L	-
			Coastal Protected Areas			A	3	M	Y		A	2	L	-
			Tourism and Leisure			A	3	M	Y		A	2	L	-

Appendix D: Survey Data

2006 Gardline Survey

Gardline Geosurvey carried out a rig site survey for Peak Well Management Ltd on behalf of Serica Energy, in UKCS 23/16f; the object was to investigate the proposed 23/16f-K well locations using single and multi-beam echo sounder, sidescan sonar, hull-mounted pinger, coring, and high resolution seismic equipment. An environmental programme was also undertaken to identify potentially sensitive habitats protected under Annex 1 of the EU Habitats Directive, using digital stills camera and video system. No potentially sensitive habitats were found at any of the survey stations (Gardline, 2006).

The analogue survey was conducted over an area measuring 7 kilometres by 3 kilometres, covering both proposed locations; main survey lines were orientated 175°/355° (grid). The digital grid comprised two 1 kilometre by 1 kilometre sites centred over both locations, with the same line orientation. Mainlines of 5 kilometres connected the two locations (Gardline, 2006).

A total of five stations were investigated with the digital stills camera and video system. This included one station at each of the two well locations, with the remaining three stations selected to cover the various sediment changes within the survey area (Gardline, 2006).

Table D.1 presents the seabed sampling stations for the 2006 Gardline survey and a summary of the data collected at each. All data was collected by the survey vessel *MV Ocean Seeker* between 11th July and 18th July 2006 (Gardline, 2006). The location of each station is presented in Figure 3.1 in Section 3.

Table D.1. Seabed Sampling Locations of the 2006 Gardline Survey (Gardline, 2006)

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF [N1]
Northern Site							
ENV N1	North Location	445366	6359460	86m	Y	0	0
ENV N2	1,494m 319deg (NW)	444400	6360600	86m	Y	0	0
Southern Site							
ENV S1	South Location	445710	6355490	87m	Y	0	0
ENV S2	994m 174.9deg (S)	445800	6354500	87m	Y	0	0
ENV S3	1,420m 212.3deg (SSW)	444950	6354290	87m	Y	0	0

Notes
CAM = camera; PC = physico-chemistry sample; MF = Macrofauna sample replicates.
[N1] Macrofaunal (MF) samples were sieved through a 0.5mm mesh size.
Coordinates are given in European Datum 1950 UTM Zone 31N.

2007 Gardline Survey

In August and September 2007, Gardline Environmental Ltd (Gardline) carried out an environmental baseline survey (EBS) on behalf of Floyd & Associates Ltd for BG Group in UKCS 23/21. The objective was to establish baseline figures for the current benthic macrofaunal communities, sediment chemistry and granulometry around the proposed 'Columbus development'. In addition, the survey provided seabed and geological information with which to identify potentially sensitive habitats, such as *Sabellaria spinulosa* reefs, as protected under Annex 1 of the EU Habitats Directive (Gardline, 2007).

Benthic samples were recovered using an in-house constructed, modified, stainless-steel $0.1m^2$ Day grab. The analogue survey was conducted over an area measuring 4 kilometres by 4 kilometres with a smaller digital survey covering an area measuring 2 kilometres by 2 kilometres, both centred on the proposed Columbus location. Main survey lines were orientated 000°/180° (grid) (Gardline, 2008).

Ten stations were samples; positioned in a modified cruciform pattern centred on the original proposed well location and allowing investigation of features of interest on the seabed (including mottled, high and low reflectivity patches). A reference station was also selected. Following completion of the survey, the proposed well location was revised due to the presence of gas hazard (Gardline, 2007).

Table D.2 presents the seabed sampling stations for the 2007 Gardline survey and a summary of the data collected at each. The location of each station is presented in Figure 3.1 in Section 3. No species or habitats of conservation significance under the EC Habitat Directive (92/43/EEC) were observed in the surveyed area (Gardline, 2007)

Table D.2. Seabed Sampling Locations of the 2007 Gardline Survey (Gardline, 2007)

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF [N1]
ENV1	Adjusted cruciform, Area of mixed high and low reflectivity	447435	6353720	86m	N	1	3
ENV2	Adjusted cruciform, Area of low reflectivity	447700	6353750	86m	N	1	3
ENV3	Cruciform	447803	6353650	86m	N	1	3
ENV4	Cruciform	448004	6353650	86m	N	1	3
ENV5	Adjusted cruciform, Area of high reflectivity	447608	6354630	86m	N	1	3
ENV6	Cruciform	447700	6354048	85m	N	1	3
ENV7	Cruciform	447704	6353550	86m	N	1	3
ENV8	Cruciform	447704	6353247	86m	N	1	3
ENV9	Adjusted cruciform, Area of high reflectivity	447689	6352590	86m	N	1	3
ENV10	Reference Station	447115	6352905	86m	N	1	3

Notes

CAM = camera; PC = physico-chemistry sample; MF = Macrofauna sample replicates.

[N1] Macrofaunal (MF) samples were sieved through a 0.5mm mesh size.

Coordinates are given in European Datum 1950 UTM Zone 31N.

2007 UTEC Survey

On the instructions of AGR Peak and on behalf of Serica Energy (UK) Limited, UTEC Survey Limited performed a full shallow gas and seabed hazard survey over the proposed location, 23/16f-L (57° 21' 53.731"N, 02° 05' 29.212"E, ED50) for the installation of a jack up drilling rig. Geophysical data was acquired over the survey area in a dual pass digital and analogue survey from the *MV Kommandor Iona*, at UKCS 23/16f in the central North Sea. Survey operations occurred between the 14th April 2007 and the 17th April

2007. This survey was an extension of a previous survey carried out by Gardline Geosurvey over the proposed 23/16f-K location in July 2006 (Gardline Report no 6834).

The analogue survey comprised an irregular grid measuring 1.1 kilometres by 4.05 kilometres extending the previous survey to the west. The analogue survey was conducted using side scan sonar, 'pinger' and single beam echosounder. The digital survey comprised an irregular grid 1.95 kilometres by 2.6 kilometres infilling and extending to the west the original Gardline survey. Twenty four fold 2D High Resolution digital seismic data with a 4 by 40 cubic inch sleeve air gun source was acquired.

No seabed samples were acquired as part of this survey.

2008 Gardline Survey

Gardline carried out an EBS for AGR Peakwell Management on behalf of their client Serica Energy. Fieldwork was conducted on board the *MV Ocean Observer* between 18th August and 19th August 2008, in UKCS Block 23/16, 23/21, 22/24 and 22/25. The scope of work called for seabed and geological information with which to establish the baseline physico-chemical characteristics and benthic community along the proposed Columbus Well 1 to Well 2, and Columbus Well 1 to ETAP CPF Platform pipeline routes (Gardline, 2008).

0.1 m^2 Day grab samples were taken at six stations. Two stations were located to sample within the vicinity of the proposed Columbus Wells 1 and 2. The remainder were positioned along the proposed Columbus Well 1 to ETAP CPF Platform pipeline route to sample locations with a wide range in (sonar) reflectivity (Gardline, 2008).

The environmental survey was completed in conjunction with a geophysical site survey and habitat assessment, which utilised a single and multi-beam echo sounder, sidescan sonar, hull mounted pinger, magnetometer, digital stills and video camera, grab, vibrocore and CPT equipment. The proposed Columbus Well 1 to ETAP CPT Platform and Columbus Well 1 to Columbus Well 2 pipeline routes are 26.599 kilometres and 3.09 kilometres long, respectively. The route corridors were 400 metres wide (Gardline, 2008).

Table D.3 presents the seabed sampling stations for the 2008 Gardline survey and a summary of the data collected at each. The location of each station is presented in Figure 3.1 in Section 3.

Table D.3. Seabed Sampling Locations of the 2008 Gardline Survey (Gardline, 2008)

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF [N1]
ENV1	Columbus Well 1 77 m S of KP 0.063	445559	6355355	87m	N	1	3
ENV2	Columbus Well 2 63 M w of KP 3.011	445291	6358433	87m	N	1	3
ENV3	Boundary between high and moderate reflectivity KP 2.894	442732	6355190	88m	N	1	3
ENV4	High reflectivity 77 m N of KP 12.735	432924	6354364	93m	N	1	3
ENV5	High reflectivity 70 m NNW of KP 19.253	426645	6352626	94m	N	1	3

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF N1
ENV6	High reflectivity 84 m N of KP 24.944	421218	6350956	95m	N	1	3

Notes
CAM = camera; PC = physico-chemistry sample; MF = Macrofauna sample replicates.
N1 Macrofaunal (MF) samples were sieved through a 0.5mm mesh size.
Coordinates are given in European Datum 1950 UTM Zone 31N.

2010 Gardline Surveys

2010 Gardline (Route) Survey

Gardline Geosurvey carried out a pipeline route survey linking the Serica Columbus site with the proposed BG Lomond BLP location in UKCS 23/16 and 23/21 for Senergy Survey & Geoengineering on behalf of BG Group and Serica. Fieldwork was conducted between 4th August and 15th August 2010. The objective was to determine the suitability of the proposed pipeline route by establishing the geological, topographical and macrofaunal characteristics of the pathway (Gardline, 2010a; 2010b).

Geophysical data were acquired using single and multi-beam echo sounder, sidescan sonar, magnetometer, pinger, boomer, vibrocore and CPT equipment. The proposed pipeline route is 11.164 kilometres long, with a 590 metres wide corridor. Lines were extended to 500 metres beyond the start point of the route, with the end point lying near the proposed Lomond BLP location. Cross lines 500 metres in length were spaced at approximately 1 kilometre intervals, coinciding with the selected geotechnical sampling locations (Gardline, 2010a).

In addition, environmental baseline and habitat assessment surveys were undertaken. Sampling locations were spread along the proposed pipeline route with multiple stations placed within the two distinct sediment types seen on the geophysical survey data, as well as any points of interest (scars). Five stations were chosen for investigation with the camera system and 0.1m² Day grab, encompassing both high and non-high reflectivity areas. No evidence of sensitive habitats, as protected under Annex 1 of the EU Habitats Directive, was identified (Gardline, 2010b).

Table D.4 presents the seabed sampling stations for the 2010 Gardline (route) survey and a summary of the data collected at each. The location of each station is presented in Figure 3.1 in Section 3.

Table D.4. Seabed Sampling Locations of the 2010 Gardline (Route) Survey (Gardline, 2010a; 2010b)

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF N1
ENV1	Low reflectivity area with trawl scars 3 m WSW of KP0.679	444930	6358355	85m	Y	1	3
ENV2	High reflectivity area 80 m WSW of KP2.831	445310	6356235	86m	Y	1	3
ENV3	Low reflectivity area 43 m ENE of KP3.471	445585	6355835	86m	Y	1	3

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF N1
ENV4	Low reflectivity area 47 m SW of KP6.613	447305	6353115	85m	Y	1	3
ENV5	High reflectivity area 88 m NE of KP9.68	449805	6351080	85m	Y	1	3

Notes
CAM = camera; PC = physico-chemistry sample; MF = Macrofauna sample replicates.
N1 Macrofaunal (MF) samples were sieved through a 0.5mm mesh size.
Coordinates are given in European Datum 1950 UTM Zone 31N.

2010 Gardline (Site) Survey

Gardline Environmental Ltd carried out an environmental baseline survey for Senergy & GeoEngineering on behalf of their client BG Group, prior to the installation and operation of the new Lomond Bridge Linked Platform (BLP) and associated infrastructure in UKCS Block 23/21, central North Sea. The objective as defined in the scope of work was to establish the baseline physico-chemical characteristics and the benthic community composition in the area surrounding the proposed Lomond BLP location. The survey was conducted in August 2010 from the survey vessel *MV Ocean Researcher* (Gardline, 2010c).

The analogue survey was conducted over an area measuring 1.5 kilometre by 1.5 kilometres, centred on the Lomond Platform centre, with main survey lines orientated 110^o/290^o. Sidescan sonar data were acquired utilising a 75 metres range, 500kHz setting in the vicinity of the Lomond Platform, and a 150 metres range, 100kHz setting through the remainder of the site. The geophysical survey utilised single beam and multi-beam echo sounders, sidescan sonar, pinger, boomer, vibrocorer, CPT and ultra high resolution seismic and geotechnical sampling equipment (Gardline, 2010c).

The scope of work called for ten stations to be sampled. However with the limitation of samples having to be taken >100 metres from the existing seabed assets, eight stations were deemed to provide sufficient coverage of the survey area. Station locations were located in order to sample both sediment types and were sampled with a 0.1 m^2 Day grab and camera equipment (Gardline, 2010c).

Table D.5 presents the seabed sampling stations for the 2010 Gardline (route) survey and a summary of the data collected at each. The location of each station is presented in Figure 3.1 in Section 3.

Table D.5. Seabed Sampling Locations of the 2010 Gardline (Site) Survey (Gardline, 2010c)

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF N1
ENV1	Low reflectivity, north edge of site 665m NW N2	450205	6350420	85m	Y	1	3
ENV2	Low reflectivity 805m W N2	449820	6350012	86m	Y	1	3
ENV3	High reflectivity 1240m WSW N2	449505	6349362	85m	Y	1	3

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF [N1]
ENV4	Low reflectivity 710m WSW [N2]	449960	6349635	85m	Y	1	3
ENV5	High reflectivity, within 500m of Lomond BLP 250m NNE [N2]	450742	6350115	85m	Y	1	3
ENV6	High reflectivity, within 500m of Lomond BLP 295m SSE [N2]	450735	6349625	85m	Y	1	3
ENV7	High reflectivity 720m SSE [N2]	450995	6349285	85m	Y	1	3
ENV8	High reflectivity, south edge of site 885m S [N2]	450588	6349013	85m	Y	1	3

Notes
CAM = camera; PC = physico-chemistry sample; MF = Macrofauna sample replicates.
[N1] Macrofaunal (MF) samples were sieved through a 0.5mm mesh size.
[N2] Distance and direction from the proposed Lomond BLP (57° 17' 17.177" N, 2° 10' 50.892" E)
Coordinates are given in European Datum 1950 UTM Zone 31N.

2015 Gardline Survey

During August and September 2015, Gardline carried out an EBS for Dana n the central North Sea. The survey was undertaken by the *MV Ocean Observer*, mobilising in Montrose on 10th August 2015 and demobilising in Montrose after completion on 29th September 2015. The survey consisted of two sites and a pipeline route as follows:

- The Arran North Site (6.65 kilometres by 4.2 kilometres) and incorporated Arran North Drill Centre Option 1 (NDC1) and Option 2 (NDC2) and three associated relief well (RW) options all in UKCS 23/11 and 23/16;
- The Arran South Site (4.4 kilometres by 3.6 kilometres) and incorporated Arran South Drill Centre (SDC) and two associated RW options in UKCS 23/16;
- Section 1 was 7.240 kilometres in length and connected NDC1 with SDC crossing UKCS 23/11 into 23/16;
- Section 2 was 7.249 kilometres in length and connected NDC2 with SDC in UKCS 23/16;
- Section 3 was 38.751 kilometres long and extended from SDC in UKCS 23/13 and crossing through UKCS 23/21 and 22/25 to the Scoter Manifold in UKCS 22/30;
- Section 4 of the pipeline was 11.713 kilometres in length extended from the Scoter Manifold to the Shearwater A platform in UKCS Block 22/30.

The objective of the geophysical surveys was to assess the seabed and sub-seabed for potential drilling hazards, conditions that could impair pipelaying or trenching operations and to gather the necessary data for the ES. Geophysical data were acquired using side scan sonar, multi-beam echo sounder, magnetometer, pinger, squid 500 sparker, sub-tow boomer, vibrocore, cone penetrometer test and 2D high resolution seismic equipment (Gardline, 2015b).

The objective of the environmental baseline survey was to assess the seabed physico-chemical characteristics and macrofaunal community surrounding the two sites and pipeline routes. This involved revisiting six stations previously investigated in 2009 across the then Barbara and Phyllis survey areas (Gardline project reference 8130; Gardline, 2010d). Sampling also took place at a further ten stations pre-selected by the client as well as 17 stations identified during the survey. Nine additional stations were selected for investigation as part of the habitat assessment only Overall, a total of 42 stations were investigated with digital stills camera followed by sampling at 33 of these stations with a double (2 x 0.1m^2) van Veen grab (Gardline, 2016a).

Table D.6 presents the seabed sampling stations for the 2010 Gardline (route) survey and a summary of the data collected at each. The location of each station is presented in Figure 3.1 in Section 3.

Table D.6. Seabed Sampling Locations of the 2015 Gardline Survey (Gardline, 2016a)

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF [N1]
Arran North Site							
ENV1	Predetermined (Gardline, 2010d revisit) 131m WSW (NDC1)	441479	6373944	85m	Y	1	3
ENV2	Predetermined (Gardline, 2010d revisit) 181m N (NDC1)	441619	6374169	84m	Y	1	3
ENV3	Predetermined (Gardline, 2010d revisit) 338m SW (NDC1)	441399	6373719	85m	Y	1	3
ENV4	Predetermined 250m NNE (NDC2)	440898	6371690	84m	Y	1	3
ENV5	Predetermined 30m W (NDC2)	440772	6371459	85m	Y	1	3
ENV6	Predetermined 250m SSW (NDC2)	440706	6371228	85m	Y	1	3
ENV35	Medium Reflectivity with Texture 1,221m S (NDC1)	441516	6372771	84m	Y	-	-
ENV36	Medium Reflectivity with Texture 1,085m NNE (NDC2)	441064	6372512	84m	Y	-	-

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF N1
ENV37	Depression with Medium Reflectivity 778m SE (NDC1)	442120	6373409	85m	Y	-	-
Arran South Site							
ENV7	Predetermined 250m NNE (SDC)	448096	6370831	80m	Y	1	3
ENV8	Predetermined 30m W (SDC)	447970	6370600	80m	Y	1	3
ENV9	Predetermined 250m SSW (SDC)	447904	6370369	80m	Y	1	3
ENV31	Sediment boundary between low reflectivity and high reflectivity 883m SSE (SDC)	448458	6369845	80m	Y	-	-
ENV32	High reflectivity 1,054m E (SDC)	449038	6370776	84m	Y	-	-
ENV33	Sediment Boundary between low reflectivity and high reflectivity 667m NNW (SDC)	447786	6371232	81m	Y	-	-
ENV34	Sediment Boundary between low reflectivity and high reflectivity 1,178m SE (SDC)	448787	6369724	80m	Y	-	-
Pipeline Route – Section 1							
ENV27	Predetermined 9m SSW of KP2.40	443719	6372858	84m	Y	1	3
ENV38	High reflectivity/boulder 60m NNE of KP3.11	444380	6372585	84m	Y	-	-
ENV28	Predetermined 7m NNE of KP4.80	445847	6371748	82m	Y	1	3
ENV20	Predetermined (Gardline, 2010d revisit) 416m NNE of KP5.16	446360	6371940	82m	Y	1	3
Pipeline Route – Section 2							

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF [N1]
ENV39	Medium reflectivity with texture 80m N of KP1.61	442414	6371347	84m	Y	-	-
ENV29	Predetermined KP2.40	443185	6371175	83m	Y	1	3
ENV16	Predetermined (Gardline, 2010d revisit) 504m S of KP2.60	443330	6370650	84m	Y	1	3
ENV30	Predetermined KP4.80	445568	6370890	81m	Y	1	3
Pipeline Route – Section 3							
ENV11	Predetermined (Gardline, 2010d revisit) 695m ESE of KP0.90	448400	6369530	78m	Y	1	3
ENV10	Low reflectivity 29m ESE of KP2.22	447378	6368467	82m	Y	1	3
ENV12	Low reflectivity with light texture 103m ESE of KP5.52	446485	6365291	86m	Y	1	3
ENV13	Low reflectivity with texture. Point contact boulder 113m ESE of KP8.80	445534	6362146	85m	Y	1	3
ENV14	Low reflectivity with light texture. 308m ESE of KP10.121.	445335	6360831	85m	Y	1	3
ENV15	Low reflectivity with texture. Linear debris. 33m ESE of KP12.123.	444487	6358997	85m	Y	-	-
ENV15A	ENV15 grab moved 30m E to avoid cable. 61m ESE of KP12.112.	444517	6359000	85m	N	1	3
ENV17	Low reflectivity with light texture. 31m ESE of KP14.749.	443745	6356482	86m	Y	-	-

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF [N1]
ENV17A	ENV17 grab moved 30m NE to avoid cable. 51m ESE of KP14.727.	443770	6356499	86m	N	1	3
ENV18	Low reflectivity with light texture. Point contact boulder. 61m WNW of KP17.141.	443125	6354170	86m	Y	1	3
ENV19	Low reflectivity. 61m WNW of KP19.302.	442646	6352062	87m	Y	1	3
ENV21	Linear feature with some high reflectivity. 184m ESE of KP21.704.	442353	6349665	86m	Y	-	-
ENV21A	ENV21 grab moved 30m WSW to avoid cable. 214m ESE of KP21.707.	442381	6349655	86m	N	1	3
ENV22	Low reflectivity with light texture 116m ESE of KP24.35	441699	6347095	87m	Y	-	-
ENV22A	ENV22 grab moved 30m WSW to avoid cable 98m ESE of KP24.37	441675	6347076	87m	N	1	3
ENV23	Low reflectivity with light texture 31m WNW of KP26.94	440982	6344605	86m	Y	1	3
ENV24	Low reflectivity with texture 194m ESE of KP30.12	440497	6341454	87m	Y	1	3
ENV25	Low reflectivity point contact boulder 37m ESE of KP33.37	439622	6338313	87m	Y	1	3
ENV26	Low reflectivity with texture. Point contact boulder 109m ESE of KP35.93	439126	6335808	87m	Y	1	3
Pipeline Route – Section 4							
ENV42	Medium reflectivity with texture 137m E of KP1.82	439073	6331176	89m	Y	1	3

Station	Rationale	Easting (m)	Northing (m)	Depth	CAM	Grab Samples Acquired	
						PC	MF [N1]
ENV40	Medium reflectivity with texture 63m ESE of KP5.17	438468	6327883	89m	Y	1	3
ENV41	Low reflectivity. Point contact boulder. Pipeline Route 182m ESE of KP8.84	437447	6324358	91m	Y	1	3

Notes
CAM = camera; PC = physico-chemistry sample; MF = Macrofauna sample replicates.
[N1] Macrofaunal (MF) samples were sieved through a 0.5mm mesh size.
Coordinates are given in European Datum 1950 UTM Zone 31N.

E Noise Propagation Modelling

E.1 Underwater Noise and Sounds Transmission

E.1.1 Introduction

Underwater sound is characterised with reference to two metrics; its frequency measured in Hertz (Hz), and the sound or intensity of the sound measured in decibels (dB).

Sound manifests itself as pressure (i.e. a force acting over a given area). It is expressed in terms of 'sound pressure levels' (SPL), which use a logarithmic scale of the ratio of the measured pressure to a reference pressure (expressed as decibels relative to one micro-Pascal (dB re 1µPa)). The logarithmic nature of the scale means that each 10 dB increase in SPL is a ten-fold increase in acoustic power and a 20 dB increase is a 100-fold increase in acoustic power (OSPAR, 2009; DOSITS, 2017). SPLs are quoted at a standard range from the source, usually one metre (dB re 1µPa.m).

To take account of variations in sound it can also be viewed in terms of the received sound energy, the "sound exposure level" (SEL). SEL is based on the assumption that sounds of equivalent energy will have similar effects on the auditory systems of exposed individuals, even if they differ in SPL, duration and/or temporal exposure pattern (Genesis, 2011). It measures the sounds energy (pressure) received from the noise referenced to one second in time (dB re 1 $\mu Pa^2 s$). SEL allows pulse and non-pulse sound of various durations to be compared and characterised in terms of overall sound energy for the purposes of impact assessment.

Sound frequency is an important characteristic of the source noise. High frequency sounds are attenuated in seawater more quickly than low frequency sounds: for example, a 100 Hz sound may be detectable after travelling hundreds or even thousands of kilometres, whereas a 100 kilohertz (kHz) sound may travel for only a few kilometres (Swan *et al*., 1994; MMC, 2007).

E.1.2 Sound Propagation Model

Underwater sounds spread spherically from the noise source to a range approximately equal to water depth. This is followed by the cylindrical spreading of sound waves (FAS, 1998). As sound spreads underwater, it decreases in intensity (attenuates) with distance from the source. The rate of attenuation is affected by a number of factors including sound absorption or scattering by organisms in the water column, reflection or scattering of the sound wave at the seabed (which varies depending on sediment type), water temperature, stratification, salinity and weather (Munk and Zachariasen, 1991; Richardson *et al*., 1995). Consequently, actual sound transmission has considerable temporal and spatial variability that is difficult to quantify.

Various models for calculating the propagation of underwater sound have been proposed. The model proposed by Richardson *et al*. (1995), which assumes spherical spreading, is the most widely used, and is shown below:

$$\textbf{Transmission Loss} = 20\log(R/R_0)\ \text{dB}$$

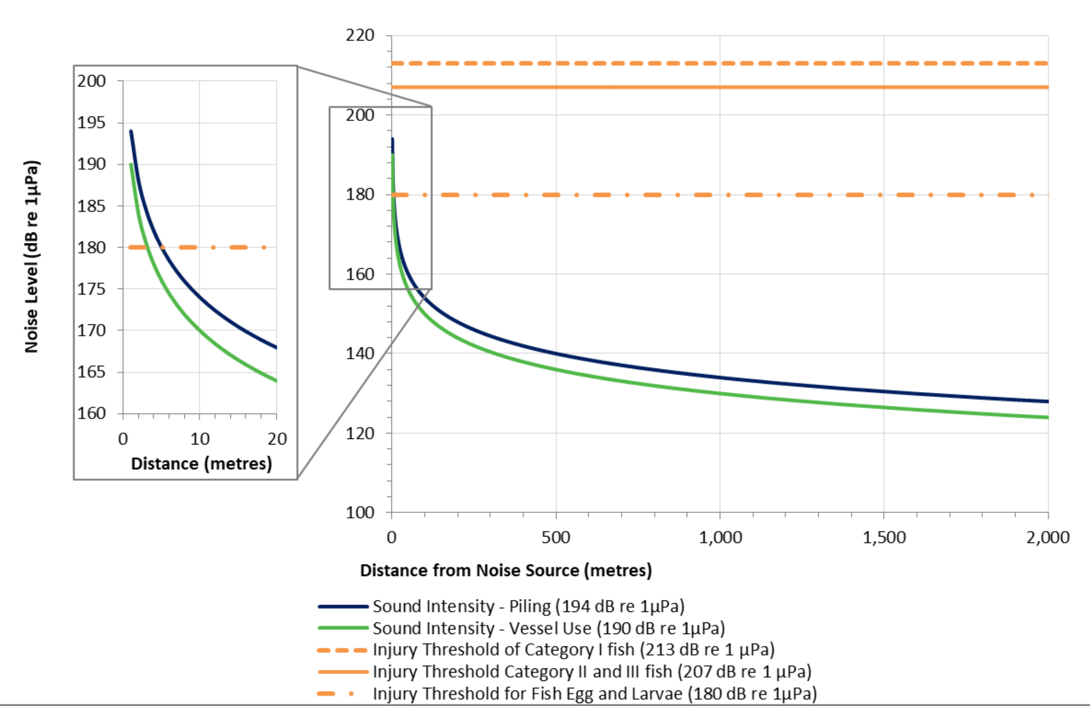
Spherical spreading is assumed.
R_0 = the reference range, usually 1 metre.
R = the distance from the reference range.

This provides a measure of sound given to a 1 m reference distance but is based on a number of assumptions; sound transfer is through a homogenous medium (i.e. no attenuation due to variations in temperature, salinity, bathymetry etc.) and infinite space for the sound wave to spread. This method provides a conservative estimate of sound propagation with distance as it struggles to extrapolate sound attenuation in the near field (within tens of metres of the noise source), due to interference between sound waves and reverberation and therefore generally overestimates transmission of sound from the source. As such, it is considered sufficient to examine a 'worst-case' scenario for noise impacts on marine fauna and has been used to assess the potential effects of underwater noise from the proposed Columbus Development operations. The results of the modelling are illustrated below.

E.1.3 Modelling Results

Potential Impact on Fish

Figure E.1. Sound Propagation in Water from Piling Operations and Vessel Use (assuming spherical spreading) Against Popper *et al*. (2014) and Turnpenny and Nedwell (1994) Fish Injury Criteria



Potential Impact on Marine Mammals

Figure E.3. Sound Propagation in Water from Piling Operations and Vessel Use (assuming spherical spreading) Against Southall *et al*. (2007) Significant Behavioural Change (TTS-Onset) Criteria for Marine Mammals to Multi-Pulse Noise

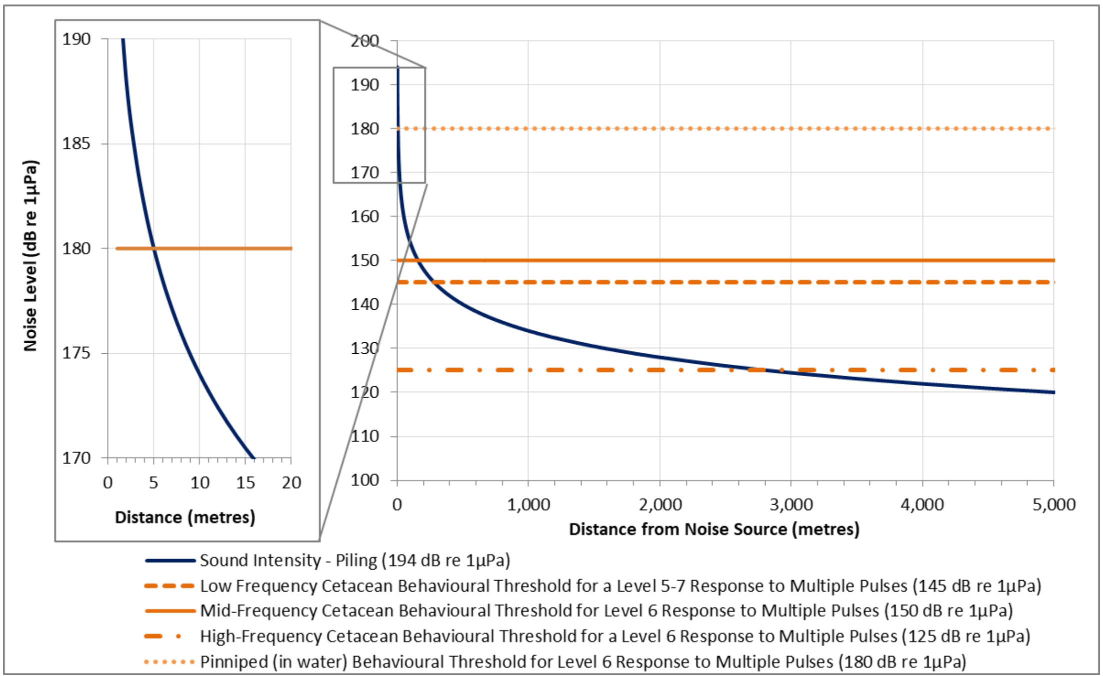
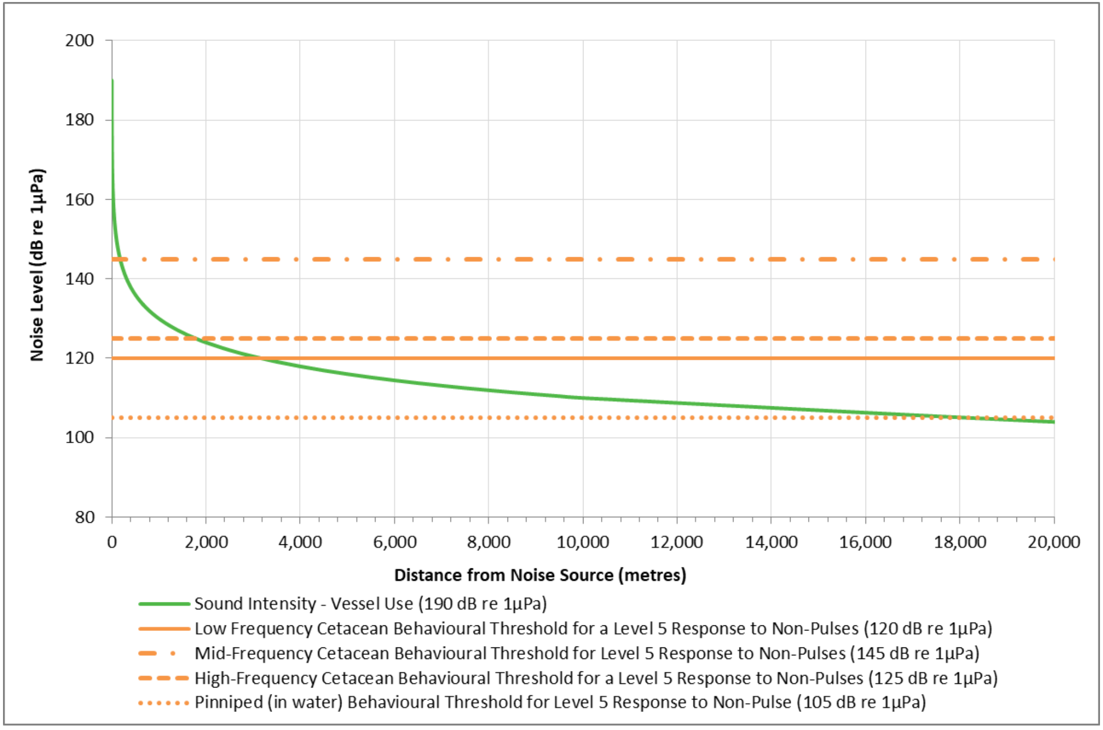


Figure E.4. Sound Propagation in Water from Piling Operations and Vessel Use (assuming spherical spreading) Against Southall *et al*. (2007) Significant Behavioural Change (TTS-Onset) Criteria for Marine Mammals to Non-Pulse Noise

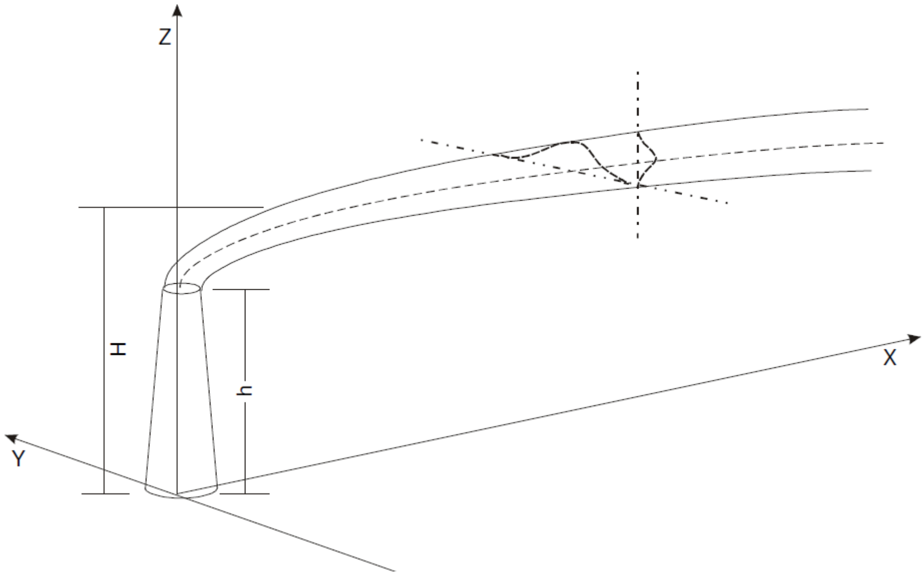


F.1 Atmospheric Dispersion Modelling

The simple model used as a spreadsheet based and derived from "*Davis, M.L. and D.A. Cornwell. (1991). Introduction to Environmental Engineering. McGaraw-Hill International. Page 459*".

The analytical model is based on the Gaussian diffusion equation. The Gaussian element refers to the observation that the concentration of a gas released from a point follows an approximate normal distribution perpendicular to the centre line of the plume.

Figure F.1. A Graphical Representation of the Gaussian Equation



The concentration along the centre line is inversely proportionate to the distance from the source, although very close to the source the concentration is decreased due to plume rise. Thus, a skewed concentration curve is characteristic of this sort of model. The governing equation is shown below:

$$X(x, y, 0, H) = \left[\frac{Q}{\pi s_y s_z u}\right]\left[\exp\left[-\frac{1}{2}\left(\frac{y}{s_y}\right)^2\right]\right]\left[\exp\left[-\frac{1}{2}\left(\frac{H}{s_z}\right)^2\right]\right]$$

Where $X(x,y,0,H)$ = downwind concentration at ground level, g/m^3
Q = emission rate of pollution, g/s
s_y,s_z = plume standard deviations, m
u = wind speed, m/s

The basic Gaussian diffusion equation has the following assumptions:

- Atmospheric stability, that is the amount of mechanical mixing in the air, is uniform throughout the layer into which the gas stream is discharged (normally the boundary layer);
- Turbulent diffusion is random and therefore the dilution of the contaminated gas stream in both the vertical and horizontal direction can be described by the Gaussian or normal equation;
- The gas stream is released into the atmosphere at a distance above ground level that is equal to the stack height plus the plume rise (caused by convection if the released gas is hotter than the ambient temperature);
- The degree of dilution is inversely proportional to the wind speed (although wind speed data is not actually used within this model);
- Pollutant material that reaches the ground is totally reflected back into the atmosphere.

The calculation of H is obtained from adding ΔH and h via Holland's formula:

$$\Delta H = \frac{v_s d}{u}\left[1.5 + \left(2.68\times10^{-2}(P)\left(\frac{T_s - T_a}{T_s}\right)d\right)\right]$$

Where v_s = stack velocity, m/s
d = stack diameter
P = Pressure, kPa
T_s = stack tempreture, Kelvin
T_a = air temperature, Kelvin

Specific assumptions for the modelling of the atmospheric emissions produced from power generation of the Columbus Development are:

Physical Parameters

- Height of discharge (h) 50 metres above LAT (taken to represent ground level).
- Temperature of (Ts) 200 degrees Celsius, 473 Kelvin.

Atmospheric Conditions

- Wind speed (u) of 10 metres per second.
- Temperature (Ta) 15 degrees Celsius, 288 Kelvin.
- Pressure (P) 95.0 kPa (thousand Pascals).
- Overcast conditions (neutral stability).

Discharge Characteristics:

- <u>Emission from power generation during drilling activities</u>:
  - Daily fuel consumption of MODU and ERRV of 23 tonnes/day generating the following releases:
    - 1.37 tonnes per day NO_x (molecular weight: 46g/mol);
    - 0.092 tonnes per day SO_2 (molecular weight: 64g/mol);
    - 0.05 tonnes of VOC per day (molecular weight: 40g/mol).
  - Emission factors from DECC (2008).
- <u>Emissions from power generation during installation and commissioning activities</u>:
  - Daily fuel consumption of DSV of 22 tonnes/day generating the following releases:
    - 1.31 tonnes per day NO_x (molecular weight: 46g/mol);
    - 0.088 tonnes per day SO_2 (molecular weight: 64g/mol);
    - 0.04 tonnes of VOC per day (molecular weight: 40g/mol).
  - Emission factors from DECC (2008).

Please note the modelling was conducted using a combined annual release of NOx and VOCs and not in separate batches. This represents a worst case assessment.

Appendix G: Oil Spill Modelling Study

This appendix presents the results of the oil spill modelling study undertaken to support the Columbus Development in order to gain an understanding of the behaviour of potential worst-case oil spill scenarios in the marine environment.

G.1 OILMAP Modelling Package

The oil spill modelling study has been undertaken using OILMAP (Version 7.1.5.0), an advanced oil modelling tool developed and licensed by RPS ASA. OILMAP provides rapid predictions of the fate and transport of spilled oil and can calculate the probability of key areas being impacted.

The model estimates the temporal variation of the oil's areal coverage, oil thickness, and oil viscosity. It also predicts the oil mass balance or the amount of oil on the free surface, in the water column, evaporated, on the shore, and outside the study domain versus time. The fate processes in the model include spreading, evaporation, entrainment or natural dispersion, and emulsification.

RunStoch is the stochastic module used for computing probability of key areas being impacted by oil. In the stochastic mode spill simulations are performed stochastically varying the environmental data used to transport the oil. Either winds, currents, or both may be stochastically varied. The multiple trajectories are then used to produce contour maps showing the probability of surface and shoreline oiling. The trajectories are also analysed to give travel time contours for the spill.

Stochastic modelling has been conducted for all four seasons; winter (December – February), spring (March – May), summer (June – August) and autumn (September – November), with 100 simulations run per season.

All modelling has been undertaken in accordance with the requirements outlined in Appendix B of the OPRED Guidance Notes for Preparing Oil Pollution Emergency Plans for Offshore Oil & Gas Installations and Relevant Oil Handling Facilities (Revision 4: December 2017).

G.2 Modelled Scenarios

G.2.1 Worst Case Spill Scenario

The following worst-case spill scenario have been modelled for the Columbus field development:

- **Scenario 1**: subsea blowout release at the Columbus CDev-1 well location with a cumulative release of 95,400 m^3 of 47.6° API condensate.

The justification as to why this scenario has been chosen is provided in Section 10.4.

E.2.2 Columbus Condensate Properties

Different oil characteristics lead to differences in behaviour of the oil at sea.

The properties of the condensate from the Columbus reservoir are presented in Table G.1. The Columbus condensate is an ITOPF Group 1 oil with an API of 47.6° and specific gravity of 0.79. This indicates that it contains a high proportion of volatile components and would therefore be subject to very high rates of evaporation (>50%) when exposed to the marine environment (ITOPF, 2011d).

It also has an asphaltene content of 0.15% indicating that it is unlikely to readily form an emulsion and a low wax content (3.3%) and pour point (-36°C); therefore, even if the ambient temperature is low, the oil will remain a liquid with high evaporation rates (ITOPF, 2011d).

Table G.1. Columbus Condensate Profile

Property	Columbus Condensate
ITOPF Group	Group 1
API (°)	47.6
Specific Gravity	0.79
Viscosity	2.226cSt @ 10°C; 1.775cSt @ 20°C
Pour Point (°C)	-36
Wax Content (% by weight)	3.3
Asphaltene Content (% by weight)	0.15

E.2.3 Modelling Inputs

Table G.2 summarises the parameters that were entered into OILMAP to model the fate of the Columbus worst-case spill scenario.

Table G.2. Modelling Input Parameters for Scenario 1: Well Blowout Scenario at Columbus

Scenario 1: Well Loss Parameters			
Loss from Well / FPSO / Rig (please specify)	Well Blowout	**Instantaneous Loss?**	No
Worst-case volume	95,400 m^3	**Will the well self-kill? If yes, when**	No, it is assumed a relief well would be required.
Flow rate	1,590 m^3 / day		
Justification for predicted worst-case volume	This represents the anticipated worst case blowout scenario for the CDev-1 well (it assumes the flow can only be stemmed by drilling a relief well which would take a total of 60 days to drill).		

Location			
Spill Source point Latitude (N/S)	57° 20’ 56.2’’ N	**Spill source point Longitude (E/W)**	02° 05’ 08.2’’ E
Installation / Facility Name	Columbus CDev-1 Well	**Quad / Block**	23/16

Hydrocarbon Properties			
Hydrocarbon name	Condensate		
Assay available	Yes	**Was an analogue used for spill modelling?**	No

Assay	**Name**	**ITOPF Category**	**Specific Gravity**	**API**	**Viscosity at temp**	**Pour Point (°C)**	**Wax Content (%)**	**Asphaltene Content (%)**
	Columbus Condensate	Group 1	0.79	47.6	2.226cP @ 10°C; 1.775cP @ 20°C	-36	3.3	0.15

Metocean Parameters				
Sea surface temperature	Winter (Dec – Feb)	6	Summer (June – Aug)	14
	Spring (Mar – May)	9	Autumn (Sep – Nov)	10
Wind data	Data period	2008 – 2016		
	Data reference	NAVGEM (NAVy Global Environmental Model)		
Current data	Data period	2008 – 2016		
	Data reference	HYCOM (HYbrid Coordinate Ocean Model) general ocean circulation model, and TPXO8 tidal harmonics		

Modelled Release Parameters			
Surface or Subsurface	Subsurface	**Depth**	85 m
Release duration	60 Days	**Instantaneous?**	No
Persistence duration	10 Days	**Release rate**	1,590 m^3 / day
Total simulation time	70 Days	**Total release**	95,400 m^3
No. of Runs	100		

Oil Spill Modelling Software			
Name of software	OILMAP	**Version**	7.1.5.0

G.3 Oil Spill Modelling Results

G.3.1 Stochastic Modelling: Scenario 1 (Well Blowout)

For Scenario 1 (95,400 m^3 condensate (47.6°API) released over 60 days), Table G.3 summarises the predicted minimum time and maximum probability for the slick to cross international median lines and /or to beach for each season modelled. This information is also presented graphically as follows:

- Figure G.1 presents the minimal arrival time of surface oil for each season modelled. Note, the figure excludes areas where there is less than a 10% probability of surface oiling to a minimum thickness of 0.3µm;
- Figure G.2 presents the probability of sea surface oiling to a minimum thickness of 0.3µm for each season modelled. Note, the figure excludes areas where there is less than a 10% probability of surface oiling to a minimum thickness of 0.3µm;
- Figure G.3 and Figure G.4 present the probability of shoreline oiling to a minimum thickness of 1.0µm for each season modelled;
- Figure G.5, Figure G.6 and Figure G.7 illustrate those protected areas which may be at risk from surface oiling to a minimum thickness of 0.3 µm and shoreline oiling to a minimum thickness of 1.0µm.

The modelling results show that there is an extremely high probability that a worst case release of condensate from the CDev-1 well location would cross the UK / Norway median line in all seasons, with shortest arrival time after 6 hours in autumn. There is a fairly low probability (up to 8% in winter) that the spill would also cross the median line between Norway and Denmark.

There is a fairly low probability (up to 6%) that a spill could beach on coastline of the Shetland Islands, with the shortest arrival time after 596 hours in winter. There is also a low probability that beaching will occur on the Aberdeenshire (5%) and Highland (1%) coasts. The greatest volume beached is 227.1 m^3 in winter. There is a low to moderate probability that beaching could occur on the Norwegian (up to 17%) and Danish coastlines (11%), with the shortest arrival time to Norway after 330 hrs in winter. In addition, beaching could occur on German coastlines, however the probability is very low (up to 1%).

There is the potential for a number of marine protected areas to be subject to surface oiling, however, all but one of these sites are designated for subsea features and, as such, no potentially significant environmental effects are predicted at these sites. The potential impact to the remaining site; the Southern Trench NC MPA, which is of importance for minke whale, is assessed in Section 10.

A number of UK coastal marine protected areas may also be subject to shoreline oiling, although the probability of beaching as noted above is fairly low (up to 6%).

Table G.3. Oil Spill Modelling Results for Scenario 1 (Well Blowout)

Scenario 1 - Well Blowout					
Spill Scenario / Descriptor: 95,400 m^3 of condensate (47.6°API) released over 60 days					
Season		Winter (December – February)	Spring (March – May)	Summer (June – August)	Autumn (September – November)
Median Crossing Note 1					
Identified Median Line	**Probability and Shortest Time to Reach (Minimum Thickness of 0.3µm)**				
UK / Norway	**Maximum Probability**	100 %	100 %	100 %	100 %
	Shortest Arrival Time	7 hrs	8 hrs	8 hrs	6 hrs
Norway / Denmark	**Maximum Probability**	8 %	1 %	n/a	3 %
	Shortest Arrival Time	129 hrs	392 hrs	n/a	323 hrs
Landfall N1					
Predicted Locations	**Probability and Shortest Time to Reach (Minimum Thickness of 1µm)**				
Shetland	**Maximum Probability**	6 %	n/a	n/a	3 %
	Shortest Arrival Time	596 hrs	n/a	n/a	765 hrs
Aberdeenshire	**Maximum Probability**	5 %	3 %	n/a	n/a
	Shortest Arrival Time	960 hrs	623 hrs	n/a	n/a
Highlands	**Maximum Probability**	1 %	n/a	n/a	n/a
	Shortest Arrival Time	1,130 hrs	n/a	n/a	n/a
Norway	**Maximum Probability**	12 %	1 %	2 %	17 %
	Shortest Arrival Time	330 hrs	926 hrs	1,202 hrs	425 hrs
Denmark	**Maximum Probability**	11 %	3 %	1 %	9 %

Scenario 1 - Well Blowout					
	Shortest Arrival Time	508 hrs	799 hrs	942 hrs	564 hrs
Germany	**Maximum Probability**	1 %	1 %	n/a	1 %
	Shortest Arrival Time	1,366 hrs	1,020 hrs	n/a	1,028 hrs
Greatest Volume Beached (m^3)		227.1	3.1	1.1	160.6

Key Sensitivities at Risk			
Site / Designation (refer to Figure G.5 & Figure G.6)	**Qualifying Features**	**Site Description[1, 2, 3, 4]**	**Socio-Economic Considerations**
Offshore Surface Oiling with a Minimum Thickness of 0.3 µm			
1. Norwegian Boundary Sediment Plain NC MPA	OSPAR Threatened and/or Declining species (ocean quahog).	The site is home to the long-lived ocean quahog *Arctica islandica*. The main threat to the ocean quahog is disturbance of the sea bed, most often from bottom fishing activities, but licensed activities, such as oil, gas and aggregate extraction, can also directly and indirectly affect this species.	Oil and gas; Fisheries; Shipping.
2. East of Gannet and Montrose Fields NC MPA	OSPAR Threatened and/or Declining species (ocean quahog). MPA protected features (offshore deep-sea muds).	This site is designated for its ocean quahog aggregations and protects the full extent of an area of offshore deep sea mud. It is one of the few examples of Atlantic-influenced offshore deep sea mud habitats on the continental shelf in the region.	Oil and gas; Fisheries; Shipping.

[1] SNH (2018) *Marine Protected Areas (MPAs)*. Available from: http://www.snh.gov.uk/protecting-scotlands-nature/protected-areas/national-designations/marine-protected-areas-(mpa)/ [Accessed June 2018].
[2] JNCC (2018a) *Special Areas of Conservation (SACs)*. Available from: http://jncc.defra.gov.uk/page-23 [Accessed June 2018].
[3] JNCC (2018b) *Special Protected Areas (SPAs)*. Available from: http://jncc.defra.gov.uk/page-162 [Accessed June 2018].
[4] JNCC (2018c) *Marine Conservation Zones (MCZs)*. Available from: http://jncc.defra.gov.uk/page-4525 [Accessed June 2018].

Scenario 1 - Well Blowout			
3. Central Fladen NC MPA	OSPAR Threatened and/or Declining habitat (Burrowed mud). Geomorphological feature (Sub-glacial tunnel valley representative of the Fladen Deeps).	This site is designated for a particular type of mud habitat that is characterised by feather-like soft corals called sea pens, and the burrows made by crustaceans such as mud shrimp and the Norway lobster (*Nephrops norvegicus*). Burrowed mud is considered by OSPAR to be a Threatened and/or Declining habitat across the North-east Atlantic. The site also includes an unusual tunnel valley, representing part of a Key Geodiversity Area known as the Fladen Deeps or 'The Holes'. It is thought these valleys were created by erosion of melt water under an ice sheet in former ice ages.	Oil and gas; Fisheries; Shipping.
4. Turbot Bank NC MPA	Single protected feature (Sandeels)	Turbot Bank is important for sandeels, particularly Raitt's sand eel *Ammodytes marinus*. The site contains the type of sandy sediment with low silt and clay components that sandeels prefer. The sandeels present within Turbot Bank are an important component of the larger sandeel population in the northern North Sea. Sandeels play an important role in the wider North Sea ecosystem, providing a vital source of food for seabirds such as Atlantic puffin and black-legged kittiwake, fish such as plaice and marine mammals such as dolphins.	Oil and gas; Fisheries; Shipping.
5. Scanner Pockmark SAC and proposed boundary extension	Annex I habitat: submarine structures made by leaking gases.	The Scanner pockmark complex comprises of two large pockmarks with a combined area of approximately 320,000 m^2 and depths of up to 16.7 m below the surrounding sea floor. At the base of the pockmarks, blocks of methane derived authigenic carbonate have been recorded. There is some evidence of chemosynthetic bacteria in the Scanner pockmark which grow by oxidising sulphur and may support some of the site's other notable fauna.	Oil and gas; Fisheries; Shipping.
6. Braemar Pockmarks SAC and proposed boundary extension	Annex I habitat: submarine structures made by leaking gases.	The Braemar pockmarks are a series of crater-like depressions on the sea floor at a depth of approximately 120 m. There are 27 Pockmark depressions within the site of various sizes, from 40 cm deep and 330 m^2 to 4m deep with an area of 10000 m^2. A further 21 pockmarks are located within 1 km of the site boundary. Large blocks, pavement slabs and smaller fragments of methane derived authigenic carbonate have been deposited through a process of precipitation during the oxidation of methane gas.	Oil and gas; Fisheries; Shipping.
7. Fulmar MCZ	OSPAR Threatened and/or Declining species (ocean quahog). MPA protected features (offshore deep-sea muds and mixed sediments).	Fulmar MCZ, located approximately 224 km from the Northumberland coast, is designated for its offshore deep-sea muds and mixed sediments which provide important spawning sites, food and shelter for marine mammals. The site, which ranges from 50 m to 100 m deep is also designated for the presence of Ocean Quahog.	Oil and gas; Fisheries; Shipping

Scenario 1 - Well Blowout			
8. Southern Trench NC MPA (proposed)	OSPAR Threatened and/or Declining habitat (Burrowed mud). Annex II species: Minke whale	The 10 km long site, located on the south-eastern coast of the Moray Firth, consists of a large undersea valley extending between Banff and Fraserburgh. Two protected features are present at the site: burrowed mud and minke whale *Balaenoptera acutorostrata*. The site is also thought to be an important nursery area for many fish species.	Fisheries; Shipping
Shoreline Oiling with a Minimum Thickness of 1.0 µm			
9. Mousa to Boddon NC MPA	Two protected features (sandeels and marine geomorphology of the Scottish Shelf seabed)	The site, located to the south of the Shetland mainland, is designated for the presence of important burrowing grounds of sandeels. Sandeels play an important role in the wider North Sea ecosystem, providing a vital source of food for seabirds such as Atlantic puffin and black-legged kittiwake, fish such as plaice and marine mammals such as dolphins.	Tourism.
10. Fetlar to Haroldswick NC MPA	Protected features (black guillemot; circalittoral sand and coarse sediment communities; horse mussel beds; kelp and seaweed communities on sublittoral sediment; maerl beds; shallow tide-swept coarse sands with burrowing bivalves); marine geomorphology of the Scottish Shelf Seabed.	The clear shallow waters in the inner part of the MPA are ideal for maerl, a nodular red seaweed with a hard chalky skeleton, which carpets the sea bed in places. Maerl beds provide shelter and protection to a wide range of animals and plants including some important commercial fish species. In some of the narrows between the islands, tide-swept coarse, gravelly sands support an abundance of bivalves such as tellins and surf clams that burrow into the sediment, as well as worms, shrimp-like crustaceans and sand hoppers. In some places luxuriant growths of sugar kelp, bootlace weed and other red and brown seaweeds are to be found. Horse mussel beds are found in the slightly deeper tide-swept areas and support dense brittlestar communities that form a mesmerising sea of waving arms, together with starfish, sea urchins, feather stars, sponges and dead man's fingers.	Fisheries.
11. Fair Isle SPA	Breeding bird assemblage; seabird assemblage of international importance (regularly supporting at least 20,000 seabirds).	Fair Isle SPA, which encompasses the waters surrounding Fair Isle, is designated as an special protected area for supporting important breeding and migratory bird assemblages, as well as hosting an internationally important breeding seabird assemblage of 180,000 individual seabirds.	Tourism; Fisheries

Scenario 1 - Well Blowout			
12. Mousa SAC / SPA	Annex I habitats: reefs and sea caves. Annex II species: harbour seal Qualifying interests include breeding bird assemblages.	The site, located in the southern part of the Shetland Islands, is designated for the presence of Annex I listed habitats reefs and submerged sea caves, in addition to Annex II listed species harbour seal *Phoca vitulina*. Mousa SAC / SPA also supports important breeding assemblages of seabirds.	Tourism.
13. Noss SPA	Qualifying interests include breeding bird assemblages and a seabird assemblage of international importance (regularly supporting at least 20,000 seabirds).	The site, situated on the island of Bressay in the eastern part of the Shetland Islands, is designated for hosting important migratory populations of gannet, great skua and guillemot. The site also supports over 100,000 individual seabirds during the breeding season	Tourism.
14. Feltar SPA	Annex I species; Seabird assemblage of international importance (regularly supporting at least 20,000 seabirds).	This site comprises a range of habitats including species-rich heathland, marshes and lochans, cliffs and rocky shores. The principal areas of importance for birds are the northernmost part of the island and the south-western peninsula of Lamb Hoga. Fetlar SPA is of importance for a number of northern breeding waders, as well as breeding seabirds, which nest especially on the moorlands as well as in some of the other wetlands.	Tourism.
15. Ramna Stacks and Gruney SPA	Qualifying interests include breeding bird assemblage.	The site is composed of a small group of rocky islets, located 2 km from the northernmost point of Mainland Shetland. The Ramna Stacks and Gruney SPA is designated for the resident colony of Leach's petrel *Oceanodroma leucorhoa*, which is one of only seven colonies in Britain and one of eight in Europe.	Tourism.
16. Hermaness, Saxa Vord and Valla Field SPA	Breeding bird assemblage; seabird assemblage of international importance (regularly supporting at least 20,000 seabirds).	The Hermaness, Saxa Vord and Valla Field SPA is located in the north-west corner of the island of Unst, Shetland, and is comprised of high sea cliffs, grassland, blanket bog and heath. The site is designated for supporting important breeding populations of red throated diver *Gavia stellata* and other seabirds, as well as regularly hosting 152,000 individual seabirds during the breeding season.	Tourism.

Scenario 1 - Well Blowout			
17. Sumburgh Head SPA	Breeding bird assemblage; seabird assemblage of international importance (regularly supporting at least 20,000 seabirds).	Sumburgh Head SPA comprises the beaches, sea cliffs and waters surrounding Sumburgh Head, the most southern tip of the Shetland mainland. The site is designated for supporting important breeding populations of several seabirds which forage in the waters of the SPA. During the breeding season, the area regularly supports 35,000 individual seabirds.	Tourism
18. East Mainland Coast, Shetland pSPA	Qualifying interests include breeding and non-breeding bird assemblages.	The qualifying interests for the site are breeding Red-throated diver and non-breeding common eider, gret northern diver, long-tailed duck, red-breated merganser and Slavonian grebe. The site encompasses the marine waters to the east of mainland Shetland, from Samphrey in the north to Aith Ness in the south. In winter, these waters are a stronghold for great northern divers, grebes and sea ducks. In the summer months, these waters also provide rich feeding grounds for over 15% of the British population of breeding red-throated divers.	Tourism.
19. Bluemull and Colgrave Sounds pSPA	Qualifying interests include breeding bird assemblages.	The qualifying interests for the site are breeding Red-throated diver. This site lies in the north east of Shetland, between the islands of Unst, Yell and Fetlar. This marine area provide important feeding grounds for over 15% of the British population of breeding red-throated divers. The breeding range of these divers in Great Britain is restricted to Scotland and within Shetland their numbers are particularly high on Unst and Yell.	Tourism.
20. East Caithness Cliffs NC MPA / SPA	Breeding bird assemblage; seabird assemblage of international importance (regularly supporting at least 20,000 seabirds) MPA protected feature black guillemot	The East Caithness Cliffs NC MPA / SPA encompasses the sea cliffs and the nearshore coastal waters between Wick and Helmsdale, on the Caithness Coast. The site is designated for supporting important populations of breeding seabirds, including Annex I listed peregrine falcon *Falco peregrinus*, in addition to a year-round population of black guillemot *Cepphus grylle*. During the breeding season, the site regularly supports an internationally important breeding seabird assemblage of 300,000 individual seabirds.	Fisheries; Tourism; Shipping.
21. Buchan Ness to Colliston Coast SPA	Qualifying interests include breeding bird assemblages and a seabird assemblage of international importance (regularly supporting at least 20,000 seabirds).	The site comprises a 15 km stretch of seacliff hosting a variety of vegetation including maritime heath, grassland and brackish flushes. During the breeding season, the area regularly supports 95,000 individual seabirds including guillemot, kittiwake, herring gull, shag and fulmar.	Tourism; Shipping.

Scenario 1 - Well Blowout			
22. River Dee SAC	Annex II species: Atlantic salmon, freshwater pearl mussel and otter	The Dee is a major east coast Scottish river, which flows uninterrupted for some 130 km from its upland reaches in the Cairngorms to the North Sea. The site supports healthy and nationally important populations of otter *Lutra lutra*, Atlantic salmon *Salmo salar* and freshwater pearl mussel *Margaritifera margaritifera*, which are all Annex II listed species.	Fisheries; Tourism.
23. Troup, Pennan and Lion's Heads SPA	Qualifying interests include breeding bird assemblage; seabird assemblage of international importance (regularly supporting at least 20,000 seabirds)	The Troup, Pennan and Lion's Heads SPA covers a 9 km stretch of seacliffs along the Banff and Buchan coast of the south-eastern Moray Firth. The cliffs provide ideal nesting for seabirds which feed in the rich waters offshore, particularly guillemot. The site supports an internationally important seabird assemblage during the breeding season of over 150,000 individuals.	Fisheries; Tourism; Shipping.
24. Fowlsheugh SPA	Qualifying interests include breeding bird assemblages and a seabird assemblage of international importance (regularly supporting at least 20,000 seabirds).	The site, located 4 km south of Stonehaven on the east coast of Aberdeenshire in north-east Scotland, is designated for supporting important breeding populations of fulmar, guillemot, herring gull, kittiwake and razorbill, as well as hosting 145,000 individual seabirds during the breeding season.	Fisheries; Tourism; Shipping.
25. Ythan Estuary, Sands of Forvie and Meikle Loch pSPA	Aggregations of breeding birds	This site, located on the Eastern Aberdeenshire coast, covers the proposed marine extension to the Ythan Estuary, Sands of Forvie and Meikle Loch SPA. These waters serve as important foraging grounds for breeding little terns *Sternula albifrons* and Sandwich terns *Thalasseus sandvicensis*, which nest of the dune systems of the SPA itself and dive for their prey in the estuary and adjacent coastal waters.	Tourism; Shipping; Fisheries.
26. Moray Firth pSPA	Qualifying interests include breeding and non-breeding bird assemblages.	This site, situated in the inner Moray Firth, is proposed for designation due to the non-breeding population of Annex I listed bird species great northern diver *Gavia immer*, red-throated diver and Slavonian grebe *Podiceps auritus*, which are all of European importance. In addition, the proposed SPA supports wintering populations of eight migratory bird species.	Shipping; Tourism

Notes

[N1] Shortest arrival time and maximum probability values are not necessarily linked to the same run. The results represent a worst case scenario for each feature based on the analysis of all model runs.

Figure G.1. Scenario 1 – Seasonal Arrival Time Plot (Well Blowout)

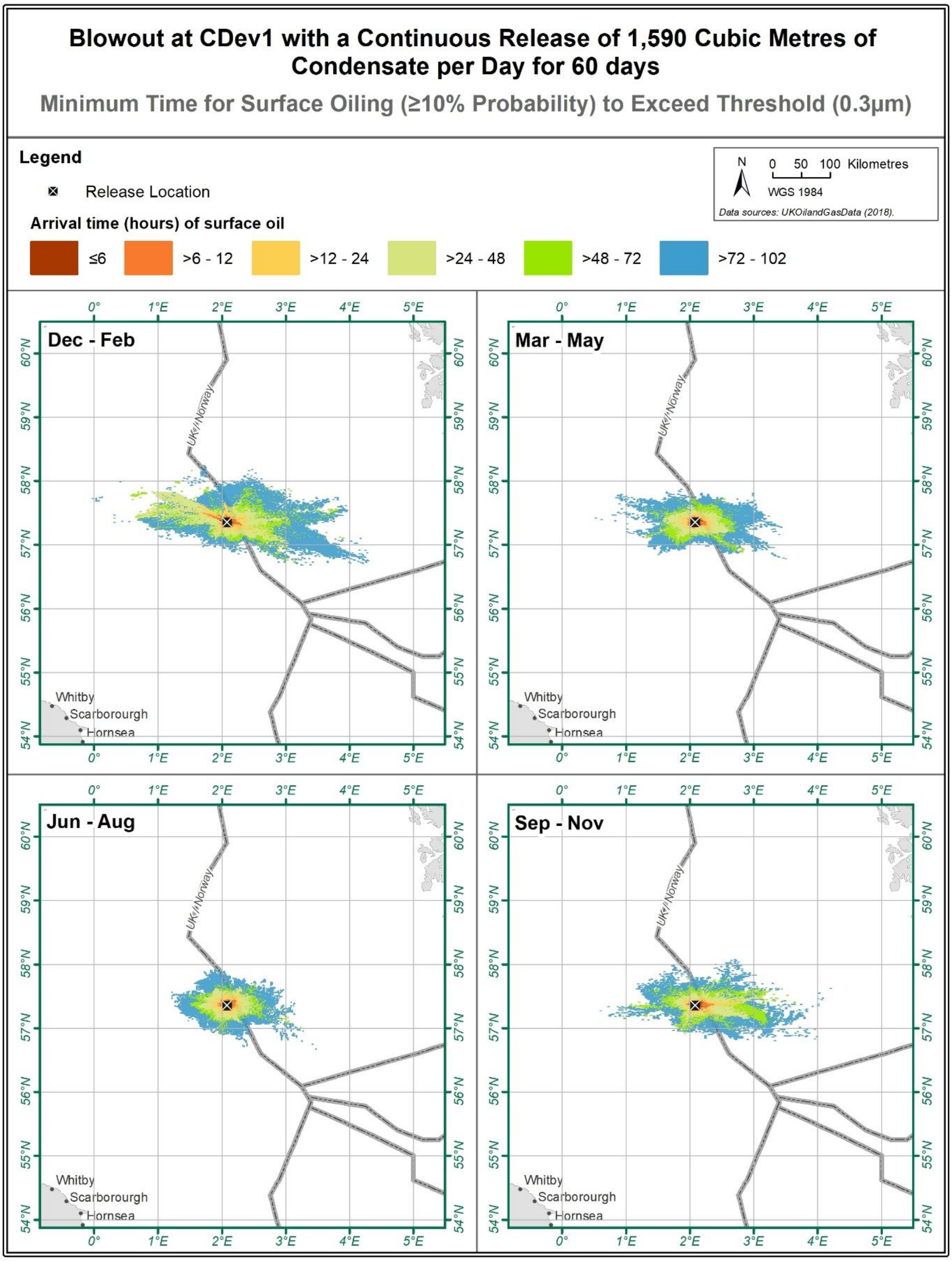


Figure G.2. Scenario 1 – Probability of Surface Oiling (Well Blowout)

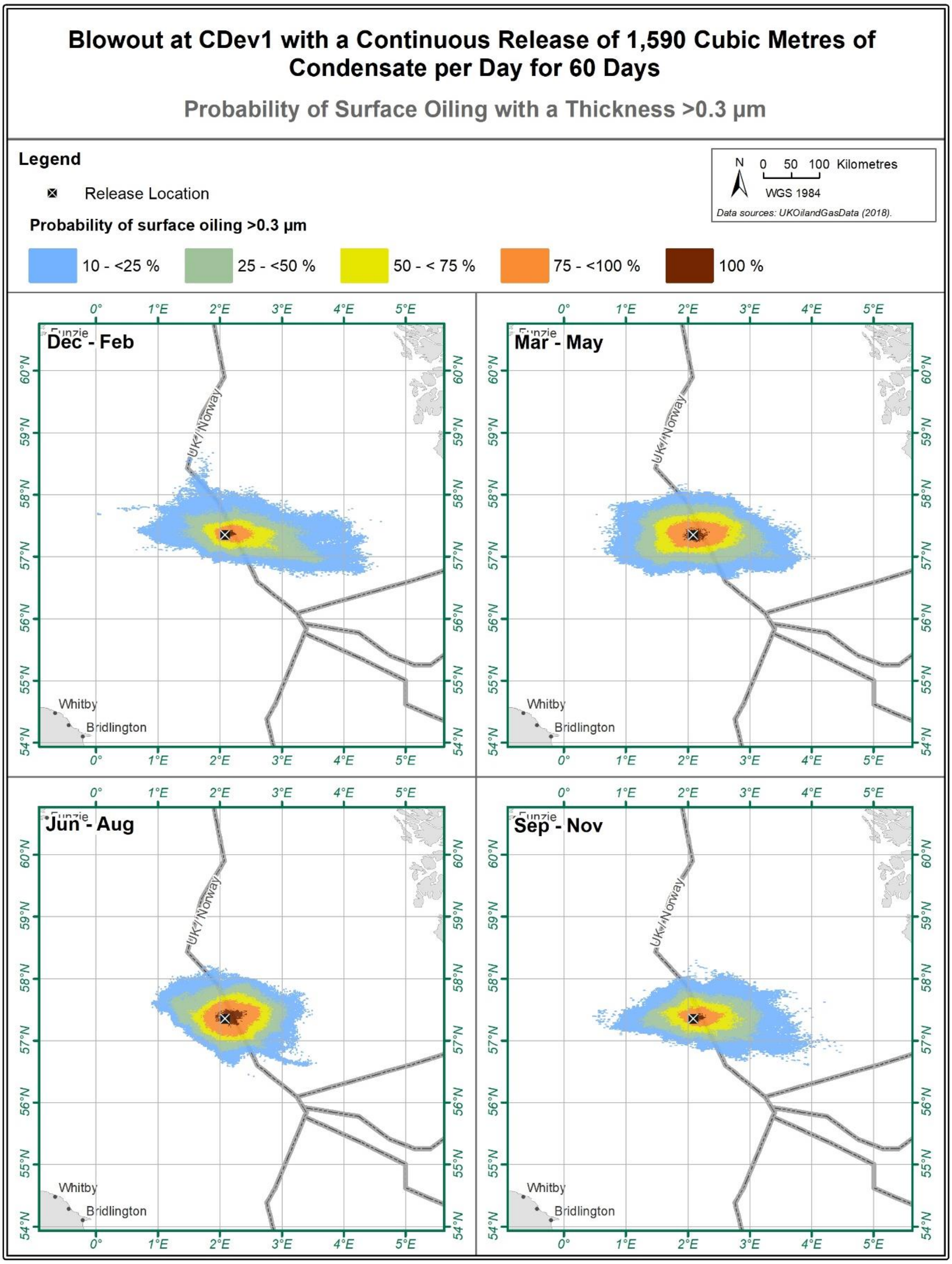


Figure G.3. Scenario 1 – Probability of Shoreline Oiling (Well Blowout), Map 1

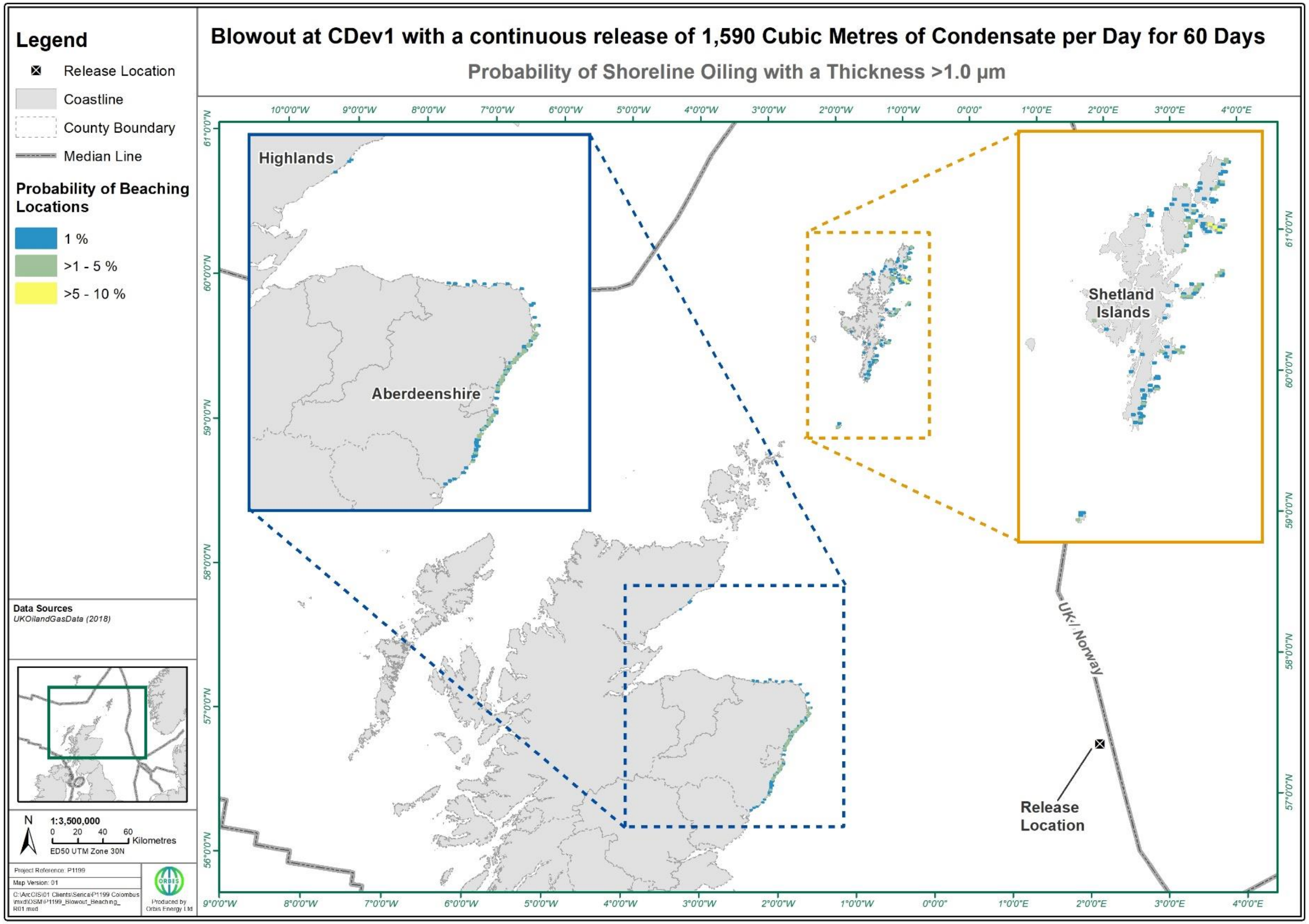


Figure G.4. Scenario 1 – Probability of Shoreline Oiling (Well Blowout), Map 2

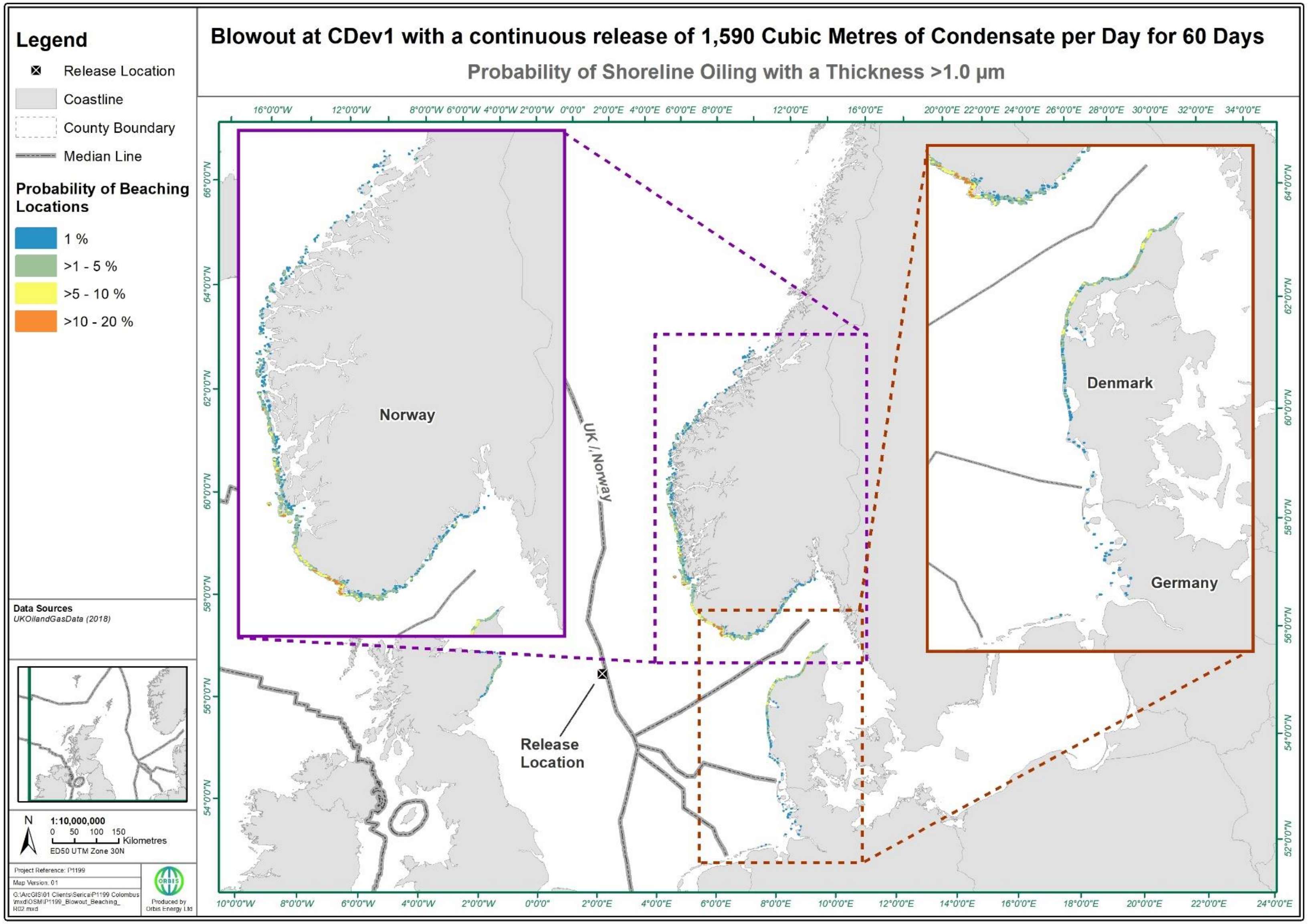


Figure G.5. Scenario 1 – Protected Areas at Risk from Oiling (Well Blowout), Map 1

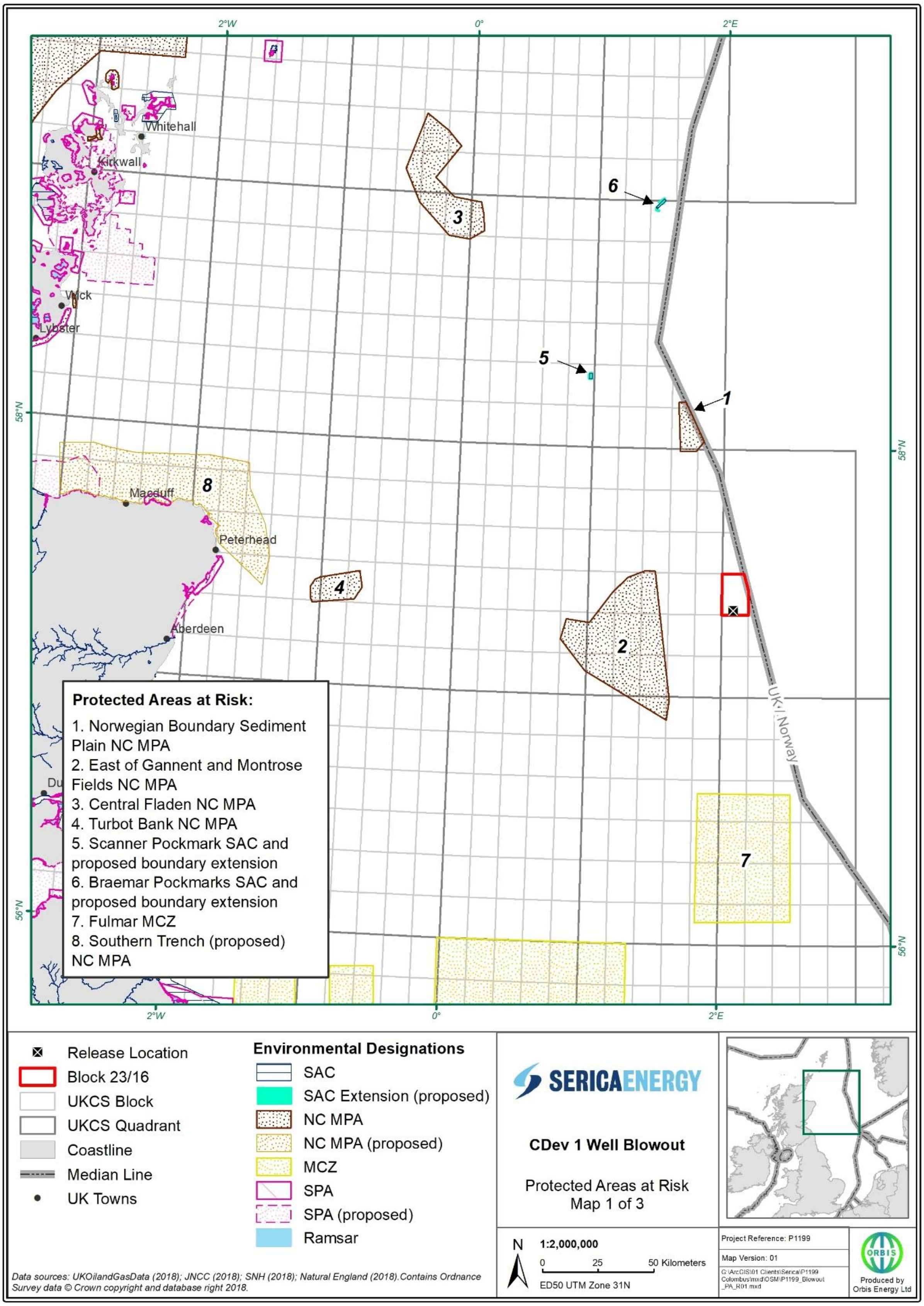


Figure G.6. Scenario 1 – Protected Areas at Risk from Oiling (Well Blowout), Map 2

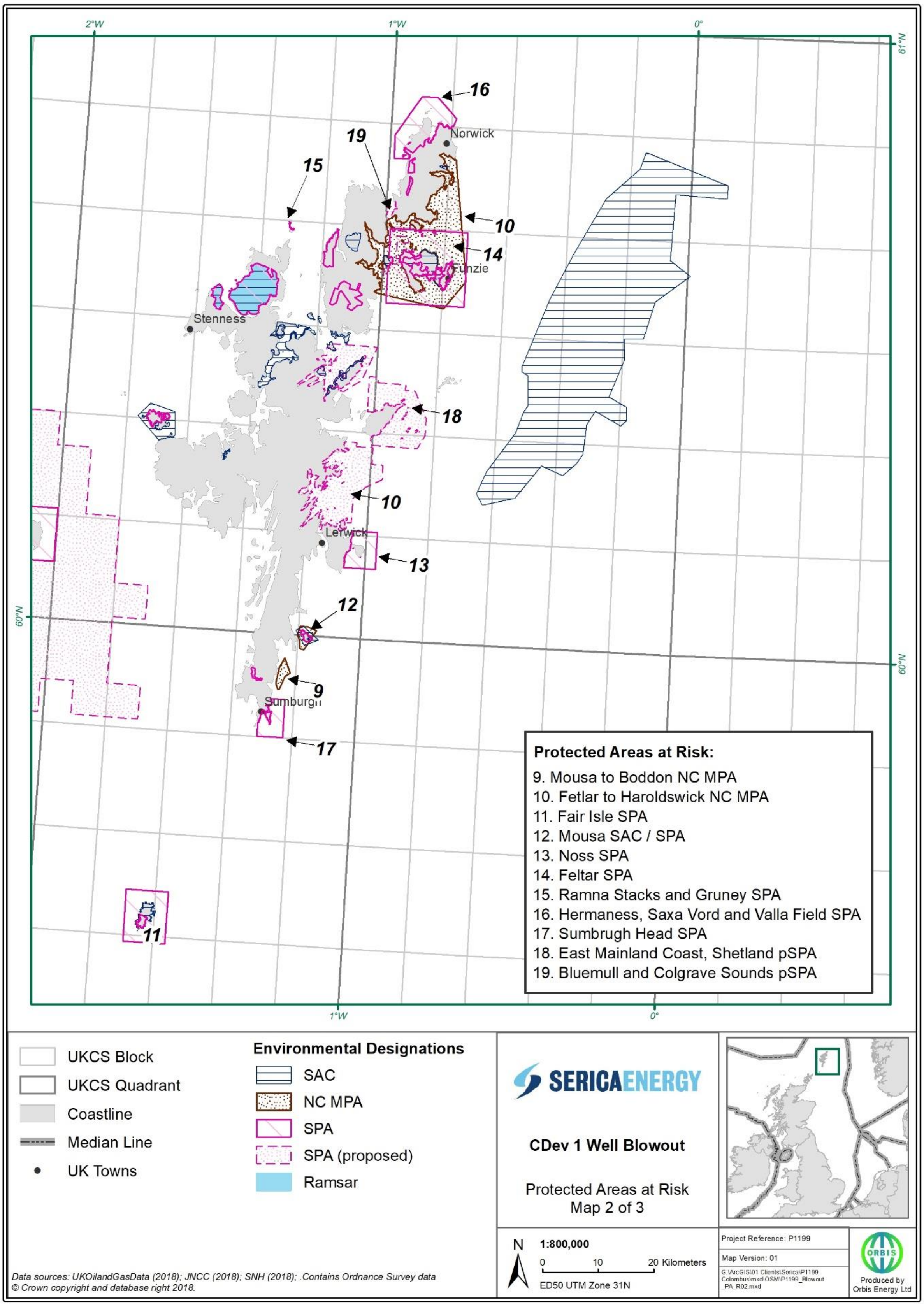
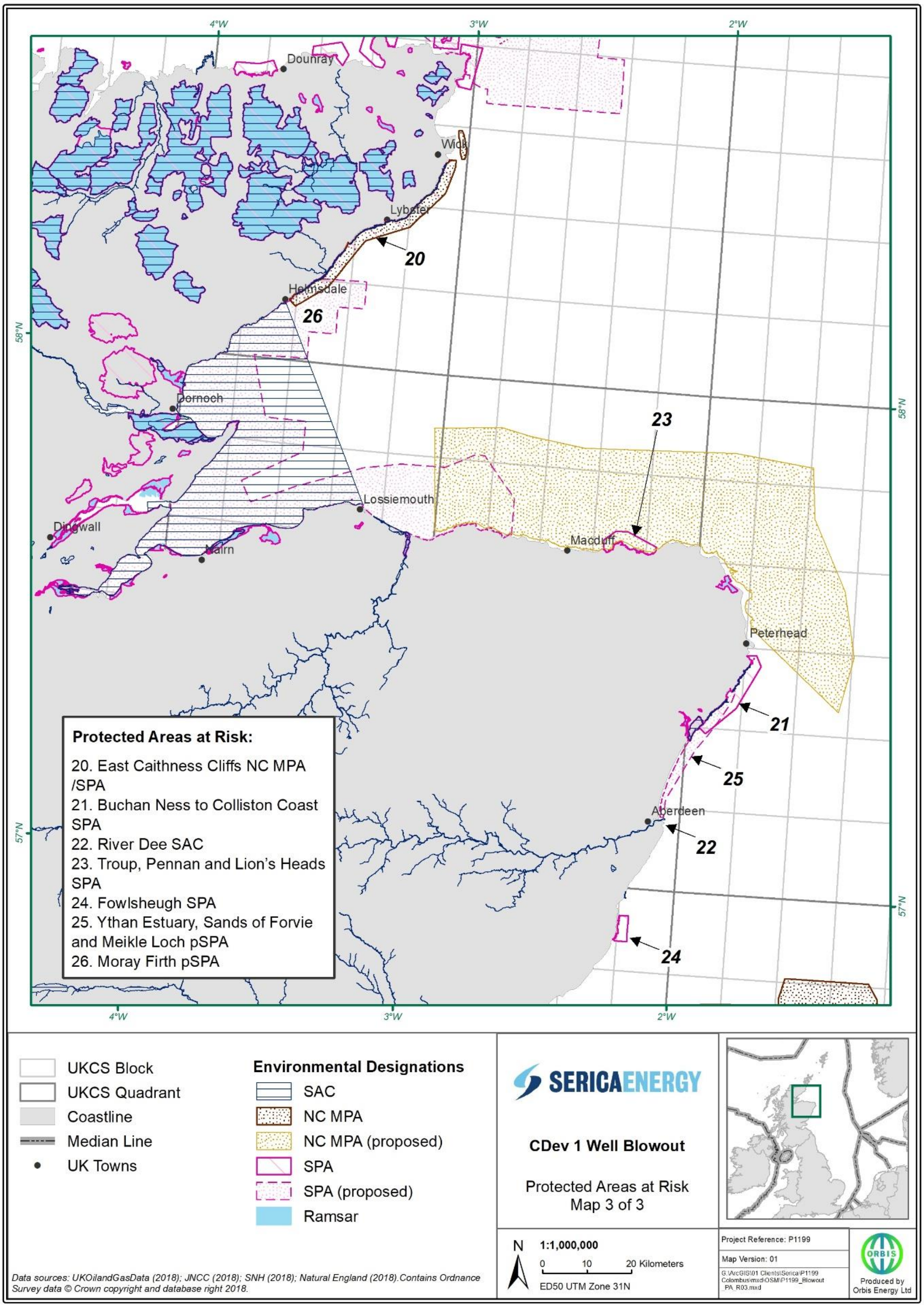


Figure G.7. Scenario 1 – Protected Areas at Risk from Oiling (Well Blowout), Map 3



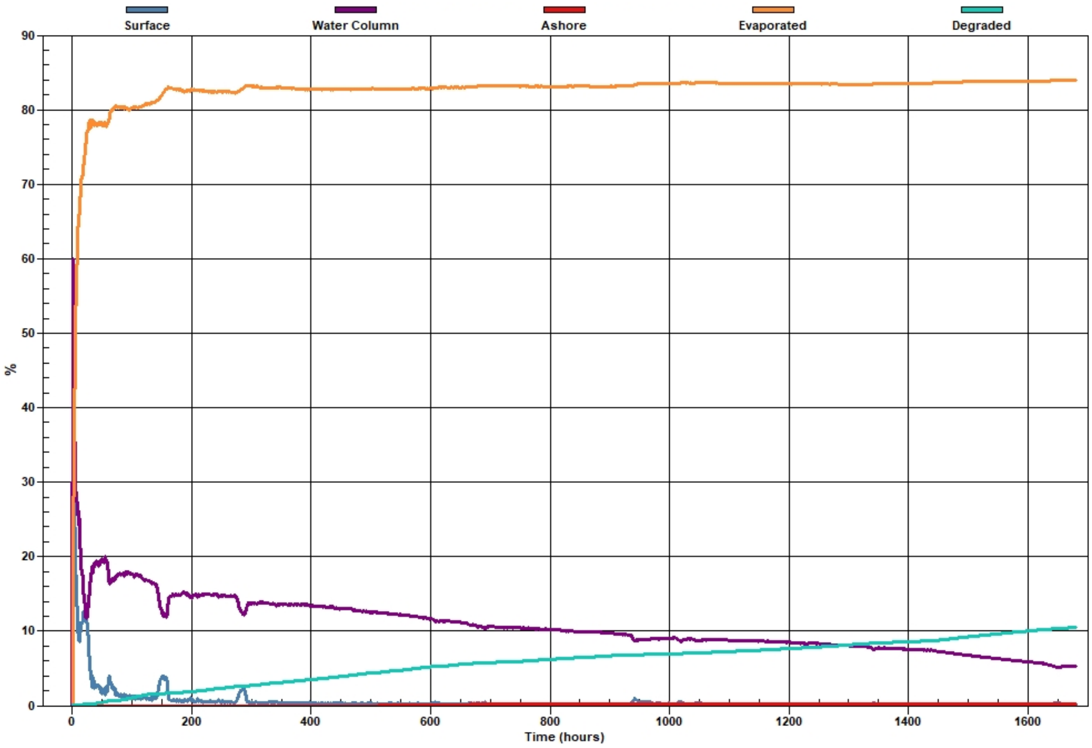
G.3.2 Trajectory Modelling

The blowout stochastic modelling found that the largest volume of oil beached in any one run was 224.2 m^3 (refer to Figure G.8).

The worst-case trajectory for shoreline oiling was a release commencing on the 1st December 2013 at 00:00 hrs (Stochastic Run 92 out of 100, starting in winter). The trajectory data has been extracted to perform a fates analysis and to show the extent of the oiling.

Figure G.8 illustrates the fate of the modelled crude over time, based on the worst-case trajectory run for shoreline oiling. After day 1 (24 hours), 1,666 m^3 of crude oil has been released into the environment with 0 % ashore, 11.3 % remaining on the sea surface, 76.6 % evaporated, 11.9 % sub-surface and 0.2 % degraded. At the end of the simulation, on day 70 (1,680 hours), 95,400 m^3 of crude oil has been released into the environment with 0.2 % ashore, 10.5 % degraded, 84.0 % evaporated, 5.2 % sub-surface and 8.46 % on the sea surface.

Figure G.8. Fate of the Condensate Released from the CDev-1 Well over 70 Days [N1]



Notes

[N1] The analysis has been undertaken on a trajectory run using ocean conditions from a release commencing on the 1st December 2013 at 00:00 hrs (Stochastic Run 92 out of 100, starting in winter).