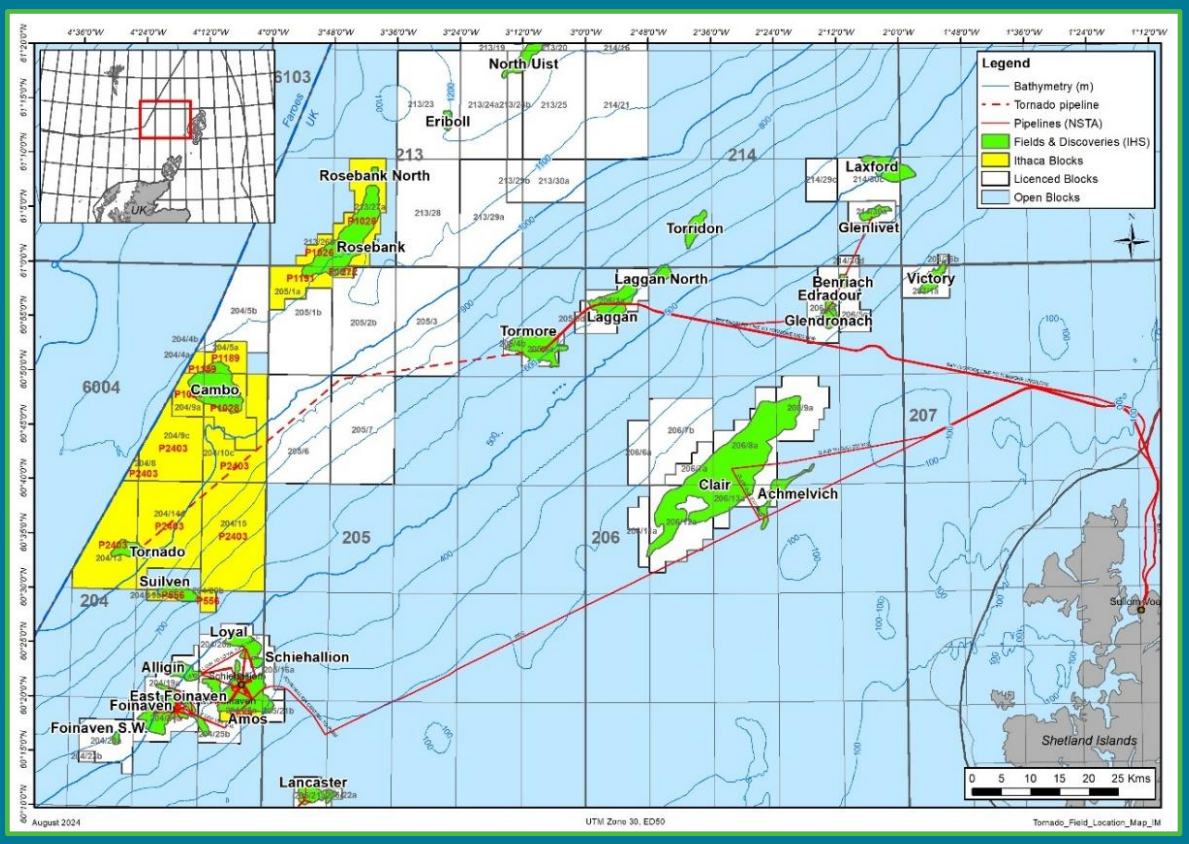
Ithaca SP E&P Limited

# Tornado Field Development Environmental Statement




**OPRED Reference Number: ES/2024/020**

**February 2026**

ITHACA ENERGY

# ENVIRONMENTAL STATEMENT DETAILS

## Section A: Administrative Information

### A1 – Project Reference Number

**Number:** ES/2024/020

### A2 – Developer Contact Details

**Company Name:** Ithaca SP E&P Limited

**Contact Name:** [redacted]

**Contact Title:** Environmental Advisor

### 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 |
|---|---|---|---|
| [redacted] | Orbis Energy Limited | Director | Over 20 years environmental consultancy experience in the oil and gas industry. She has a first class B.Sc (Hons) degree in Environmental Science. |
| [redacted] | Orbis Energy Limited | Director | Over 20 years environmental consultancy experience in the oil and gas industry. He has a M.Sc (by research) in Environmental Science (Environmental Toxicology) and a B.Sc (Hons) in Marine & Freshwater Biology. |
| [redacted] | Orbis Energy Limited | Senior Consultant | Over 12 years environmental consultancy experience in the oil and gas industry. He has a first class master's degree in Environmental Science (MEnvSci). |
| [redacted] | Orbis Energy Limited | Consultant | Over 3 years environmental consultancy experience in the oil and gas industry. She has a B.Sc (Hons) degree in Marine Biology. |
| [redacted] | Orbis Energy Limited | Consultant | Over 2 years environmental consultancy experience in the oil and gas industry. She has a B.Sc (Hons) degree in Environmental Management. |
| [redacted] | Orbis Energy Limited | Consultant | Over 2 years environmental consultancy experience in the oil and gas industry. He has a first class B.Sc (Hons) degree in Geography. |

### A5 – Licence Details

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

**Licence number(s):** P2403

b) Please confirm licences and current equity

| **Licence Number:** P2403 | |
|---|---|
| **Licensee** | **Percentage Equity** |
| Ithaca SP E&P Limited | 50% |
| Adura Operations Limited | 50% |

## Section B: Project Information

### B1 – Nature of Project

a) Please specify the name of the project.

**Name:** Tornado 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:

Ithaca SP E&P Limited, (an affiliate of Ithaca Energy (UK) Limited (Ithaca Energy (UK) Limited and it's affiliated companies being referred to throughout this Environmental Statement as 'Ithaca') and Adura Operations Limited are planning to develop the Tornado gas condensate discovery in United Kingdom Continental Shelf (UKCS) Blocks 204/13 and 204/14d in the Faroe-Shetland channel, West of Shetland (WoS), located approximately 153 km west of the Shetland Islands. The Tornado discovery sits within Licence P.2403, and is jointly held by Ithaca (50%) and Adura Operations Limited (50%). Ithaca is operator on behalf of the Joint Venture (JV).

The Tornado field will be developed as a subsea gas development tied back via a new production pipeline (ca. 86 km in length, 16 inch) and Monoethylene glycol (MEG) line to TotalEnergies E&P UK Limited's existing Greater Laggan Area (GLA) network infrastructure at Tormore (subject to ongoing negotiation). Control of the well will be from a separate control umbilical between Tormore and Tornado.

The field will be operated from the GLA control room at the Shetland Gas Plant (SGP) located onshore on the north coast of the main island of Shetland. When the production fluids arrive onshore, the liquids (condensates) will be removed and piped to the nearby Sullom Voe oil terminal, while the gas will be processed before being transported to the UK grid via the Shetland Island Regional Gas Export System (SIRGE) and Frigg UK Association (FUKA) pipelines.

Ithaca conducted detailed engineering surveys; a rig site survey and pipeline corridor survey in 2024, to allow development drilling to be undertaken between Q2 and Q3 of 2028 and subsea installation activities to be undertaken between Q2 and Q3 of 2029. First gas is targeted for end of Q4 2029.

Tornado peak production day rates are anticipated to be at 9,462,562 cubic metres (334 million standard cubic feet) of gas per day and 619.1 tonnes (783.4 cubic metres) of condensate per day by around 2029.

The Tornado subsea infrastructure is expected to produce hydrocarbons between 6 and 10 years depending on the reserves, the production rate and the life of the GLA infrastructure. On cessation of production, the Tornado 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.

| Aspect | Tornado Drill Centre | Tormore Tie-in Location |
|---|---|---|
| Location (Lat/Long) [1] | 60° 33’ 43.752”N<br>04° 25’ 45.193”W | 60° 52’ 19.093”N<br>03° 08’ 7.26”W |
| UKCS Block | 204/13 | 205/5 |
| Distance to nearest coastline (Shetland) | 153 km | 94 km |
| Distance to nearest median line (UK / Faroe) | 6.5 km | 53 km |
| Nearest Marine Protected Area (MPA) | 8.5 km NW of Faroe-Shetland Sponge Belt Nature Conservation Marine Protected Area (NCMPA) | Within Faroe-Shetland Sponge Belt NCMPA |

[1] ED50 UTM Zone 30N.
[2] Contingent third well

## 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**.

N/A

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# Abbreviations

| | |
|---|---|
| % | Percentage |
| ˚C | Degrees Celsius |
| “ | Inch |
| ° | Degrees |
| ‰ | Parts per thousand |
| 2D | Two-Dimensional |
| 3D | Three-Dimensional |
| ACA | Action Co-ordinating Authority |
| AFEN | Atlantic Frontier Environmental Network |
| AIS | Automatic Identification System |
| Al | Aluminium |
| ALARP | As Low As Reasonably Practicable |
| APS | Announced Pledges Scenario |
| AR5 | Assessment Report Five |
| AR6 | Sixth Assessment Report |
| AR6 | Assessment Report Six |
| ARPA | Automatic Radar Plotting Aids |
| As | Arsenic |
| AUV | Autonomous Underwater Vehicle |
| Ba | Barium |
| BAC | Background Assessment Concentrations |
| BAOAC | Bonn Agreement Oil Appearance Code |
| BAP | Biodiversity Action Plan |
| bbl | Barrels |
| BC | Background Concentrations |
| BCF | Billion Cubic Feet |
| BEIS | Department for Business, Energy & Industrial Strategy |
| BGS | British Geological Society |
| BoCC | Birds of Conservation Concern |
| boe | Barrel of Oil Equivalent |
| BOP | Blowout Preventer |
| BP | BP plc |
| BSL | Below Sea Level |
| ca. | Circa |
| CAN | Conductor Anchor Nodes |
| CAPEX | Capital Expenditure |
| CB | Carbon Budget |

| | |
|---|---|
| CBGDP | Carbon Budget and Growth Delivery Plan |
| CCC | Climate Change Committee |
| CCS | Carbon Capture and Storage |
| Cd | Cadmium |
| CDP | Carbon Disclosure Project |
| CEFAS | Centre for Environment, Fisheries and Aquaculture Science |
| $CH_4$ | Methane |
| $CH_4$ | Methane |
| CGR | Condensate Gas Ratio |
| CHARM | Chemical Hazard Assessment and Risk Management |
| CIN | CHARM Implementation Network |
| cm | Centimetres |
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |
| $CO_2e$ | Carbon Dioxide Equivalent |
| COLREG | International Regulations for Preventing Collisions at Sea |
| CoP | Cessation of Production |
| COP | Conference of the Parties |
| CPI | Carbon Preference Index |
| CPT | Cone Penetration Test |
| Cr | Chromium |
| CRA | Collision Risk Assessment |
| CSV | Construction Support Vessel |
| CtL | Consent to Locate |
| Cu | Copper |
| dB | Decibel |
| dB re 1µPa @ 1 m | Decibels relative to one micro-Pascal |
| DECC | Department of Energy and Climate Change |
| DESNZ | Department for Energy Security and Net Zero |
| DP | Dynamic Positioning |
| DTI | Department of Trade and Industry |
| EBS | Environmental Baseline Survey |
| EC | European Commission |
| EDGAR | Emissions Database for Global Atmospheric Research |
| EDR | Effective Deterrent Range |
| EEMS | Environmental and Emissions Monitoring System |
| EEZ | Exclusive Economic Zone |
| EFL | Electrical Flying Lead |

| | |
|---|---|
| EIA | Environmental Impact Assessment |
| EJ | Exajoules ($10^{18}$ J) |
| EMODnet | European Marine Observation and Data Network |
| EMS | Environmental Management System |
| ENVID | ENVironmental and socio-economic impact IDentification |
| EOL | End of Line |
| EOSPS | East of Shetland Pipeline System |
| EPS | Early Production System |
| EPS | European Protected Species |
| ERAP | Emissions Reduction Action Plan |
| ERL | Effects Range Low |
| ERRV | Emergency Rescue and Recovery Vessel |
| ES | Environmental Statement |
| ESAS | European Seabirds at Sea |
| ESOS | Energy Savings Opportunity Scheme |
| ETS | Emissions Trading Scheme |
| EU | European Union |
| EUNIS | European Nature Information System |
| EUR | Estimated Ultimate Recovery |
| F | Far-field |
| FDP | Field Development Plan |
| Fe | Iron |
| FeAST | Feature Activity Sensitivity Tool |
| FEED | Front-End Engineering Design |
| FLAGS | Far North Liquid and Associated Gas System |
| FLET | Flowline End Termination |
| FLIP | Flow Induced Pulsation |
| FLO | Fisheries Liaison Officer |
| FOCI | Feature of Conservation Importance |
| FPSO | Floating Production Storage and Offloading |
| FRP | Favourable Reference Population |
| ft | Feet |
| FUKA | Frigg UK Association |
| g/cm$^3$ | Grams per cubic centimetre |
| GCB | Global Carbon Budget |
| | |
| GHG | Greenhouse Gas |
| GIIP | Gas Initially In Place |
| GLA | Greater Laggan Area |

| | |
|---|---|
| GML | Global Monitoring Laboratory |
| GRP | Glass Fibre Reinforced Polymer |
| GST | Global Stocktake |
| Gt | Gigatonnes ($10^{12}$ kg) |
| GWP | Global Warming Potential |
| $H_2S$ | Hydrogen Sulfide |
| HA | Habitat Assessment |
| HC | Hydrocarbon |
| HF | High Frequency |
| HFL | Hydraulic Flying Lead |
| Hg | Mercury |
| HM | Heavy Metal |
| HMCS | Harmonised Mandatory Control Scheme |
| hMPA | historic Marine Protected Areas |
| HPAI | Highly Pathogenic Avian Influenza |
| HPHT | High Pressure High Temperature |
| HSE | Health, Safety and Environment |
| HVO | Hydrotreated Vegetable Oil |
| Hz | Hertz |
| I | Intermediate-field |
| ICES | International Council for the Exploration of the Sea |
| IEA | International Energy Agency |
| IEMA | The Institute of Environmental Management and Assessment |
| IHS | IHS Markit |
| IMMA | Important Marine Mammal Area |
| IMO | International Maritime Organization |
| $in^3$ | Cubic Inches |
| INTOG | Innovation and Targeted Oil and Gas |
| IOGP | International Association of Oil & Gas Producers |
| IPCC | Intergovernmental Panel on Climate Change |
| ISGP | Ithaca's Stage Gate Process (ISGP) |
| ISO | International Standards Organisation |
| Ithaca | Ithaca SP E&P Limited, (an affiliate of Ithaca Energy (UK) Limited (Ithaca Energy (UK) Limited and it's affiliated companies being referred to throughout this Environmental Statement as 'Ithaca') |
| ITOPF | International Tanker Owner Pollution Federation |
| IUCN | International Union for the Conservation of Nature |
| J | Joule |
| JNCC | Joint Nature Conservation Committee |

| | |
|---|---|
| JV | Joint Venture |
| kg | Kilograms |
| kHz | Kilohertz |
| km | Kilometres |
| $km^2$ | Squared kilometres |
| KPI | Key Performance Indicators |
| kt | Kilotonnes ($10^6$ kg) |
| ktCO2e | Kilotonne Carbon Dioxide Equivalent |
| L x W x H | Length x Width x Height |
| LAT | Lowest Astronomical Tide |
| $LC_{50}$ | Lethal Concentration, 50% |
| $L_{E,p}$ | Sound Exposure Level |
| $L_{E,p,ss}$ | Sound Exposure Level, single strike ($SEL_{ss}$) |
| LF | Low Frequency |
| LMRP | Lower Marine Riser Package |
| LNG | Liquified Natural Gas |
| LOC | Loss of Containment |
| LoF | Life of Field |
| Log $P_{ow}$ | Octanol-water partition coefficient |
| $L_{p,pk}$ | Sound Pressure Level peak ($SPL_{peak}$) |
| $L_{p,RMS}$ | Root Mean Square Sound Pressure Level |
| L-T | Laggan-Tormore |
| LTOBM | Low Toxicity Oil Based Mud |
| m | Metres |
| m/s | Metres per second |
| $m^2$ | Squared metres |
| $m^3$ | Cubic metres |
| MARPOL | International Convention for the Prevention of Pollution from Ships |
| MAT | Master Application Template |
| Mbbl | Million barrels ($10^6$ bbl) |
| MBES | Multibeam Echosounder |
| MCA | Maritime and Coastguard Agency |
| MCZ | Marine Conservation Zone |
| MEG | Monoethylene Glycol |
| MEI | Major Environmental Incident |
| MER | Maximising Economic Recovery |
| $mg.kg^{-1}$ | Milligrams per kilogram |
| Mg/l | Milligrams per litre |
| mm | Millimetres |

| | |
|---|---|
| $Mm^3$ | Million cubic metres ($10^6$ $m^3$) |
| MMMU | Marine Mammal Management Units |
| MMO | Marine Management Organisation |
| MMO | Marine Mammal Observer |
| MMPATF | Marine Mammal Protected Areas Task Force |
| MMscf | Million Standard Cubic Feet |
| MMscfd | Million Standard Cubic Feet per Day |
| Mn | Manganese |
| MoD | Ministry of Defence |
| MODU | Mobile Offshore Drilling Unit |
| MPA | Marine Protected Area |
| MPS | Marine Policy Statement |
| $ms^{-1}$ | Metres per second |
| Mt | Megatonnes ($10^9$ kg) |
| Mtoe | Million Tons of Oil Equivalen |
| MU | Management Unit |
| MUDMAP | Three-dimensional dispersion model |
| N | Near-field |
| $N_2$ | Nitrogen |
| $N_2O$ | Nitrous Oxide |
| $N_2O$ | Nitrous Oxide |
| NAEI | National Atmospheric Emissions Inventory |
| NAVAREA | Navigational Area |
| NAVTEX | Navigational Telex |
| NB | Nominal bore |
| NCMPA | Nature Conservation Marine Protected Area |
| NCPs | National Contingency Plans |
| NDC | Nationally Determined Contribution |
| Ni | Nickel |
| nm | Nautical miles |
| NMFS | National Marine Fisheries Service |
| NMP | National Marine Plan |
| NOAA | National Oceanic and Atmospheric Administration |
| NOCS | National Oceanography Centre, Southampton |
| $NO_x$ | Nitrogen Oxides |
| NSTA | North Sea Transition Authority |
| NSTD | North Sea Transition Deal |
| NTS | National Transmission System |
| NZE | Net Zero Emissions by 2050 Scenario |

| | |
|---|---|
| OESEA | Offshore Energy Strategic Environmental Assessment |
| OFL | Optical Flying Lead |
| OGA | Oil and Gas Authority |
| OMAR | Offshore Major Accident Regulator |
| OMV | OMV (U.K.) Limited |
| OOC | Oil On Cuttings |
| OPEP | Oil Pollution and Emergency Plan |
| OPOL | Offshore Pollution Liability Agreement |
| OPRED | Offshore Petroleum Regulator for Environment and Decommissioning |
| OSPAR | Oslo and Paris Commission |
| OSRL | Oil Spill Response Limited |
| PAH | Polycyclic Aromatic Hydrocarbons |
| PAM | Passive Acoustic Monitoring |
| PARLOC | Pipeline and Riser Loss of Containment |
| Pb | Lead |
| PC | Physico-chemical sample |
| PCW | Phocid Carnivores in Water |
| PDCA | Plan-Do-Check-Act |
| PE | Parabolic Equation |
| PEC | Predicted Environmental Concentration |
| PETS | Portal Environmental Tracking System |
| Pg | Petagrams |
| PIG | Pipeline Integrity Gauge |
| PLEM | Pipeline End Manifold |
| PLONOR | Pose Little or No Risk |
| PMF | Priority Marine Feature |
| PNEC | Predicted No Effect Concentration |
| POB | Personnel on Board |
| PON | Petroleum Operations Notice |
| PON 1 | Petroleum Operations Notice 1 |
| ppb | Parts per billion |
| ppm | Parts Per Million |
| PSA | Particle Size Analysis |
| PSD | Particle Size Distribution |
| PTS | Permanent Threshold Shift |
| RCP | Representative Concentration Pathway |
| RfS | Request for Service |
| RMS | Root Mean Square |
| ROV | Remotely Operated Vehicle |

| | |
|---|---|
| ROVSV | Remotely Operated Vehicle Support Vessel |
| SAC | Special Area of Conservation |
| SAT | Subsidiary Application Template |
| SAT | Subsidiary Application Template |
| SBP | Sub-bottom Profiler |
| SCANS | Small Cetacean Abundance of the North Sea |
| SCR | Safety Case Regulations |
| SDG | Sustainable Development Goal |
| SDM | Species Distribution Model |
| SEA | Strategic Environmental Assessment |
| SECR | Streamlined Energy and Carbon Reporting |
| SEL | Sound Exposure Level |
| $SEL_{cum}$ | Cumulative Weighted Sound Exposure Level |
| $SEL_{ss}$ | Sound Exposure Level, single strike |
| SEPA | Scottish Environmental Protection Agency |
| SFF | Scottish Fishermen's Federation |
| SFGT | St. Fergus Gas Terminal |
| SGMD | Scottish Government Marine Directorate |
| SGP | Shetland Gas Plant |
| SHEFA | Shetland Fibre Optic Cable |
| SIMOPS | Simultaneous Operations |
| SIMPROF | Similarity Profile Analysis |
| SIRGE | Shetland Island Regional Gas Export |
| SNCBs | Statutory Nature Conservation Bodies |
| $SO_2$ | Sulphur Dioxide |
| SOL | Start of Line |
| SOPEP | Ship Oil Pollution Emergency Plan |
| SOSI | Seabird Oiling Sensitivity Index |
| $SO_x$ | Sulphur Oxides |
| SPA | Special Protection Area |
| SPE | Siccar Point Energy |
| SPI | Shot Point Interval |
| SPL | Sound Pressure Level |
| $SPL_{peak}$ | Sound Pressure Level peak |
| SSP | Shared Socio-economic Pathways |
| SSS | Sidescan Sonar |
| SUB | Substitution |
| SVT | Sullom Voe Terminal |
| t | Tonne ($10^3$ kg) |

| | |
|---|---|
| TCFD | Task Force on Climate-Related Financial Disclosures |
| TEG | Triethylene glycol |
| TEPUK | TotalEnergies E&P UK Limited |
| THC | Total Hydrocarbon Concentration |
| $Tm^3$ | Trillion cubic metres ($10^{12}$ $m^3$) |
| TOC | Total Organic Carbon |
| TOM | Total Organic Matter |
| TS | Threshold Shift |
| TSS | Total Suspended Solids |
| TTS | Temporary Threshold Shift |
| TVDSS | True Vertical Depth Sub Sea |
| UET | Umbilical End Termination |
| UK | United Kingdom |
| UK BAP | United Kingdom Biodiversity Action Plan |
| UKCS | United Kingdom Continental Shelf |
| UKETS | UK Emissions Trading Scheme |
| UKHO | United Kingdom Hydrographic Office |
| UN | United Nations |
| UNEP | United Nations Environmental Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| V | Vanadium |
| VHF | Very High Frequency |
| VMS | Vessel Monitoring System |
| VOCs | Volatile Organic Compounds |
| VSP | Vertical Seismic Profile |
| VTS | Vessel Traffic Survey |
| $W/m^2$ | Watts per square metre |
| WBM | Water Based Mud |
| WD | Water Depth |
| WG1 | Working Group 1 |
| WMO | World Meteorological Organisation |
| WMP | Waste Management Plan |
| WOAD | Worldwide Offshore Accident Database |
| WoS | West of Shetland |
| WOSPS | West of Shetland Pipeline System |
| yr | Year |
| Zn | Zinc |
| ZRF | Zero Routine Flaring |
| µm | Micrometres |

# Non-Technical Summary

## Introduction

Ithaca SP E&P Limited, (an affiliate of Ithaca Energy (UK) Limited (Ithaca Energy (UK) Limited and it's affiliated companies being referred to throughout this Environmental Statement as 'Ithaca') and Adura Operations Limited are planning to develop the Tornado gas condensate discovery in United Kingdom Continental Shelf (UKCS) Blocks 204/13 and 204/14d in the Faroe-Shetland channel, West of Shetland (WoS), located approximately 153 km west of the Shetland Islands. The Tornado discovery sits within Licence P.2403 and is jointly held by Ithaca (50%) and Adura Operations Limited (50%). Ithaca is Operator on behalf of the Joint Venture (JV).

The Tornado field is located within a water depth of approximately 1,060 m and was discovered by the OMV operated well 204/13-1 in 2009, and appraised by side-track well, 204/13-1Z. Ithaca is now proposing to develop the Tornado field via up to three deviated subsea wells, drilled from a single drill centre and is aiming to deliver first gas by end of Q4 2029.

An Environmental Statement (ES) has been prepared to present the findings of the Environmental Impact Assessment (EIA) carried out for the proposed Tornado Field Development (hereafter referred to as 'the Tornado Development' or 'the Project'), as required under The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020. The ES has been prepared by Ithaca in conjunction with Orbis Energy Limited (the EIA Consultant). This section forms the non-technical summary of the ES. The EIA has been undertaken with reference to the new supplementary guidance for assessing the effects of downstream Scope 3 emissions on climate from offshore oil and gas projects (DESNZ, 2025a).

## Project Description

The Tornado field will be developed via up to three close cluster deviated subsea wells tied back via a new production pipeline (approximately 86km in length and 16 inch in diameter) and dedicated 4-inch Nominal Bore (NB) MEG pipeline to TotalEnergies E&P UK Limited's existing Greater Laggan Area (GLA) network infrastructure at Tormore (subject to ongoing negotiation). The location of the proposed Tornado field development is shown in Figure 1. Control of the subsea wells will be from a separate control umbilical between Tormore and Tornado. The field will be operated from the GLA control room at the Shetland Gas Plant (SGP) located onshore on the north coast of the main island of Shetland. When the Tornado field comes online, Tornado production fluids will arrive onshore at the SGP, with the gas treated and compressed for export into the Shetland Island Regional Gas Export (SIRGE) pipeline for onwards transmission to the St Fergus Gas Terminal and the National Transmission System (NTS). Small volumes of unstabilised condensate will be piped to the neighbouring Sullom Voe Terminal (SVT) for further processing.

### Drilling Operations

The Tornado subsea wells will be drilled from a single drill centre located at 60° 33' 43.752"N, 04° 25' 45.193"W (ED50 UTM Zone 30N) using a dynamically positioned (DP) mobile offshore drilling unit (MODU). Due to the soft upper seabed sediments in the Tornado area, prior to the MODU arriving on location, Ithaca plan to install up to five Conductor Anchor Nodes (CAN-ductors) units into the seabed; one CAN-ductor at each well location and two parking-CAN units for subsea storage of the horizontal Xmas trees. CAN-ductors are proposed to be used as they increase top hole wellbore stability and reduce the overall drilling time, which also reduces the carbon footprint of well construction activities. However, in case of any currently unforeseen circumstances that may prevent the use of CAN-ductors, conventional top hole well sections will be drilled by the MODU, with the Xmas trees installed directly from the MODU or a vessel. For the purposes of this ES, the assessment of drill cuttings discharges and atmospheric emissions resulting from fuel consumption has been based on the worst case scenario of drilling all wells with conventional top hole sections.

If the Tornado wells are drilled conventionally (i.e. without CAN-ductor), the top two-hole sections will be drilled riserless with seawater and frequent bentonite "sweeps" passed down the wells to clean out the hole. Cuttings from these top-hole sections will be discharged directly from the wellbore at the seabed. For the deeper well sections, a marine riser will be situated between the well and the drilling deck so that cuttings and drilling fluid are circulated back up to the MODU.

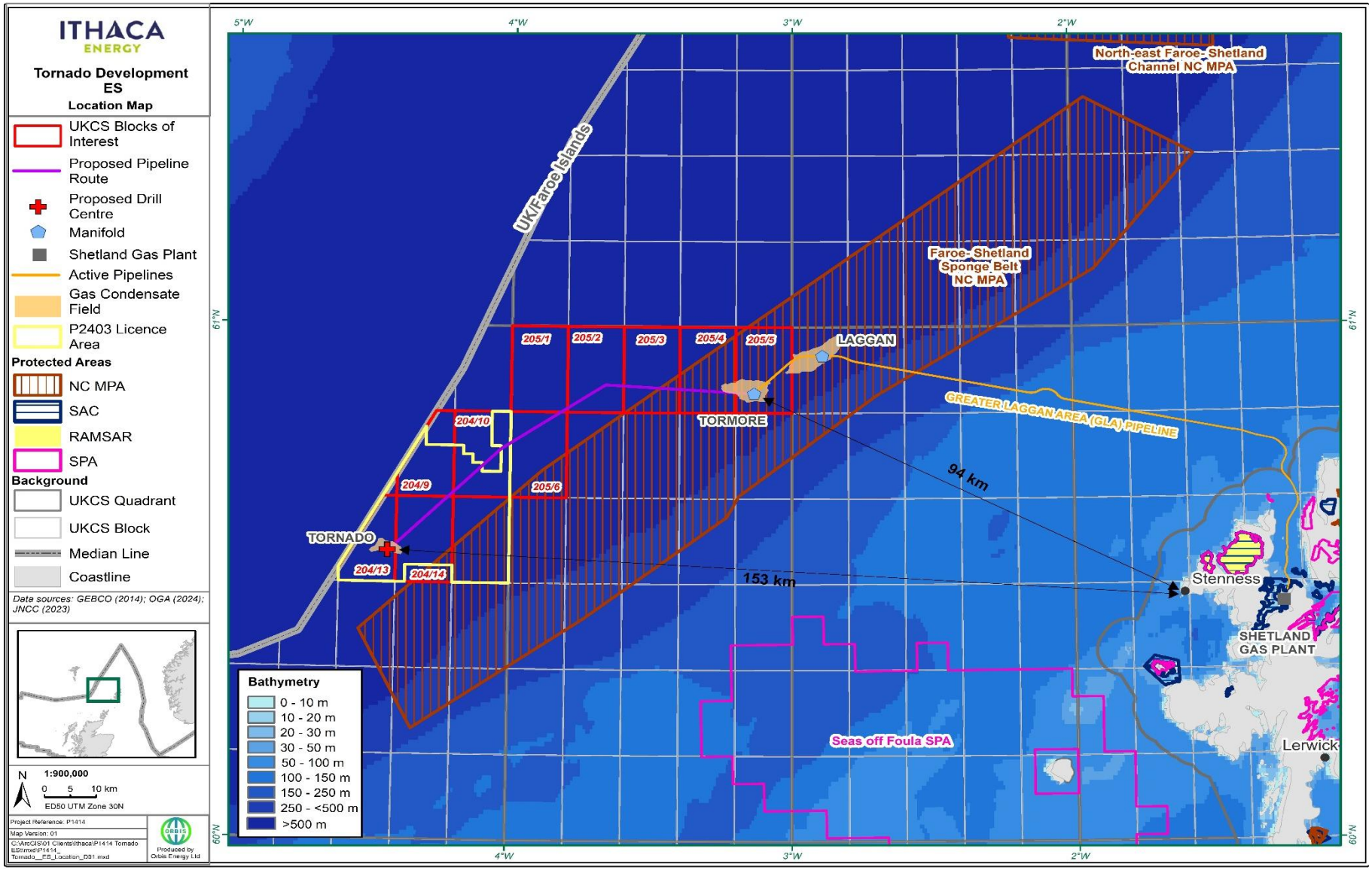



**Figure 1. Location of the Proposed Tornado Development**

For the deeper well sections there are two options for drill fluid and cuttings disposal:

- Option 1: Water Based Mud (WBM) with cuttings disposal to sea;
- Option 2: Low Toxicity Oil Based Mud (LTOBM) with offshore clean-up / disposal to sea.

In the event LTOBM is used to drill the deeper well sections, due to the remote location of Tornado and harsh environment, it is anticipated that a thermal cuttings treatment unit will be installed on the MODU to process the drill cuttings to an acceptable overboard disposal limit (<1% oil on cuttings) to minimise the need for drilling waste to be shipped to shore for treatment and disposal. However, for the purposes of this ES, conventional drilling with WBM has been assumed, with all drill cuttings and associated WBM from the Tornado wells discharged to sea.

## Tornado Drill Centre

At the proposed Tornado drill centre location, Ithaca proposes to install a production gathering manifold (the 'Tornado manifold'), comprising pigging headers for the production and MEG pipelines and three well tie-in slots. The structure will have a suction pile foundation and therefore pile hammer operations are not required.

Two Flowline End Termination (FLET) structures will be installed at the Tornado end of the pipelines to facilitate initiation and laydown and to accommodate isolation valves and diverless connectors on the 16" production and 4" MEG pipelines. There may also be a requirement to install an Umbilical End Termination (UET), which will be confirmed during detailed design. The FLETs and UET will be gravity based structures.

Tie-in spools will connect the FLET structures to the Tornado manifold. A 8" production spool, 2" MEG spool, an electrical flying lead and a hydraulic flying lead, will be surface laid between the Tornado manifold and each well.

The layout of the subsea wells and infrastructure at the proposed Tornado drill centre is illustrated in Figure 2. Due to the water depth at Tornado (ca 1,060 m), the subsea facilities do not require protection from fishing interaction (i.e. there is no requirement to deposit grout bags or concrete mattress).

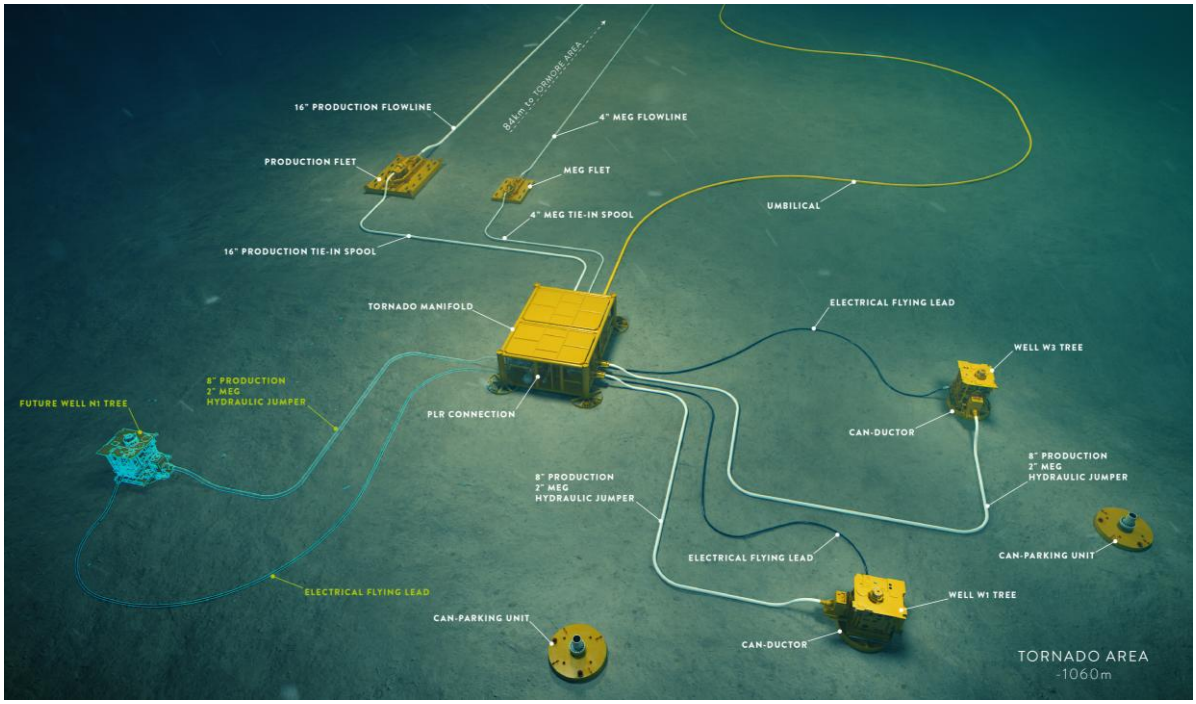



**Figure 2. Tornado Drill Centre Layout**

## Tormore Tie-in Arrangement

At the Tormore end of the pipeline route, Ithaca proposes to install a Pipeline End Manifold (PLEM). The structure will be designed to be overtrawlable and will have suction anchor foundations. Two FLET structures will be installed to facilitate initiation and laydown and to accommodate isolation valves and diverless connectors on the 16" production and 4" MEG pipelines. There may also be a requirement to install a UET, which

will be confirmed during detailed design. The FLETs and UET will be gravity based structures and will be designed to be overtrawlable.

Tie-in spools will connect the new Tornado FLET structures to the Tornado PLEM and the Tornado PLEM to the existing Laggan-Tormore FLET structures. An infield control umbilical / individual flying leads, will connect the Tornado PLEM to the existing umbilical supplies within the Tormore Facilities.

Work is ongoing to refine the reconfiguration works in the vicinity of Tormore to minimise the overall impact to the seabed. For the purposes of this ES, a worst case scenario in terms of seabed impacts has been assessed, which assumes the Tornado tie-in spools, flying leads and jumpers will be protected by GRP structures and associated rock berms.

## Pipeline Installation

Subject to confirmation by the installation contractor, the 16 inch Tornado carbon steel production pipeline will be installed from a reel lay or S-lay vessel. The 4 inch MEG pipeline will be installed from a reel lay vessel or piggybacked onto the production pipeline from an S-lay vessel. The control umbilical will be installed from a Construction Support Vessel with suitable carousel.

For the purposes of this ES, it is assumed that the pipelines and umbilical are to be designed for fishing interaction in water depths shallower than 800 m as the worst-case scenario. The pipelines and umbilical route can therefore be divided into two distinct sections as described in Table 1, each with a different installation method.

**Table 1: Sections of the Pipeline / Umbilical Route from Tornado to Tormore**

| Section of Route | Kilometre Point (from Tornado)[2] | Main Installation Method |
|---|---|---|
| 1 | KP0 - KP 68 | Surface lay of production pipeline, MEG pipeline [1] and umbilical, with no protection (water depth is >800 m)<br>Potential for numerous boulders requiring boulder removal<br>Rock stabilisation may be required to correct freespans |
| 2 | KP68 - KP86 | Production pipeline surface laid with no post installation protection [1]<br>Protection required for MEG pipeline [1] and umbilical (water depth is <800m)<br>Potential for numerous boulders requiring boulder removal<br>Trenching and/or post lay rock installation for the MEG pipeline and umbilical<br>Rock stabilisation may be required to correct freespans |

[1] There is an alternate option to piggyback the MEG pipeline onto the production pipeline during installation, which would necessitate protection of both pipelines by a single rock berm in water depths less than 800m. This installation method would optimise the width of the installation corridor and reduce the overall number of vessel days to install both lines. Pipeline installation via a piggyback system will therefore be investigated during the detailed engineering phase.
[2] Distances are rounded to the nearest kilometre for clarity.

In water depths greater than 800 m (Section 1 of the route) the production pipeline, MEG pipeline and umbilical will be surface laid with no protection. Rock stabilisation may be required to correct freespans.

In water depths less than 800 m (Section 2 of the route), the production pipeline will also be surface laid and remain exposed on the seabed as it will be designed to resist fishing interaction loads. Within Section 2 of the route, where possible, the MEG pipeline and umbilical will be trenched and buried to a minimum depth of cover of 0.6 m. There may be a requirement to deposit rock over sections of the lines to mitigate against potential upheaval buckling, however, it is intended to keep remedial rock protection to an absolute minimum. If trenching is deemed feasible, the selected trenching method shall be based upon detailed survey outputs, project experience in the area and equipment availability.

Numerous boulders (>0.3 m) have been identified along the proposed pipeline route. Boulders inhibit the use of the trenching equipment, and boulder clearance may be required prior to trenching. In the event the MEG

pipeline and umbilical are not trenched, boulders may still need to be cleared from the lay corridors. Boulders may also need to be cleared from the lay corridor of the production pipeline. While laying over exposed boulders may be acceptable from a pipeline strength and stabilisation perspective any free-spans will present a snagging risk to fishing interaction.

Where boulder density or size prevents implementation of the clearance strategy, the production pipeline, MEG pipeline and control umbilical would be surface laid and protected by overtrawlable rock berms. Seabed topography could also necessitate the installation of pre-lay rock along some sections of the route (within both Section 1 and 2 of the route) due to the presence of seabed features such as boulders, depressions and mounds. A routing assessment will be carried out during detailed design with a view to avoiding these seabed features where possible. There may be the option to utilise sleepers and mattresses to reduce the volume of rock for pre-lay remediation however use of only rock provides the worst-case permanent seabed footprint and rock tonnage and is therefore considered as the base case for the purpose of the assessment presented in this ES.

Towards the Tormore end of the route, two cables (FARICE and SHEFA2 Seg 7) and one pipeline (Rosebank) cross the installation corridor. Crossing designs are not yet matured and may entail concrete structures and/or mattresses and rock placement. For the purposes of this ES, a worst-case scenario of mattresses and rock placement has been assumed.

### Production

Following first gas which is currently targeted for Q4 2029, Tornado production rates are anticipated to peak in 2030 at 9,462,562 cubic metres (334 million standard cubic feet) of gas per day and 619.1 tonnes (783.4 cubic metres) of condensate per day (Max case hydrocarbon profile), after which there is a steady decline over the life of the field.

As Tornado will be a subsea development, production from the field will be processed onshore at the SGP. Atmospheric emissions during the Tornado production phase will therefore mainly arise from power generation requirements at SGP. Any condensate water generated during processing of the Tornado production fluids will be disposed at the SGP via the existing produced water system, the impact from which is outside of the scope of this ES.

### Decommissioning

The Tornado subsea infrastructure is expected to produce hydrocarbons between 6 and 10 years depending on the reserves, the production rate and the life of the GLA infrastructure. On cessation of production, the Tornado facilities will be decommissioned in accordance with the requirements of the prevailing UK and International law.

## Concept Selection

Initial technical studies confirmed that the optimum development option for Tornado in terms of economics, risk and environmental impact is via a subsea tie-back to existing infrastructures. An initial screening exercise concluded that gas from Tornado could potentially be exported via two pre-existing infrastructure systems; either the TotalEnergies E&P UK Limited operated GLA pipelines or the BP operated West of Shetland Pipeline System (WoSPS).

The viability and environmental impact of the following host options which met the criteria for detailed screening assessment included:

- **Host Option 1**: Subsea tie-back via a ca. 86 km 16 inch pipeline to the GLA Tormore manifold, which would then flow to the Shetland Gas Plant (SGP).
- **Host Option 2**: Subsea tie-in via ca. 38 km pipeline to a spare riser slot at Glen Lyon Floating Production Storage and Offloading (FPSO), which would then flow to the WoSPS.

The assessment concluded that the development of Tornado as a two- or three-well subsea tie-back to the GLA Tormore manifold via a ca. 86 km subsea production pipeline has capability to deliver significant Tornado reserves to the NTS via the SGP. Extensive study work has demonstrated this to be technically viable, employing proven technologies and installation methodologies. Cost and schedule estimates demonstrate the potential for an economically viable development.

Whilst a firm commitment on service is required from the SGP owners to de-risk the project economics sufficiently to constitute a sanctionable development project, all technical assessments clearly support SGP as the preferred host for Tornado. On this basis, and on the assumption that SGP as a gas processing hub remains available to receive Tornado hydrocarbons a, SGP is selected as the preferred host for Tornado.

The Glen Lyon Host Option 2 was rejected as the Glen Lyon FPSO has limited gas handling ullage, topsides space and weight availability in comparison to Host Option 1.

Following the decision on what would be the preferred host option, a pipeline feasibility study was undertaken to determine the viability and environmental impact of the following three pipeline route options (Figure 3):

- **Pipeline Route Option 1**: ca. 80 km pipeline route, in which 68 km of the pipeline passes through the Faroe-Shetland Sponge Belt Nature Conservation Marine Protected Area (NCMPA) and 20 km of the pipeline is in water depths more than 800 m.
- **Pipeline Route Option 2**: ca. 86 km pipeline route, in which ca. 18 km of the pipeline passes through the Faroe-Shetland Sponge Belt NCMPA and 69 km of the pipeline is in water depths more than 800 m.
- **Pipeline Route Option 3**: ca. 81 km pipeline route, in which 17.5 km of the pipeline passes through the Faroe-Shetland Sponge Belt NCMPA and 64 km of the pipeline is in water depths more than 800 m.

The assessment concluded that Route 2 was the preferred option on the basis that it:

- Minimises the length of the pipeline within the Faroe-Shetland Sponge Belt NCMPA;
- Greatly lowers snagging risk, reducing the need for protective rock deposits, and offers the most robust alignment for minimising conflicts with legal fishing activities and seabed consenting that were anticipated on route 1;
- Route 3 was discounted due to the presence of deep gullies.

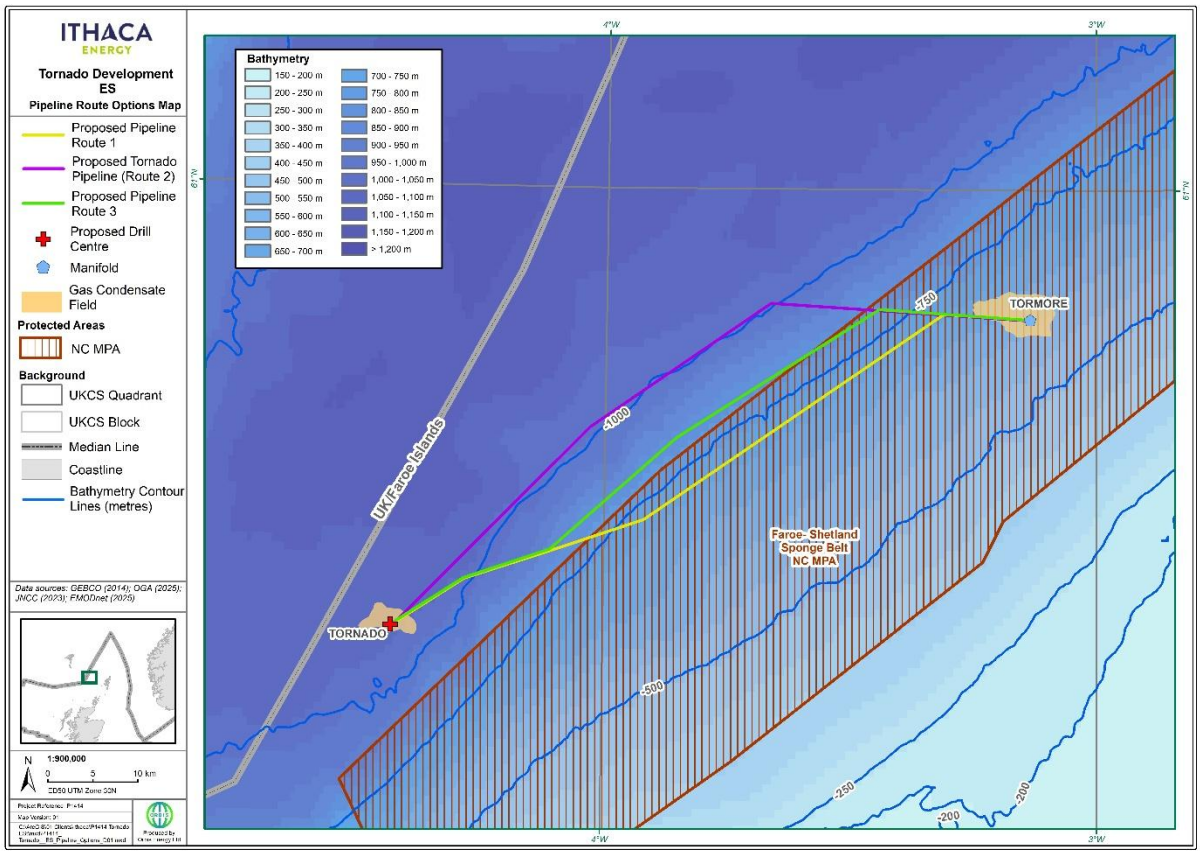



**Figure 3. Tornado to Tormore Pipeline Route Options**

## Project Schedule

The indicative timeline for the proposed Tornado Development is provided in Figure 4.

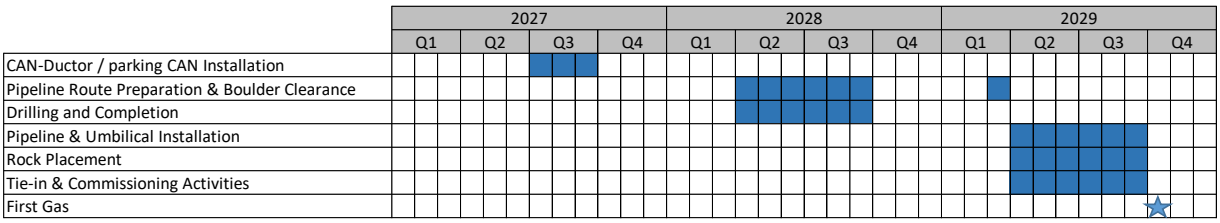



**Figure 4. Indicative Timeline for the Tornado Development**

## 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 Tornado Development area is provided below.

The description of the baseline environment is largely based on data provided in the OPRED Offshore Energy Strategic Environmental Assessment (SEA) Reports (2003-2016), as well as other published data sources, supported by site-specific survey data.

Ithaca has collected habitat assessment and an environmental baseline survey data in 2024 at the proposed Tornado drill centre location and along the Tornado to Tormore pipeline route. The oil and gas infrastructure in the wider area has also been subject to a number of site-specific surveys over the years. Several of these surveys are in close proximity to the proposed Tornado Development area and have therefore been used to inform the environmental baseline description, where relevant, including surveys at the Rosebank and Cambo fields. The Tornado Development is located approximately 9 km from the proposed Cambo development and 13 km from the proposed Rosebank development.

### Physical Environment

The proposed Tornado Development is located on the Atlantic continental margin over the eastern side of the Faroe-Shetland Channel approximately 94 km north west of the Shetland Islands at the closest point (Figure 1). The water depth at the proposed drill centre location is 1,061.5 m Lowest Astronomical Tide (LAT). Water depth across the Tornado site survey area vary from a minimum of 1,040.5 m LAT to a maximum of 1,074.1 m LAT and water depths along the proposed pipeline route corridor decrease from a maximum of 1,090.0 m below LAT in the south west at Kilometre Point (KP) 3.229, to a minimum of 593.8 m below LAT in the north east at KP 84.942 (Fugro, 2024a).

Seabed depressions and sediment mounds, thought to have formed due to the action of strong bottom currents known to exist in the area, are also common in the pipeline route corridor and present across the site survey area. The mounds comprise accumulations of gravel and cobbles (Fugro, 2024a; Fugro, 2024b).

The seafloor across the Tornado site survey area was found to be largely homogenous, comprising gravelly sandy mud/muddy sand with cobbles and boulders (Figure 5; Fugro, 2025a). Within the proposed Tornado to Tormore pipeline route corridor, the sediment type observed was gravelly sandy mud/muddy sand with pebbles and sporadic cobbles and boulders, and sandy mud/muddy sand with sparse pebbles and cobbles (Fugro, 2025b).

Analysis of the seabed sediments collected during the Tornado survey found that organic content (Total organic carbon (TOC) and total organic matter (TOM)) was typical of background levels, and hydrocarbon profiles showed low-level n-alkanes with trace petrogenic inputs, likely from shipping. Total hydrocarbon content was at or below Atlantic Frontier Environmental Network (AFEN) regional means. The majority of metal concentrations were below their respective effects range low (ERL) values and therefore it is unlikely that detrimental impacts to the benthic communities would occur, shown by the low variability in the composition of the macrofaunal community present at the survey area.



**Figure 5: Example Seabed Image of Gravelly Sandy Mud/ Muddy Sand with Cobbles and Boulders within the Site Survey Area (Fugro, 2025a)**

Net flow of surface waters in the Faroe-Shetland Channel is to the northeast. Currents are strongest along the upper continental slope, where they average around 0.3 metres per second (m/s). The mean velocity of the shelf edge current is approximately 0.4 m/s towards the northeast, and in the lower water mass 0.15 m/s towards the southwest (Saunders, 1990). Measured near-bottom current velocities indicate peak currents over 0.75 m/s on the upper continental slope to the WoS (BEIS, 2022).

Analysis of wave height and direction for the Tornado area indicates that waves most frequently originate from the west and southwest. Mean significant wave heights were found to be between 1 and 4 m, with the 100-year maximum significant wave height found to be approximately between 32.3 m (PhysE, 2018) and 33 m (Fugro, 2018).

Although offshore winds around Tornado may blow from any direction, they principally blow from west to south-west, with winds of force 5 (8 m/s) or greater reported 70% of the time in winter and 30% of the time in the summer (BEIS, 2022). Mean wind speeds in the area surrounding Tornado were found to be between 7 and 11 m/s (winds of force 5).

### Climate Change and GHG Emissions

Over recent decades, scientific consensus has confirmed that the Earth's climate is undergoing significant change, largely driven by anthropogenic greenhouse gas (GHG) emissions. Global mean concentrations for well-mixed GHGs (carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$)) in 2019 correspond to increases of about 47%, 156%, and 23%, respectively, above the levels in 1750 (representative of the pre-industrial era) (high confidence) (IPCC, 2023).

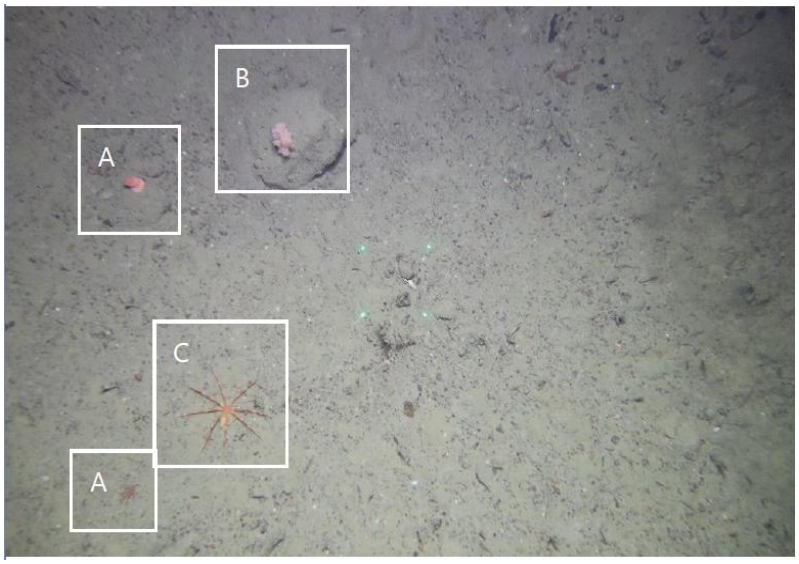
The United Nations Framework Convention on Climate Change (UNFCCC) commits countries to stabilise GHG levels, with the Conference of the Parties (COP) as its decision-making body. COP21 in 2015 created the Paris Agreement, requiring nations to limit warming to well below 2°C and pursue 1.5°C through nationally determined contributions (NDCs). Progress is reviewed every five years via the Global Stocktake (GST), which at COP28 in 2023 showed warming projections of 2.4–2.6°C, above the 1.5°C goal, demanding cuts of 43% by 2030 and net zero $CO_2$ by 2050. Records show that 2024 was the first calendar year that the average global temperature exceeded 1.5°C above its pre-industrial level and in the near term (2021–2040), global warming is predicted to continue to increase mainly due to increased cumulative $CO_2$ emissions (IPCC, 2023b).

These findings draw on the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) cycle, which outlines Shared Socio-economic Pathways (SSPs) and Representative Concentration Pathways (RCPs), ranging from high-emission futures (SSP3-7.0, SSP5-8.5) to low-emission pathways (SSP1-1.9, SSP1-2.6) where $CO_2$ falls to net zero mid-century.

## Biodiversity

The collective term plankton describes the plant-like organisms (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. The zooplankton community in the Tornado area includes the larval stages of fish (ichthyoplankton), larval decapods (crustaceans) and echinoderms, as well as copepods and krill (also crustaceans).

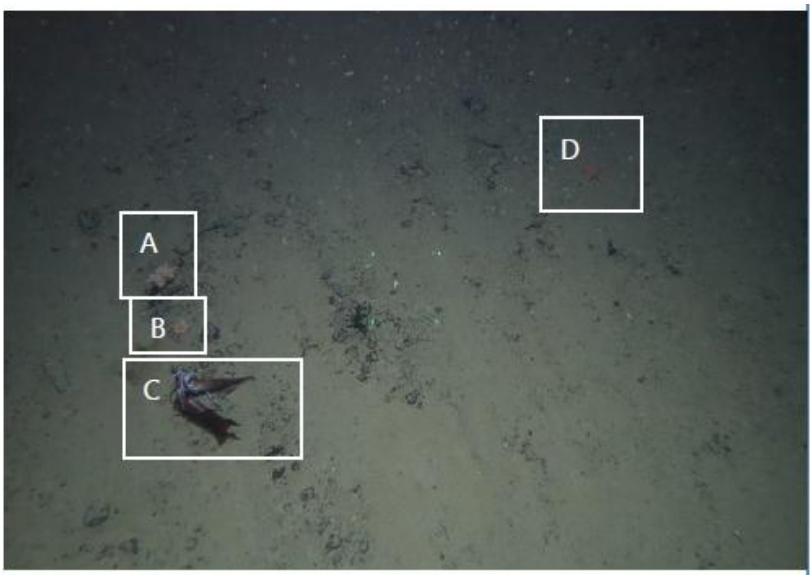
Benthos describes the organisms that live within and on the seabed. Benthic organisms can be classified further into infauna, organisms that live within the sediment, and epifauna, organisms that live on top of the seabed (attached or mobile). In general, the seabed faunal community in the vicinity of the Tornado Development is expected to be relatively sparse; characteristic of sandy and gravelly sediments. Deep-sea mixed sediment has not been sampled widely for infauna, so little is currently known about infaunal community structure. Epifauna tend to be sparse mobile species (EEA, 2022a). The most commonly observed fauna during the Tornado site survey and route survey were brittlestars, sponges, carnation corals, starfish, sea spiders, feather stars and stalked crinoids, anemones, tube worms and faunal turf (Figure 6 and Figure 7) (Fugro, 2025a; 2025b).




**Sediment Type:**
Gravelly sandy mud/muddy sand with cobbles and boulders

**Fauna:**
A: Anemone (Actiniaria)
B: Carnation coral (Malacalcyonacea)
C: Sea spider (*Colosssendeis proboscidea*)
D: Anemone (?Halcampidae)

**Figure 6. Example of fauna found within the Tornado site survey (Fugro, 2025a)**




**Sediment Type:**
Gravelly sandy mud/muddy sand with cobbles and boulders

**Fauna:**
A: Carnation coral (Malacalcyonacea)
B: Anemone (Actiniaria)
C: Squid (Decapodiformes)
D: Starfish (Asteroidea possible *Pontaster* sp.)

**Figure 7. Example of fauna found along the Tornado route survey (Fugro, 2025b)**

A number of fish species are likely to be present within the Tornado Development area. Species that may spawn within the vicinity include blue whiting and Norway pout. The area surrounding the Tornado Development may also act as a nursery grounds for blue whiting (high intensity), ling, mackerel and Norway pout. Species of sharks, skates and rays may also be present in the vicinity of the Tornado Development, these include basking sharks, porbeagle shark, Portuguese dogfish, spurdog (spiny dogfish), leafscale gulper shark and Arctic skate.

A number of seabirds are present in the vicinity of the Tornado Development area throughout the year; the area is considered important for Atlantic puffin and northern fulmar in the breeding season. Seabird sensitivity to oil pollution within the Tornado Development area varies between medium to low in January, February, March, April and June, high to low in May, low in July, August and December, extremely high to low in September and October and very high to low in November.

Species of marine mammals likely to be present in the waters WoS include harbour porpoise, killer whale, pilot whale, minke whale, Risso's dolphin, white-sided dolphin and white-beaked dolphin. Additionally, blue whale, fin whale, sei whale, humpback whale, sperm whale, right whale and northern bottlenose whale have been observed in the waters surrounding the proposed Tornado Development. Seals are widely distributed along the west coast of Scotland; however, studies of grey and harbour seals have indicated that their density within the proposed Tornado Development area is extremely low.

The nearest Marine Protected Area (MPA) to the proposed Tornado Development area is the Faroe-Shetland Sponge Belt NCMPA, which is crossed by approximately 18 km of the proposed pipeline route at the Tormore manifold end. This NCMPA is designated for the protection of nine features of conservation interest: deep sea sponge aggregations, ocean quahog (*Arctica islandica*) aggregations, Atlantic and Arctic influenced offshore subtidal sand and gravel habitats, an area of the Faroe-Shetland Channel continental slope and five geodiversity (geomorphological) features representative of the West Shetland Margin paleo-depositional system and the West Shetland Margin Contourite Deposits key geodiversity areas.

In the Tornado site survey area, sponge aggregations were sporadic and low in abundance, falling short of criteria for further assessment. Along the pipeline route, demosponges met OSPAR density thresholds at one transect, but associated faunal assemblages showed no distinction from surrounding communities, and the areas of suitable density were too small (<25 $m^2$). Consequently, the NCMPA protected feature 'Deep-sea sponge aggregations' was not considered present within the Tornado Development area based on photographic evidence.

No ocean quahog individuals were recorded in the macrofauna data at Tornado, no potential relict shells were observed along video transects and no live individuals or their distinctive siphons were noted during analysis of video footage and still photographs from the survey area.

The Tornado habitat surveys found that Arctic upper bathyal mixed sediment (ME41) and sand (ME51) fall within Scotland's Priority Marine Feature (PMF) 'Offshore subtidal sands and gravels', which is also a protected feature of the NCMPA.

An Annex I habitat stony reef assessment has also been conducted over the Tornado site survey and along the proposed pipeline route. In the site survey area, two occurrences of 'Low Reef' in terms of overall reefiness were found. There were no occurrences of 'Medium Reef' or 'High Reef', with all other ground-truthing data indicating areas with no cobbles and boulders or were classified as 'Not a Reef'. Within the pipeline route corridor, aggregated cobbles and boulders, classified as 'Low reef', were found along sections of 13 transects . However, the areas of the 'low reef' observed along 12 of these transects did not exceed 25 $m^2$ and did not satisfy the area criteria for 'Reefs'. Only one patch was observed from the photographic data to exceed 25 $m^2$ and was thus classed as 'Low Reef'. Patches of 'Medium' stony reef meeting the composition and elevation criteria were observed along sections of four transects, but the size of these areas observed from the photographic data did not exceed 25 $m^2$. There were no occurrences of 'High Reef', with all other ground-truthing data indicating areas with no cobbles and boulders or were classified as 'Not a Reef'.

## Human Environment

Fishing activity with the Tornado Development area is low. EU Regulation 2016/2336 prohibits all bottom trawling fishing at depths deeper than 800 m. Fishing potential within the Faroe Shetland Sponge Belt NCMPA has been further restricted by The Offshore Fishing (Prohibition of Fishing Methods) (Scotland) Order 2025 which prohibits demersal mobile gear and demersal mobile gear and static gear in zones of the NCMPA.

Commercial shipping activity within the vicinity of the Tornado Development is considered to be very low. Commercial traffic in this region WoS is likely to include vessels en-route to/from SVT and vessels, such as containers, ferries and cruise liner traffic, in transit across the Atlantic.

The proposed Tornado pipeline will tie back into the existing GLA network infrastructure at Tormore operated by TotalEnergies E&P UK Limited. The GLA network infrastructure is part of TotalEnergies E&P UK Limited's WoS operations, which includes the producing Laggan, Tormore, Edradour and Glenlivet fields. The proposed Tornado pipeline route will cross the recently installed Rosebank gas export pipeline, which forms part of Adura's proposed Rosebank field development, at a point approximately 13.5 km west of the Tormore manifold. The closest surface oil and gas infrastructure to the proposed Tornado Development are the Clair Ridge platforms (operated by BP) located approximately 38 km southeast of the proposed pipeline route.

There are no planned, consented or operational offshore wind farms or carbon capture and storage sites within the vicinity of the proposed Tornado Development. In addition, there are no military Practice and Exercise Areas or wrecks designated as historic Marine Protected Areas, scheduled monuments or war graves within the vicinity of the proposed Tornado Development area.

## Identification and Assessment of Potentially Significant Impacts

The EIA process undertaken for the Tornado Development has aimed to identify and assess all potentially significant environmental effects arising from the proposed project (both from planned activities and unplanned (accidental) events). Cumulative and transboundary impacts have also been considered. Key areas under assessment include:

- Physical Presence
- Seabed Disturbance
- Underwater Noise Emissions
- Greenhouse Gas Emissions
- Marine Discharges
- Accidental Events

For planned activities, the significance of environmental effects has been evaluated by considering the sensitivity of the receptor affected in combination with the magnitude of impact that is likely to arise. For unplanned events, such as accidental hydrocarbon releases, significance has been determined using a risk assessment approach, where the likelihood (probability) of the unplanned event occurring is considered against the consequence (significance of effect) if the event was to occur.

An initial scoping exercise identified a number of aspects (activities or events) which could potentially result in significant environmental effects. A comprehensive assessment was therefore undertaken for these aspects and, where necessary, measures identified to prevent or reduce what might otherwise be significant adverse environmental effects through design evolution or operational mitigation measures. These aspects were then reassessed assuming the successful implementation of the identified mitigation measures to determine residual effects.

A summary of the main findings of the EIA process is provided below.

### Physical Presence

The physical presence of the Tornado 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 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 a 500 m safety zone, patrolled by an Emergency Rescue and Recovery Vessel (ERRV), which will be in place around the MODU for the duration of the proposed drilling operations. Fishing vessels may be temporarily displaced from the Tornado Development area during the drilling and installation phases, with an area of 0.8 $km^2$ at the Tornado drill centre location lost for the life of the field development. This is considered to be a very small area in comparison to the alternative fishing grounds available in the wider WoS area and fishing activity in the Tornado Development area is low. Below the sea surface the long term presence of the seabed development infrastructure will pose a potential snagging hazard to fishing gears. This risk is greatest at the Tormore end of the pipeline route as bottom trawling is prohibited at water depths greater than

800 m, although the use of mobile demersal fishing gear is also currently prohibited within the northern section of the Faroe-Shetland Sponge Belt NCMPA. All seabed infrastructure at the Tormore tie-in location and the pipelines and umbilical in water depths less than 800 m will be designed taking into account potential fishing interaction risks, which may include, as a worst case, rock protection. To minimise the snagging risk whilst pipeline and umbilical installation activities are ongoing, two guard vessels will be used to patrol the length of the lines in water depths less than 800m. In conclusion, no significant adverse residual effects to other sea users (shipping and fishing) are predicted as a result of the physical presence of the Tornado Development.

### Seabed Disturbance

The seabed will be disturbed through the placement of the CAN-ductors, parking-CAN units, pipeline pre-lay boulder clearance, the discharge of drill cuttings, muds and cement and the installation of the Tornado subsea infrastructure, pipelines, umbilical and protection/stabilisation material. The worst case total area of seabed that will be directly impacted temporarily by the Tornado Development is estimated at around 8.24 $km^2$, and the worst case total area of seabed that will be subject to long term / permanent impacts is estimated at around 0.53 $km^2$. Impacts to the seabed have the potential to interfere and cause adverse effects to water quality, seabed sediments, seabed communities (i.e. benthic flora and fauna) and fish.

As a worst case, it is assumed that the WBM drill cuttings discharged from the Tornado wells will be deposited within an area of up to 1.9 $km^2$, surrounding all three wells (based on a threshold for bottom deposition of ≥1 mm). A high exposure level of WBM cuttings (based on a threshold for bottom deposition of ≥10 mm) is likely to be deposited within an area of ca. 0.06 $km^2$. 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. However, near seabed current velocities and sediment mobility in the WoS area appear generally sufficient to prevent detectable local accumulation of cuttings from persisting in the short to medium term. In contrast, the creation of a cement patio surrounding each of the wells, which is estimated to have a radial spread of up to 14.2 m, will result in the loss of sandy and gravelly sediment habitat and the introduction of novel hard substrata to the area. The closest stony reefs recorded during the Tornado surveys were 0.6 km and 1.7 km respectively from the proposed well locations, therefore it has been assessed that the discharge of cuttings, mud and cement will not affect these recorded reefs.

The subsea infrastructure installation activities will result in the loss of some sandy and gravelly sediment habitat, and also the introduction of novel hard substrata. This will mostly comprise of subsea infrastructure items, pipelines, the control umbilical, pre-lay rock carpets and post-lay rock cover. The total area of long-term sandy and gravelly sediment habitat loss is estimated to amount to approximately 0.53 $km^2$; this is small in comparison to the area of similar habitat available across the wider area (ca. 10,000 $km^2$ within the Faroe-Shetland region). The area beneath the subsea infrastructure and protection material will become unavailable for re-colonisation by sandy and gravelly sediment inhabiting infauna and over time a new rocky substrate habitat will become established. Ultimately, this new seabed feature is expected to be colonised by the same types of mobile and encrusting epifaunal animals already present on cobbles and boulders in the wider area. The introduction of novel hard substrata by the Tornado Development is very small and, whilst it will represent a change to the benthic environment locally it is not expected to cause any widespread changes to the marine life present in the area.

Ocean quahog is on the OSPAR list of threatened and/or declining species and is a PMF in Scottish waters, although not recorded during the Tornado site survey and pipeline survey areas, is known to be present in the wider area. Moreover, the Faroe-Shetland Sponge Belt NCMPA is designated for the conservation of ocean quahog, in which part of the Tornado Development is located. The ocean quahog is highly sensitive to physical pressures and changes in seabed habitat types (i.e. the introduction of new hard substrata). Any impacts will, however, be in a very localised area, such that any effects on the population of ocean quahog in the wider WoS region are not predicted to be significant.

In the Tornado site survey area, the sponge aggregations observed were sporadic and of low abundance and therefore did not reach the criteria for further assessment. However, due to observations of demosponges, the presence of 'Deep-sea sponge aggregations' was considered along the proposed pipeline route. The assessment found that along two sections of one transect, the density of demosponges satisfied the density criteria for the OSPAR threatened and/or declining habitat 'Deep-sea sponge aggregations'. In the Tornado survey, the faunal assemblages associated with sponges were not different from the surrounding assemblages. Additionally, the

areas where sponges satisfied the density criterion did not exceed 25 $m^2$ and therefore no qualifying criteria were met. Therefore, due to the limited aggregations of deep sea sponges recorded within the proposed development area, the installation of the Tornado Development subsea infrastructure is unlikely to cause direct mortality to deep sea sponges. In addition, densities of sponges are highest in a very narrow depth range within the Faroe-Shetland Channel (400 m to 600 m depth) and it should be noted that the majority of the Tornado Development is not located within this depth range.

Approximately 18 km of the Tornado to Tormore pipeline route is located within the Faroe-Shetland Sponge Belt NCMPA. The proposed installation of the subsea infrastructure, pipelines, umbilical, protection / stabilisation materials and use of temporary laydown areas have the potential to impact the designated features of the NCMPA. Any long term disturbance caused by the proposed Tornado Development will result in a very small, permanent reduction in potential protected habitat type (0.007% (0.386 $km^2$) of the total area of the Faroe-Shetland Sponge Belt NCMPA). Any other impacts are deemed temporary and of a small scale (0.034% (1.81 $km^2$)) of the total area of the Faroe-Shetland Sponge Belt NCMPA). The long-term habitat loss by other projects within the Faroe-Shetland Sponge Belt NCMPA, represents a relatively small percentage of the total NCMPA area at ca. 0.02%. Based on the small area of seabed that will be permanently impacted (0.386 $km^2$), in comparison to the overall NCMPA area (5,278 $km^2$), no likely significant effects are predicted as a result of the proposed activities either alone or in-combination with other plans or projects. Therefore, it is considered that the Tornado Development will not undermine the site's conservation objectives or result in an adverse effect on site integrity.

In conclusion, no significant adverse residual effects to seabed sediments, seabed communities and fish are predicted from seabed disturbance associated with the Tornado Development operations.

### Underwater Noise Emissions

Underwater noise generated during the proposed Tornado 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 the contingent Vertical Seismic Profile (VSP) survey activities when (3 x 250 cubic inch) seismic airguns may be used. The MODU used to drill the Tornado wells and other vessels for other activities will use Dynamic Positioning (DP) thrusters. However, all of these activities will be temporary in nature. Ithaca will implement a range of measures to mitigate any potential impacts including optimising duration of drilling and installation activities to minimise vessel usage, and adhering to the Joint Nature Conservation Committee (JNCC) guidelines for minimising injury and disturbance to marine mammals. In conclusion, no significant adverse residual effects to fish and marine mammals are predicted from noise associated with the Tornado Development operations.

### Greenhouse Gas Emissions

Greenhouse gas (GHG) emissions to the atmosphere will be produced during the field life of the Tornado Development. These emissions can be categorised into:

(i) Scope 1 emissions, the direct GHG emissions a company produces from its own operations;

(ii) Scope 2 emissions, GHG emissions associated from the energy a company purchases (not applicable to this ES); and

(iii) Scope 3 emissions, namely indirect GHG emissions in the value chain from upstream (e.g. transportation) and downstream (e.g. end use of sold products) activities.

During the development of the Tornado field, combustion of hydrocarbons for power generation on the MODU, vessels, and helicopters, as well as flaring of hydrocarbons during the well flow test, will result in GHG emissions, referred to as 'indirect, upstream Scope 3 emissions'.

During the production phase, hydrocarbons from the Tornado field will be processed at the SGP (subject to ongoing negotiations). When the production fluids arrive onshore at the SGP, the liquids (condensates) will be removed and piped to the nearby SVT, while the gas will be processed before being transported to the UK grid via the SIRGE and FUKA pipelines for onwards transmission to St Fergus and the NTS. For the purposes of the assessment presented in this ES, the incremental GHG emissions directly associated with processing at SGP as a result of Tornado coming online are considered to be 'direct Scope 1 emissions' as Tornado production is controlled by Ithaca. During production, all GHG emissions associated with processing at SGP will be reported and administered by the SGP operator as their Scope 1 emissions, not Ithaca.

As a worst-case GHG estimate, it is assumed that all hydrocarbons produced by Tornado (gas and condensate) will be combusted in their end-use, although in reality this is unlikely. The hydrocarbons path from the well to their final destination has also been factored, which includes the further refinement, transport and distribution of the hydrocarbons, known as 'well-to-tank' (WTT). As the WTT GHG conversion factors encompass the emissions associated with the extraction, refining and transportation of hydrocarbons prior to their end use, these already account for the incremental emissions that would be generated at SGP as a result of Tornado coming online. Therefore, to prevent double-counting, the SGP fuel gas and flare volumes attributed to Tornado have been deducted from the gas production profiles in order to calculate the WTT emissions for gas. Collectively, the emissions generated from WTT and the end use of sold products are referred to as 'indirect downstream Scope 3 emissions'.

In summary, the worst-case total gross GHG emissions generated over the life of the Tornado Field are estimated to be ca. 35,692.81 kilotonnes of $CO_2e$, based on the Max production case, which represents a 'worst case' emissions profile.

It is recognised that development of the Tornado field will contribute to overall volumes of GHG emissions in the atmosphere in combination with the other projects and activities emitting GHG emissions. Ithaca is committed to minimising the amount of GHG emission produced. During drilling and installation operations, vessel days and fuel consumption will be reduced, as far as practicable. The well test and well clean-up activities will be designed not only to achieve their goals but to provide an optimal duration and reduce flaring to minimise the GHG emissions produced.

The GHG emissions associated with the Tornado Development are aligned with global climate targets and pathways, including those set out by *The Paris Agreement*. The *Paris Agreement* is a legally binding International Treaty adopted in 2015 that commits countries to limit global warming to well below 2°C, ideally 1.5°C, through emissions reductions and climate adaptation. Under SSP 1 – 1.9, Tornado has an insignificant contribution to global GHG emissions of less than 0.02605% in 2030, with the proportion decreasing under each higher SSP scenario. Tornado will also contribute a very small percentage towards predicted global oil and gas production rates in international pathways consistent with limiting warming 2°C. Furthermore, Tornado field life emissions represent less than 0.01519% of the remaining global carbon budget under a 1.5°C scenario. Tornado is therefore not expected to affect the trajectory of global temperature rise or the achievement of international climate targets in a significant way.

As global reduction pathways have been used to contextualise the assessment of the magnitude of impact the Tornado Development's GHG emissions will have on the climate, this approach is considered to be inherently cumulative as these pathways take into account a wide range of existing and planned projects and other activities. These forward-looking pathways provide a proxy for the evolving baseline, as they incorporate anticipated GHG emissions from existing and planned oil and gas developments, such as Tornado, as well as broader sectoral and policy trends - including those relating to future oil and gas development and consumption.

From a UK perspective, the GHG emissions associated with the Tornado Development represent a small proportion of GHG emissions typically arising from oil and gas developments in the UKCS and will contribute a small fraction of $CO_2e$ emissions towards future UK carbon budget targets (ca. 1.37644% of carbon budget 5 and 1.22368% of carbon budget 6). This is also true for the UK's NDCs, as Tornado's total gross GHG emissions will account for ca. 3.50164% of the 2030 NDC allowance and ca. 1.69765% of the 2035 NDC allowance. Given these proportions, the GHG emissions generated by the Tornado Development would not have a significant influence on the UK's ability to meet its Carbon Budget and NDC emissions reduction targets. All gas produced from the Tornado field will flow into the NTS via the SGP and will be used domestically and not exported.

Ithaca strives for Industry leading levels of environmental performance. Key to this ambition is the Company's commitment to significantly reduce GHG emissions from its operations in line with the global transition to a low carbon economy and the UK Government's Net Zero targets.

In summary, development of the Tornado field provides the UK with a comparatively low carbon indigenous gas source during the transition to renewable energy, helping contribute to energy security and does not detriment the delivery of Net Zero UK carbon emissions by 2050.

### Marine Discharges

The main operational discharges into the marine environment from the proposed Tornado Development will occur as a result of the discharge of drill cuttings, muds and cement, residual hydrocarbons when drilling through the payzone, chemicals during drilling, installation and hook-up and commissioning activities, completion brine during well clean-up activities, and water-based hydraulic fluids during production maintenance activities. Upon release, these discharges will be subject to rapid dilution and dispersion and are not expected to persist within the marine environment. Additionally, a number of studies have shown that any impacts will be limited to the local area in the immediate vicinity of the discharge location and therefore no significant adverse residual effects are predicted.

Ithaca will implement a range of measures to mitigate any potential impacts including undertaking a chemical risk assessment to identify the risk profile of chemicals being used and / or discharged in accordance with the requirements of the Offshore Chemicals Regulations 2002 (as amended). Where practicable, chemicals with a higher risk profile will be substituted out in favour of those with an improved environmental profile. During the proposed drilling operations, any discharges of residual reservoir hydrocarbons will be treated to meet oil-in-water limits of less than or equal to 30 milligrams per litre (mg/l). The discharge stream will also be monitored and sampled in accordance with an approved Oil Discharge Permit.

### Accidental Events

All offshore activities associated with the Tornado 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, Ithaca'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 hydrocarbon 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 Tornado Development would be an uncontrolled flow of condensate from one of the wells (i.e. a well blowout). Oil spill modelling has been conducted to determine the fate of Tornado hydrocarbons released from this worst case scenario. As the UK/Faroe Islands median line is located approximately 6.5 km to the southeast, there is a 100% potential for a surface slick of condensate to cross the median line. There is low potential to cross the UK/Norway median line (3% in winter). The maximum probability of shoreline oiling on the Shetland Islands occurs with a 3% chance and the minimum time to shore occurs during the winter, with oil reaching the coastline within 189 hours. However, the Tornado condensate is a light hydrocarbon 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 Tornado 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 Tornado subsea facilities once operational will be covered in approved oil pollution 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 Tornado Development is considered to be Medium to Low depending on the receptor impacted, but in all cases the risk has been reduced through mitigation measures and good industry practice and is therefore not considered to be significant.

## Waste Management

Several different waste streams will be generated throughout the lifespan of the Tornado Development. Waste management will be undertaken in compliance with current environmental legislation and Ithaca's own waste procedures. The management of offshore waste generated on the UKCS is strictly regulated and the UK has well-established infrastructure in place to manage this waste effectively.

## Environmental Management

Ithaca conducts all of its activities and operations in accordance with an externally verified Environmental Management System (EMS), which has been designed to meet the requirements of ISO 14001. This system provides the structured management framework within which environmental impacts are identified, assessed, controlled, and monitored.

The Ithaca EMS 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 Tornado 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 Tornado Development.

## Conclusion

In summary, it is concluded that the proposed Tornado Development will not result in any significant environmental effects provided that all identified mitigation measures are implemented.

# 1 Introduction

## 1.1 Background

Ithaca SP E&P Limited, (an affiliate of Ithaca Energy (UK) Limited (Ithaca Energy (UK) Limited and it's affiliated companies being referred to throughout this Environmental Statement as 'Ithaca') is planning to develop the Tornado gas condensate discovery in UKCS Blocks 204/13 and 204/14d in the Faroe-Shetland channel, WoS, located approximately 153 km west of the closest landfall on the Shetland Islands and approximately 6.5 km south east from the UK/Faroes transboundary line (Figure 1.1). The Tornado discovery sits within Licence P.2403, in a water depth of approximately 1,060 m, and is jointly held by Ithaca (50%) and Adura Operations Limited (50%). Ithaca is operator on behalf of the Joint Venture.

Ithaca is proposing to develop Tornado as a subsea gas development tied back via a new production pipeline (ca. 86 km in length) and MEG pipeline to TotalEnergies E&P UK Limited's existing GLA network infrastructure at Tormore, with production to be processed onshore at the SGP. A separate control umbilical between Tormore and Tornado is also required. First gas is currently targeted for start Q4 2029.

In order to obtain a Development and Production Consent for Tornado, Ithaca is required to submit a Field Development Plan (FDP) to the North Sea Transition Authority (NSTA). As the proposed development will extract more than 500,000 cubic metres of gas per day, the FDP must be supported by an ES, which needs to be submitted to the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) for approval under The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020.

This document is the ES for the proposed Tornado Field Development (hereafter referred to as 'the Tornado Development' or 'the Project') and presents the findings of the EIA undertaken to determine if there are any significant effects of the Project on the environment.

## 1.2 Project Overview

Tornado will be developed via up to three close cluster deviated subsea wells tied back via a ca. 86 km, 16-inch production pipeline to the existing Tormore 18-inch Flowline End Termination (FLET) structure for entry into the GLA, Laggan-Tormore (L-T) pipeline system for onwards transmission to SGP for processing. The wells will be drilled from a single drill centre using a dynamically positioned MODU. Electro-hydraulic controls for Tornado will be provided by extending the existing L-T system from the Tormore manifold to Tornado by means of a dedicated control umbilical. A dedicated 4-inch MEG pipeline will be extended from Tormore to Tornado to provide continuous MEG injection for hydrate inhibition.

The route of the pipelines and umbilical are required to pass through the Faroe-Shetland Sponge Belt NCMPA for a length of approximately 18 km to reach the tie-in point at Tormore which sits within the NCMPA (Figure 1.1). The Faroe-Shetland Sponge Belt was designated as a NCMPA in July 2014, which post-dated regulatory approval and development of the Laggan-Tormore subsea facilities. The proposed Tornado pipeline route has been selected to minimise the length that passes through the NCMPA; it takes the most direct path up the slope from the 1,000 m Faroe-Shetland Channel bottom to Tormore, avoiding the downslope gullies that would likely necessitate significant pre-lay rock deposits to support the pipelines and prevent unacceptable free spans.

The Tornado field will be operated from the GLA control room at SGP, located ca. 45 km north of Lerwick on the main island of the Shetland Isles. When the produced hydrocarbons arrive onshore, they will be processed with the gas treated and compressed for export into the SIRGE pipeline for onwards transmission to St Fergus and the National Transmission network. Small volumes of unstabilised condensate will be piped to the neighbouring SVT, for further processing with liberated gas exported from SVT to SIRGE and stabilised liquid hydrocarbons piped to storage tanks for export via tanker with other SVT liquid streams.

The location of the proposed Tornado infrastructure is summarised in Table 1.1.

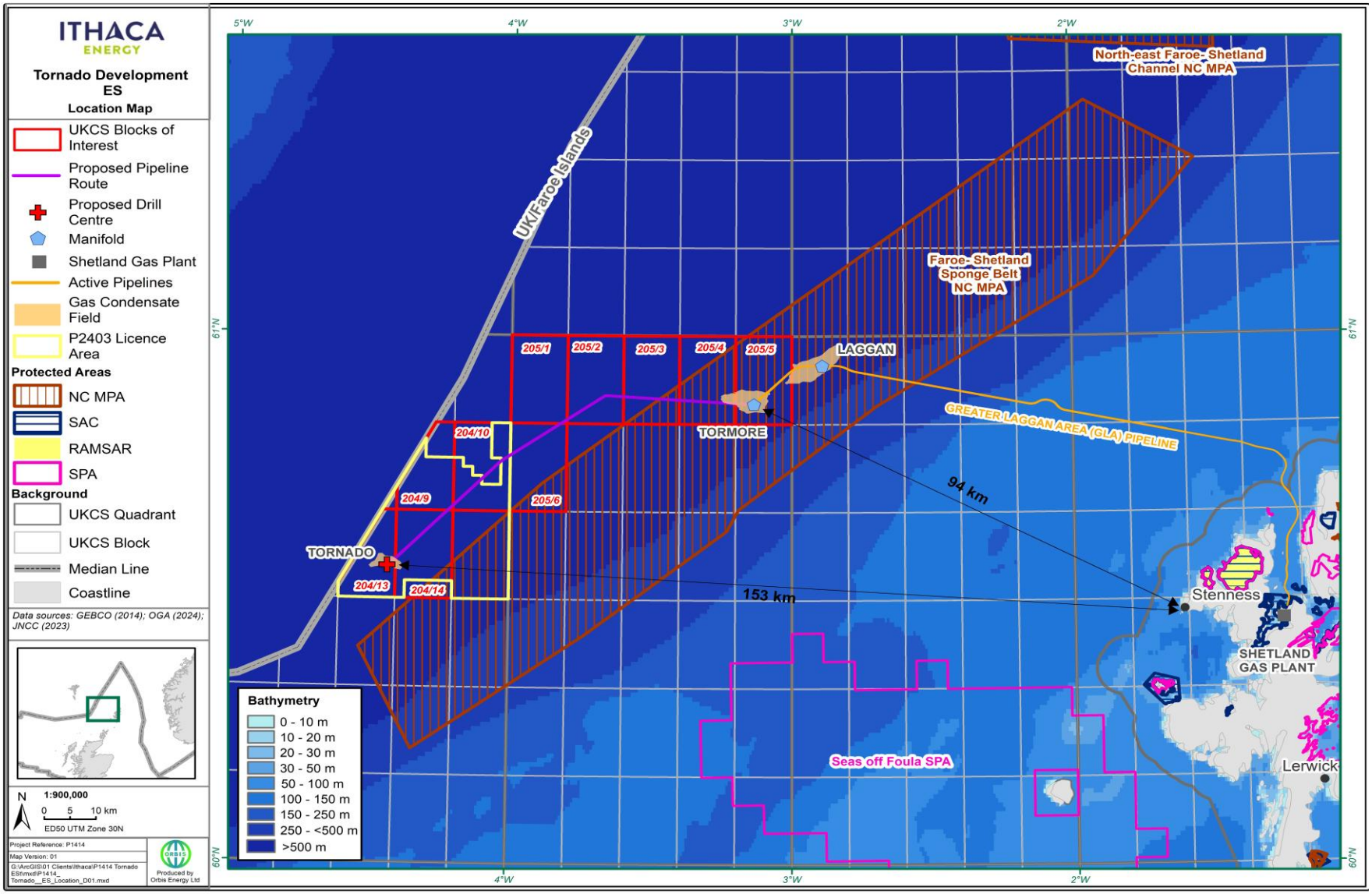



**Figure 1.1: Location of the Proposed Tornado Development**

**Table 1.1. Location of Proposed Tornado Development Infrastructure**

| Aspect | Tornado Drill Centre | Tormore Tie-in Location |
|---|---|---|
| Location (Lat/Long) [1] | 60° 33' 43.752"N<br>04° 25' 45.193"W | 60° 52' 19.093"N<br>03° 08' 7.26"W |
| UKCS Block | 204/13 | 205/5 |
| ICES Rectangle | 50E5 | 50E6 |
| Distance to nearest coastline (Shetland Isles) | 153 km | 94 km |
| Distance to nearest median line (UK / Faroe Islands) | 6.5 km | 53 km |
| Nearest Marine Protected Area | 8.5 km NW of Faroe-Shetland Sponge Belt NCMPA | Within Faroe-Shetland Sponge Belt NCMPA |

[1] ED50, UTM Zone 30N Central Meridian 3° West.

First gas is currently targeted for start Q4 2029, with WoS metocean conditions driving seasonal drilling and installation campaigns. Subject to the necessary permits and consents being in place, installation of the CAN-ductors (if used) is planned for 2027 (refer to Section 3.3.3), with drilling and completion activities to be undertaken in 2028, and the bulk of subsea installation works planned for 2029 to avoid SIMOPs with the MODU.

Tornado production rates are anticipated to peak in 2030 at 9,462,562 cubic metres (334 million standard cubic feet) of gas per day and 619.1 tonnes (783.4 cubic metres) of condensate per day (Max case, based on a three well development scenario). The field is expected to produce hydrocarbons for circa six to ten years, depending on the reserves and production rate.

On cessation of production, the Tornado infrastructure will be decommissioned in accordance with the requirements of the prevailing UK and International law.

## 1.3 Scope and Purpose of the ES

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

- The drilling and completion of up to three production wells at the Tornado field;
- Installation of subsea infrastructure, including production pipeline, MEG pipeline and umbilical, to support tie-back of the wells to the existing GLA network infrastructure at Tormore;
- Operation, maintenance and inspection of the Tornado facilities;
- Decommissioning of the Tornado infrastructure on cessation of production.

The purpose of this ES is to provide an assessment of the potential environmental effects that may arise from the proposed Tornado Development and to identify the measures, which will be put in place to minimise these effects.

## 1.4 Structure of the ES

The structure of this ES is summarised in Table 1.2 on the following page.

**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 Tornado Development (the Project) and its main environmental impacts and proposed mitigation measures. |
| **Main Document** | |
| Section 1: Introduction | Introduces the Project, outlines the scope and purpose of the ES, lists applicable environmental legislation, identifies areas of uncertainty and summaries the key issues raised during the stakeholder engagement process. |
| Section 2: Project Alternatives | Outlines the main concept options (alternatives) considered for the Project. |
| Section 3: Project Description | Describes the subsea infrastructure to be installed for the Project and provides an overview of each lifecycle phase of the Tornado Development, including drilling, installation, production, inspection and maintenance, and decommissioning activities. |
| Section 4: Existing Environmental Baseline | Describes the baseline environment in the Project area, with particular emphasis on those aspects which are likely to be affected by the proposed development operations. |
| Section 5: Assessment Methodology | Presents the impact assessment methodology used for the EIA and identifies those aspects of the environment that are likely to be significantly affected by the Project. |
| Sections 6 – 11: Assessment Sections | These sections assess if the Project is likely to have any significant effects on the environment, define the proposed mitigation measures which will be implemented and determine the residual impacts (i.e. they document the assessment results). Where relevant, transboundary, in-combination and cumulative impacts are also assessed. |
| Section 12: Waste Management | Provides a high-level description of Ithaca's waste management strategy for the proposed Tornado Development. |
| Section 13: Environmental Management | Describes Ithaca's EMS and the management processes that will be applied throughout the Project to ensure adverse impacts on the environment are minimised. Includes a register of Project commitments. |
| Section 14: Conclusions | Reports the conclusions of the EIA process. |
| Section 15: References | List sources of information referenced throughout the ES. |
| **Appendices** | |
| Appendix A: Legislation and Marine Policy | Provides a summary of applicable environmental legislation and marine policy pertinent to the Project. |
| Appendix B: ENVID Registers | Presents the results from the ENVironmental and socio-economic impact IDentification (ENVID) workshop undertaken for the Project. |
| Appendix C: Drill Cuttings Modelling | Presents the results of the drill cuttings and muds dispersion modelling study undertaken for the Project. |
| Appendix D: Underwater Noise Modelling | Presents the results of the underwater noise modelling study undertaken for the Project. |
| Appendix E: Pipeline Dewatering Modelling | Presents the results of the pipeline dewatering modelling study undertaken for the Project. |
| Appendix F: Oil Spill Modelling | Presents the results of the oil spill modelling study undertaken for the Project. |
| Appendix G: Production Profile Tables | Presents the Tornado max, high, low and mid case production profiles. |
| Appendix H: Quantification of GHG Emissions | Sets out the methodology (calculations, emissions factors and assumptions) used to quantify the total GHG emissions generated from the Project. |

## 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 NSTA to grant licences that confer exclusive rights to 'search and bore for and get' petroleum.

The NSTA license, regulate and influence the UK oil and gas industry, supporting UK energy security, driving emissions reduction from UK supplies and helping to accelerate the transition to Net Zero to realise the potential of the North Sea as an integrated energy basin.

The Petroleum Act is supplemented by various environmental Acts and Regulations, which Ithaca will need to ensure compliance with. OPRED is responsible for regulating environmental and decommissioning activity for offshore oil and gas operations on the UKCS and is part of the Department for Energy Security and Net Zero (DESNZ).

As noted in Section 1.1, the EIA undertaken for Tornado as reported in this ES has been carried out in accordance with the Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020 (the 'EIA Regulations'). These regulations require that where a project falls within Schedule 1 of the Regulations there is a mandatory requirement for an EIA and the application for a development and production consent must be supported by an ES. The Tornado Development qualifies as a Schedule 1 project as it will involve the extraction of natural gas for commercial purposes where the amount extracted exceeds 500,000 cubic metres per day. Peak production levels may also exceed 500 tonnes of condensate a day. The EIA has been undertaken with reference to the Offshore EIA Regulations Guidance (DESNZ, 2021a), as well as the new supplementary guidance for assessing the effects of downstream Scope 3 emissions on climate from offshore oil and gas projects (DESNZ, 2025a).

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

- The Climate Change Act 2008 (as amended);
- The Energy Act 2008 (as amended);
- Marine and Coastal Access Act 2009 (as amended);
- The Marine (Scotland) Act 2010;
- The Merchant Shipping (Oil Pollution Preparedness, Response and Cooperation) Regulations 1998 (as amended);
- The Offshore Chemicals Regulations 2002 (as amended);
- The Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations 2015;
- The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (as amended);
- The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended).

Further detail on these items of legislation, as well as other international treaties and agreements such as the OSPAR Convention, applicable to the Project is provided in Appendix A.

### 1.5.2 Marine Planning Policy

The Marine and Coastal Access Act 2009 and The Marine (Scotland) Act 2010 established a legislative and management framework for the marine environment allowing the competing demands on the sea to be managed in a sustainable way across all of Scotland's seas.

The framework includes the following elements:

- UK Marine Policy Statement (MPS): the UK Administrations share a common vision of having clean, healthy, safe, productive and biologically diverse oceans and seas.
- Scottish National Marine Plan (NMP): sets out strategic policies for the sustainable development of Scotland's marine resources out to 200 nautical miles.
- Regional Marine Plans: marine planning will be implemented at a local level within Scottish Marine Regions, extending out to 12 nautical miles (nm). Applicable to the Tornado field is The Shetland Islands Regional Marine Plan.

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

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

The proposed Tornado Development, as described in this ES, has been assessed against all relevant NMP objectives and policies, as well as relevant policies in The Shetland Islands Regional Marine Plan, to confirm that the Project will not adversely impact them (see Appendix A for further details).

### 1.5.3 UK Government's Energy Policy and Net Zero Target

The UK's Climate Change Act 2008 (as amended) sets a legal requirement to achieve a 100% reduction in GHG emissions by 2050 relative to 1990 levels ('Net Zero'). This delivers on the commitment that the UK made by signing the Paris Agreement[1]. The Act requires the UK government to set five-yearly legally-binding carbon budgets, 12 years in advance, from 2008 to 2050, which restrict the amount of GHGs the UK can emit (refer to Section 9.3.2).

For the UK oil and gas industry, the revised Oil and Gas Authority (OGA) Strategy (OGA, 2020), which amends the Maximising Economic Recovery (MER) UK Strategy, came into force in February 2021 and places an obligation on the oil and gas industry to assist the Secretary of State in meeting the Net Zero target by 2050. Specifically, the industry must take the steps necessary to:

a. Secure that the maximum value of economically recoverable petroleum is recovered from the strata beneath relevant UK waters; and, in doing so,

b. Take appropriate steps to assist the Secretary of State in meeting the Net Zero target, including by reducing as far as reasonable in the circumstances GHG emissions from sources such as flaring and venting and power generation, and supporting carbon capture and storage projects.

Upstream, the North Sea Transition Deal (BEIS, 2021) sets out an ambitious plan for how the UK's offshore oil and gas sector and the government will work together to meet stretching GHG emissions reduction targets, including development and implementation of the NSTA's Net-Zero Asset Stewardship Expectation 11 (NSTA, 2021). The deal includes early reductions in offshore production emissions of 10% by 2025; 25% by 2027; and 50% by 2030, against a 2018 baseline, to meet the sector's aim of creating a Net Zero basin by 2050.

More recently, the OGA Plan to reduce UKCS GHG emissions (NSTA, 2024a) sets out requirements for industry to meet the Net Zero obligation in the OGA Strategy and builds on and consolidates guidance on flaring and venting and the NSTA's Net-Zero Asset Stewardship Expectation 11.

The British Energy Security Strategy (HM Government, 2022), highlights the need to reduce the UK's dependence on imported oil and gas and notes that the cleanest and most secure way to do this is to

[1] The Paris Agreement aims to restrict global temperature change to well under 2°C, and pursue efforts to keep it below 1.5°C.

source more of it domestically. Domestic gas production equated to around half of UK demand in 2024, with the remainder coming from imports; gas through pipelines from Europe and tankers of LNG from various countries (NSTA, 2025a). Government forecasts show that domestic gas production will remain an important part of the UK's energy mix for the foreseeable future, with the DESNZ's recent consultation on Building the North Sea's Energy Future (DESNZ, 2025b) acknowledging that oil and gas will play a role in the UK and around the world for decades to come. Powering Up Britain, The Net Zero Growth Plan (DESNZ, 2023b) also acknowledges that fossil fuels will retain a crucial role in the energy system until there are credible clean energy alternatives that can replicate their role, with natural gas playing a role for years to come, particularly in the hardest to decarbonise sectors.

In November 2025, the UK Government published the North Sea Future Plan (DESNZ, 2025f), which outlines a comprehensive strategy aimed at managing the North Sea's oil and gas resources while transitioning to clean energy.

The North Sea Future Plan sets out the UK Government's vision for the North Sea, namely:

*"To foster an internationally-leading offshore clean energy industry, which ensures good, long-term jobs, growth and investment in communities across the North Sea, in tandem with a sustainable transition in oil and gas – boosting the country's economy and energy security, in line with our climate obligations."*

It acknowledges that North Sea oil and gas production will continue to play an important role in the UK's energy mix in the decades to come, as well as its non-energy uses, such as in the petrochemicals industry. Ongoing investment and continued opportunities in oil and gas – particularly in the next few years – are fundamental to UK Government's ambition to ensure that oil and gas workers experience a fair, orderly and prosperous transition in the North Sea.

The North Sea Future Plan also outlines changes to the NSTA's objectives to allow the NSTA to move beyond MER to cover economic, Net Zero and transition factors. The NSTA's revised objectives, which will be legislated for in the future, will now broadly cover:

- Objective 1 (Economic) – To maximise societal economic value of a relevant activity.
- Objective 2 (Net Zero) – To assist the Secretary of State in meeting the duty under section 1 and section 4(1)(b) of the Climate Change Act 2008 including supporting decarbonisation of relevant upstream activities.
- Objective 3 (Transition) – To enhance the long-term benefits of the transition to clean energy technologies in the UKCS by considering workers, communities and supply chains.

Further information on UK legislation and policies, including oil and gas specific strategies, which aim to mitigate climate change is provided in Section 9.3.

## 1.6 Areas of Uncertainty

This ES is prepared prior to detailed engineering studies being concluded. As a result, some assumptions have been made during the EIA process, including:

- It is assumed that both the MEG pipeline and control umbilical will be protected in water depths less than 800 m. The requirement for protective measures will depend on the findings of ongoing studies assessing the intensity of fishing activity and the potential for damage.
- Facilities reconfiguration within the Tormore 500m zone - work is ongoing to refine the reconfiguration works in the vicinity of Tormore to minimise overall environmental impact;
- Crossing designs are not yet matured and may entail concrete structures and/or mattresses and rock placement. Much will depend on the crossing design required to maintain the pipelines within their design condition; and
- Commissioning philosophies are provisional and may differ from finalised commissioning methodologies.

Where assumptions have been made, the environmental worst-case option has been assessed in this ES.

In addition to the above, to assess the effects of downstream scope 3 emissions on climate from the Tornado Development, Ithaca has made the assumption that all end use Tornado hydrocarbons are eventually combusted (refer to Section 9).

# 2 Project Alternatives

## 2.1 Introduction

Ithaca has evaluated various concepts to develop the Tornado field. This section of the ES describes the main alternatives considered, the associated environmental implications of each option and the reasons why the selected concept has been chosen. It references the 'Tornado Development Concept Select Report' (Ithaca, 2025) undertaken to determine the optimum development plan for the field in terms of economics, technical risk and operability and environmental impacts.

The proposed Tornado Development concept has been selected and defined with consideration to the central obligation of the OGA Strategy (OGA, 2020), being to:

- Secure that the maximum value of economically recoverable petroleum is recovered from the strata beneath relevant UK waters; and, in doing so;
- Take appropriate steps to assist the Secretary of State in meeting the Net Zero target, including by reducing as far as reasonable in the circumstances greenhouse gas (GHG) emissions from sources such as flaring and venting and power generation, and supporting carbon capture and storage projects.

Ithaca is also cognisance of the requirements of NSTA's Net Zero Stewardship Expectation 11 (NSTA, 2021).

The NSTA provided its non-objection to the selected concept on 4th July 2025.

## 2.2 Development Concept

Development of Tornado is being progressed in accordance with Ithaca's Stage Gate Process (ISGP) for projects, as illustrated in Figure 2.1, which outlines a six-stage decision making process (Initiate, Assess, Select, Define, Execute and Handover). It provides a process for a common understanding and alignment amongst project teams, management, joint venture partners and other key stakeholders on strategic project issues which is key to ensure that the field development opportunity is appropriately framed. This ensures that decision criteria for the selection of alternatives are agreed and established early in the project life cycle i.e. during the Assess and Select Phases.

| | INITIATE | ASSESS | SELECT | DEFINE | EXECUTE | HANDOVER |
|---|---|---|---|---|---|---|
| Stage Objective | Identify opportunity | Evaluate and validate opportunity | Review alternatives and recommend preferred concept | Refine selected concept and produce project execution plan | Develop detailed engineering designs, procure equipment and execute construction activities in line with HSEQ, cost and schedule targets | Complete construction, commission facilities and transition to Operations |
| Gate Decision | This opportunity is worth pursuing and fits the portfolio. | Commercial and technical viability assessment completed.<br><br>Focus is on reservoir potential and economics of development before assessing readiness to enter Select (handover from Exploration to Technical). | Optimal concept selected.<br><br>Evaluate if project is appropriately funded, sufficiently resourced and organised to proceed. | Project definition is ready, and the project is attractive enough to take to sanction. | Construction and pre-commissioning are complete.<br><br>It is safe to energize and / or introduce hydrocarbons. | Project is delivered and reached steady-state. Operations can accept the project.<br><br>Lessons Learned collected. |

**Figure 2.1: Illustration of Ithaca's Stage Gate Process**

The Concept Select work for Tornado builds on feasibility work carried out in 2023 and earlier work carried out by Siccar Point Energy (SPE), which was acquired by Ithaca in 2022. Studies commissioned by SPE through 2018 and 2019 ruled out all standalone and non-conventional development options for Tornado but highlighted the potential for Tornado to support a subsea tie-back via existing WoS infrastructure.

Feasibility study work estimated the development Capital Expenditure (CAPEX) of a standalone concept, i.e. a dedicated Tornado central processing facility (floater) with gas and liquid export routes, at >£1 billion. This is nearly double the estimated CAPEX of developing Tornado via an existing host. Tornado estimated recoverable volumes are not sufficient to support CAPEX of this magnitude, and other discoveries and prospects within the Nueva Basin Gas Hub where Tornado is located (i.e. Suilven discovery and Spitfire and Mustang prospects; Figure 2.2) are inadequate to support a standalone processing hub at or near Tornado. On this basis, standalone development of Tornado was deselected as a viable option in the Feasibility phase of the project.

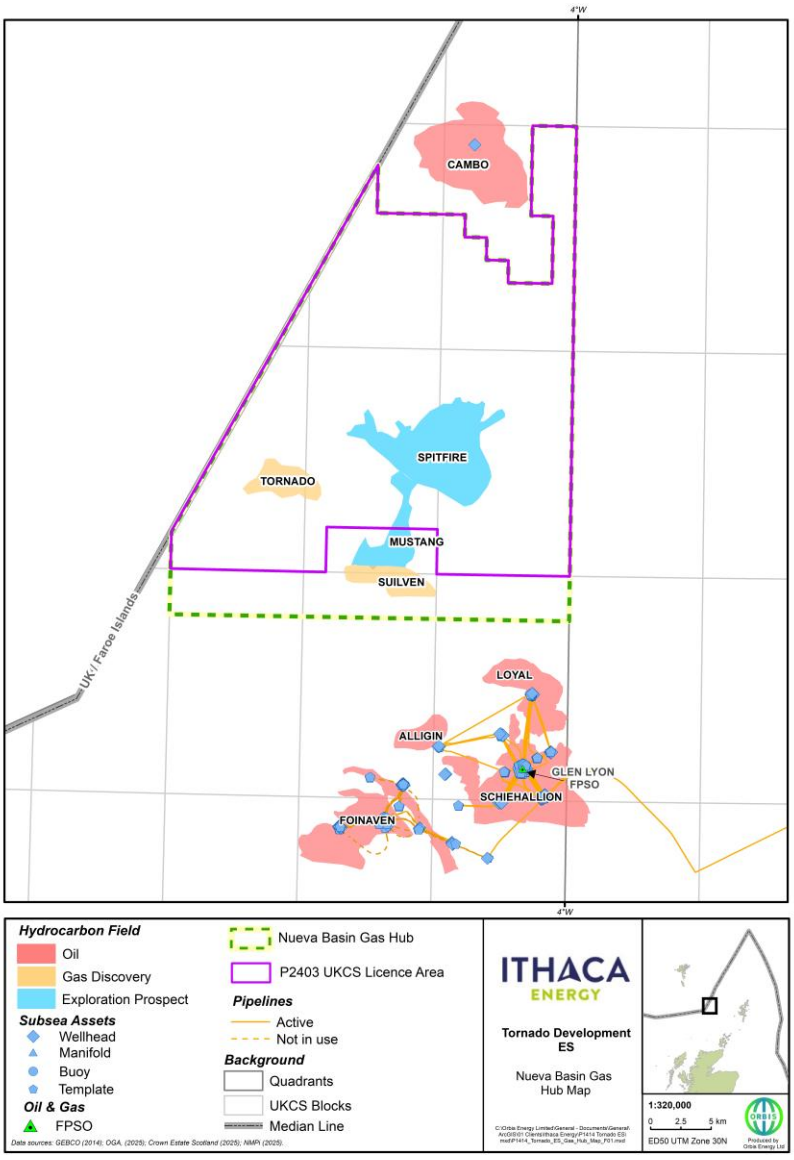



**Figure 2.2: Nueva Basin Gas Hub**

Concept Select work therefore focused on screening hosts which could support Tornado as a subsea tie-back.

**Concept Decision:** Subsea tie-back

### 2.2.1 Initial Host Screening

The host selection was carried out in two stages. The initial stage involved identification and high-level screening of all potential hosts in the vicinity of Tornado, as illustrated in Figure 2.3. Of the eight potential host options identified, only three (GLA / SGP), Glen Lyon FPSO vessel and Clair Phase 1 / Clair Ridge) were considered to be potentially viable hosts for a gas development, as detailed in Table 2.1.

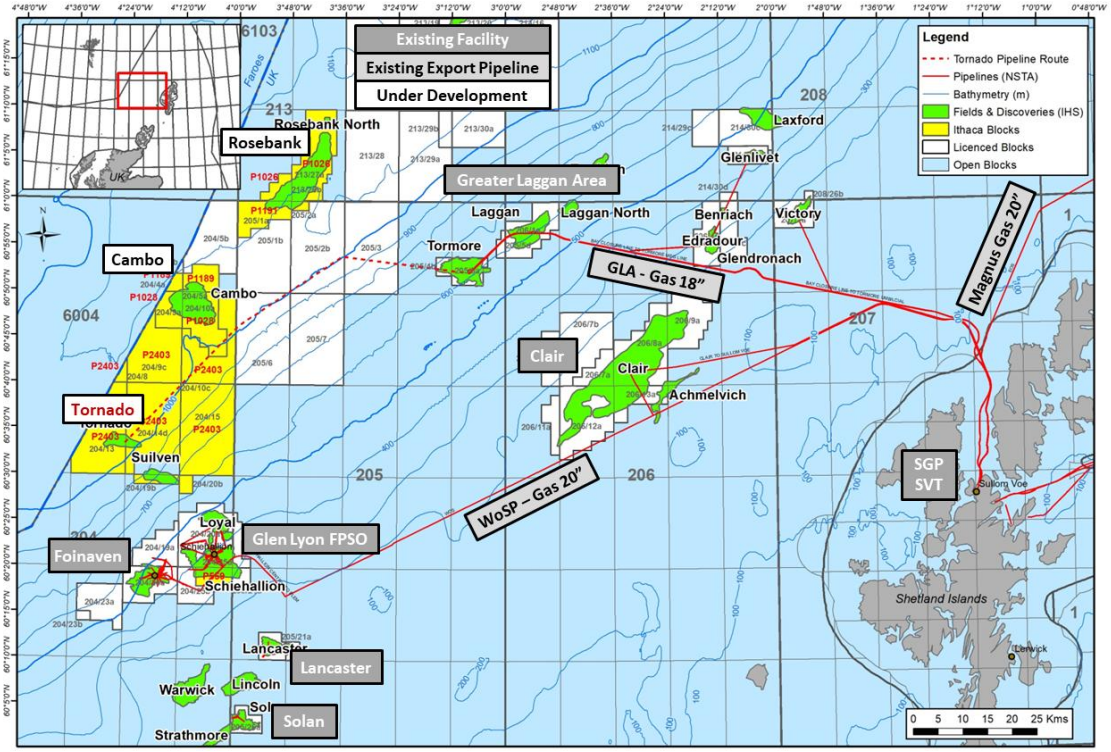



**Figure 2.3: Potential hosts for the Tornado Development**

**Table 2.1: Summary of potential 3rd party tie-back hosts for the Tornado Development**

| Prospective Host | Approx. Distance to Tornado | Comments on Suitability |
|---|---|---|
| Key: Viable host | | May be a viable host / Not a viable host |
| Greater Laggan Area/ Shetland Gas Plant | ca. 86 km (to Tormore) | Subsea wet gas tie-in at Tormore facility, ullage to support Tornado within subsea system and Shetland Gas Plant (SGP) processing facility. |
| Glen Lyon FPSO | 38 km | Glen Lyon FPSO has limited gas handling ullage, topsides space and weight availability. Processed gas from Glen Lyon is exported to shore via the West of Shetland Pipeline System (WOSPS). |
| Clair (Clair Phase 1 / Clair Ridge) | 110 km (to Clair Ridge) | Fixed platforms with limited gas handling ullage, topsides space and weight availability. Processed gas from Clair is exported to shore via WOSPS. |
| Lancaster (Aoka Mizu FPSO) | 55 km | Early Production System (EPS) with no existing gas export route (excess gas is flared). Limited rated (mothballed) gas handling capacity of 35 MMscfd. Planned Cessation of Production (CoP) predates Tornado First Gas. Aoka Mizu deselected based on CoP timeline and absence of export route. |
| Solan | 65 km | Normally unmanned platform with limited gas capacity and no existing gas export route (excess gas is flared). |

| Prospective Host | Approx. Distance to Tornado | Comments on Suitability |
|---|---|---|
| | | Planned CoP predates Tornado First Gas. Solan deselected based on CoP timeline and absence of export route. |
| Foinaven | 35 km | The Petrojarl Foinaven FPSO was removed from station in 2022 for decommissioning. No line of sight to redevelopment timeline or concept. Foinaven deselected based on redevelopment timeline and concept uncertainty. |
| Cambo | 35 km | Oil-led development with limited gas handling capacity 60mmscfd with only 35mmscfd available for Gas Export. Project has not yet been sanctioned and timeline remains uncertain. Cambo deselected based on project timeline and limited gas export ullage. |
| Rosebank FPSO (Petrojarl Knaar FPSO) | 70 km | Oil-led development with limited gas handling capacity (66 MMscfd total). Project is in execution with the Petrojarl Knaar FPSO being reconditioned for reassignment on Rosebank. Processed gas from Rosebank will be exported to shore via a subsea gas export pipeline (design capacity 120 MMscfd) tying into WOSPS (installed in 2025). Rosebank deselected based on project timeline and limited gas handling capacity. |

### 2.2.2 Comparison of Viable Hosts

The second stage of the host selection process involved a more detailed comparison of the three potentially viable hosts (GLA/SGP, Glen Lyon and Clair). The assessment used data provided by the relevant host facility operator in response to Requests for Service (RfS) letters issued by Ithaca.

Although included in the screening assessment, Clair (operated by BP) was subsequently deselected as a viable host as it is severely restricted on gas capacity and potential for expansion.

As such, only GLA/SGP and Glen Lyon were subject to a detailed screening assessment with consideration to the following factors, which are consistent with the central obligation of the OGA Strategy (OGA, 2020):

- **Value** - *Maximise the expected net value of economically recoverable petroleum from relevant UK waters, not the volume expected to be produced*.
- **Environmental** - *Take appropriate steps to assist the Secretary of State in meeting the Net Zero target, including by reducing as far as reasonable in the circumstances greenhouse gas emissions from sources such as flaring and venting and power generation, and supporting carbon capture and storage projects*.
- **Strategic** - *Commission and construct infrastructure in a way that meets the optimum configuration for maximising the value of economically recoverable petroleum that can be recovered from the region in which the infrastructure is to be located*.
- **Technical** - *Short listed host concepts are required to be technically achievable in terms of design, installation, commissioning, operation, and decommissioning*.

Table 2.2 summarises the outcome of the screening assessment, with a focus on the Technical and Environmental Impact aspects, providing a comparison of GLA/SGP and Glen Lyon as potential hosts. Sections 2.2.3 and 2.2.4 provide further detail on the suitability of both the GLA/SGP and Glen Lyon host options.

**Table 2.2: Host Comparison Summary**

| Key: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Does not meet requirements. Barrier to progress. | | Negative differentiator / Relative disadvantage | | Neutral – not a differentiator / not assessed | | Positive differentiator / Relative advantage | | |

| Potential Host | RFS Response | Technical | | | | | | Environmental Impact | |
|---|---|---|---|---|---|---|---|---|---|
| | | Approx. Distance to Tornado | Gas Ullage | Tie-in Location | Space/weight for new facilities | Longevity | Export Routes | Host Emissions [1] | Seabed Disturbance |
| GLA/SGP | Positive response from TEPUK. Host Concept Select stage study carried out by TEPUK in support of RfS. | ca. 86 km | 200 MMscfd (limited by velocity constraint at outlet of single GLA pipeline). Potential to increase through use of two GLA pipelines. | Suitable subsea tie-in location identified at Tormore manifold. Existing subsea control system and chemical supply can be extended. Design matured to pre-FEED level | Onshore facility. Weight and space constraints generally not an issue | 2046 Design life | Gas: SIRGE<br><br>Condensate: SVT | When calculating incremental SGP emissions for Tornado LoF, the GHG Intensity is estimated to be 13.6 $kgCO_2e/BOE$ [2]. This represents a considerable reduction when compared to the UKCS average of 28 kg $CO_2e/boe$. SGP ERAP lists emissions reduction initiatives that may be enacted by the SGP Operator. | Longer pipeline footprint, but pipeline route optimised to minimise impact on Marine Protected Area (~18 km). |
| Glen Lyon FPSO | Information provided by BP to support assessment | 38 km | Max 40 MMscfd (due to flow induced pulsation limitation on gas export pipeline). Capacity offered on a "reasonable endeavours" basis only and could be < 40 MMscfd. | Spare riser slots available but use may limit BP's ability to develop their own gas resource. BP advise subsea tie-in unlikely to be feasible. | Space and weight constrained – limited capacity for any new equipment (e.g. subsea controls, chemicals). | 2047 CoP | Gas: WOSPS-SVT-SIRGE/EOSPS<br><br>Condensate: Direct to market, tanker export | Incremental Glen Lyon emissions for Tornado LoF are unavailable, but it is noted that Glen Lyon's GHG intensity was reported as 15.8 kg $CO_2e/boe$ in 2023 which is well below the UKCS average of 28 kg $CO_2e/boe$. No line of sight to major decarbonisation initiatives for Glen Lyon. | Seabed footprint reduced due to shorter pipeline length, but increased overlap with sensitive Marine Protected Area (~23 km). |

| Key: | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Does not meet requirements. Barrier to progress. | | Negative differentiator / Relative disadvantage | | Neutral – not a differentiator / not assessed | | Positive differentiator / Relative advantage |

| Potential Host | RFS Response | Technical | | | | | | Environmental Impact | |
|---|---|---|---|---|---|---|---|---|---|
| | | Approx. Distance to Tornado | Gas Ullage | Tie-in Location | Space/weight for new facilities | Longevity | Export Routes | Host Emissions [1] | Seabed Disturbance |
| Clair Phase 1 | BP identified material blockers | 110 km | Ullage severely constrained on gas handling capacity (< 2.5 MMscfd up to 2027) | No provision for subsea tiebacks | Space and weight constrained – limited capacity for any new equipment | 2038 CoP | Gas: WOSPS-SVT-SIRGE/EOSPS | - | - |
| Clair Ridge | | | Ullage severely constrained on gas handling capacity (< 2.5 MMscfd up to 2027) | Provision for subsea tiebacks, native production prioritised over 3rd party | Space and weight constrained. Next phase of Clair development would likely be prioritised over 3rd party. | 2055 CoP | Condensate: SVT Gas to SIRGE Liquids tanker export | - | - |

[1] For both host options, the GHG intensity (kg $CO_2$e/boe) of the facilities are well below the UKCS average of 28 kgCO2e/boe, hence a "neutral" score has been assigned.

[2] The GHG intensity for the GLA/SGP option has been calculated based on data provided by TotalEnergies E&P UK Limited (the SGP operator) at the time the Tornado Concept Select work was undertaken. Note, since then, Ithaca has obtained additional data from TotalEnergies E&P UK Limited to more accurately quantify Tornado's incremental GHG emissions at SGP, which has been used to inform the assessment presented in Section 9.

### 2.2.3 Host Option 1: Greater Laggan Area (GLA) / Shetland Gas Plant (SGP)

Host Option 1 is to develop Tornado as a subsea tie-back (two or three wells) to the GLA Tormore manifold via a ca. 86 km subsea production pipeline. From here, Tornado production would flow via the existing GLA subsea pipeline(s) to SGP for processing and onward transportation.

SGP has both capacity and ullage to accept Tornado production, can support Tornado through its full production life (SGP design life extends to 2046) and has established export routes for gas into the NTS. Unprocessed condensate from SGP would be exported to the neighbouring SVT for stabilisation, with liberated gas exported by SVT to SIRGE for onward entry into NTS and liquids blended for tanker export with existing SVT liquid streams.

With a production constraint of 200 MMscfd, caused by the superficial velocity limit of a single flowline in the Laggan-Tormore pipeline system (in Low Pressure mode), the mid-case gas recovery for this development option is estimated to be 339 billion cubic feet (BCF).

Development of Tornado as a subsea tieback to GLA/SGP is aligned with the optimal philosophy identified in NSTA's WoS Gas Area Plan being 'to utilise existing infrastructure of the GLA subsea facilities and SGP', and extension of the GLA pipeline system to Tornado presents the opportunity to develop stranded gas prospects in the Nueva Basin (Figure 2.2).

GHG emissions will be generated from offshore operations, namely the Tornado drilling, installation, inspection, maintenance and decommissioning activities. The relative magnitude of these GHG emissions is not considered a material differentiator between hosts.

Direct emissions from the treatment of Tornado hydrocarbons at SGP are categorised as Tornado Scope 1 emissions herein, and for the purposes of this assessment (refer to Section 9 for further details). Estimated incremental emissions from SGP treatment of Tornado hydrocarbons, as provided by TotalEnergies E&P UK Limited (the SGP operator) at the time the Tornado Concept Select work was undertaken, are summarised in Table 2.3 below. Note, since then, Ithaca has obtained additional data from TotalEnergies E&P UK Limited to more accurately quantify Tornado's incremental GHG emissions at SGP, which has been used to inform the assessment presented in Section 9.

**Table 2.3: SGP Host Incremental Emissions (Tornado Max Case)**

| Year | Emission Profiles | | | | | |
|---|---|---|---|---|---|---|
| | SGP | | Tornado | | SGP + Tornado | |
| | Base Case Emissions | | Incremental Emissions | | Total Emissions | |
| | ktpa $CO_2e$ | kg $CO_2e$/boe | ktpa $CO_2e$ | kg $CO_2e$/boe | ktpa $CO_2e$ | kg $CO_2e$/boe |
| 2029 | 88 | 22.7 | 71 | 10.6 | 160 | 15.1 |
| 2030 | 0 | 0.0 | 275 | 11.0 | 275 | 10.1 |
| 2031 | 0 | 0.0 | 267 | 13.5 | 267 | 13.5 |
| 2032 | 0 | 0.0 | 232 | 14.7 | 232 | 14.7 |
| 2033 | 0 | 0.0 | 181 | 14.5 | 181 | 14.5 |
| 2034 | 0 | 0.0 | 138 | 14.1 | 138 | 14.1 |
| 2035 | 0 | 0.0 | 120 | 15.8 | 120 | 15.8 |
| 2036 | 0 | 0.0 | 98 | 23.1 | 98 | 23.1 |
| **Total:** | **88 kt $CO_2e$** | **7.6 kg $CO_2e$/boe** | **1,383 kt $CO_2e$** | **13.6 kg $CO_2e$/boe** | **1,472 kt $CO_2e$** | **14.5 kg $CO_2e$/boe** |

SGP is a relatively modern processing facility with low GHG intensity. The 2024 Emissions Reduction Action Plan (ERAP) for SGP details how a 31% reduction in GHG emissions has been achieved at SGP over the period 2018 to 2023 through successful emissions reduction initiatives.

The ERAP lists the following as future potential emissions reduction initiatives:

- **Flare Reduction Projects:**
  - Flare gas composition studies; understand ratio of hydrocarbon and $N_2$; develop real-time burn efficiency monitoring.
  - Localised recovery and compression; target individual sources and recompress rather than build standalone Flare Gas Recovery System.
- **Fuel Gas Reduction Projects:**
  - Single heating medium pump; reduce redundancy for reliable high-power demand equipment.
  - Condensate export batching; export liquids in batches rather than continuously to reduce average power demand.
- **Import Power Projects:**
  - Partial Electrification, upgrade of grid connection from 2MW to 6MW - reduce use of fuel gas by importing all plant electricity from the grid, purchasing green energy.

Responsibility for identification and implementation of Emissions Reduction Initiatives at SGP resides with the SGP operator under the regulation of the Scottish Environmental Protection Agency (SEPA) and NSTA in their respective capacities as regulators of onshore Oil and Gas facilities. Ithaca, as the operator of Tornado, will support the SGP operator as they continue to assess and implement reasonable decarbonisation strategies for SGP.

### 2.2.4 Host Option 2: Glen Lyon

The BP operated Glen Lyon FPSO is located approximately 38 km from the Tornado field in 400 m water depth and processes oil, associated gas and produced water from a large network of subsea wells. Glen Lyon gas is exported via the WOSPS to SVT where it goes through sweetening ($H_2S$ removal) prior to onwards export to the Magnus Platform (located 160 km north east of the Shetland Islands) via the East of Shetland Pipeline System (EOSPS). At Magnus, it is used for Enhanced Oil Recovery with recycled processed gas exported to the Far North Liquid and Associated Gas System (FLAGS) pipeline for onwards export to St Fergus (in Aberdeenshire) for ultimate entry into the NTS. A project is currently underway to enable direct export from SVT to SIRGE for onward entry into NTS via Frigg UK Association (FUKA) pipelines and the St Fergus terminal. The majority of available gas compression capacity on Glen Lyon is used to provide lift gas to the subsea production wells.

BP have advised that gas export is limited to 40 MMscfd, which corresponds to <25% of the peak rate of single flowline operation of the alternate SGP host, due to longstanding mechanical constraints. Furthermore, whilst overall gas handling ullage is forecast by BP to average up to 40 MMscfd, this could be significantly reduced depending on the future gas lift requirements of the well stock.

In practical terms this would limit the development of Tornado via Glen Lyon to a single production well, constrained to 40 MMscfd wellhead production. With a Glen Lyon CoP in 2048, the estimated gas recovery for this development is 257 BCF in the mid-case reservoir outcome, which is significantly lower than the recoverable volumes through GLA/SGP.

Moreover, there is significant downside potential if export ullage is lower than 40 MMscfd. Should ullage be constrained to 75% or 50% of the 40 MMscfd, the recovery reduces to 193 BCF and 129 BCF, respectively. Because the available ullage remains the production bottleneck, there is very limited upside and, even in the high-case reservoir outcome, recovery does not increase above 258 BCF.

Key project risks include access to a suitable production riser and availability of space and weight on the FPSO to extend the subsea control system and supply chemicals, particularly hydrate inhibition chemicals, to the single Tornado well.

From environmental perspective, Glen Lyon offers a shorter pipeline route and therefore reduced seabed footprint compared to GLA (38 km vs ca. 86 km), but increased overlap with the Faroe-Shetland Sponge Belt NCMPA (23 km vs 18 km).

As noted above, GHG emissions will be generated from the Tornado drilling, installation, inspection, maintenance and decommissioning activities. The relative magnitude of these GHG emissions is not considered a material differentiator between hosts.

Developing Tornado via Glen Lyon would also result in direct incremental emissions from the FPSO because of processing the Tornado gas. Emissions from the treatment of Tornado hydrocarbons at Glen Lyon are categorised as Tornado Scope 1 emissions. Whilst BP provided a GHG emissions forecast for Glen Lyon as part of their RfS response, they did not provide an estimate of the incremental emissions associated with Tornado. However, it is noted that Glen Lyon's GHG intensity was reported as 15.8 kg $CO_2$e/boe in 2023 which is well below the UKCS average of 28 kg $CO_2$e/boe. No line of sight to major decarbonisation initiatives for Glen Lyon.

BP (Glen Lyon Operator) have not provided any details on decarbonisation plans for Glen Lyon but are understood to be evaluating emissions reductions options in line with NSTA stewardship expectations.

### 2.2.5 Preferred Host Option

Key differentiators between GLA/SGP and Glen Lyon as potential hosts for the Tornado Development include:

- The available ullage (40 vs 200 MMscfd) and the corresponding recovery (257 vs 339 BCF), clearly positions SGP as the preferred host when considering the central obligations of the OGA strategy to maximise economic recovery.
- Glen Lyon host offers no upside potential given the technical constraints in the export system but carries significant downside risk due to the lack of firm commitment on ullage from the owners – which would result in clearly uneconomic outcomes.
- SGP offers significant upside potential in terms of ullage, being technically able to accommodate high-case and max-case production profiles.
- SGP enables potential development of further stranded WoS prospects and discoveries via the extended GLA pipeline network.
- Glen Lyon carries high execution cost and schedule risk due to topsides weight and space constraints and the scope of offshore brownfield modifications on a floating asset, WoS that has personnel on board (POB) constraints.
- Glen Lyon offers a shorter pipeline route and therefore reduced seabed footprint compared to GLA due to the shorter pipeline length (38 km vs ca. 86 km), but increased overlap with the Faroe-Shetland Sponge Belt NCMPA (23 km vs 18 km).
- No significant difference between the GHG intensity generated from offshore drilling, construction, inspection and maintenance operations, with both GLA/SGP and Glen Lyon options estimated to have a GHG intensity in the order of <1 kg $CO_2$e/boe.
- The GHG intensity (kg $CO_2$e/boe) for both host options are similar and below the UKCS average of 28 kg$CO_2$e/boe.

In summary, development of Tornado as a two- or three-well subsea tie-back to the GLA Tormore manifold via a ca. 86 km subsea production pipeline has capability to deliver significant Tornado reserves to the NTS via the SGP. Extensive study work has demonstrated this to be technically viable, employing proven technologies and installation methodologies. Cost and schedule estimates demonstrate the potential for an economically viable development.

Whilst acceptable terms of service are required from the SGP owners to de-risk the project economics sufficiently to constitute a sanctionable development project, all technical assessments clearly support SGP as the preferred host for Tornado. On this basis, and on the assumption that SGP as a gas processing hub remains available to receive Tornado hydrocarbons and that there is reduced footprint through the NCMPA, SGP is selected as the preferred host for the Tornado Development.

**Host Decision:** Tie-back to GLA/SGP

## 2.3 Well Count and Pipeline Diameter

For the development of Tornado as a subsea tie-back to the GLA system, the key Select Phase subsurface decisions included:

1. Well count;
2. Well placement (impact on drill centre configuration);
3. Tubing size and tree-type; and
4. Diameter of the Tornado to Tormore production pipeline.

These decisions are interrelated and are illustrated in Figure 2.4.

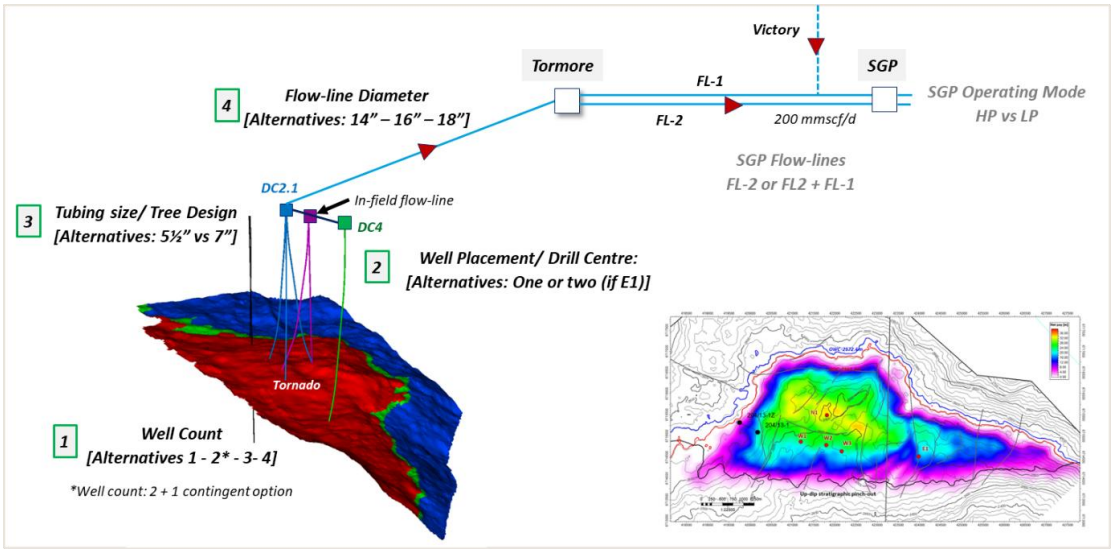



**Figure 2.4: Alternative development schemes evaluated during Concept Select**

Subsurface models were used to generate production profiles for alternative development schemes. Economic metrics for alternative schemes were compared and traded off against secondary criteria, including project risk, cost and schedule.

The preferred development scheme, as assessed in this ES, includes:

- **Well Count** - a two-well development, with an option to drill a third, contingent well (N1).
- **Well Placement / Drill Centre** - W1 + W3, deviated wells in the Western Culmination, drilled from single drill centre (DC2.1).
- **Production Tubing Size / Tree Design** - wells completed with 7" production tubing and horizontal X-mas Tree.
- **Pipeline Diameter** - Tornado to Tormore production pipeline diameter: 16" flowline and MEG pipeline diameter: 4" flowline.

The key elements of decision logic supporting this recommendation include:

- Two-well development has robust recovery across all reservoir outcomes.
- Incremental recovery associated with a three-well development are not sufficiently compelling; however, retaining the ability to execute a third well provides mitigation against well failure / low productivity and allows upside capture (access to 2nd GLA flowline).
- 16" flowline favours accelerated production compared to 14" (providing some mitigation against the risk of SGP integrity), has better operability than an 18" (turndown rate) and offers greater optionality in terms of installation.
- 4" MEG flowline required to meet peak MEG flow rate requirement (18.0 $m^3/h$) based on max case peak production levels of 9,462,562 cubic metres ($m^3$) (334 MMscf) of gas per day.
- 7" tubing enables higher well deliverability, with a horizontal Xmas tree is the preferred subsea tree system for a 7" completion.

## 2.4 Pipeline Route and Installation Selection

### 2.4.1 Pipeline Route Options

The pipeline feasibility study initially considered three route options between Tornado and Tormore, as depicted in Figure 2.5 and discussed in Table 2.4. Note, all pipeline routes are required to pass through the Faroe-Shetland Sponge Belt NCMPA for some length to reach the Tormore tie-in point.

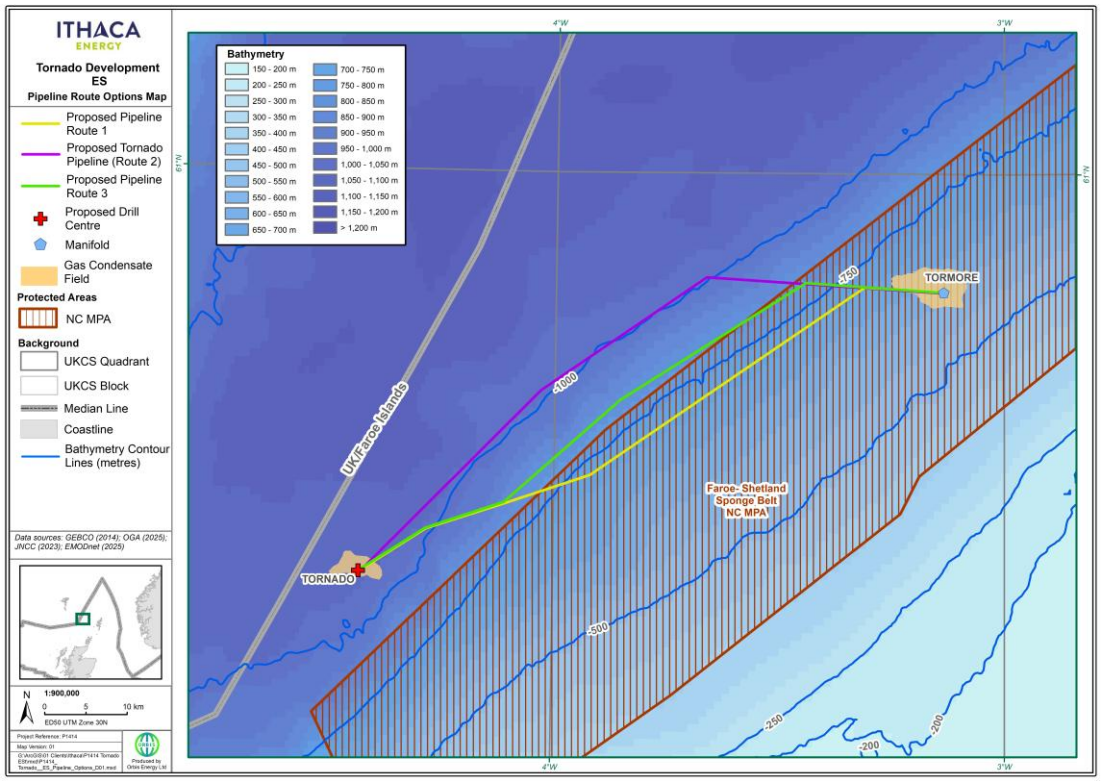



**Figure 2.5: Tornado Field location and pipeline route options to Tormore**

**Table 2.4: Pipeline Route Options**

| Criteria | Route 1: Discounted | Route 2: Recommended | Route 3: Discounted |
|---|---|---|---|
| Total route length: | 79.97 km | 84.29 km [3] | 81.31 km |
| Route length within Faroe-Shetland Sponge Belt NCMPA[1]: | 68 km (85%) | 17.8 km (21.1%) | 17.5 km (21.5%) |
| Route length >800m (legal bottom trawling limit)[2]: | 20 km (20%) | 69 km (82%) | 64 km (78%) |
| Liquid Hold Up – Flow Assurance | Increased risk of liquid loading on the well due to limited (ca. 8 km) length before gradient change in pipeline route. | Reduced risk of liquid loading on the well due to pipeline length before inclined approach to Tormore. | Increased risk of liquid loading on the well due to limited (ca. 8 km) length before gradient change in pipeline route. |

| Criteria | Route 1: Discounted | Route 2: Recommended | Route 3: Discounted |
|---|---|---|---|
| SHEFA-2 crossing depth: | 700 m Water Depth (WD) (within MPA) | 1,000 m WD | 800 m WD (on shelf slope) |
| FARICE-1 crossing depth: | 675 m WD (within MPA) | 675 m WD (within MPA) | 675 m WD (within MPA) |
| Maximum slope along route: | >10° | <5° | Up to 20° |
| Subsea hazards: | Downslope gullies. | Debris Fan – relic seabed feature believed to be stable | Passes through 50 m deep gullies with side slopes of 15° to 20° and Contourites. |

[1] Crossing into the Faroe-Shetland Sponge Belt NCMPA is unavoidable due to the location of the Tormore tie-in point.
[2] Based upon EU Regulation 2016/2336. See bullet point below on commercial fishing.
[3] Following completion of the pipeline feasibility study work, the Route 2 length has been increased to 86 km to allow a worst case assessment in terms of seabed disturbance to be presented in this ES. The final length will be defined during detailed design.

The key differentiators between the pipeline route options can be summarised as follows:

- **Seabed disturbance:** A key environmental consideration in selecting the preferred pipeline route is the extent to which each option passes through the Faroe-Shetland Sponge Belt NCMPA. 85% of Route 1's length is within the NCMPA, whereas the length of Routes 2 and 3 within the NCMPA are broadly similar at ca. 21%. However, Routes 1 and 3 are more likely to necessitate pre-lay rock protection to suitably support the pipelines and prevent unacceptable free spans in the locality of upslope gully crossings. By comparison, Route 2 is designed to optimise route length and minimise seabed disturbance within the NCMPA. Only 17.8 km of Route 2 lies within the MPA and the alignment avoids steep gullies and dynamic features that would otherwise necessitate extensive rock protection.
- **Commercial fishing (trawling):** EU regulation (2016/2336) prohibits on-bottom trawling at depths greater than 800 m. Fishing potential with the Faroe Shetland Sponge Belt NCMPA has been further restricted by The Offshore Fishing (Prohibition of Fishing Methods) (Scotland) Order 2025 which prohibits demersal mobile gear and demersal mobile gear and static gear in zones of the NCMPA, as illustrated in Figure 2.6 and discussed in Section 4.4.1. These restrictions inform the likelihood of interaction and the need for protection of subsea assets. However, for the purposes of this ES, protection to the 800m contour has been assumed, noting this reflects a worst case scenario and does not take account of the Scottish Order that came into effect on the 16th of October 2025. As the pipeline feasibility study was undertaken prior to the Scottish Order 2025 coming into effect, Route 1, with only 20% of its length deeper than 800 m was considered to present the highest risk of interaction with fishing activity. Route 3, with approximately 78 % of its length at or below the 800 m depth threshold, reduced but did not fully eliminate the risk. Route 2 is most favourable in this respect, with 82% of the route lying in waters deeper than 800 m. This greatly reduces the risk of pipeline snagging by fishing gear and may also lower the requirement for post-lay protective rock deposits in trawlable zones. Consequently, Route 2 offers the most robust alignment from the perspective of minimising operational conflicts with fishing vessels, minimising requirements for pipeline protection rock placement and easing consenting related to seabed use.

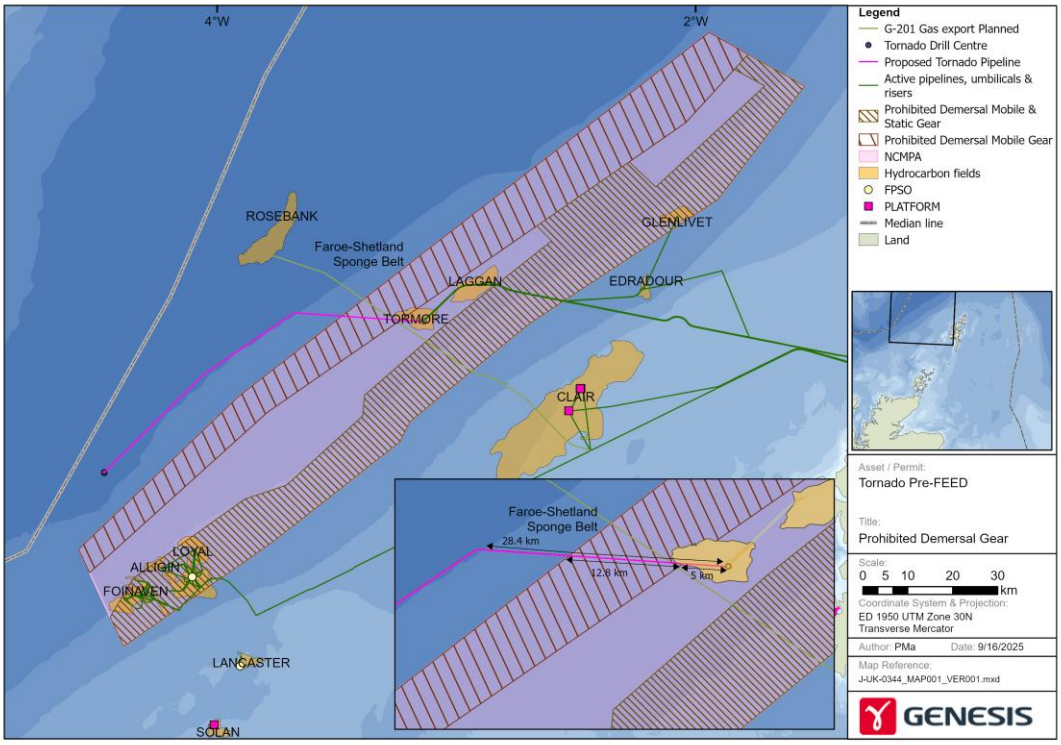



**Figure 2.6: Fishing Restrictions within the Faroe-Shetland Sponge Belt NCMPA**

- **Pipeline and cable crossings:** All three pipeline routes intersect the SHEFA-2 and FARICE-1 communication cables and the Rosebank gas export pipeline. While the crossings themselves are technically manageable, the depth at which they occur influences the required mitigation. Routes 1 and 3 cross SHEFA-2 in shallower water (700–800 m) within the Faroe-Shetland Sponge Belt NCMPA, necessitating both pre- and post-lay rock protection to ensure separation and avoid snagging risks in trawlable waters. Route 2 crosses the same cable at a greater depth (1000 m), where only pre-lay rock protection is required due to the lower likelihood of fishing interaction. All three routes share the same crossing point for FARICE-1 and Rosebank, and these crossings are not considered technically differentiating.

- **Flow assurance:** Considering route bathymetry, it is likely that Route 1 and 3 would lead to increased liquid holdup near the Tornado manifold during a shutdown as there is little flat distance before the incline up the shelf, and during a shutdown all of this liquid will drain towards Tornado. This is likely to increase the liquid head that must be overcome for well restart potentially increasing the turndown rates of the wells. For this reason, Route 2 is more favourable despite being slightly longer overall.

- **Seabed slopes:** The primary differentiating technical risk factor between the three considered options is the slope angles of the deep downslope gullies that are incised into the West Shetland slope extending down from 465 m water depth to the channel floor between 940 m and 995 m (Figure 2.7). Seabed slope and terrain present significant constructability challenges, particularly for Routes 1 and 3. Route 1 crosses downslope gullies with seabed side slopes up to 10°, while Route 3 transits mid-slope gullies with even steeper side slopes between 15° and 20°. These steep gradients increase the risk of unsupported free spans in the pipeline, which could result in stress concentration, structural fatigue, or snagging by trawling gear. To mitigate this, pre-lay rock would likely be required to provide a stable pipeline bed, but this introduces additional cost and technical uncertainty, particularly regarding rock stability in active or mobile seabed areas. Route 2, by contrast, is aligned to avoid steep gullies altogether by running along the base of the slope in the Faroe-Shetland Channel, where gradients are more moderate (2–3°), significantly reducing the risk of free-spanning and the need for complex seabed preparation.

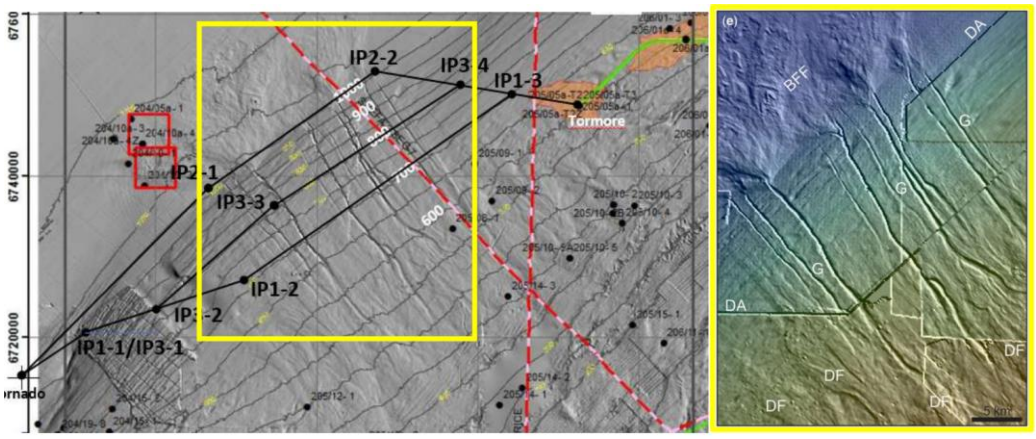



**Figure 2.7: Pipeline Route Options Overlaid on Seabed Bathymetry & Detailed Image of Downslope Gullies Incised into the West Shetland Slope**

- **Seabed features and hazards:** Interaction with seabed features such as debris fans and contourite features is another factor influencing pipeline stability. Route 2 crosses a large debris fan at the base of the continental slope. Although these features are relics from the last glacial maximum and generally considered stable, they may contain unconsolidated materials. However, even in the worst-case scenario, crossing the debris fan is less hazardous than transiting the steep gullies and contourite features encountered by Routes 1 and 3. The contourite features crossed by Routes 1 and 3 are undulating sediment waves with variable amplitude and wavelength that may increase the risk of pipeline freespans due to seabed mobility and scour. As Route 2 avoids the contourites entirely, it again ranks best from a technical risk perspective in terms of seabed features.
- **Installation and laydown considerations:** All routes require pipeline initiation and termination in water depths ranging from 1,060 m (Tornado) to 600 m (Tormore). While these depths present challenges for initiation and laydown, they are within the capabilities of modern deepwater pipelay vessels. The routes are designed with conservative bend radii to ease installation. However, Route 2 is the most installation-friendly, as it avoids the steeper slopes and complex topography of the other two routes, reducing the risk of pipeline misalignment or excess tension during lay.

In conclusion, Route 2 has been selected as the preferred option on the basis that it minimises the length of the pipeline within the Faroe-Shetland Sponge Belt NCMPA. It also minimises the potential for fishing interaction and avoids steep seabed conditions and features anticipated on Route 1. Option 3 was discounted due to the presence of deep gullies. Route 2 also minimises liquid hold-up risks providing the best flow assurance concept.

**Pipeline Route Decision:** Route 2 with smallest footprint in the NCMPA

### 2.4.2 Pipeline Installation Methods

The production pipeline will be surface laid and will remain exposed on the seabed as it will be designed to resist fishing interaction loads, although some rock cover may be required to correct freespans or for protective measures in required areas such as crossings.

The requirement for protective measures for the MEG pipeline and control umbilical will depend on the findings of ongoing studies assessing the intensity of fishing activity and the potential for damage. Installation methods for these components are still under consideration as part of the detailed engineering phase. Options under review include trenching and backfill, installation of rock protection before and/or after laying, and seabed preparation such as boulder removal. For the purposes of this ES, it is assumed that both the MEG pipeline and control umbilical will be protected in water depths <800 m (refer to Section 3.4 for further details).

Subject to selection of the installation contractor and pipelay vessel, there is an option to install the MEG pipeline piggybacked to the production pipeline. This installation method would optimise the

width of the installation corridor, and reduce the overall number of vessel days to install both lines. Piggybacking the MEG pipeline to the production pipeline would necessitate protection of both lines by a single rock berm in water depths less than 800m. This is driven by the snagging risk of the piggybacked line and inability to design the MEG line to be inherently resistant to fishing interaction. A single rock berm protecting the piggybacked lines would be larger in volume and footprint than the equivalent single berm protecting either pipeline. A piggyback system would also necessitate combining the MEG and Production FLETs into a single structure. Pipeline installation via a piggyback system will be investigated during the detailed engineering phase.

## 2.5 Tormore Tie-in Arrangement

The tie-in arrangement at Tormore has been assessed and potential optimisations have been identified that may reduce the complexity and impact of the subsea construction works. Adoption of the optimised tie-in arrangement is contingent upon acceptance by the SGP Operator and detailed technical proposals from the installation contractors. The base case and alternate tie-in arrangements are show in Figure 2.8 and Figure 2.9 for information. For the purposes of this ES, the base case proposal has been assessed as this represents the worst case scenario in terms of seabed impacts.

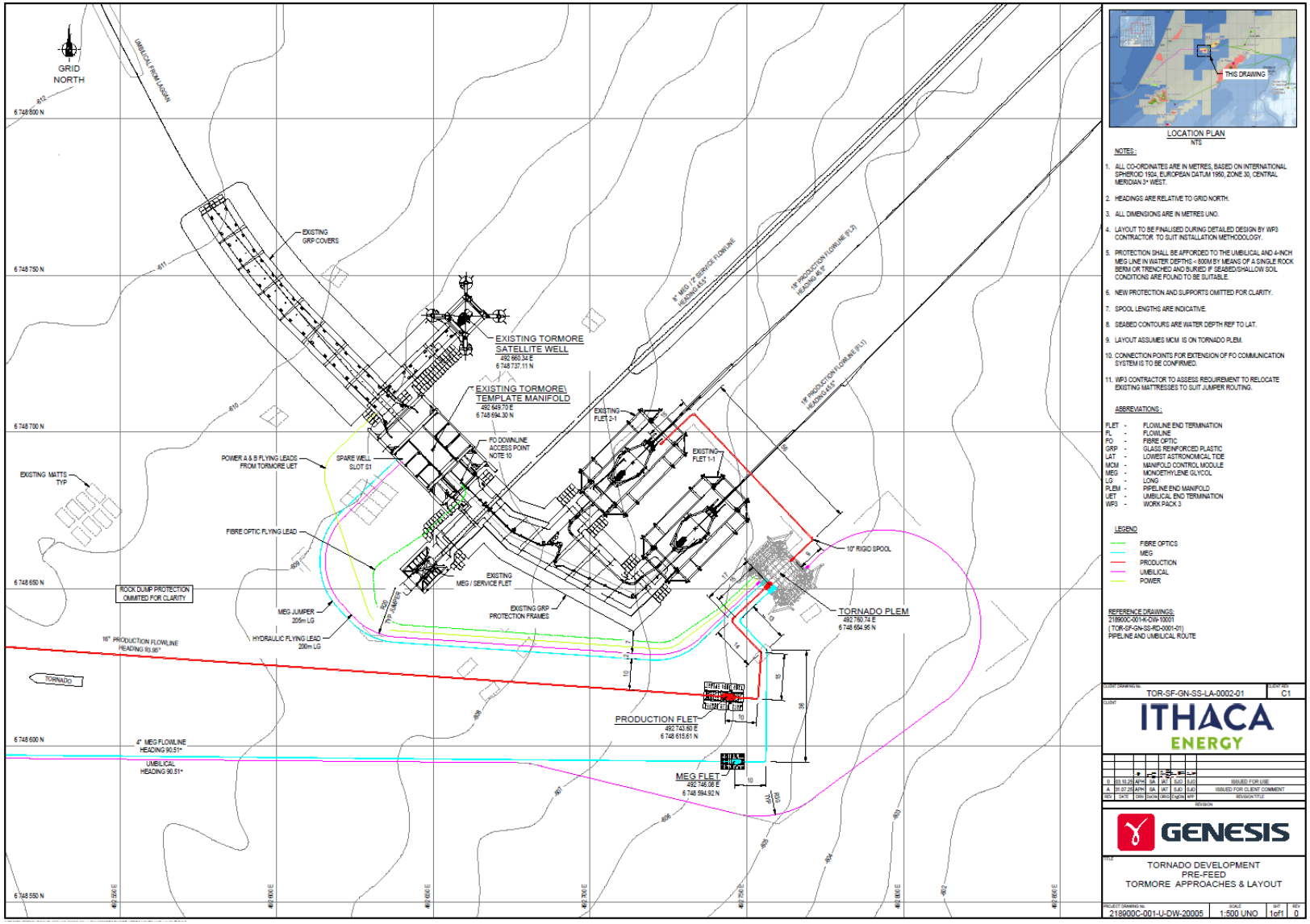



**Figure 2.8: Tormore Tie-in Arrangement Option - Optimised Tormore arrangement**

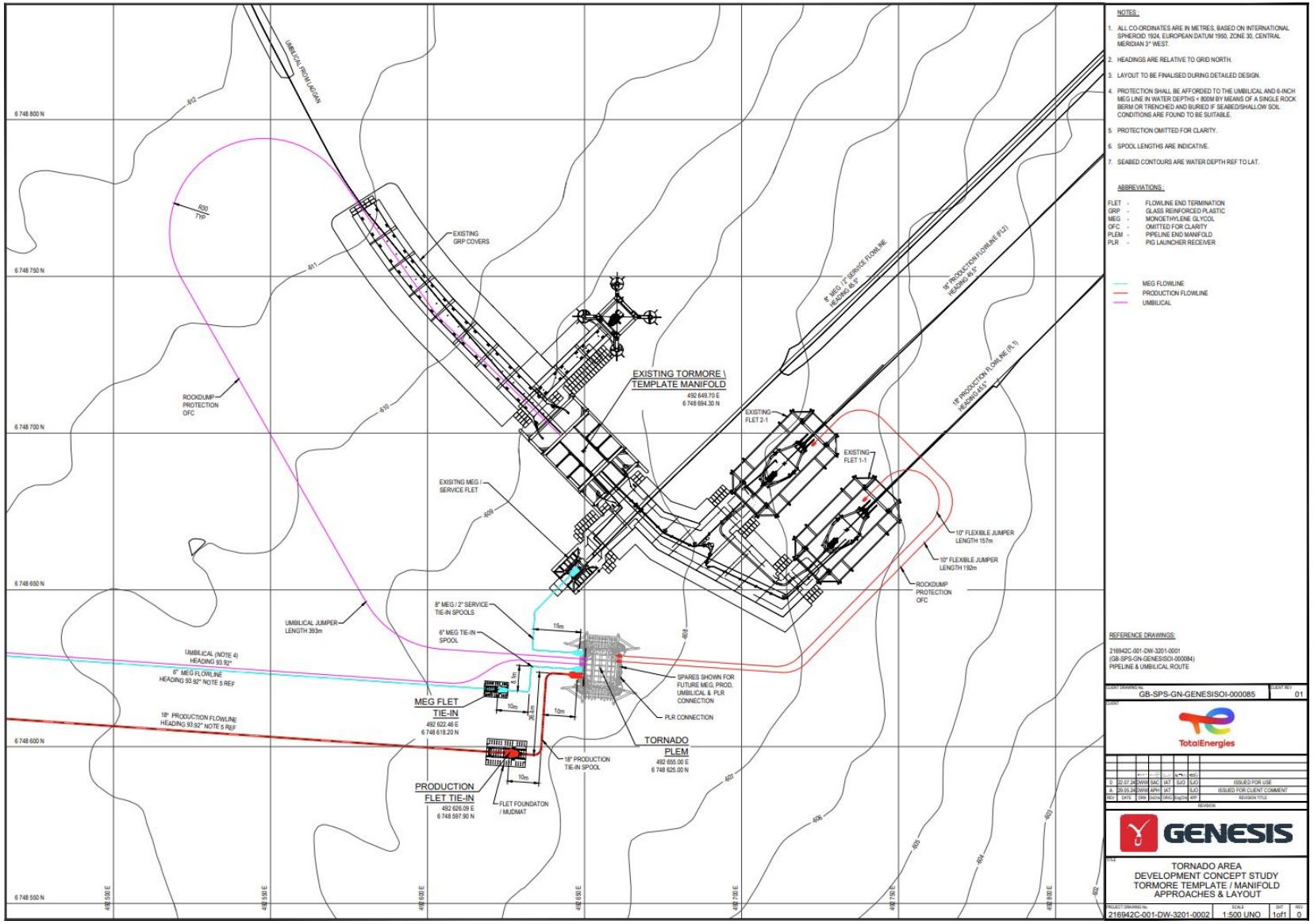



**Figure 2.9: Tormore Tie-in Arrangement Option - Base case Tormore arrangement**

## 2.6 Drilling Operations

### 2.6.1 Mobile Offshore Drilling (MODU) Type

A MODU is required to drill the Tornado wells. Given the deepwater harsh environment at Tornado, the wells will be drilled and completed from a DP harsh environment semi-submersible MODU. Furthermore, a DP MODU (as opposed to wire/chain moored) can be repositioned more readily in the field under harsh weather conditions and reduces the potential environmental impacts from anchor positioning. Operational efficiency in subsea completions and subsea tree installations will be considered when reviewing the type of MODU to be used. In addition, Ithaca will consider the MODU's cumulative GHG emissions during the rig tendering process, with a focus on fuel consumption and overall operability.

### 2.6.2 Well Design

The indicative profiles for the Tornado wells are detailed in Section 3.3.4 of the Tornado Project Description. The top-hole conductor section of the wells will either be drilled conventionally with a 36" x 30" diameter conductor pipe cemented in place, or a suction piled CAN-ductor with an integrated wellhead housing and conductor extension joint.

Due to the soft upper seabed sediments in the Tornado area, Ithaca's preference is to use 'Conductor Anchor Nodes' (CAN-ductors) on the wells. This increases top hole wellbore stability and reduces the overall drilling time along with reducing the carbon footprint of well construction activities. The pre-drilling activity associated with the CAN-ductor installation is detailed in Section 3.3.3 of the Tornado Project Description.

However, to allow for design flexibility, the ES has assessed both the use of CAN-ductors and conventional conductor cementing options for Tornado.

### 2.6.3 Drill Fluids and Cuttings Disposal

If the Tornado wells are drilled conventionally (i.e. without CAN-ductor), the top two-hole sections (36" and 26") will be drilled riserless with seawater and frequent bentonite "sweeps" passed down the wells to clean out the hole. Cuttings from these top-hole sections will be discharged directly from the wellbore at the seabed.

For the deeper 17½", 12¼" and 8½" (underreamed up to 12¼") sections, a marine riser will be situated between the well and the drilling deck so that cuttings and drilling fluid are circulated back up to the MODU. For the deeper well sections there are two options for drill fluid and cuttings disposal:

- Option 1: Water Based Mud (WBM) with cuttings disposal to sea;
- Option 2: Low Toxicity Oil Based Mud (LTOBM) with offshore clean-up / disposal to sea.

In the event LTOBM is used to drill the deeper well sections, due to the remote location of Tornado and harsh environment, it is anticipated that a thermal cuttings treatment unit will be installed on the MODU to process the drill cuttings to minimise the need for drilling waste to be shipped to shore for treatment and disposal.

However, for the purposes of this ES, as a worst case scenario, conventional drilling with WBM has been assumed, with all drill cuttings and associated WBM from the Tornado wells discharged to sea. To inform this decision, preliminary drill cuttings and muds dispersion modelling was run for the following two concepts:

- Concept 1: conventional drilling with WBM, with all drill cuttings and associated WBM from the Tornado wells discharged to sea.
- Concept 2: conventional drilling with LTOBM, with LTOBM contaminated cuttings processed via a thermal cuttings treatment unit to an acceptable limit (<1% oil on cuttings) for discharge at the sea surface.

Both concepts were evaluated using the MUDMAP 3D sediment dispersion plume model with a 10-year oceanographic dataset (2010-2019). Discharges were modelled for all three well locations; W1, W3 and N1, with a total of 150 trajectory simulations (50 per well) conducted to represent seasonal variability and support a robust cumulative impact assessment.

The aim of the modelling was to quantify the distribution and sediment thicknesses on the seabed and the total suspended solids (TSS) concentrations in the water column resulting from proposed drilling concepts to determine the concept which resulted in the greatest impact to the marine environment.

The dispersion modelling applied standard environmental thresholds to evaluate potential effects on the seabed and in the water column (Table 2.5). These were used to define zones of undetectable, low, and high potential ecological exposure for both sediment deposition and water column turbidity.

**Table 2.5: Drill Cuttings and Muds Dispersion Modelling - Environmental Thresholds**

| Reporting Criteria | Total Sediment Thickness on Seabed (millimetres (mm)) | Total Suspended Solids Concentration (mg/l) |
|---|---|---|
| Minimum Reporting Threshold | 0.1 | 5 |
| Low Exposure | 1 – 10 | 10 – 1,830 |
| High Exposure | >10 | > 1,830 |

The modelling results indicated that for both concepts the near-bottom riserless discharges from the release locations were responsible for the greatest thicknesses of deposited cuttings on the seafloor. A maximum (conservative) bottom deposition thicknesses of >2 m was predicted to occur within 20 m of the release locations for both concepts. The total combined seabed footprint for the high exposure threshold was also the same for both concepts at 0.06 km² and both concepts showed peak TSS concentrations at 313.7 mg/l occurring in the immediate vicinity of the release locations (within 50 m).

The WBM scenario resulted in a larger seabed footprint exceeding biological thresholds at low exposure (1 mm); 1.9 km² for the WBM scenario versus 1.4 km² for the LTOBM scenario. The LTOBM scenario resulted in a larger plume area in the water column where the TSS concentration exceeded biological thresholds at low exposure (10 mg/l); 2.5 km² for the LTOBM scenario versus 1.4 km² for the WBM scenario.

However, TSS effects are short-lived, with dispersion reducing concentrations rapidly away from the discharge source, whereas the deposition of cuttings on the seabed results in long term smothering impacts to benthic communities, particularly in deep water habitats like Tornado (at ca. 1,060 m), where recovery is slow.

Greater weighting has therefore been placed on the impact resulting from the deposition of cuttings on the seabed and, as such, the modelling results from the WBM concept have been used to inform the Tornado EIA.

Further detail of the modelling undertaken for the WBM concept is provided in Section 7 (Seabed Disturbance) and Section 10 (Marine Discharges), with the full modelling report provided for reference in Appendix C.

# 3 Tornado Project Description

## 3.1 Tornado Reservoir and Development Overview

Tornado is a gas condensate discovery that straddles UKCS Blocks 204/13 and 204/14d in the Judd Basin, WoS. It was discovered by the OMV operated well 204/13-1 in 2009, and appraised by side-track well, 204/13-1Z. Both wells encountered a gas column with a thin, underlying oil rim. Based on recent subsurface mapping, Tornado is estimated to contain a low to high range of 342 to 640 bcf GIIP (gas initially in place). The mapped crest of the field is at 2,480 m True Vertical Depth Sub Sea (TVDSS), which would support a gas column of 83 m, and is underlain by an oil rim of 9 m. The reservoir is normally pressured. The gas is a relatively lean gas condensate with an initial condensate gas ratio (CGR) of ca. 20 barrels per million standard cubic feet (bbl/MMscf). The oil rim has a gravity of 32° API, but is not planned for development.

Ithaca plan to develop Tornado via up to three deviated subsea wells, drilled from a single drill centre. The wells will be tied-back to the Tormore facilities of the TotalEnergies E&P UK Limited operated GLA subsea development.

The GLA comprises four fields (Laggan, Tormore, Edradour, and Glenlivet) which are tied back to the onshore SGP via two 18-inch Nominal Bore (NB) pipelines (see Figure 3.1). An 8-inch NB MEG pipeline with 2-inch NB service line piggyback, and main umbilical run in parallel to the 18-inch NB pipelines from the SGP, terminating at the Tormore manifold. Production from the GLA fields is commingled and processed with gas treated and compressed for export into the Shetland Island Regional Gas Export (SIRGE) pipeline for onwards transmission to St Fergus and the National Transmission network. Small volumes of unstabilised condensate are piped to the neighbouring SVT, for further processing with liberated gas exported from SVT to SIRGE and stabilised liquid hydrocarbons piped to storage tanks for export via tanker with other SVT liquid streams.

Tornado production fluids are proposed to be exported via a new 16-inch NB ca. 86 km export pipeline to the existing Tormore (FL2-1) FLET structure for entry into the L-T pipeline system for onwards transmission to the SGP for processing. The electro-hydraulic controls for Tornado will be provided by extending the existing L-T system from the Tormore manifold to Tornado by means of a dedicated ca. 86 km control umbilical. A dedicated 4-inch NB MEG pipeline will be extended from the Tormore MEG FLET to Tornado to provide continuous MEG injection for hydrate inhibition, with the injected MEG dosed with corrosion inhibitor at SGP to protect the carbon steel production pipeline system. The proposed Tornado Development is expected to produce hydrocarbons for ca. 6 to 10 years depending on the reserves, the production rate and the life of the GLA infrastructure.

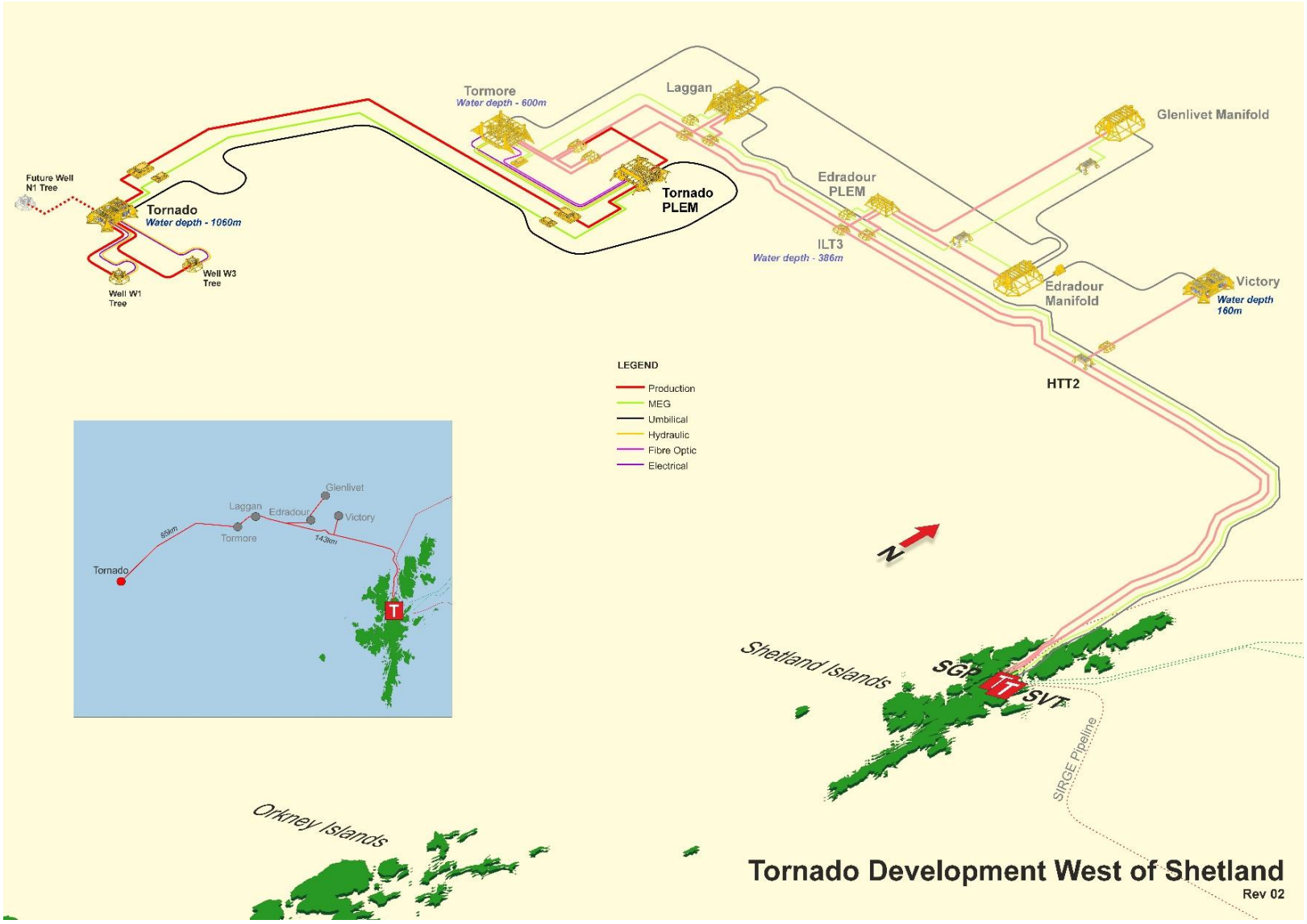



**Figure 3.1: Tornado Development Schematic**

## 3.2 Project Schedule

Figure 3.2 provides an indicative overview of the proposed timeline for the drilling and installation phase of the proposed Tornado Development. First gas is targeted for start Q4 2029.

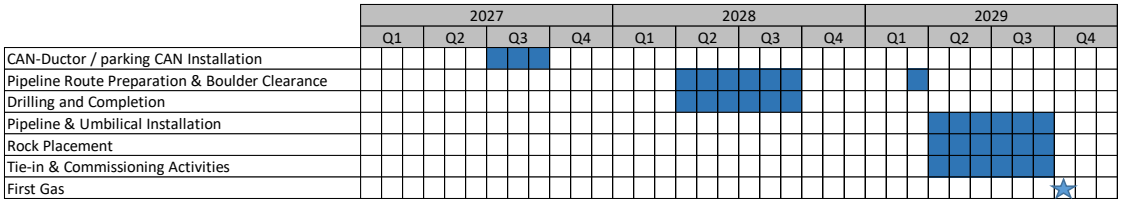



**Figure 3.2: Indicative Timeline for Proposed Tornado Development**

The Tornado Development Project is currently in the Define phase of the project life cycle. The following sections provide a detailed description of the current base-case design for the project. Some design parameters will be further refined during the detailed design phase and may therefore be subject to change. However, the design parameters presented are deemed realistic, yet conservative (i.e. worst-case) with regards to the potential environmental impacts, based on the current project scope and definition.

## 3.3 Drilling Operations

### 3.3.1 Overview

Ithaca proposes to drill up to three subsea production wells in the Tornado field. The two firm wells (W1 and W3) are located high on the structure in the western part of the accumulation. A contingent third well (N1) may be drilled based on several pre- and post-first gas factors including the ability to access the second 18 inch NB GLA flowline and/or well performance and reservoir behaviour. The scope of the EIA and resultant ES is based on the drilling and completion of three production wells, reflecting a worst case scenario.

The wells will be drilled from a single drill centre located at 60° 33’ 43.752”N, 04° 25’ 45.193”W (ED50 UTM Zone 30N). Table 3.1 provides the proposed top hole coordinates for all three wells, with the layout of the wells illustrated in Figure 3.3.

The wells will be completed solely within the gas column; there is no plan to develop the oil rim. As the reservoir interval is relatively thin, the wells are designed to have in the order of 60° inclination through the reservoir. Sand face completion is planned to be an open hole gravel pack.

**Table 3.1: Tornado Well Coordinates (top hole locations) [1]**

| Well Number | Latitude | Longitude | Easting | Northing |
|---|---|---|---|---|
| 204/13b-W1 (W1) | 60° 33’ 42.920”N | 04° 25’ 47.257”W | 421,606.00 | 6,715,004.00 |
| 204/13b-W3 (W3) | 60° 33’ 43.328”N | 04° 25’ 45.371”W | 421,635.00 | 6,715,016.00 |
| 204/13b-N1 (N1) | 60° 33’ 46.104”N | 04° 25’ 48.777”W | 421,585.00 | 6,715,103.00 |

[1] ED50, UTM Zone 30N Central Meridian 3º West

Due to the soft upper seabed sediments in the Tornado area, Ithaca plans to use CAN-ductors as the wells foundation. This increases top hole wellbore stability and reduces the overall drilling time along with reducing the carbon footprint of well construction activities. To optimise well operations, Ithaca

also proposes to install two parking-CANS for subsea storage of the horizontal Xmas trees (refer to Section 3.3.3).

However, in case of any currently unforeseen circumstances that may prevent the use of CAN-ductors, conventional top hole sections will be drilled by the MODU, with the Xmas trees installed directly from the MODU or a vessel, on wire. For the purposes of this ES, the assessment of drill cuttings discharges and atmospheric emissions resulting from fuel consumption has been based on the worst case scenario of drilling all wells with conventional top hole sections.

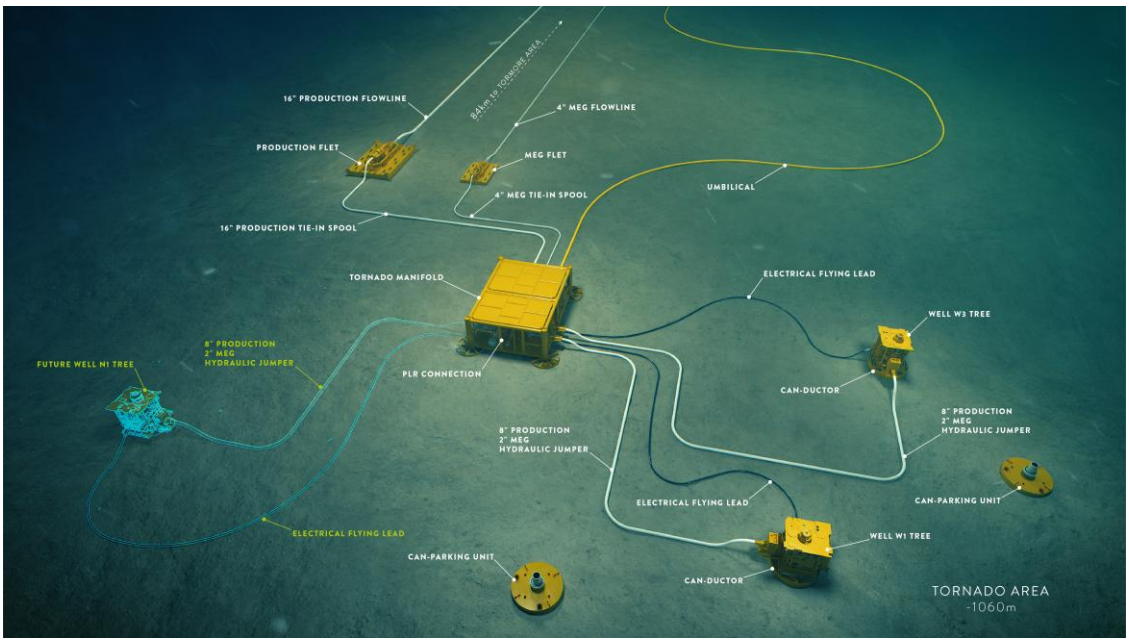



**Figure 3.3: Tornado Drill Centre Layout**

### 3.3.2 Drilling Unit, Logistics and Support

A drilling rig has yet to be contracted for the project, but given the deepwater harsh environment at Tornado, it is expected that the development wells will be drilled and completed from a DP harsh environment semi-submersible MODU.

As the MODU will be retained on station by DP, no anchoring will be required, thereby minimising the disturbance to the seabed. The DP technology uses satellite navigation and acoustic transponders on the seabed to keep the MODU in place. The acoustic transponders are deployed in an array using clump weights. The transponders emit a signal which is received by the MODU, which in turn calculates position and adjusts its thrusters as required to maintain position. The transponders will be deployed for the duration of the drilling campaign and will be recovered by Remotely Operated Vehicle (ROV) once the drilling campaign is finished.

A 500 m radius safety zone will be in place around the MODU for the duration of the drilling operations, anticipated to last up to 80 days per well. An ERRV will be stationed in the vicinity of the MODU to assist in the event of an emergency and enforce the 500 m safety exclusion zone.

The MODU will also be supported by two supply vessels, used to transport drilling equipment, supplies, water, fuel and food to the well location from a supply base in North East of Scotland and return waste and surplus equipment to shore.

Personnel will be transferred to the MODU either via fixed wing aircraft or helicopter from Aberdeen. Typically, around seven scheduled flights will be made to the MODU per week throughout the proposed drilling operations.

As noted in Section 3.3.1, Ithaca plans to use CAN-ductors on the Tornado wells, with two parking-CANS for subsea storage of the horizontal Xmas trees. Parking- CANS shall facilitate the ability to wet store the subsea Xmas tree's (deployed on wire by CSV), on the seabed prior to MODU arrival. This provides

an optimised and efficient solution for installing the Xmas trees on the wells during construction operations.

A summary of the vessel and helicopter requirements for the proposed Tornado drilling operations, along with typical fuel consumption rates are provided in Table 3.2.

**Table 3.2: Vessel and Helicopter Requirements for Tornado Drilling Campaign**

| Vessel | Function | Total No. of Vessel Days [1, 2] | Fuel Type | Fuel Consumption Rate | Total Fuel Consumption (tonnes) |
|---|---|---|---|---|---|
| **Drilling using CAN-ductors (base case)** | | | | | |
| MODU | Drill and complete wells (excluding top hole sections) | 240 | Diesel | 45 tonnes per day | 10,800 |
| ERRV | Assist in the event of an emergency | 246 | Diesel | 1.5 tonnes per day | 369 |
| Supply vessels | Logistic support and transportation of goods, tools, equipment | 490 | Diesel | 8 tonnes per day | 3,920 |
| CSV | Installation of CAN-ductors / parking-CANs / wet storage of Xmas tree | 14 | Diesel | 25 tonnes per day | 350 |
| | | | | **Total Diesel Consumption:** | **15,439** |
| Helicopter | Transfer crew to and from MODU | 7 return flights per week | Aviation fuel | 1.96 tonnes per return flight | 470.4 |
| **Conventional Drilling (without CAN-ductors / parking-CANs) (worst case)** | | | | | |
| MODU | Drill and complete wells | 255 | Diesel | 45 tonnes per day | 11,475 |
| ERRV | Assist in the event of an emergency | 261 | Diesel | 1.5 tonnes per day | 391.5 |
| Supply vessels | Logistic support and transportation of goods, tools, equipment | 505 | Diesel | 8 tonnes per day | 4,040 |
| | | | | **Total Diesel Consumption:** | **15,906.5** |
| Helicopter | Transfer crew to and from MODU | 7 return flights per week | Aviation fuel | 1.96 tonnes per return flight | 499.8 |

[1] Includes an allowance for vessel mobilisation, transit and demobilisation, where relevant.
[2] The total number of vessel days are considered conservative based on the drilling of up to three wells, but do not account for a re-spud scenario or contingency sidetracks as these are unplanned events.

### 3.3.3 Pre-drilling Activity

Prior to the MODU arriving on location at Tornado, Ithaca plans to install up to five CAN-ductor units into the seabed; one CAN-ductor (a well construction technology designed to replace a conventional top-hole section and associated conductor) at each well location and two parking-CANS (see description below).

CAN-ductors are proposed for Tornado to provide conductor stability during the proposed drilling operations. Historically, the nearby Handcross well (204/18b-2A), located ca. 8 km southeast of Tornado, installed a conventional conductor which slumped resulting in a re-spud, delays to the drilling programme and increased emissions and discharges. Pre-installing CAN-ductors will allow the foundation of the Tornado wells to be established ahead of the MODU arrival, shortening the overall

time the MODU will be on location by removing the 36" hole drilling, conductor running and cementing operations, and reducing the volume of cuttings / fluids discharged to the seabed.

The CAN-ductor is a specially designed cylindrical suction anchor containing an integrated continuous conductor pipe (Figure 3.4). The outer structure is approximately 16.5 m long, with a 6 m diameter and an exposed surface area of 28.3 $m^2$ after installation.

The CAN-ductors will be accurately positioned on the seabed via a crane from a CSV and allowed to partly self-penetrate the seabed under its own weight. A pump, based on a ROV is then connected to the CAN-ductor via a hot-stab. The ROV pumps water out of the can, creating negative pressure within it, allowing the pressure differential on the can to drive the remaining extent of the CAN-ductor into the seabed. Once the top of the CAN-ductor is at target penetration depth, typically no more than 1 m above the seabed, with the integrated conductor pipe projecting roughly 2 m above the sediment surface, valves on the CAN-ductor are closed stopping embedment and installation equipment is recovered to the CSV. CAN-ductor units are fitted with recording devices that accurately measure inclination, elevation and orientation during the installation operation.

To optimise well operations there is also the potential to install two parking-CANS for subsea storage of the horizontal Xmas trees (Figure 3.4). These would be located within 200 m of the proposed development wells and would likely stay in place for the duration of the well life to be removed when the field infrastructure is decommissioned. The parking-CANs are shorter than the CAN-ductors, at 12 m long, due to the reduced load requirement but have the same diameter (6 m) and exposed footprint on the seabed (28.3 $m^2$).

Table 3.3 presents an overview of the physical footprint of the well infrastructure on the seabed, based on using CAN-ductors for all wells. This results in the largest potential footprint compared with a typical wellhead, which has a footprint of around 0.7 $m^2$ each.

**Table 3.3: Seabed Footprint of CAN Infrastructure**

| Infrastructure | Well Number | Dimension (m) [1] | Footprint on Seabed ($m^2$) [2] |
|---|---|---|---|
| Wellhead / CAN-ductor | W1 | 6 (W) x 1 (H) | 28.3 |
| Wellhead / CAN-ductor | W3 | 6 (W) x 1 (H) | 28.3 |
| Wellhead / CAN-ductor | N1 | 6 (W) x 1 (H) | 28.3 |
| CAN-parking unit | - | 6 (W) x 1 (H) | 28.3 |
| CAN-parking unit | - | 6 (W) x 1 (H) | 28.3 |
| | | **Total:** | **141.5** |

[1] Width (W) is the diameter of the CAN units, Height (H) is the height of the CAN unit above the seabed
[3] Footprint on seabed are for the CAN units only. Refer to Section 7 of this ES for details of the seabed disturbance from the proposed drilling operations.

i) CAN-ductor unit



ii) Xmas tree on CAN-parking unit



**Figure 3.4: CAN Units**

*(Image courtesy of Neodrill. © Neodrill All Rights Reserved)*

### 3.3.4 Well Design

Indicative profiles for the Tornado wells are detailed in Table 3.4 (on the worst case assumption that conventional top hole sections are drilled) and illustrated in the well schematic provided in Figure 3.5.

If the wells are drilled conventionally (i.e. without CAN-ductor), a 42" × 36" diameter top-hole section will be drilled into the seabed, into which the 36" × 30" diameter conductor pipe is cemented. The second (26") section will then be drilled through the conductor and a 20" surface casing installed and cemented into place.

The casings of the two top-hole sections, firmly cemented into the borehole, will then provide a firm foundation for the BOP, which will be installed on the drilling riser at the seabed. The drilling riser connects the well to the MODU, therefore providing a conduit to return the mud and cuttings from the deeper sections of the well back up to the MODU. The deeper 17½", 12¼" and 8½" sections of the wells will then be drilled with the drilling fluids circulated back to the MODU. Note, the 8½" reservoir sand section will be underreamed up to 12¼" (i.e. enlarged past its original drill size), as illustrated in Figure 3.6.

**Table 3.4: Indicative Well Profiles**

| Hole Diameter (inches) | Casing Diameter (inches) | Casing Type | Section Length (ft) | Section Length (m) |
|---|---|---|---|---|
| **W1** | | | | |
| 42 x 36 | 30 | Conductor | 394 | 120 |
| 26 | 20 | Surface casing | 2,011 | 613 |
| 17½ | 13⅝ | Intermediate casing | 1,969 | 600 |
| 12¼ | 9⅝ | Production liner | 1,289 | 393 |
| 8½ (underreamed to 12¼") | - | - | 394 | 120 |
| | | **Total** | **6,057** | **1,846** |
| **W3** | | | | |
| 42 x 36 | 30 | Conductor | 394 | 120 |
| 26 | 20 | Surface casing | 2,011 | 613 |
| 17½ | 13⅝ | Intermediate casing | 1,969 | 600 |
| 12¼ | 9⅝ | Production liner | 1,289 | 393 |
| 8½ (underreamed to 12¼") | - | - | 830 | 253 |
| | | **Total** | **6,493** | **1,979** |
| **N1 (contingent well)** | | | | |
| 42 x 36 | 30 | Conductor | 394 | 120 |
| 26 | 20 | Surface casing | 2,011 | 613 |
| 17½ | 13⅝ | Intermediate casing | 1,969 | 600 |
| 12¼ | 9⅝ | Production liner | 1,289 | 393 |
| 8½ (underreamed to 12¼") | - | - | 459 | 140 |
| | | **Total** | **6,122** | **1,866** |

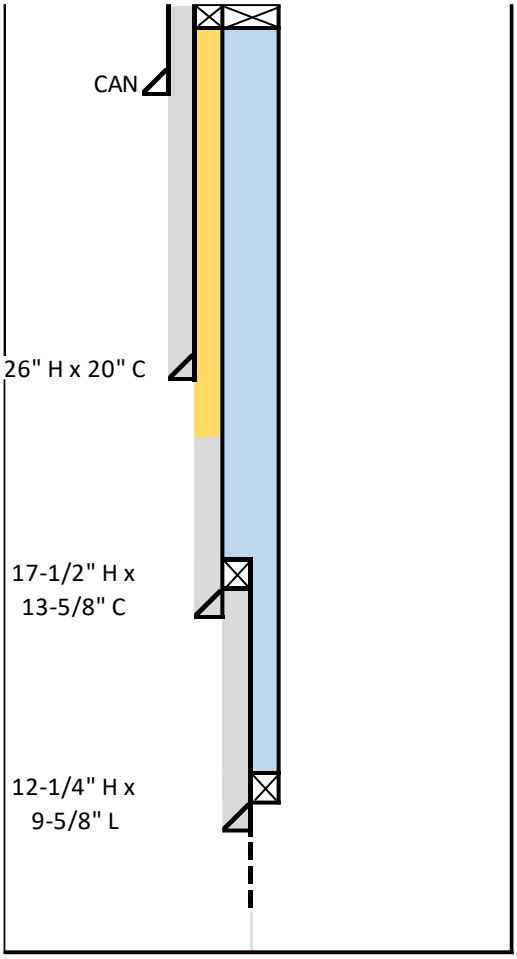



**Figure 3.5: Tornado Well Schematic (using CAN-ductors)**




**Figure 3.6: Schematic of 8½" hole section underreamed up to 12¼"**

### 3.3.5 Mud System, Cuttings Disposal and Chemical Use

During the proposed 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 rig and lubricants for certain equipment and machinery. The BOP and Xmas tree will also require chemicals for control and operation in the form of hydraulic and water based control fluids.

The use and discharge of the chemicals in offshore waters is regulated through The Offshore Chemicals Regulations (2002) (as amended). Prior to drilling the Tornado wells, Ithaca will therefore seek consent from OPRED for the use and discharge of chemicals during the proposed drilling operations. A Drilling

Operations Master Application Template (MAT) and associated Chemical Permit Subsidiary Application Template (SAT) will be submitted via the Portal Environmental Tracking System (PETS) on the UK Energy Portal. All chemicals proposed to be used will be selected based on their technical specifications and environmental performance. Chemicals with Substitution (SUB) warnings will be avoided where technically possible.

### Drilling Mud and Cuttings

Drilling mud serves a number of functions including maintaining hydrostatic pressure within the wellbore, circulating rock fragments (termed 'cuttings') back to the drilling rig, preservation of the wellbore to facilitate casing / completion installation and cooling and lubrication of the drill bit.

If the Tornado wells are drilled conventionally (i.e. without CAN-ductor), the top two hole sections (42" x 36" and 26") will be drilled riserless with seawater and frequent bentonite "sweeps" passed down the wells to clean out the hole. Cuttings from these top-hole sections will be discharged directly from the wellbore at the seabed.

For the deeper 17½, 12¼" and 8½" (underreamed to 12¼") sections, a marine riser will be situated between the well and the drilling deck so that cuttings and drilling fluid are circulated back up to the MODU. These sections may be drilled with WBM or LTOBM, to be determined during detailed design.

For the purposes of this ES, as a worst case scenario, conventional drilling with WBM has been assumed, with all drill cuttings and associated WBM from the Tornado wells discharged to sea (refer to justification in Section 2.5.3). The mud and cuttings returned to the MODU from the deeper well sections will therefore pass through shale shakers, a device used to separate the cuttings from the drilling fluid by running it through a vibrating wire-cloth screen. The liquid phase of the mud passes through the screen, while the larger solids (i.e. the cuttings) are retained. The separated cuttings are then passed through a cleaning system and discharged to sea from the drilling rig just below the sea surface. The recovered WBM will be recycled downhole by the mud pump in a closed loop system, ensuring that the mud is continuously recycled during the drilling programme.

In the event LTOBM is used to drill the deeper well sections, due to the remote location of Tornado and harsh environment, a thermal cuttings treatment unit will be installed on the MODU to process the drill cuttings minimising the need for drilling waste to be shipped to shore for treatment and disposal. The purpose of the thermal cuttings treatment unit will be to safely treat the LTOBM contaminated cuttings to an acceptable overboard disposal limit (<1% oil on cuttings (OOC). The remaining water and oil vapour will be then condensed into the relevant streams and collected separately. Recovered oil will be pumped back into the mud system and water will be disposed overboard if the oil in water content is < 30 mg/l.

Table 3.5 provides an estimate of the quantity of cuttings generated and WBM discharged for the Tornado wells (on the assumption that conventional top hole sections are drilled). To account for any unforeseen mechanical or geological issues, a re-spud scenario and contingency 26", 12¼", 17½", and 8½" sidetracks have been added to the longest well profile (W3) to represent a worst-case scenario.

The overall combined amount of WBM cuttings discharged in the event all three wells are drilled is 5,274,310 kilograms (kg) (5,275 tonnes), which reduces to 3,143,520 kg (3,144 tonnes) if all wells are drilled with CAN-ductors.

**Table 3.5: Maximum WBM Volumes and Cuttings Generated for the Tornado Wells [1]**

| Hole Diameter (inches) | Discharge Point | Section Length (m) | Section Volume ($m^3$) | Cuttings Discharged (kg) | WBM Discharged ($m^3$) |
|---|---|---|---|---|---|
| **W1** | | | | | |
| 42 x 36 | Seabed | 120 | 78.80 | 245,920 | 141.88 |
| 26 | | 613 | 209.97 | 655,270 | 378.04 |
| 17½ | Surface | 600 | 93.1 | 290,560 | 848.75 |
| 12¼ | | 393 | 29.88 | 93,260 | 651 |
| 8½ (underreamed to 12¼") | | 120 | 4.39 | 23,550 | 479.38 |
| | **Total:** | **1,846** | **416.14** | **1,308,560** | **2,499.05** |
| **W3** | | | | | |
| 42 x 36 | Seabed | 120 | 78.80 | 245,920 | 141.88 |
| 42 x 36 (re-spud) | | 120 | 78.80 | 245,920 | 141.88 |
| 26 | | 613 | 209.97 | 655,270 | 378.04 |
| 26 sidetrack | | 613 | 209.97 | 655,270 | 378.04 |
| 17½ | Surface | 600 | 93.1 | 290,560 | 848.75 |
| 17½ sidetrack | | 600 | 93.1 | 290,560 | 848.75 |
| 12¼ | | 393 | 29.88 | 93,260 | 651 |
| 12¼ sidetrack | | 393 | 29.88 | 93,260 | 651 |
| 8½ (underreamed to 12¼") | | 253 | 9.26 | 41,210 | 486 |
| 8½ sidetrack (underreamed to 12¼") | | 253 | 9.26 | 41,210 | 486 |
| | **Total:** | **3,958** | **842.02** | **2,652,440** | **5,011.34** |
| **N1 (contingent well)** | | | | | |
| 42 x 36 | Seabed | 120 | 78.80 | 245,920 | 141.88 |
| 26 | | 613 | 209.97 | 655,270 | 378.04 |
| 17½ | Surface | 600 | 93.1 | 290,560 | 848.75 |
| 12¼ | | 393 | 29.88 | 93,260 | 651.32 |
| 8½ (underreamed to 12¼") | | 140 | 5.13 | 28,300 | 481.20 |
| | **Total:** | **1,866** | **416.88** | **1,313,310** | **2,501.19** |

[1] Volumes are worst case based on a conventional drilling scenario (noting that the base case scenario is to use CAN-ductors) and include the contingency re-spud and sidetrack of W3 well.

### Reservoir Hydrocarbons

When drilling through the pay zone, it is anticipated that the drill cuttings and muds may contain residues of reservoir hydrocarbons; this would be bound in the rock removed from the well by the drilling fluid. If drilling with WBM, a small amount of reservoir hydrocarbons could therefore be discharged to sea with the cuttings after they have passed through the cuttings cleaning system, with the remainder transferred into the mud in negligible volumes (i.e. unmeasurable except through laboratory analysis). If drilling with LTOBM, the contaminated cuttings would be treated via the thermal cuttings treatment unit prior to discharge.

Ithaca will seek permission to discharge the potentially contaminated drill cuttings and muds via the submission of an Oil Discharge Permit SAT on the UK Energy Portal, as required under The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended).

It is estimated that each well will penetrate the reservoir zone over a length of 100 m (based on the underreamed hole section up to 12¼ inch), generating 23,730 kg (23.73 tonnes) of cuttings per well, which could be contaminated with a total of 130 kg (0.13 tonnes) of hydrocarbons.

### Cementing Operations

The casings used to prevent the well from collapsing will be cemented into place inside the borehole. Depending on whether a CAN-ductor is used, the cementing programme and associated discharges will be different for either option.

If a CAN-ductor is used, the conductor will already have been welded into the CAN-ductor onshore, and hence there will be no cement overspill pumped to the seabed from the first top hole section. The 20" casing will be cemented through the CAN-ductor. The cement will be pumped down the casing string and forced back up to the surface through the annulus. Most cement will remain in the annulus between the casing and the rock formation, but typically some cement will be squeezed out the top of the well and onto the seabed immediately around the well. 300% excess cement of the open hole volume for the conductor will be used to ensure that the space between the casing and the wellbore is completely filled with cement. In theory, this could result in 55 $m^3$ (350 bbl) of cement slurry being pumped (or squeezed out) onto the seabed per well.

On any well where a CAN-ductor cannot be used, the conductor will be cemented into the top hole section of the well. In this case an allowance will be made to pump up to 300% excess cement to allow for washout and cratering of the wellbore. However, a ROV will monitor the return flow at the seabed and all attempts will be made to identify returns and reduce the pumped slurry volume when possible and safe to do so. A dye will be added to the cement spacer to assist in visually identifying the returns from the wellhead. At this point the remaining cement in the drill string will have to be circulated out, and it is estimated this may result in a discharge of 16 $m^3$ (100 bbl) of cement being pumped out to the seabed per well. The cementing of the 20" casing will be very similar to that of the conductor option, using 100% open hole excess cement, which will amount to a theoretical maximum of 85 $m^3$ (536 bbl) of mixed cement being pumped out to the seabed. Hence, up to 156 $m^3$ (16 $m^3$ + 85 $m^3$ + 55 $m^3$) cement slurry may be pumped out to the seabed per well.

The pumping of cement slurry onto the seabed will result in the creation of a cement patio surrounding each of the wells. Assuming uniform spread radially from the centre of the well, it is estimated that the radial spill of cement will be within 14.2 m of each well where the conductor is cemented into the top hole section of the well versus within 10.3 m of each well if a CAN-ductor is used, noting that the radial spread from the CAN-ductor is ejected from one point onto the seabed so will not circle the CAN-ductor.

The cementing of the 13⅜" and 9⅝" casings for the deeper well sections will be engineered so that the cement will not reach to top of the casing, and thus no cement is expected to be returned to the surface from these sections. The only potential discharge during this part of the cementing operations, would be from an unplanned event, such as an aborted cement job due to technical or mechanical failures. If for any reason cement is circulated back to the MODU, it would need to be discharged to sea before it solidifies. No unmixed cement will be discharged overboard. In addition, in between cementing operations, there will be a requirement to discharge small, residual volumes of cement, associated with cleaning of cement tanks between the cementing applications.

### 3.3.6 Vertical Seismic Profiling (VSP)

A VSP is designed to gather high-resolution data on the subsurface geology within the wellbore itself. For the purposes of this ES, as a worst case scenario, it is assumed that a contingent zero-offset VSP will be conducted on each of the Tornado wells on completion of the drilling operations. It is assumed that the VSP will be conducted from the MODU over a period of 24 hours and will utilise 3 x 250 cubic inch air guns, with a total source volume of 750 cubic inch.

Ithaca will seek permission conduct a VSP survey via the submission of a Geological Survey SAT on the UK Energy Portal, as required under The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (as amended).

### 3.3.7 Well Clean-Up and Testing Operations

Before production begins, each well will undergo a thorough clean-up to eliminate any residual drilling fluids and debris in the wellbore. Initially, the wellbore is displaced using in-situ drilling mud, which is then replaced with completion brine that is sufficiently clean to minimise the risk of plugging of the lower completion. Afterward, the lower completion is installed and a gravel pack operation is carried out. Once the gravel pack is completed, the area above the lower completion is displaced using a suitable brine (this may be mixed with viscosified pills, solvents, and surfactants; these will be segregated and if contaminated will be transported onshore for disposal). Finally, the upper completion will be installed. Throughout this process, it is estimated that approximately 3,000 barrels (477 $m^3$) of completion brine will be discharged per well.

The clean-up will be followed by a flowing period to allow data acquisition for the assessment of productivity (well test). At this time, it is not known what quantity of well fluids will be flared during the well test, however it will not exceed 2,000 tonnes of hydrocarbons over a 96-hour period (per well).

The information gained from each well test will be assessed with a view to reducing the volumes of hydrocarbons to be flared during well testing for each subsequent well. A worst case assumption has been made for the ES that all three wells will be subject to a flow test.

## 3.4 Subsea Installation Operations

### 3.4.1 Overview of Subsea Infrastructure

Table 3.6 provides a summary of the subsea infrastructure that will be installed for Tornado.

**Table 3.6: Tornado Subsea Infrastructure to be Installed**

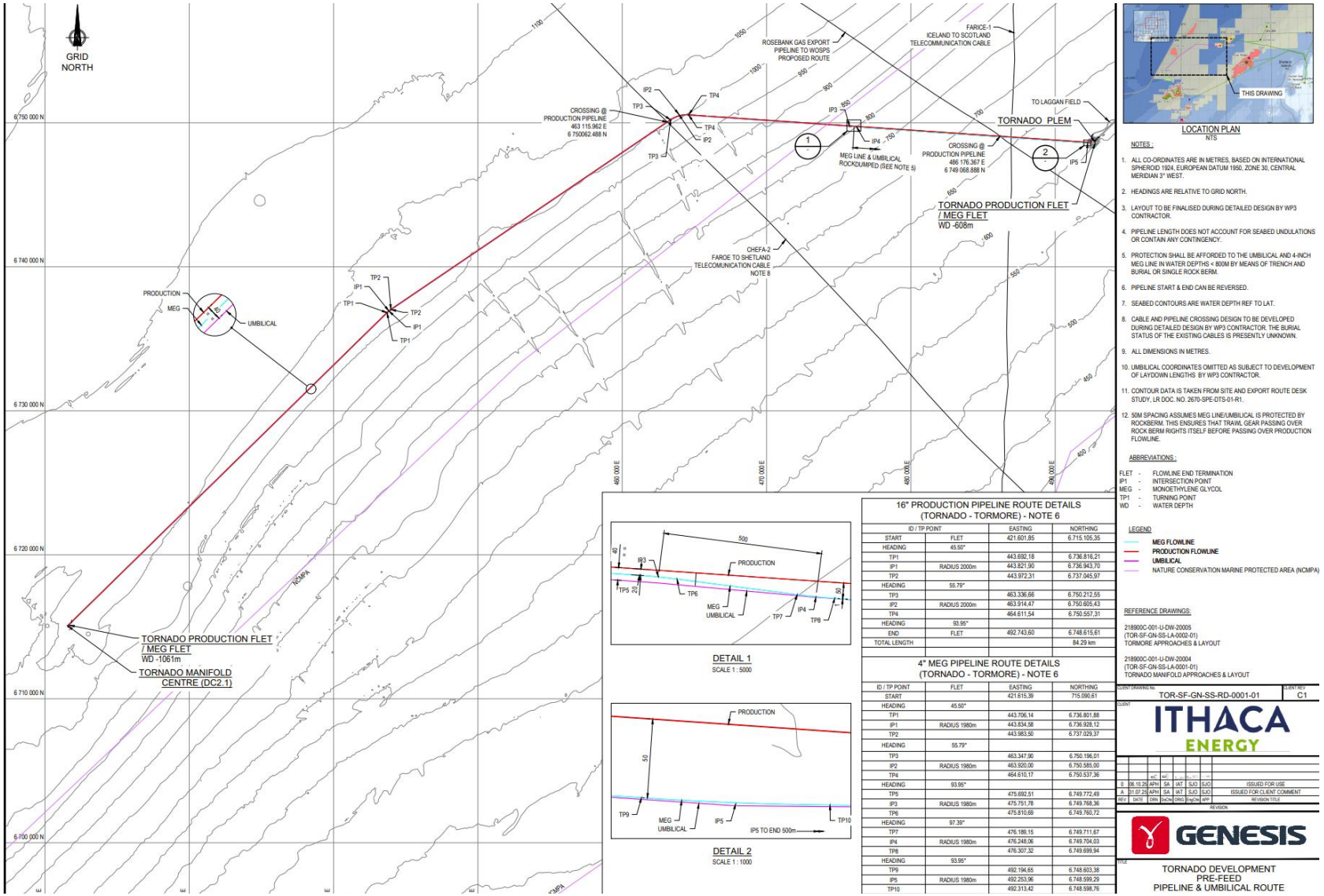
| Subsea Item | Number | Dimensions | Dry Weight (Te) [1] |
|---|---|---|---|
| **Tornado Drill Centre (see Figure 3.3 and Figure 3.10)** | | | |
| Xmas tree [2] | 3 | 6 m (L) x 6 m (W) x 4.5 m (H) | 70 |
| Tornado manifold | 1 | 21 m (L) x 15 m (W) x 4 m (H) | 400 |
| FLET | 2 | 20 m (L) x 15 m (W) x 7 m (H) | 95 |
| UET [3] | 1 | 6 m (L) x 6 m (W) x 4 m (H) | 150 |
| **Production and MEG Pipelines and Control Umbilical (see Figure 3.7)** | | | |
| 16" production pipeline | 1 | ca. 86 km in length [4] | - |
| 4" MEG pipeline | 1 | ca. 86 km in length [4] | - |
| Control umbilical | 1 | ca. 86 km in length [5] | - |
| **Tormore Tie-in Arrangement (see Figure 3.8)** | | | |
| Tornado PLEM | 1 | 30 m (L) x 20 m (W) x 7.5 m (H) | 600 |
| UET [3] | 1 | 6 m (L) x 6 m (W) x 4 m (H) | 150 |
| FLET | 2 | 13 m (L) x 12 m (W) x 7 m (H) | 95 |

[1] Dry weight relates to each individual structure.
[2] CAN-ductor requirements are detailed in Section 3.3.
[3] UET dimension and weight to be confirmed during detailed design. Figure 3.8 and Figure 3.10 show the UET connecting within the Tornado PLEM and Tornado manifold.
[4] 1.5% overage allowed on 84.29 km route length. Final length to be defined during detailed design.
[5] 2.5% overage allowed on 84.29 km route length. Final length to be defined during detailed design.

Figure 3.7 presents the proposed pipelines and umbilical route from Tornado to Tormore. The arrangement of the production pipeline, MEG pipeline and control umbilical is provisional and will be refined during the detailed engineering phase. The alternative arrangements currently being considered are described in Section 2.5.

Figure 3.8 presents the proposed tie-in arrangement at Tormore, with typical GRP protection covers shown for the area in Figure 3.9. The arrangement shown in Figure 3.8 and Figure 3.9 results in the worst case seabed footprint for the purposes of this ES and will be refined during detailed design. The alternative arrangement currently being considered is described in Section 2.5.

Figure 3.10 presents the proposed tie-in arrangement at the Tornado drill centre, although the parking-CAN units are not shown.




NOTES :

1. ALL CO-ORDINATES ARE IN METRES, BASED ON INTERNATIONAL SPHEROID 1924, EUROPEAN DATUM 1950, ZONE 30, CENTRAL MERIDIAN 3° WEST.
2. HEADINGS ARE RELATIVE TO GRID NORTH.
3. LAYOUT TO BE FINALISED DURING DETAILED DESIGN BY WP3 CONTRACTOR.
4. PIPELINE LENGTH DOES NOT ACCOUNT FOR SEABED UNDULATIONS OR CONTAIN ANY CONTINGENCY.
5. PROTECTION SHALL BE AFFORDED TO THE UMBILICAL AND 4-INCH MEG LINE IN WATER DEPTHS < 800M BY MEANS OF TRENCH AND BURIAL OR SINGLE ROCK BERM.
6. PIPELINE START & END CAN BE REVERSED.
7. SEABED CONTOURS ARE WATER DEPTH REF TO LAT.
8. CABLE AND PIPELINE CROSSING DESIGN TO BE DEVELOPED DURING DETAILED DESIGN BY WP3 CONTRACTOR. THE BURIAL STATUS OF THE EXISTING CABLES IS PRESENTLY UNKNOWN.
9. ALL DIMENSIONS IN METRES.
10. UMBILICAL COORDINATES OMITTED AS SUBJECT TO DEVELOPMENT OF LAYDOWN LENGTHS BY WP3 CONTRACTOR.
11. CONTOUR DATA IS TAKEN FROM SITE AND EXPORT ROUTE DESK STUDY, LR DOC. NO. 2670-SPE-DTS-01-R1.
12. 50M SPACING ASSUMES MEG LINE/UMBILICAL IS PROTECTED BY ROCKBERM. THIS ENSURES THAT TRAWL GEAR PASSING OVER ROCK BERM RIGHTS ITSELF BEFORE PASSING OVER PRODUCTION FLOWLINE.

ABBREVIATIONS :

FLET - FLOWLINE END TERMINATION
IP1 - INTERSECTION POINT
MEG - MONOETHYLENE GLYCOL
TP1 - TURNING POINT
WD - WATER DEPTH

LEGEND

MEG FLOWLINE
PRODUCTION FLOWLINE
UMBILICAL
NATURE CONSERVATION MARINE PROTECTED AREA (NCMPA)

REFERENCE DRAWINGS:

218900C-001-U-DW-20005 (TOR-SF-GN-SS-LA-0002-01) TORMORE APPROACHES & LAYOUT

218900C-001-U-DW-20004 (TOR-SF-GN-SS-LA-0001-01) TORNADO MANIFOLD APPROACHES & LAYOUT

16" PRODUCTION PIPELINE ROUTE DETAILS (TORNADO - TORMORE) - NOTE 6

| ID / TP POINT | | EASTING | NORTHING |
|---|---|---|---|
| START | FLET | 421.601,85 | 6.715.105,35 |
| HEADING | 45.50° | | |
| TP1 | | 443.692,18 | 6.736.816,21 |
| IP1 | RADIUS 2000m | 443.821,90 | 6.736.943,70 |
| TP2 | | 443.972,31 | 6.737.045,97 |
| HEADING | 55.79° | | |
| TP3 | | 463.336,66 | 6.750.212,55 |
| IP2 | RADIUS 2000m | 463.914,47 | 6.750.605,43 |
| TP4 | | 464.611,54 | 6.750.557,31 |
| HEADING | 93.95° | | |
| END | FLET | 492.743,60 | 6.748.615,61 |
| TOTAL LENGTH | | | 84.29 km |

4" MEG PIPELINE ROUTE DETAILS (TORNADO - TORMORE) - NOTE 6

| ID / TP POINT | FLET | EASTING | NORTHING |
|---|---|---|---|
| START | | 421.615,39 | 715.090,61 |
| HEADING | 45.50° | | |
| TP1 | | 443.706,14 | 6.736.801,88 |
| IP1 | RADIUS 1980m | 443.834,58 | 6.736.928,12 |
| TP2 | | 443.983,50 | 6.737.029,37 |
| HEADING | 55.79° | | |
| TP3 | | 463.347,90 | 6.750.196,01 |
| IP2 | RADIUS 1980m | 463.920,00 | 6.750.585,00 |
| TP4 | | 464.610,17 | 6.750.537,36 |
| HEADING | 93.95° | | |
| TP5 | | 475.692,51 | 6.749.772,49 |
| IP3 | RADIUS 1980m | 475.751,78 | 6.749.768,36 |
| TP6 | | 475.810,69 | 6.749.760,72 |
| HEADING | 97.39° | | |
| TP7 | | 476.189,15 | 6.749.711,67 |
| IP4 | RADIUS 1980m | 476.248,06 | 6.749.704,03 |
| TP8 | | 476.307,32 | 6.749.699,94 |
| HEADING | 93.95° | | |
| TP9 | | 492.194,65 | 6.748.603,38 |
| IP5 | RADIUS 1980m | 492.253,96 | 6.748.599,29 |
| TP10 | | 492.313,42 | 6.748.598,76 |

CLIENT DRAWING No. TOR-SF-GN-SS-RD-0001-01 CLIENT REV C1

CLIENT ITHACA ENERGY

| REV | DATE | DRN | CHCK | ORIG | ENGCHK | APP | REVISION TITLE |
|---|---|---|---|---|---|---|---|
| B | 06.10.25 | APH | SA | IAT | SJO | SJO | ISSUED FOR USE |
| A | 31.07.25 | APH | SA | IAT | SJO | SJO | ISSUED FOR CLIENT COMMENT |

REVISION

GENESIS

TITLE
TORNADO DEVELOPMENT
PRE-FEED
PIPELINE & UMBILICAL ROUTE

**Figure 3.7: Tornado Pipeline and Umbilical Route**

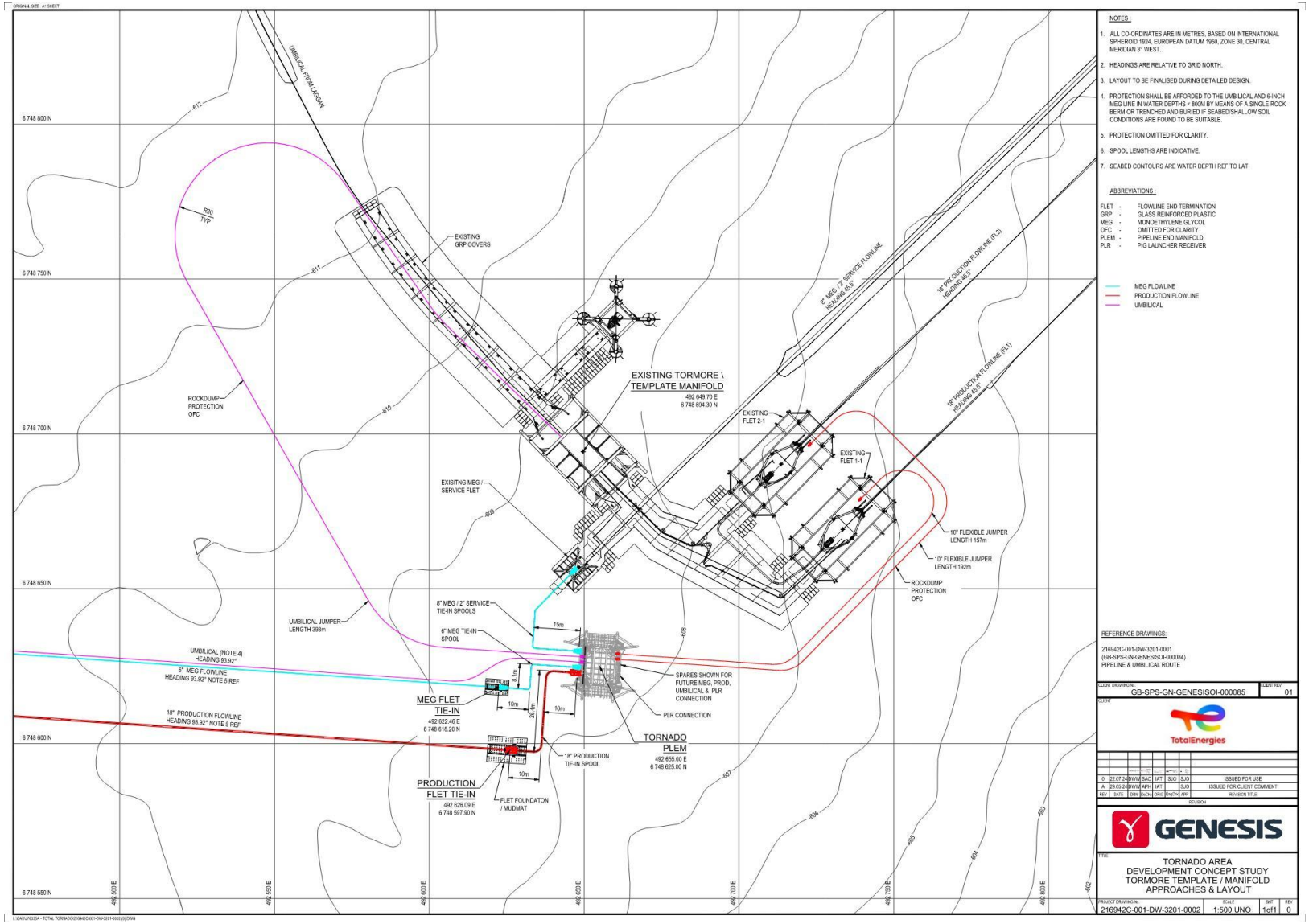



**Figure 3.8: Tormore Tie-in Arrangement**

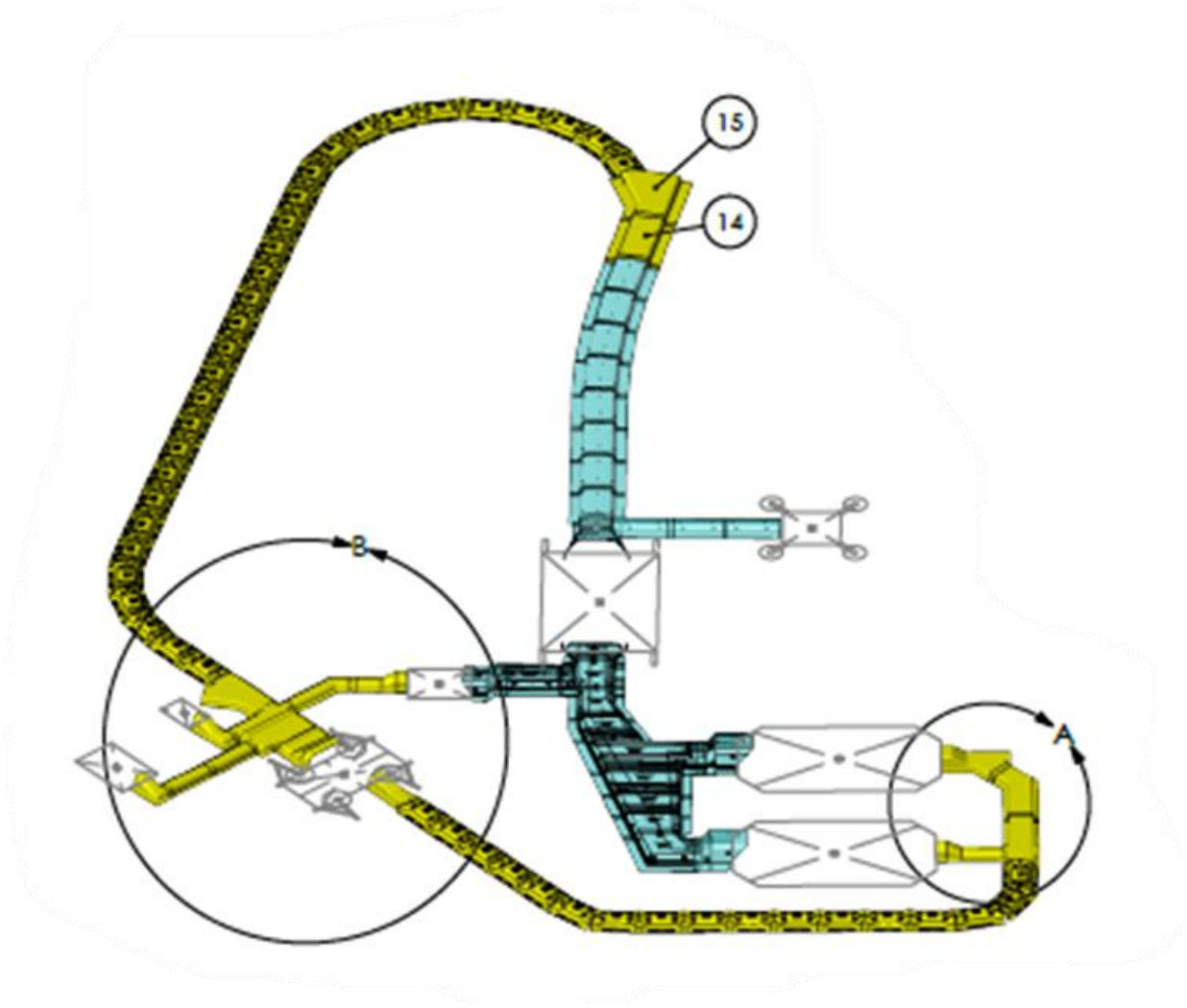



**Figure 3.9: Tormore Tie-in Typical Protection Arrangement (blue: existing protection, yellow: Tornado infrastructure protection)**

*(Image courtesy of CSUB. © CSUB- All Rights Reserved)*

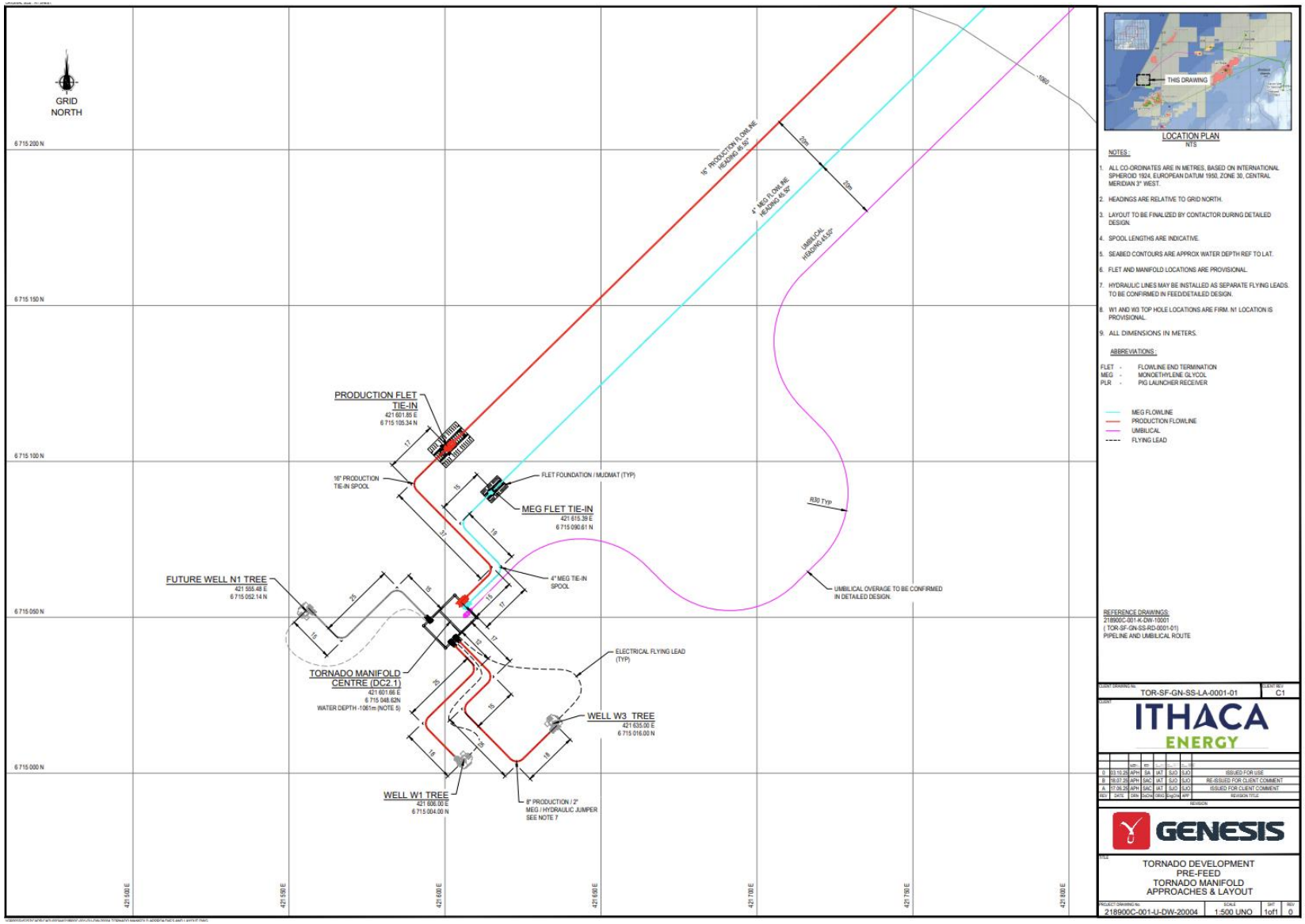



**Figure 3.10: Tornado Drill Centre Arrangement**

### 3.4.2 Tornado Drill Centre

#### Xmas Trees

Upon completion of the drilling operations, a subsea horizontal Xmas tree designed to control flow will be installed on top of each wellhead. The Xmas trees will either be installed directly from the MODU or a vessel, or if parking-CAN units have been deployed, from a CSV (refer to Section 3.3.3).

The subsea tree is the main barrier between the reservoir and the environment and also provides a mechanism for flow control and well entry (Figure 3.11). Each well will have a sub-surface safety valve installed which is an isolation device that is hydraulically operated, and fail-safe closed. The Xmas trees will be controlled remotely from the SGP onshore subsea control system.

Given the water depth at Tornado (1,061.5 m), which prohibits fishing activity in the area, no wellhead protection structures are required. The Xmas trees on top of the CAN-ductors will be 6 m (L) x 6 m (W) x 4.5 m (H) high and weigh around 70 tonnes each.

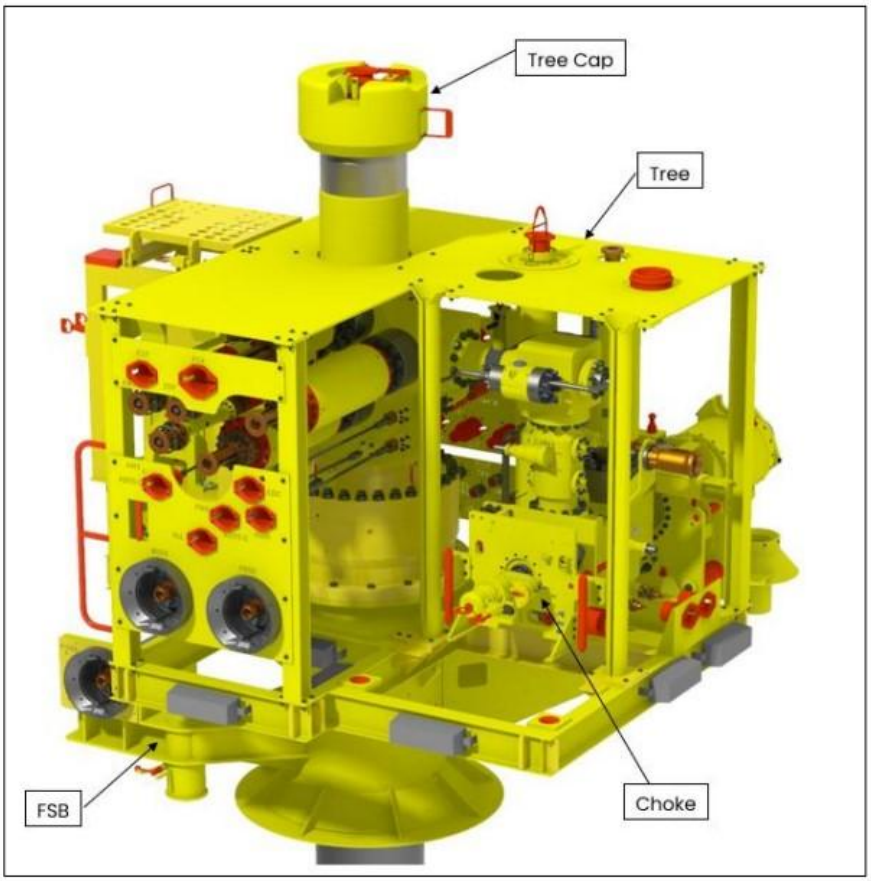



**Figure 3.11: Typical Xmas Tree Example**

*(Image courtesy of Baker Hughes. © Baker Hughes Company All Rights Reserved)*

#### Tornado Manifold

The drill centre production gathering manifold (Tornado Manifold) will comprise pigging headers for the MEG and production pipelines and 3 well tie-in slots (Figure 3.12). As noted above, given the water depth at Tornado, there is no fishing interaction design requirement and the structure can be a vertical sided, minimum footprint, box type structure providing dropped object protection. The approximate dimensions of the structure will be 15 m (L) x 9 m (W), excluding 4 x corner suction pile foundations (ca. 6 m in diameter), 4 m high and weighing approximately 400 tonnes. The total structure footprint is assumed to be 315 $m^2$ (approximately 21 m long x 15 m wide). As the structure will have a suction pile foundation, no pile hammer operations are required. It will be installed from a CSV.

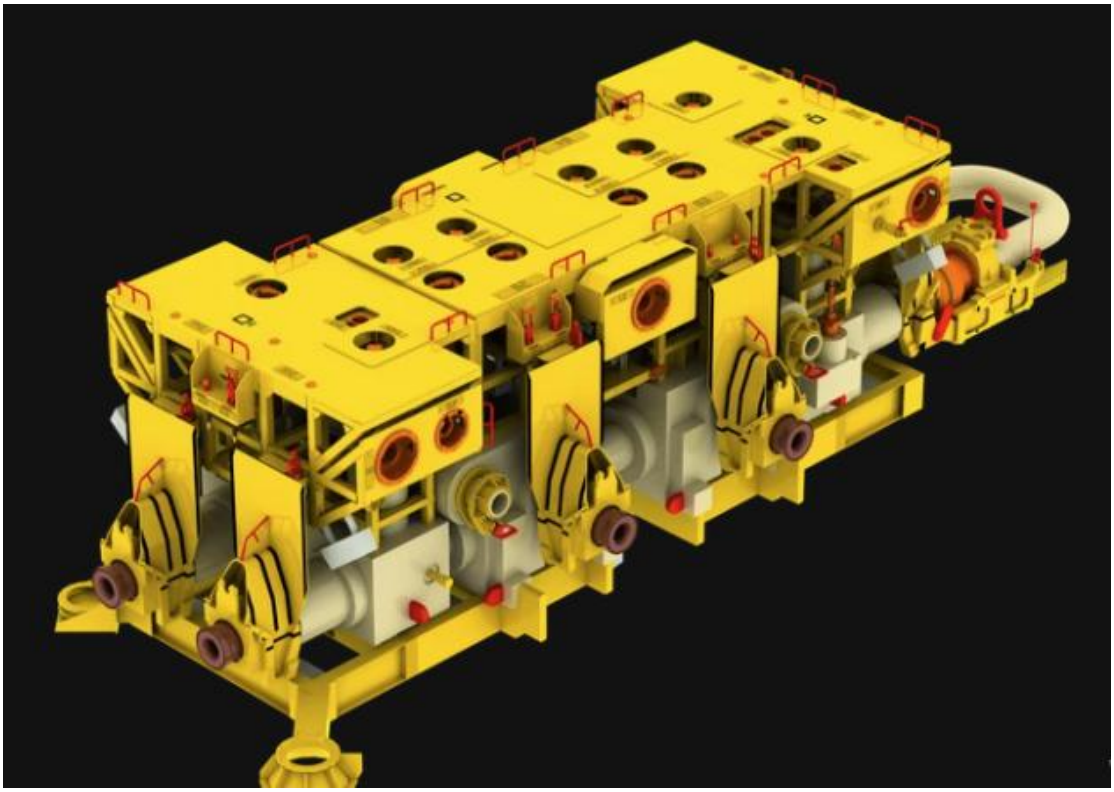


**Figure 3.12: Typical Manifold Example**

*(Image courtesy of TechnipFMC. © TechnipFMC All Rights Reserved)*

### Tornado FLETs

Two FLET structures will be installed at the Tornado end of the pipelines to facilitate initiation and laydown and to accommodate isolation valves and diverless connectors on the 16" production and 4" MEG pipelines. The FLETs will be gravity based structures (Figure 3.13), with approximate dimensions of 20 m (L) x 15 m (W) x 7 m (H) and will be deployed from the pipeline installation vessels in the pipe catenary. The FLET may be made of two sections to help with installation. The first section would contain the pipework and foundations and the second would contain the protection structure. The seabed footprint of each FLET is 300 $m^2$, resulting in a combined footprint of 600 $m^2$ for the Tornado FLETs at the Tornado end of the pipelines.

Prelay rock carpets may be required to ensure suitable foundations prior to installing the FLETs. The estimated quantity of rock that may need to be deposited for the prelay rock carpets is 13,516 tonnes, based on upon 1”-5” rock size with bulk density of 1.54 te/$m^3$, noting that the bulk density of rock is subject to rock supplier. The dimensions of these prelay rock carpets are estimated to be 53 m (L) x 46 m (W) x 1.8 m (H). The seabed footprint of each prelay rock carpets is therefore 2,438 $m^2$, resulting in a combined footprint of 4,876 $m^2$ for the FLETs at the Tornado end of the pipelines.

### Umbilical End Termination (UET)

There may be a requirement to install a UET at Tornado, which will be confirmed during detailed design. The structure will be gravity based and is anticipated to have dimensions of 6 m (L) x 6 m (W) x 4 m (H). The seabed footprint of the structure will be ca. 36 $m^2$ and will be installed from a CSV.



**Figure 3.13: Typical FLET Example**

*(Image courtesy of Allseas Group S.A. © Allseas Group S.A All Rights Reserved)*

### Tie-in Spools and Flying Leads

The tie-in arrangement at Tornado will be refined during detailed design, therefore the line lengths provided below are worst case.

An 8" production spool (rigid or flexible), a 2" MEG spool, an Electrical Flying Lead (EFL) and a Hydraulic Flying Lead (HFL), will be surface laid between the Tornado manifold and each well. A maximum length of 100 m is assumed for each of these lines.

1 x 16" production tie-in spool (rigid or flexible) will be surface laid between the Tornado manifold and the Production FLET. The maximum length of this line will be 80 m.

Bore matched MEG tie-in spool (rigid or flexible) will be surface laid between the MEG FLET and the Tornado manifold. The maximum length of this line will be 80 m.

EFLs, HFLs and Optical Flying Leads (OFL) will be surface laid between the UET and the Tornado Manifold. A maximum length of 100 m is assumed for each of these lines.

Due to the water depth at Tornado (ca 1,061.5 m), all subsea facilities are required to be diverless and do not require protection from fishing interaction (i.e. there is no requirement to deposit grout bags or concrete mattress).

### Seabed Footprint

An estimate of the total area of seabed directly impacted by the installation of subsea infrastructure at the Tornado drill centre is presented in Table 3.7.

**Table 3.7: Estimated Area of Seabed Occupied by Subsea Infrastructure at Tornado Drill Centre**

| Subsea Item | Number | Assumptions | Quantity of Rock to be Deposited (te) [3] | Total Seabed Footprint | |
|---|---|---|---|---|---|
| | | | | ($m^2$) | km [2] |
| CAN-ductor / wellhead [1] | 3 | 6 m (diameter) | - | 84.9 | 0.00008 |
| CAN-parking unit | 2 | 6 m (diameter) | - | 56.6 | 0.00006 |
| Tornado manifold | 1 | 21 m (L) x 15 m (W) | - | 315 | 0.0003 |
| FLET (and prelay rock carpet) | 2 | 53 m (L) x 46 m (W) [2] | 13,516 | 4,876 | 0.0049 |
| UET | 1 | 6 m (L) x 6 m (W) | - | 36 | 0.00004 |
| Tie-in Spools and Flying Leads | 6 | Lines will be surface laid with no requirement for protection. Maximum combined line length is 560 m with width of lay corridor assumed to be 0.5 m | - | 280 | 0.0003 |
| **Total Seabed Footprint at Tornado Drill Centre** | | | **13,516** | **5,648.5** | **0.0057** |

[1] Xmas trees will be located on top of the CAN-ductors. Note the seabed footprint does not account for creation of the cement patio, as discussed in Section 3.3.5. It is estimated that the radial spill of cement will be within 14.2 m of each well where the conductor is cemented into the top hole section of the well versus within 10.3 m of each well if a CAN-ductor is used, resulting in a maximum seabed disturbance area of 633 $m^2$ (0.0006 $km^2$).
[2] Dimensions of the prelay rock carpet, which is installed for each FLET.
[3] Bulk density of rock is subject to rock supplier. Quantities estimated upon 1”-5” rock size with bulk density of 1.54 te/$m^3$.

### 3.4.3 Tormore Tie-in Arrangement

#### Tormore PLEM

The Tornado PLEM (Pipeline End Manifold) will be designed to be overtrawlable and as such is expected to have sloped sides. The structure needs to accommodate pigging headers and is anticipated to have dimensions of 30 m (L) x 20 m (W) x 7.5 m. Consistent with the existing Tormore drilling template manifolds the Tornado PLEM will have suction anchor foundations. The seabed footprint of the structure is 600 $m^2$. It will be installed from a CSV.

#### UET

There may be a requirement to install a separate UET at Tormore, which will be determined during detailed design. The structure will be overtrawlable with a gravity base and is anticipated to have dimensions of 6 m (L) x 6 m (W) x 4 m (H). The seabed footprint of the structure will be ca. 36 $m^2$ and will be installed from a CSV.

#### FLETs

Two FLET structures will be installed at the Tormore end of the pipelines to facilitate initiation and laydown and to accommodate isolation valves and diverless connectors on the 16" production and 4" MEG pipelines. The FLETs will be gravity based structures (Figure 3.13), with approximate dimensions of 20 m (L) x 15 m (W) x 7 m (H) and will be deployed from the pipeline installation vessels in the pipe catenary. The FLET may be made of two sections to help installation. The first would contain the

pipework and foundations and the second would contain the protection structure. The seabed footprint of each FLET is 300 $m^2$, resulting in a combined footprint of 600 $^{m2}$ for the Tornado FLETs at the Tormore end of the pipelines.

Prelay rock carpets may be required to ensure suitable foundations prior to installing the FLETs. The estimated quantity of rock that may need to be deposited for the prelay rock carpets is 13,516 tonnes, based on upon 1"-5" rock size with bulk density of 1.54 te/$m^3$, noting that the bulk density of rock is subject to rock supplier. The dimensions of these prelay rock carpets are estimated to be 53 m (L) x 46 m (W) x 1.8 m (H). The seabed footprint of each prelay rock carpets is therefore 2,438 $m^2$, resulting in a combined footprint of 4,876 $m^2$ for the FLETs at the Tormore end of the pipelines.

### Tie-in Spools, Flying Leads and Jumper

Work is ongoing to refine the reconfiguration works in the vicinity of Tormore to minimise overall impact. The line lengths provided below are worst case and will be refined during detailed design. An alternative Tormore tie-in arrangement is currently being considered and is described in Section 2.5.

Rigid or flexible spools are proposed to connect the new Tornado FLET structures to the Tornado PLEM. These will be surface laid. The maximum length of the production and MEG spools will be less than 100 m each.

For the Tornado production pipeline, rigid or flexible 10" spools will be used to connect the Tornado PLEM to existing Laggan-Tormore FLET structures. A maximum length of 300 m is assumed for each of these lines. This is based upon the maximum production case requiring two sets of 10" spools connecting the Tornado PLEM to each of the Laggan-Tormore FLET structures.

For the MEG pipeline, rigid or flexible spools will be used to connect the Tornado PLEM to existing Tormore facilities. The length of these MEG spools will be less than 300 m.

An infield control umbilical / individual flying leads, will connect the Tornado PLEM to the existing umbilical supplies within the Tormore Facilities. Electric and fibre optic flying leads will connect at the existing Laggan Tormore UET or Tormore manifold. Hydraulic flying leads will connect at either a vacant well bay or via a vacant UET connection at the existing Tormore template. The maximum length of each interconnecting jumpers/umbilical will be ca. 500 m in length.

The infield control umbilical / individual flying leads may be installed via the umbilical porches within the Tormore Template Manifold. To access the umbilical porches within the Tormore Template Manifold, the existing Glass Fibre Reinforced Polymer (GRP) structures and adjacent rock berms will be removed from the Laggan umbilical and wet stored. Once the infield control umbilical / individual flying leads have been installed, the GRP structures and rock berms will be re-installed.

EFLs, HFLs and OFLs will be surface laid between the UET and the Tornado PLEM. A maximum length of 350 m is assumed for each of these lines.

The existing Tormore Tie-in Spools, Flying Leads and Jumpers are protected using GRP structures with rock berms along the edges. The total width of the GRP structure plus rock berms is 17 m. The Tornado Tie-in Spools, Flying Leads and Jumpers at Tormore will be protected by GRP structures and associated rock berms with similar dimensions along the full length of the lines. Where possible, multiple products will be protected within the same GRP structure; however, this will be confirmed during detailed engineering. Subsea mattresses may be used instead of GRP structures for protection however GRP structures are considered in this ES due to the larger impact on the seabed.

### Seabed Footprint

An estimate of the total area of seabed directly impacted by the installation of subsea infrastructure at Tormore is presented in Table 3.8.

**Table 3.8: Estimated Area of Seabed Occupied by Subsea Infrastructure at Tormore**

| Subsea Item | Number | Assumptions | Quantity of Rock to be Deposited (te) [6] | Total Seabed Footprint | |
|---|---|---|---|---|---|
| | | | | ($m^2$) | $km^2$ |
| Tornado PLEM | 1 | 30 m (L) x 20 m (W) | - | 600 | 0.00060 |
| UET | 1 | 6 m (L) x 6 m (W) | - | 36 | 0.00004 |
| FLET (and prelay rock carpet) | 2 | 53 m (L) x 46 m (W) [1] | 13,516 | 4,876 | 0.0049 |
| Tie-in Spools, Flying Leads and Jumper | 7 | Lines will be surface laid and protected by GRP structures (worst case). The dimensions of each GRP (inc. rock) are ca. 17 m (W) x 15 m (L). The maximum combined line length of the lines is 1,550 m. [2] | 23,870 [3] | 26,350 [4] | 0.02635 |
| Protection Transition at FLET | N/A | An overlap of GRP cover and rock may exist for a transition length of circa 150 m on each line. The width of seabed impacted by the rock and GRP for each line is 17 m. | 4,620 | 5,100 [5] | 0.00510 |
| **Total Seabed Footprint at Tormore** | | | **42,006** | **36,962** | **0.037** |

[1] Dimensions of the prelay rock carpet, which is installed for each FLET.
[2] The disturbance area is based upon installation of the GRP structures and adjacent rock berms but does not consider additional temporary disturbance which could occur during any the deconstruction activities of the existing GRP structures and adjacent rock berms. The temporary disturbance area for the deconstruction activities of the existing GRP structures and adjacent rock berms is estimated to be ca. 4,000 $m^2$ (40m (W) x 100m (L))
[3] Tonnage of rock required per metre of line length 15.4 te / m
[4] Disturbance width of 17 m and line length of 1,550 m, equates to 26,350 $m^2$.
[5] Disturbance width of 17 m and line length of 300 m this equates to 5,100 $m^2$.
[6] Bulk density of rock is subject to rock supplier. Quantities estimated upon 1”-5” rock size with bulk density of 1.54 te/$m^3$.

### 3.4.4 Production Pipeline, MEG Pipeline and Control Umbilical

#### Pipelay Operations

Tornado production fluids will be exported via a new 16-inch ca. 86 km pipeline to the existing Tormore FLET structure for entry into the L-T pipeline system. The carbon steel production pipeline will be installed from a reel lay or S-lay vessel and will be surface laid on the seabed. The concept design study concluded that there is no requirement to concrete coat the pipeline for on-bottom stability with only anti-corrosion coating being required.

A dedicated 4-inch ca. 86 km MEG pipeline, with anti-corrosion coating, will be extended from the Tormore MEG FLET to Tornado to provide continuous MEG injection for hydrate inhibition, with the injected MEG dosed with corrosion inhibitor to protect the carbon steel production pipeline system. The MEG pipeline will be installed from a reel lay vessel or piggybacked onto the production pipeline from an S-lay vessel.

The electro-hydraulic controls for Tornado will be provided by extending the existing L-T system from the Tormore manifold to Tornado by means of a dedicated ca. 86 km steel tube control umbilical. The umbilical will provide Low Pressure and High Pressure hydraulics for well and manifold valve actuation, Low Voltage power for subsea control module and Sensor / Multiphase Flow Meter power, as well as fibre optic cores for controls communication. Hydraulics, power and communications will have dual redundancy. The control umbilical will be installed from a CSV with suitable carousel.

As-laid surveys would be performed astern of the pipelay vessels to confirm the pipelines have been installed in the correct position. Given the water depth, all installation vessels will use DP to maintain position, therefore there will be no anchoring required for these vessels.

As noted above, FLET structures will be installed at each end of the pipeline to facilitate initiation and laydown of the pipelines. Temporary laydown areas will be required for initiation anchors (as a worst case it is assumed that drag embedment anchors would be used) and initiation wire, the length of which is assumed to be up to 1,800 m. Following a load test of the anchors and installation of the pipelines, the anchors and wire will be recovered. There will also be a requirement to temporary wet store subsea facilities and protection materials, as well as ROV tooling and baskets. In addition, depending on the sequence of installation operations, the UETs for the control umbilical may be laid down by the installation vessel for subsequent relocation into the respective protection structures if required. The dimensions of each temporary laydown area will not exceed 250 m x 250 m. It is assumed up to ten temporary laydown areas will be required for the Tornado Development, impacting a total seabed area of 62,500 $m^2$ (0.06 $km^2$). Turning bollards are not anticipated to be required along the route on account of the route adopting conservative turning radii at all bends. However, temporary lay down provisions would allow for bollards if required.

### Installation Method

EU Regulation 2016/2336 prohibits fishing with bottom trawls at a depths deeper than 800 m. Fishing potential within the Faroe Shetland Sponge Belt NCMPA has been further restricted by The Offshore Fishing (Prohibition of Fishing Methods) (Scotland) Order 2025 which prohibits demersal mobile gear and demersal mobile gear and static gear in zones of the NCMPA (refer to Section 4.4.1). For the purposes of this ES, it is assumed that the pipelines and umbilical are to be designed for fishing interaction in water depths shallower than 800 m as the worst-case scenario, not taking into account the Scottish Order that came into effect on the 16th of October 2025. The pipelines and umbilical route can therefore be divided into two distinct sections as described in Table 3.9, each with a different installation method (distances are rounded to the nearest kilometre for clarity).

**Table 3.9: Sections of the Pipeline / Umbilical Route from Tornado to Tormore**

| Section of Route | Kilometre Point (from Tornado) | Main Installation Method |
|---|---|---|
| 1 | KP0 - KP 68 | Surface lay of production pipeline, MEG pipeline [1] and umbilical, with no post-lay protection (water depth is >800 m)<br>Potential for numerous boulders requiring boulder removal<br>Rock stabilisation may be required to correct freespans |
| 2 | KP68 - KP86 [2] | Production pipeline surface laid with no post-lay installation protection [1]<br>Protection required for MEG pipeline [1] and umbilical (water depth is <800m)<br>Potential for numerous boulders requiring boulder removal<br>Trenching and/or post lay rock installation for the MEG pipeline and umbilical<br>Rock stabilisation may be required to correct freespans |

[1] Alternative option exists to piggyback the MEG pipeline onto production pipeline (refer to Section 2.4.2)
[2] The entirety of Section 2 of the pipelines and umbilicals is located within the Faroe-Shetland Sponge Belt NCMPA

For Section one and Section two of the route, the production pipeline should be surface laid and would remain exposed on the seabed as it will be designed to resist fishing interaction loads; however, some rock cover may be required to correct freespans. This may be installed prior to, or following, pipelay which will not be determined until the route is finalised and analysis conducted to determine the anticipated span lengths.

There is an alternate option to piggyback the MEG pipeline onto the production pipeline during installation. This alternate option is discussed within Section 2.4.2.

Within Section two of the route, and subject to fishing intensity and damage tolerability studies, the MEG pipeline and control umbilical may require rock protection from fishing interaction. For the purposes of this ES, it has been assumed that the MEG pipeline and control umbilical will be protected in water depths < 800 m. Where possible, the lines will be trenched and buried to a minimum target depth of cover of 0.6 m. There may also be a requirement to deposit rock over sections of the line to mitigate against potential upheaval buckling or provide additional cover for protection, however, it is intended to keep remedial rock protection to an absolute minimum.

Trenching can be carried out using either a pipeline plough or a jet trenching tool:

- A pipeline plough creates an open V shaped trench in the seabed and spoil heaps either side. The lines will be post lay trenched i.e. laid on the seabed, picked up by the plough and passed through the equipment chassis during trenching. Backfilling is subsequently carried out using a mechanical backfill plough. If ploughed, the width of the installation corridor for each line is assumed to be 30 m, with a trench width of 6 m and target trench depth of 1.5 m.
- Jet trenching uses high pressure water to fluidise the sediments and the pre-laid pipeline sinks to the base of the trench. This method does not leave spoil heaps or require mechanical backfill. If jet trenched, the width of the installation corridor for each line is assumed to be 30 m, with a trench width of 1 m and target trench depth of 2.1 m.

If trenching is deemed feasible, the selected trenching method shall be based upon detailed survey outputs, project experience in the area and equipment availability.

Numerous boulders (>0.3 m) have been identified along the proposed pipeline route (refer to Section 4.2.2). Boulders may inhibit the use of the trenching equipment, and therefore boulder clearance may be required within Section 2 of the route prior to trenching operations commencing. Within Section 1 of the route, boulders may also need to be cleared from a narrow corridor along the pipeline and umbilical routes as whilst laying over exposed boulders may be acceptable from a strength and stabilisation perspective, any free-spans may present a snagging risk to fishing interaction.

Boulder clearance will be achieved through use of a grab or a bumper bar (a tool used to nudge objects such as boulders out of the way). Based on experience from the Edradour and Glenlivet developments all boulders greater than 0.5 m would typically be removed from the lay corridors for each line and relocated to the edges of the installation corridor ideally within a 5 m corridor downstream of the prevailing current to minimise likelihood of scour developing on the route. For the boulders moved outside the lay corridors and left on the seabed, the as-left position will be recorded.

Within Section two of the route, if trenching is selected as a suitable protection method, the overall width of the installation corridor will be ca. 150 m, comprising of three individual installation corridors, one for each of the pipelines and control umbilical installation (as illustrated in Figure 3.14). This includes a 5 m corridor for boulder relocation adjacent to each individual installation corridor. Due to the potential for trawl gear interaction, a 60m spacing between products is required in case there are issues with trenching performance resulting in use of rock berms for protection. The corridor of seabed temporarily impacted is 95 m accounting for installation tolerances, boulder relocation and trencher width.

As trenching operations would not be undertaken within Section one of the route, the overall width of the installation corridor would be reduced to 60 m, plus a 5 m corridor for boulder relocation, as illustrated in Figure 3.15.

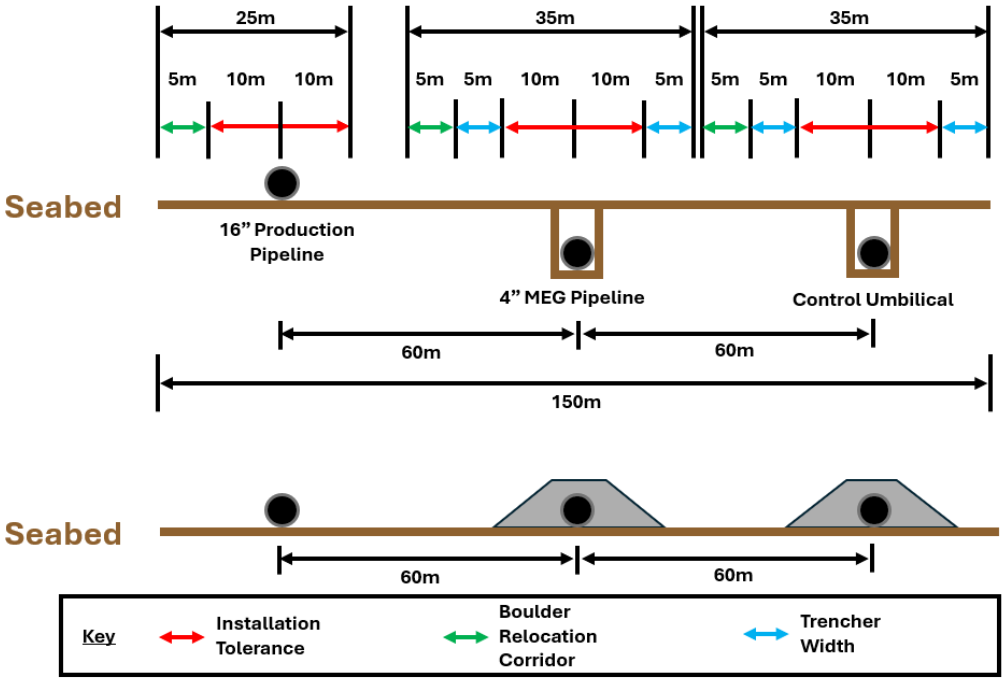



**Figure 3.14. Schematic of Installation Corridor in Route Section 2** [1]

[1] Surface lay of production pipeline, with the MEG pipeline and control umbilical trenched (water depth is <800 m). The alternative option to piggyback the MEG pipeline onto production pipeline and protect with rock, is illustrated in Figure 3.16.

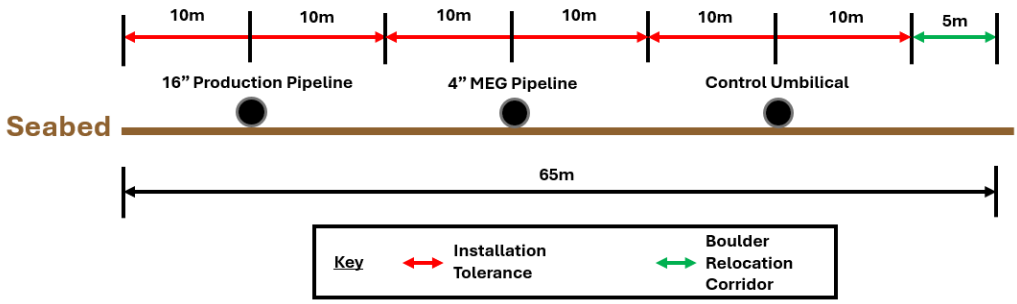



**Figure 3.15. Schematic of Installation Corridor in Route Section 1** [1]

[1] Surface lay of production pipeline, MEG pipeline and umbilical, with no protection (water depth is >800 m)

Within Section two of the route, where boulder density or size prevents implementation of the clearance strategy, the production pipeline, MEG pipeline and control umbilical would be surface laid and protected by two separate overtrawlable rock berms. The largest rock volume would occur if the MEG pipeline is piggybacked onto the surface laid production pipeline as shown in Figure 3.16. In this instance it is estimated that up to 273,814 tonnes of rock protection material, typically 1"-5" in diameter, would be deposited over the lines. The width of the pipelines rock berm on the seabed would be ca. 9.4 m, and the width of the umbilical rock berm on the seabed would be ca. 6.4 m. The total area of seabed impacted by the rock berms within Section two of the route is therefore estimated to be ca. 284,400 $m^2$ (0.285 $km^2$).

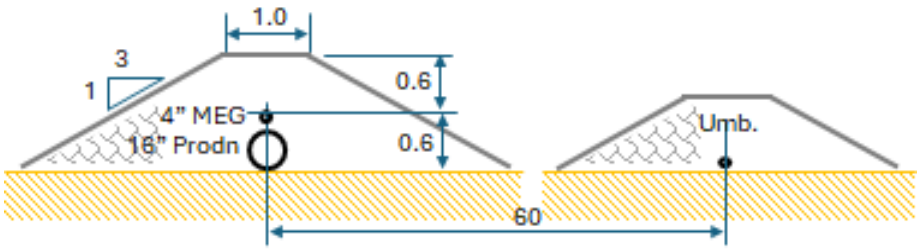



**Figure 3.16: Rock Berm Profile (Pipelines and Control Umbilical)** [1]

[1] Figure shows the minimum required rock berm height for the 16" production pipeline with piggy-backed 4" MEG pipeline and does not show the additional 0.2 m overdump which has been applied in rock quantity calculations.

In the event that the MEG pipeline is not piggybacked to the production pipeline, the MEG pipeline and umbilical would be protected by two separate overtrawlable rock berms, as illustrated in Figure 3.14. The three separate lines would be spaced apart, with a minimum spacing of 50 m between the base of berm and the adjacent pipeline or rock berm, to allow fishing trawl boards to restabilise after crossing a pipeline or rock berm. Although this results in a wider installation corridor, the amount of rock deposited and the total area of seabed impacted by the rock berms would be less than if the MEG pipeline was piggybacked onto the surface laid production pipeline.

Seabed topography could also necessitate the installation of pre-lay rock along some sections of the route (within both Section 1 and 2 of the route) due to the presence of seabed features such as boulders, depressions and mounds. A routing assessment will be carried out during detailed design and should look to avoid these seabed features where possible. It is assumed that most of the boulders can be removed or avoided, however where it is not possible to remove the boulders or reroute around the seabed features, pre-lay rock will be required. There may be the option to utilise sleepers and mattresses to reduce the volume of rock for pre-lay remediation however use of only rock provides the worst-case permanent footprint and rock tonnage and is therefore the base case for the purpose of the ES. It is estimated that 122,694 tonnes of pre-laid rock could be required based upon the production pipeline, MEG pipeline and umbilical being surface laid as separate lines within a 65 m installation corridor in Section one of the route (Figure 3.15) and 150 m installation corridor in Section two of the route (Figure 3.14).

Where pre- or post-lay rock is required, a rock placement vessel would be used to deposit the rock on the seabed or over the lines. The vessel will survey the seabed as the rock placement installation progresses to determine the exact location of the rock material and to confirm that the design requirements have been met. 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.

### Cable Crossings

Towards the Tormore end of the route, two cables (FARICE and SHEFA2 Seg 7) and one pipeline (Rosebank) cross the installation corridor. Crossing designs are not yet matured and may entail concrete structures and/or mattresses and rock placement. For the purposes of this ES, a worst-case assumption of mattresses and rock placement has been assumed. Figure 3.17 and Figure 3.18 present preliminary cross sectional drawings for the different crossing arrangements. Design of the crossings will be finalised during detailed design.

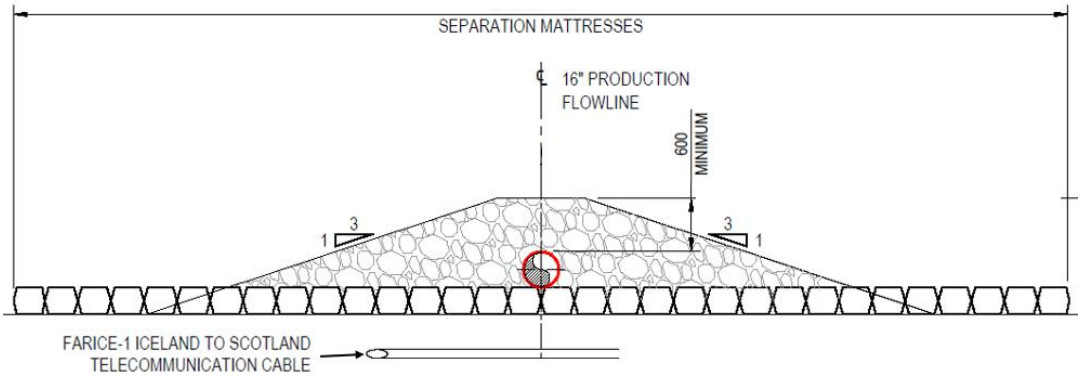



**Figure 3.17: Typical Pipeline / Cable Crossing Design (Separation Mattresses)**

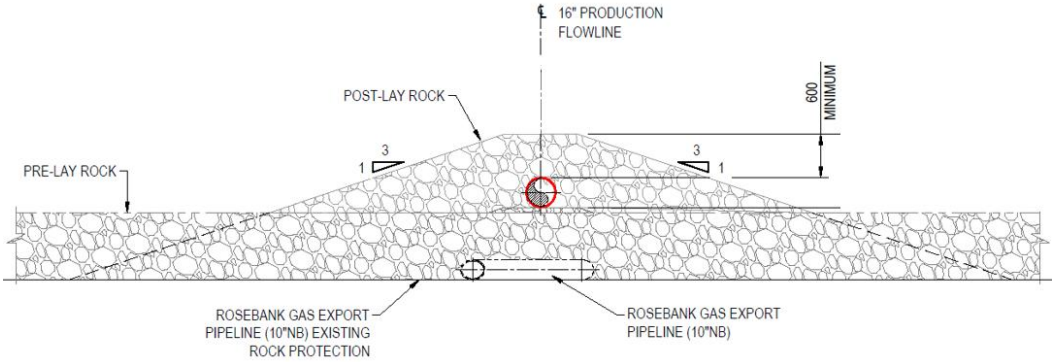



**Figure 3.18: Typical Pipeline / Cable Crossing Design (Pre-Lay Rock)**

### Rock Deposits

Table 3.10 provides a worst case estimate of the total quantity of rock (pre-lay and post-lay) which will be required to be deposited on the seabed to install the Tornado pipelines and control umbilical. Rock deposit within the Faroe Shetland Sponge Belt will be avoided as far as is practicable, noting that the presented estimates present the worst case scenario. Rock deposits shall be left in situ after Tornado production has ceased production. Where rock is being deposited for protection purposes, a minimum depth of cover of 0.6 m shall be installed to ensure that the pipelines and umbilical are adequately protected and can be left in situ upon decommissioning. During detailed design, an assessment may be performed to reduce the minimum depth of cover of rock required for protection.

**Table 3.10: Rock Quantity Estimate (worst case)**

| Installation Method | Quantity of rock to be deposited (tonnes) [1, 5] | | | Seabed Footprint ($m^2$) [8] |
|---|---|---|---|---|
| | Production Pipeline | MEG Pipeline | Control Umbilical | |
| Pre-lay Carpet [3] | 122,694 | | | 77,280 [6] |
| Post-lay Cover [4] | 289,920 | | | 284,400 |
| Crossings [7] | 6,386 | | 4,241 | 7,060 |
| **Sub-Total:** | **423,241** | | | **368,740** |
| Contingency [2]: | 84,648 | | | 73,748 |
| **Total:** | **507,890** | | | **442,488** |

[1] Bulk density of rock is subject to rock supplier. Quantities estimated upon 1"-5" rock size with bulk density of 1.54 te/$m^3$.

[2] 20% contingency has been added to the sub-total due to the pre-FEED maturity of the engineering.

[3] Estimated based upon the number of seabed features within installation corridors. Individual rock quantities for each pipeline and umbilical to be confirmed during detailed engineering.

[4] Worst case estimate based upon MEG pipeline piggybacked onto the production pipeline.
[5] Estimates are planned to be revised during detailed engineering based on findings from the seabed survey campaign.
[6] Pre-lay footprint in water depths >800m. The pre-lay footprint in water depths <800m is included in the post lay cover footprint. i.e. post-lay berm has a greater footprint than the pre-lay berm.
[7] Required in addition to the post-lay rock quantity.
[8] These seabed footprints have been accounted for in Table 3.11.

### Seabed Footprint

Table 3.11 provides a description of the worst-case estimate of potential permanent seabed impact (i.e. the introduction of a permanent hard substrate footprint on the seabed) from installation of the production pipeline, MEG pipeline and control umbilical, based on the assumptions described above.

**Table 3.11: Estimate (Worst Case) of the Area of Seabed to be Directly (Permanently) Impacted by the Production Pipeline, MEG Pipeline and Control Umbilical**

| Element | Length of Pipeline Corridor | Parameters and Assumptions for Worst Case Scenario | Worst Case Footprint [1, 2] | |
|---|---|---|---|---|
| | | | ($m^2$) | ($km^2$) |
| Section 1 KP0 –ca. KP68 Water depth > 800m | 68 km | Footprint for the production pipeline, MEG pipeline and umbilical is based upon the products being surface laid on the seabed with pre lay rock carpets installed. | 134,896 [1] | 0.135 [1] |
| Section 2 ca. KP68 – KP86 Water depth < 800m | 18 km | Footprint for production pipeline and MEG pipeline is based upon the two products being installed together via piggyback system and both products protected by a single post lay rock berm. Footprint for umbilical is based upon the product installed on its own and protected by its own post lay rock berm. | 341,280 [3] | 0.341 [3] |
| Pipeline / Cable crossings | - | Footprint for production pipeline and MEG pipeline is based upon the two products being installed together via piggyback system, laid onto a preinstalled rock carpet, and then protected by a post lay rock berm. Footprint for umbilical is based upon the product being installed on its own onto a preinstalled rock carpet and then protected by a post lay rock berm. | 8,472 | 0.008 |
| | | **Total:** | **484,648** | **0.485** |

[1] Footprints of products individually surface laid on the seabed in Section 1 is 42,160 $m^2$. Footprint of the rock Prelay in Section one is 92,736 $m^2$ (including 20% contingency). Total footprint is 134,896 $m^2$.
[2] Includes 20% contingency added to the sub-total of the seabed footprint resulting from rock placement due to the pre-FEED maturity of the engineering.
[3] Footprint of post lay rock in section two.

Table 3.12 provides a description of the worst-case estimate of temporary disturbance to the seabed from installation of the production pipeline, MEG pipeline and control umbilical, based on the assumptions described above.

**Table 3.12: Estimate (Worst Case) of the Area of Seabed to be Temporarily Impacted by the Production Pipeline, MEG Pipeline and Control Umbilical**

| Element | Length of Pipeline Corridor | Parameters and Assumptions for Worst Case Scenario | Worst Case Footprint | |
|---|---|---|---|---|
| | | | ($m^2$) | ($km^2$) |
| Section 1 KP 0 – ca. KP 68 Water depth > 800m | 68 km | The maximum corridor of temporary disturbance in section one of the route is 65 m. Footprint for the Production Pipeline, MEG pipeline and umbilical is based upon the products being surface laid on the seabed within a 60 m installation corridor. An additional 5 m corridor is required adjacent to the installation corridor due to the potential for bolder relocation. Includes Temporary laydown areas. [1] [2] | 4,518,500 | 4.52 |
| Section 2 ca. KP 68 – KP 86 Water depth < 800m | 18 km | The maximum corridor of temporary disturbance in section 2 of the route is 95 m. This is based upon a +/- 10m installation corridor for each product and a trencher with a width of 10 m. A 5 m corridor for boulder relocation from the lay routes, adjacent to each individual installation corridors (3 x 5m) has been included. Includes temporary laydown areas. [1] [2] | 1,808,500 [1, 2] | 1.81 |
| | | **Total:** | **6,327,000** | **6.33** |

[1] Includes temporary laydown area of 62,500 $m^2$ required for UETs – based upon 10 off areas 250 m x 250 m
[2] Includes temporary laydown area of 36,000 $m^2$ required for initiation anchors – based upon 1 off initiation wire used for both MEG and Production pipelines. Initiation wire length of 1,800 m and a 20m wide corridor.

### 3.4.5 Pre-Commissioning

Where feasible, as much equipment as possible will be pre-commissioned onshore. It is anticipated that the spool pieces will be hydrotested onshore and will be installed, pre-filled with chemicals to protect the infrastructure integrity typically MEG gel and potentially also dye, to facilitate leak testing. The control umbilical will be pressure tested on completion of manufacture and will be installed, pre-filled with the control lines filled with the appropriate hydraulic fluid and the chemical injection lines will be filled with MEG/Water or a suitable spacer chemical.

The production and MEG pipelines will be installed air filled which will be displaced by flooding with filtered treated seawater (e.g., oxygen scavenger (to prevent oxygen induced corrosion), biocide (to prevent bacterial growth), corrosion inhibitor and dye (which would be visible in the water column if the production pipeline leaked during pressure testing). A pipeline integrity gauge (PIG) will be pushed through the lines to detect any dents or defects in the pipeline surface that might have been caused during installation (called 'gauging') and to clean the inside of the lines as part of the flooding process.

Once the pipelines are water filled, the pressure within the pipelines will be slowly raised to help confirm that the pipeline structure is intact (hydrotesting/strength testing). Once the pressure has been raised to the intended pressure, it will be held for a period sufficient to determine that the pipeline demonstrates the required strength and integrity in accordance with the pipeline design Codes and Standards.

Following testing and installation of all of the spoolpiece, jumpers, etc., the production pipeline will be dewatered to ensure it is conditioned for gas transportation to the L-T pipeline system. A valve will be opened at the Tormore end of the pipeline and a series of pigs (a pig train) will be moved along the pipeline to force the treated seawater through the open valve at the Tornado end of the pipeline. The

pigs will be driven by hydrocarbon gas from the L-T pipeline system and up to a maximum of 8,897.20 $m^3$ of treated seawater will be discharged to the marine environment over a period of 0.65 to 2 days, depending on the speed of the PIG.

Hydrocarbon gas is proposed for the dewatering of the production line given the significant logistical challenges related to supplying, and ultimately processing at SGP, the required nitrogen volume for the same operation.

The use and discharge of chemicals during pre-commissioning operations will be detailed and assessed in the Pipeline Operations MAT and associated Chemical Permit SAT 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.

### 3.4.6 Vessel Requirements

A summary of the vessel requirements and durations associated with the Tornado subsea installation operations, along with typical fuel consumption rates, are provided in Table 3.13.

**Table 3.13: Vessel Requirements for Tornado Subsea Installation Operations**

| Operation | Vessel Type [1] | Total No. of Vessel Days [2] | Typical Fuel Consumption (tonnes per day) | Total Fuel Consumption (tonnes) |
|---|---|---|---|---|
| Boulder Clearance / Route Prep [5] | Remotely Operated Vehicle Support Vessel (ROVSV) | 60 | 25 | 1,500 |
| Crossing Preparation / Route Prep [5] | Rock Placement Vessel | 45 | 30 | 1,350 |
| Production Pipeline Installation | S-Lay Vessel | 95 | 30 | 2,850 |
| MEG Pipeline Installation | Reel Lay Vessel | 30 | 30 | 900 |
| Pipelay Support | ROVSV | 95 | 25 | 2,375 |
| Umbilical Installation | CSV | 32 | 25 | 800 |
| Installation of Subsea Structures | CSV | 24 | 25 | 600 |
| Rock Placement Operations [3] | Rock Placement Vessel | 200 | 30 | 6,000 |
| Guard Vessels for MEG pipeline and umbilical [4] | 2 x Guard Vessels | 240 | 0.8 | 192 |
| Tie- Ins and Commissioning | CSV | 85 | 25 | 2,125 |
| | **Totals:** | **906** | **-** | **18,692** |

[1] All vessels used will be DP vessels
[2] Includes an allowance for vessel mobilisation, transit and demobilisation, as well as waiting on weather (50%).
[3] Post-lay rock protection assumed as a worst case compared to trenching and backfilling.
[4] Assumes two guard vessels are required for the period between the MEG pipeline and umbilical being laid and the rock deposited or the lines trenched and backfilled, where water depths are <800m.
[5] The number of vessel days for route preparation is an estimate and is subject to routing assessment performed during detailed engineering phase.

## 3.5 Production

Tornado production fluids will be processed onshore at the SGP, with the gas treated and compressed for export into the SIRGE pipeline for onwards transmission to St Fergus and the National Transmission System. Small volumes of unstabilised condensate will be piped to the neighbouring SVT, for further processing with liberated gas exported from SVT to SIRGE and stabilised liquid hydrocarbons piped to storage tanks for export via tanker with other SVT liquid streams.

### 3.5.1 Predicted Production Profiles

The gas, oil and water production figures for Tornado are presented in Table 3.14 (Max case), with high, mid and low case production figures provided for reference in Appendix G. First gas is currently targeted for Q4 2029, therefore 2030 is the first full year of production. The Tornado field is expected to produce hydrocarbons for ca. six to ten years, depending on the reserves, the production rate and the life of the GLA infrastructure.

The production predictions are based on an ensemble of reservoir models which reflect the identified range of uncertainty in reservoir parameters and align with the application for development and production consent which will be submitted to the NSTA.

The Max case (based on a three well development scenario and assuming 100% uptime) results in the maximum volume of hydrocarbon (oil and gas) production at the maximum rate and represents the greatest potential environmental impact. The impact assessment presented in this ES (and all associated calculations for air emissions calculations) has therefore been carried out using the Max case. However, water production (from condensate) is uncertain and in the Max case scenario hydrocarbon production case is partly enabled by assuming a low side condensed water component. The High case scenario (two well development scenario) therefore results in the maximum produced condensate water volumes, with produced water peaking in 2030 at around 16.9 $m^3$ per day (refer to the High case production profile in Appendix G). Any condensate water generated during processing of the Tornado production fluids will be disposed at the SGP via the existing produced water system, the impact from which is outside of the scope of this ES, although there is sufficient capacity in the water handling system at SGP to accommodate Tornado.

Tornado hydrocarbon production rates are anticipated to peak in 2030 at 9,462,562 cubic metres (334 million standard cubic feet) of gas per day and 619.1 tonnes (783.4 cubic metres) of condensate per day (Max case), after which there is a steady decline over the life of the field (refer to Figure 3.19 and Figure 3.20).

**Table 3.14: Tornado Gas, Oil and Water Production Volumes, Max case [1]**

| Year | Oil (tonnes/d) | Oil ($m^3$/d) | Oil (bbl/d) | Gas ($m^3$/d) | Gas (MMscf/d) | Water ($m^3$/day) | Water (bbl/d) |
|---|---|---|---|---|---|---|---|
| 2029[2] | 212.4 | 268.8 | 1,691 | 2,498,089 | 88 | 0.001 | 0.0 |
| 2030 | 619.1 | 783.4 | 4,928 | 9,462,562 | 334 | 0.016 | 0.1 |
| 2031 | 315.7 | 399.5 | 2,513 | 7,678,067 | 271 | 0.027 | 0.2 |
| 2032 | 187.4 | 237.2 | 1,492 | 6,159,804 | 218 | 0.030 | 0.2 |
| 2033 | 112.7 | 142.7 | 897 | 4,906,120 | 173 | 0.030 | 0.2 |
| 2034 | 67.3 | 85.2 | 536 | 3,897,193 | 138 | 0.030 | 0.2 |
| 2035 | 44.5 | 56.3 | 354 | 3,042,199 | 107 | 0.028 | 0.2 |
| 2036 | 23.6 | 29.9 | 188 | 1,697,376 | 60 | 0.018 | 0.1 |

[1] Max case hydrocarbon profile is based on an contingency accelerated production scenario where additional capacity ullage is made available (subject to commercial negotiations) in the GLA flowline system, and the Tornado project can maximise production rates to fill the available ullage by drilling and producing from a third well at Tornado. The availability of ullage to support the Max case is uncertain at this time but has been included as a basis for the EIA as it represents the worst-case scenario in terms of total production volume, and resulting in emissions, albeit at a lower GHG intensity than all other cases. Tornado gas density = 0.766 $kgm^{-3}$.

[2] Based on 3 months production in 2029.

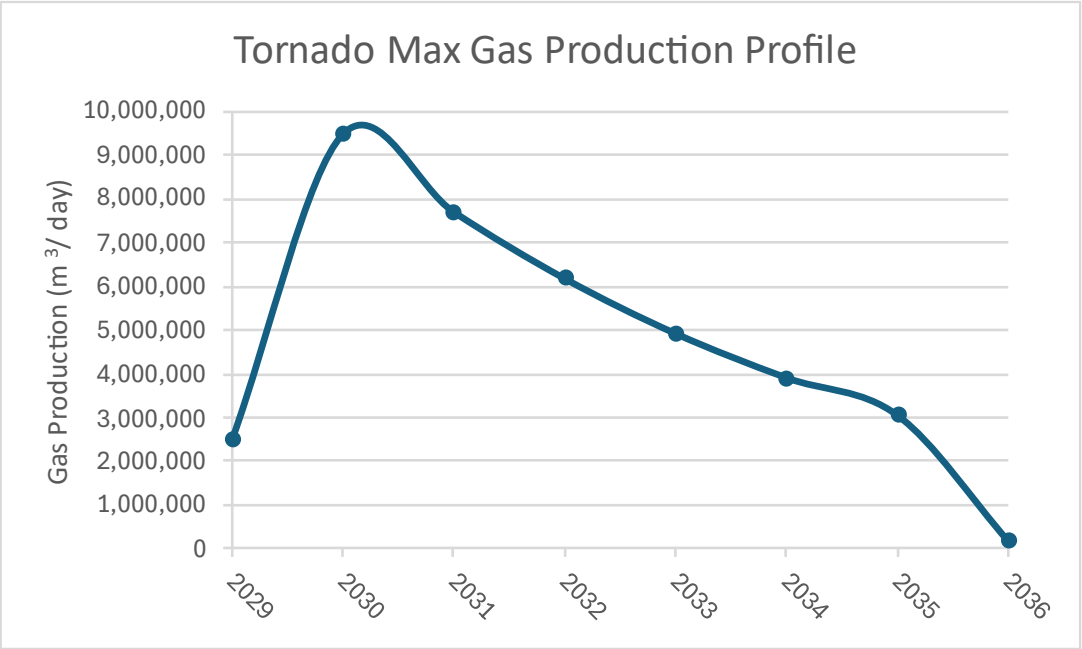



**Figure 3.19: Tornado Gas Production Profile (Max production case)**

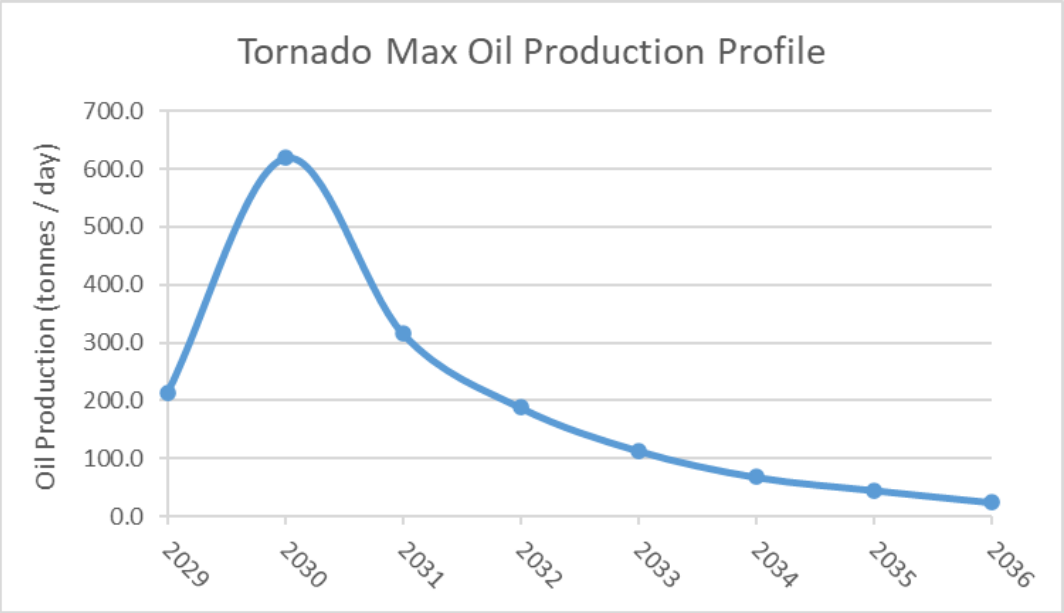



**Figure 3.20: Tornado Oil Production Profile (Max production case)**

### 3.5.2 Inspection and Maintenance

An integrity management system will be developed and inspection programmes implemented for the Tornado subsea system. However, in general, the subsea equipment is designed for the field life time such that maintenance can be minimised.

External inspection will take place through a combination of ROV/AUV and towed sonar. The frequency of such inspection and maintenance activities will be determined by ongoing risk assessment. In terms of internal maintenance, the pipelines will be designed to accommodate intelligent pigging inspection, if necessary, whereby a remote sensing PIG will be conveyed through the pipeline to undertake checks on and confirm pipeline integrity and condition.

The likely vessel requirements for inspection and maintenance of the subsea infrastructure over the life of the Tornado field is detailed in Table 3.15, based on 28 vessel days split over four, one week duration, campaigns.

**Table 3.15: Vessel Requirements for Maintenance of Subsea Infrastructure (over life of the field)**

| Vessel | Function | Total No. of Vessel Days [1] | Fuel Type | Fuel Consumption Rate (tonnes per day) [1] | Total Fuel Consumption (tonnes) |
|---|---|---|---|---|---|
| ROVSV | Inspection and maintenance of subsea infrastructure | 28 | Diesel | 25 | 700 |

[1] Includes an allowance for vessel mobilisation, transit and demobilisation

## 3.6 Decommissioning of the Tornado Development

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

The main obligations for decommissioning offshore oil and gas operations are set out in OSPAR decision 98/3 (the "Decision 98/3") which specifically prohibits the dumping or leaving in place of installations in the marine environment. However, the OSPAR provisions do not directly apply to pipelines and there are no international guidelines on the decommissioning of disused pipelines. Therefore, pipeline and umbilical decommissioning options will be assessed in accordance with UK legislation and policy in place at the time of decommissioning.

It is currently anticipated that the wells will be disconnected from their respective subsea architecture and will then be plugged and abandoned using a DP MODU or vessel with well intervention capabilities. The conductor and wellhead would be cut at a depth below the mudline and removed, the CAN-ductor and parking-CAN- units (if used) will then be reversed pumped out of the seabed and removed.

All subsea infrastructure will be depressurised and flushed to remove residual hydrocarbons and chemicals and left flooded with seawater prior to abandonment. A comparative assessment of decommissioning options will be conducted to determine the feasibility of removing the subsea infrastructure in accordance with decommissioning regulatory requirements in place at the time. Any rock deposited on the seabed as part of the Tornado Development shall remain *in situ*.

The MEG pipeline and umbilical line will be trenched and buried or rock protected for their length in water depths of less than 800 m and therefore it is also currently assumed these would remain *in situ*.

When designing the Tornado Development, consideration was given to the future re-use and/or repurposing of the reservoir. However, the reuse of the Tornado reservoir for carbon capture and storage (CCS) is not considered credible, primarily on account of the extended step out distance from shore to Tornado (>150 km), coupled with no established industrial emitters local to the pipeline landfall, necessitating carbon dioxide ($CO_2$) import, and the relatively small potential storage volume (<18 million tonnes $CO_2$) when compared to alternate stores and aquifers (e.g. Liverpool Bay which has a 150 million tonnes $CO_2$ storage capacity and Morecambe Bay (future potential) with up to 1.5 billion tonnes of $CO_2$). EnQuest are understood to be considering repurposing SVT for green projects including CCS and Green Hydrogen; however, the CCS is linked to offshore storage in their own East of Shetland reservoirs and producing Ammonia from Green Hydrogen which does not entail offshore storage. Other potential Green Hydrogen projects including Statkraft Scatsta are also Ammonia generation projects which does not entail offshore storage.

# 4 The Existing Environment

## 4.1 Introduction

This section describes the current environment at the proposed Tornado Development location. The description is based on data provided in the OPRED Offshore Energy Strategic Environmental Assessment (SEA) Reports (2003-2016), as well as other published data sources, supported by site-specific survey data as detailed below. The proposed Tornado Development is located within the SEA4 Region (the area north and west of Orkney and Shetland) (DTI, 2003) and Offshore Energy Strategic Environmental Assessment (OESEA) Regional Sea 8 (the 'Scottish Continental Shelf' area) (BEIS, 2022).

### 4.1.1 Tornado Site-specific Data

Site-specific data has been collected over the main Tornado site and along the proposed pipeline route to the Tormore tie-in location. The survey was conducted by Fugro on behalf of Ithaca during the survey period 26 June to 12 September 2024 and included a debris clearance survey, seismic geohazards survey, geotechnical survey, habitat assessment (HA) and an environmental baseline survey (EBS).

The objective of the EBS was to determine the sediment's physico-chemical and biological properties and thereby establish the baseline environmental conditions in the area for the future measure of spatial and temporal trends. The habitat assessment was required to describe the benthic habitats and epifauna present and highlight any sensitive habitats and/or species within the area, specifically habitats listed under Annex I of the EU Habitats Directive, as well as Scottish PMFs and OSPAR threatened and/or declining species and habitats.

The geophysical site and route survey comprised an AUV survey, utilising multibeam echosounder (MBES), sub-bottom profiler (SBP), dual frequency side scan sonar (SSS) at 110 and 420 kilohertz (kHz), magnetometer and camera. The AUV site survey was undertaken in an area measuring ca. 3.5 km by 0.55 km surrounding three potential Tornado drill centre locations, while the width of the AUV survey along the proposed pipeline route ranged from 0.6 km to 1.2 km and adequately covers the Project footprint area. The geophysical survey was conducted to accurately determine water depths, the nature of seafloor materials, and thicknesses of sediments and identify any seafloor and sub-seafloor features or obstructions. Once the geophysical data was acquired, the onboard environmental scientist reviewed the SSS and bathymetric data in conjunction with the onboard geophysicist to propose appropriate environmental sediment sampling and camera locations, as detailed below.

#### Site Survey

Within the Tornado site survey area, 15 sediment sampling and camera locations were selected, with five stations located around three potential drill centre locations: DC4 (RS_ST01 to RS_ST05), DC5 (RS_ST06 to RS_ST10) and DC2.1 (RS_ST11 to RS_ST15) based on spatial coverage and features of interest.

Video and stills photography were successfully acquired along all 15 camera transects and a full suite of samples (namely, a physico-chemical sample and two macrofauna samples) were successfully acquired from all 15 stations using a 0.25 square metres ($m^2$) box corer.

Figure 4.1 illustrates the location of the Tornado site survey sampling stations and camera transects.

Of note, DC2.1 has been chosen as the preferred drill centre for Tornado, therefore stations RS_ST11 to RS_ST15 provide the best representation of conditions at the proposed Tornado drill centre.

#### Pipeline Route Survey

Along the proposed Tornado to Tormore pipeline route, 24 environmental stations were selected for sampling based on spatial coverage and features of interest to inform the habitat assessment and baseline characterisation. The section of the proposed pipeline route overlapping the Faroe-Shetland Sponge Belt NCMPA was prioritised for sampling, with six box core stations (PR_ST19 to PR_ST24) and six transects (PR_TR19 to PR_TR24) located within the boundary of the MPA.

Stills and video data were acquired at all 24 proposed transects. To facilitate vessel manoeuvrability the proposed pipeline route transects ran as close as possible to the proposed box core stations. Due to camera technical issues, there are numerous short gaps in the video footage for transects PR_TR13 and PR_TR21. However, the videos were acquired in conjunction with good quality stills that were deemed adequate to describe the seafloor at the locations. Due to the presence of an uncharted cable too close in proximity to the box core station PR_ST10, an additional transect (PR_TR10_1) was run to ground truth the repositioned box core station. One further additional transect (PR_TR_CPT_19_1) was acquired in order to ground truth the cone penetration testing (CPT) location PR_CPT_19_1. AUV photography was successfully acquired at all planned locations.

A full suite of samples (namely, a physico-chemical sample and two macrofauna samples) were successfully acquired at 21 of the 24 proposed stations using a 0.25 $m^2$ box corer. No grab samples were acquired at stations PR_ST04 and PR_ST08 due to cobbles and boulders in the samples causing sediment washout. Station PR_ST11 was abandoned due to its proximity to an uncharted cable. Station PR_ST10 was relocated 200 m away from the original location due to the uncharted cable.

Figure 4.2 illustrates the location of the Tornado pipeline route survey sampling stations and camera transects.

#### Sample Processing and Analysis

Two box corer samples were sampled for macrofauna using stainless steel dividers and processed over a 0.5 mm mesh sieve, with the remaining sample sampled for particle size distribution (PSD), TOC, TOM, moisture, heavy and trace metals (HM) and hydrocarbons (HC). The results of the analysis have been compared to a variety of reference values relating to regional background levels and threshold effect levels to aid in the interpretation of the data, including OSPAR background concentrations (BCs) and BACs, and OSPAR ERL levels.

### 4.1.2 Environmental Surveys in the Wider Area

The results of the Tornado site specific surveys described above are supported by the environmental survey work conducted in August 2018 and July 2019 for the proposed Cambo field development (MMT, 2019 and Fugro, 2019), located approximately 17 km northeast of the Tornado field. The Cambo survey used a ROV to capture digital stills along eight transects, with one cross transect targeting the Faroe-Shetland Sponge Belt NCMPA. Thirteen locations were subject to sediment sampling using a dual Van Veen grab, with eight of these located within the NCMPA. The locations of the Cambo survey sampling stations in relation to the proposed Tornado Development are presented in Figure 4.3.

Site survey results for the proposed WoS Rosebank field development, as documented in the Rosebank ES (Equinor, 2022), have also been referenced, where relevant, to support the results of the Tornado site specific surveys. The Rosebank field is located approximately 45 km northwest of the proposed Tornado drill centre, with the proposed Rosebank pipeline route crossing the proposed Tornado pipeline route, at a point approximately 13.5 km west of the Tormore manifold, within the Faroe-Shetland Belt NCMPA.

Several other surveys have been conducted within the Faroe-Shetland Sponge Belt NCMPA. This includes surveys conducted by collaborations between JNCC and SGMD (formerly Marine Scotland) in 2012, 2018 and 2021 (Eggett *et al*., 2018; Tangye *et al*., 2022), involving a combination of analogue survey techniques (such as side-scan sonar and a multi-beam echo sounder) and digital stills camera/video systems and grab sampling.

In addition, several broad scale surveys have been conducted to characterise the seabed habitats and communities in the WoS and Faroe-Shetland Channel region and have been used to inform the environmental baseline description, where relevant. These include the surveys conducted by the AFEN in 1996 and 1998 (AFEN, 2000) and the Department of Trade and Industry (DTI) survey of the former White Zone in 1999 for SEA 1 (DTI, 2000). This work comprised a combination of analogue survey techniques (such as side-scan sonar and a multi-beam echo sounder) subsequently ground-truthed by digital stills camera/video systems and grab sampling.

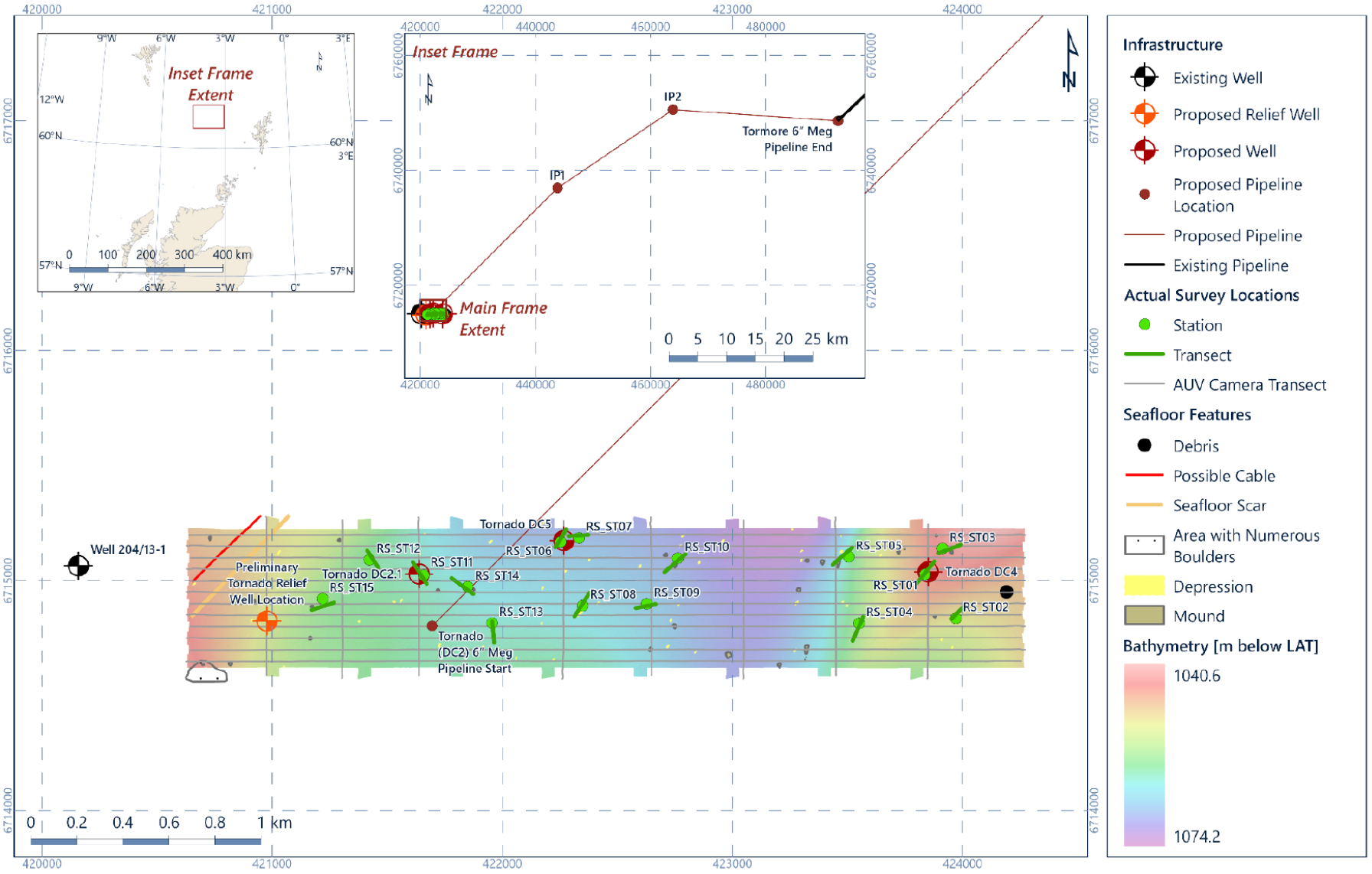



**Figure 4.1: Tornado Site Survey Area Bathymetry and Completed Environmental Sampling Locations (Fugro, 2025a)**

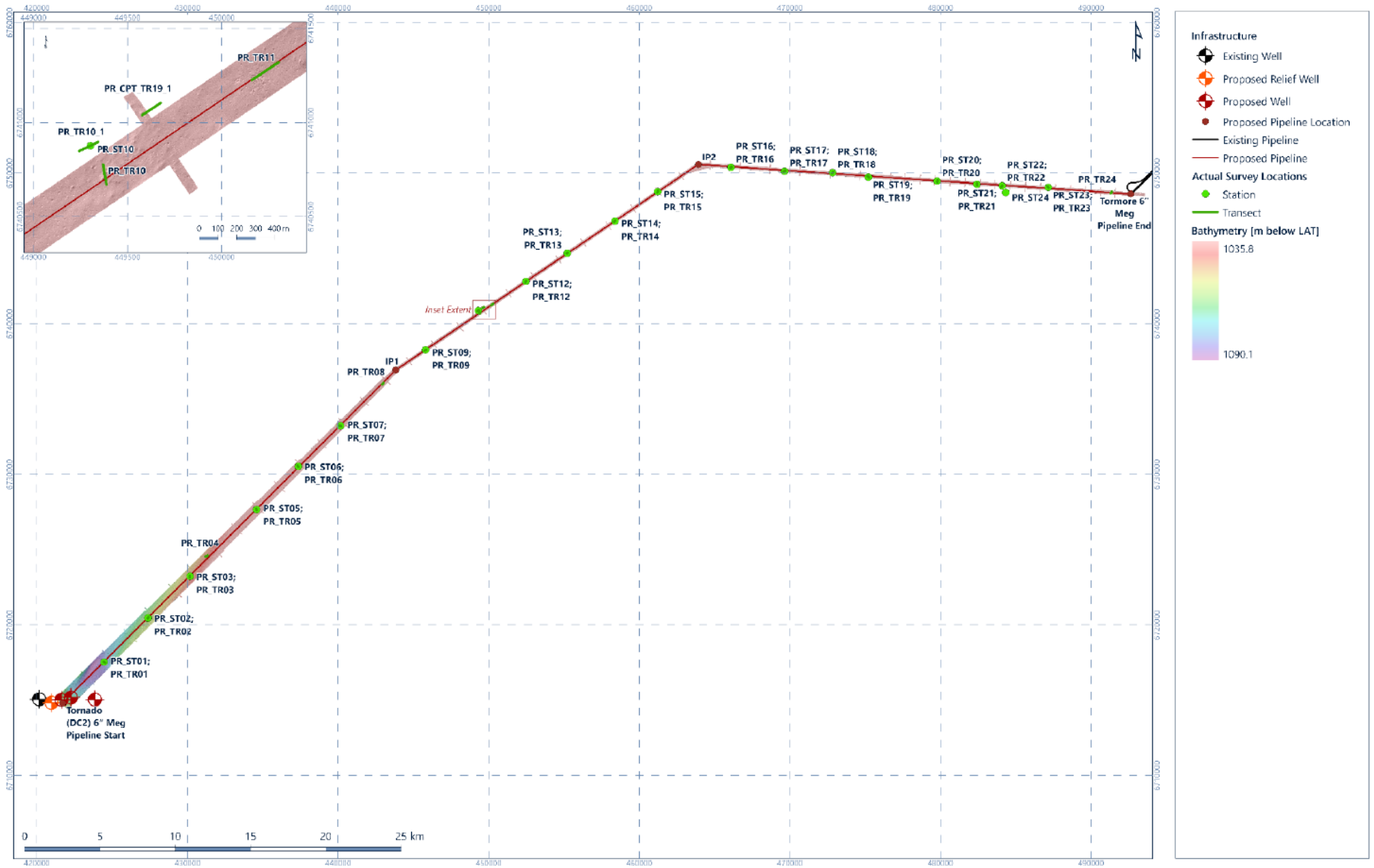



**Figure 4.2: Tornado Pipeline Route Survey Area Bathymetry and Completed Environmental Sampling Locations (Fugro, 2025b)**

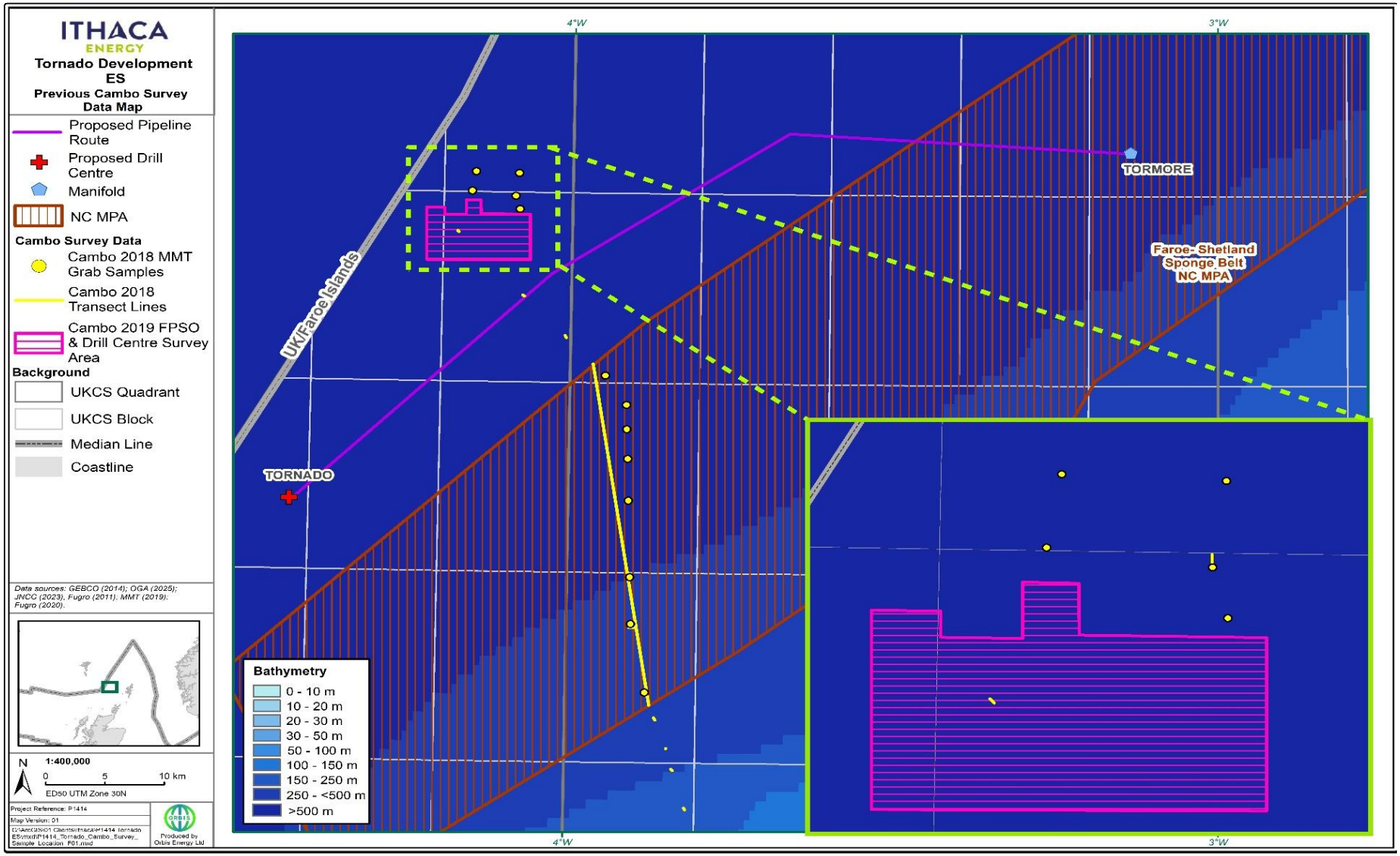



**Figure 4.3: Cambo survey sampling stations (MMT, 2019; Fugro 2019)**

## 4.2 Physical Environment

### 4.2.1 Bathymetry

The Tornado field is located on the Atlantic continental margin over the eastern side of the Faroe-Shetland Channel. The Faroe-Shetland Channel, the major topographical feature in the region, is an extensive deep water channel surrounded by the WoS continental shelf, the Faroe shelf, and the Wyville-Thompson Ridge. The average depth of the Faroe-Shetland Channel is approximately 1,200 m and it reaches a maximum depth of around 1,700 m in the north where it opens out into the Norwegian Sea basin (DTI, 2003).

The water depth at the proposed drill centre location (DC 2.1) is ca 1,061.5 m LAT. Water depth across the Tornado site survey area varies from a minimum of 1,040.5 m LAT to a maximum of 1,074.1 m LAT (Figure 4.1). Minimum water depths are found at the eastern and western limits of the site. Maximum water depths are found within a trough which crosses the central area of the site, orientated approximately north to south. From the deepest part of the trough, water depths decrease to the west with an overall gradient of approximately 1° (degree) and to the east with an overall gradient of approximately 3°. Localised gradients on the flanks of mounds and depressions (which occur across the whole site) are up to 16° (Fugro, 2024a).

Water depths along the proposed pipeline route corridor very gently decrease from a maximum of 1,090.0 m below LAT in the south west at KP 3.229, to a minimum of 593.8 m below LAT in the north east at KP 84.942 (Figure 4.2). The proposed route pipeline route ascends the Faroe-Shetland channel up to the Shetland Continental Shelf where there is a significant depth change from west to east, which correlates with the locations of the maximum and minimum water depths. The seafloor gradient within the pipeline route corridor is generally 1°, with gradients of over 10° occurring on the flanks of mounds and depressions (Fugro, 2024b).

### 4.2.2 Seabed Features

The proposed Tornado Development falls partially within the area known as the 'iceberg plough mark zone' (Bett, 2003). Iceberg sour areas are often defined by large proportions of cobbles and boulders, which may act as a stony reef or provide a substrate for biogenic cold water coral reefs. Typical plough marks can be several tens to a few hundred metres in width, with coarse gravel substrate in the ridges and finer grained material in the depressions. The Faroe-Shetland Sponge Belt NCMPA, in which 18 km of the Tornado pipeline route is within, is designated amongst other features, for the presence of iceberg plough marks (JNCC, 2014a).

Debris fans are present at the base of the continental slope. During the last glacial period, extensive volumes of glacigenic sediment were transported by ice to the edge of the West Shetland Shelf, where they directly contributed to the development of glacigenic debris flow fans along the continental slope (Stoker, 1997; Stoker et al., 1991; Stoker & Holmes, 1991 as referenced in Masson et al., 2003). In addition, significant quantities of ice-rafted debris were deposited directly into the deep basin (Stoker et al., 1998 as referenced in Masson et al., 2003). Many of the key geomorphological features that define the modern continental slope including iceberg ploughmarks, glacigenic debris flows, and sedimentary channels originated during this time. Figure 4.4 shows the location of these features in the wider Tornado area.

Post glacial gullies were the most prominent bathymetric feature observed during the Tornado pipeline route survey, crossing the corridor in a north-west to south-east orientation. Gullies on the WoS slope were created and active during the last deglaciation, with the gullies fed by sediment via sub-glacial streams. Within the gullies there are debris flow deposits (Fugro, 2024b).

Seabed depressions and sediment mounds, thought to have formed due to the action of strong bottom currents known to exist in the area, are also common in the pipeline route corridor and present across the site survey area. The mounds comprise accumulations of gravel and cobbles (Fugro, 2024a; Fugro, 2024b).

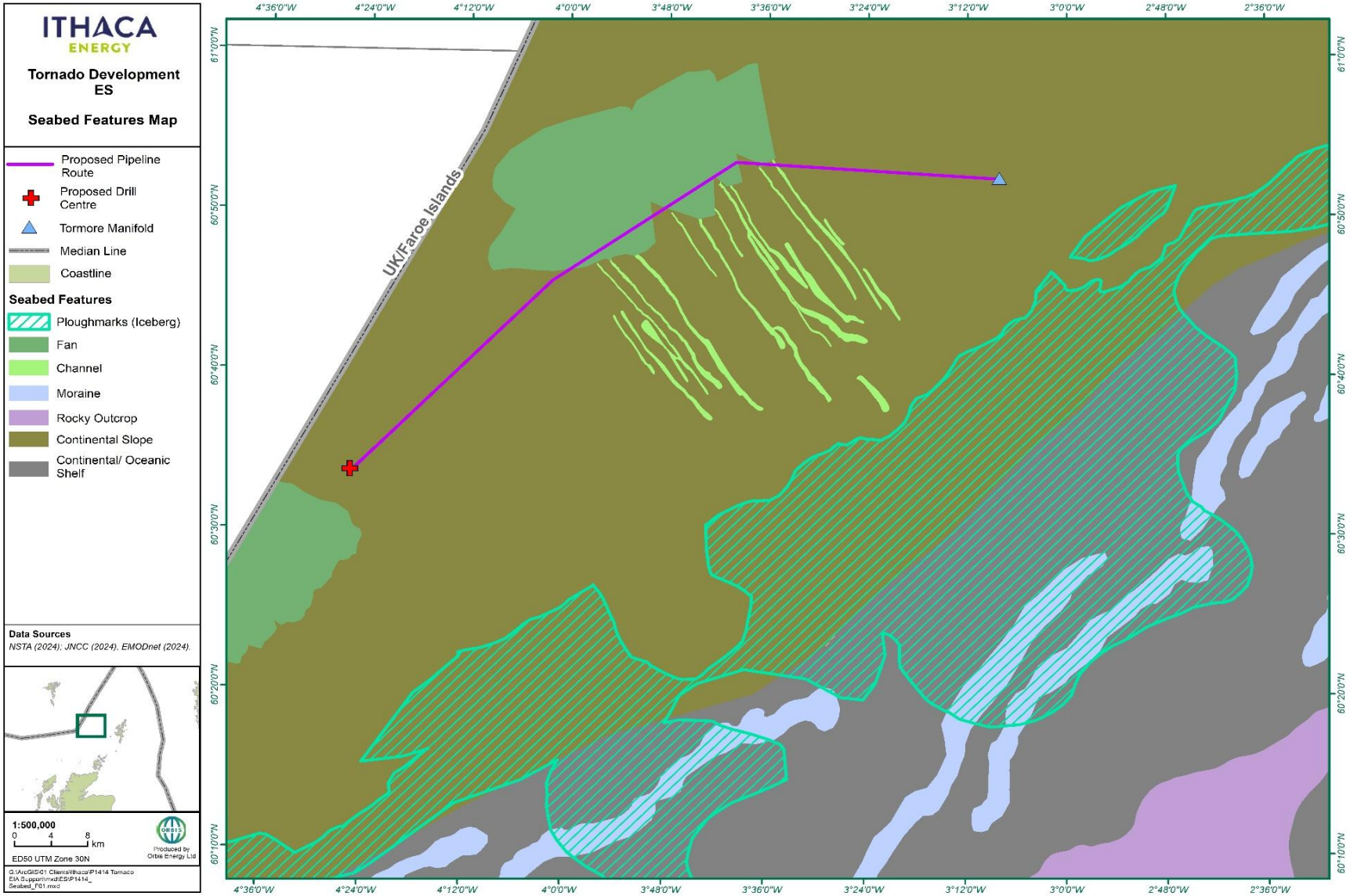



**Figure 4.4: Seabed Features in wider Tornado Area (EMODnet, 2024)**

An area of numerous boulders (approximately 180 m x 90 m) is located in the south-west corner of the site survey area (Figure 4.1), whilst a total of 26,732 isolated (randomly scattered) boulders were identified within the pipeline route corridor. The boulder density is the highest between KP 0.115 and KP 31.175, decreasing in number with increasing KP from the Tornado site, with the lowest in the section of the route between KP 55.470 and KP 85.192 (Fugro, 2024b).

### 4.2.3 Seabed Sediments

The nature of the local seabed sediments is a determining factor in the benthic communities present in the area (Kostylev, 2012). The infilling of iceberg ploughmarks over time on the WoS shelf and slope has created a complex mosaic of seabed habitats alternating between areas of coarse (cobbles and boulders) and fine sediment (Bett, 2003).

The sediments in the region were shaped during the last glacial period, during which there were high sediment deposition rates, in contrast to the low sediment input and deposition rates that feature today. Seabed sediments show a general decrease in grain size with increasing water depth, from mixed sand and gravel in the upper continental slope to mud in the deeper basins of the Faroe-Shetland Channel (Masson et al., 2003).

Regional survey work conducted to the WoS observed that the superficial seabed sediments of the continental slope were mostly sands with some gravel and mud, and typically form a layer of 5 to more than 20 centimetres (cm) thickness. The proportion of fine sediment grains (mud) generally increases with water depth; sediments in the deepest areas, below approximately 800 m, contain a significant mud fraction, and muddy sands and pebbly muddy sands dominate (AFEN, 2000). As the Faroe-Shetland Channel narrows towards the southwest, the seafloor may be characterised as gravelly sand with cobbles and boulders, indicative of an increased current flow regime and near-seafloor base rocks (Bett, 2000). The outer continental shelf consists of gravel overlain by mobile sand bedforms and iceberg plough marks (Masson et al., 2003).

British Geological Survey (BGS) seabed sediment data indicates that the seabed at the proposed Tornado drill centre location is likely to comprised of gravelly muddy sand, whereas the seabed along the proposed pipeline route consists of gravelly muddy sand and slightly gravelly sandy mud (BGS, 2015).

Integrated analysis of photographic data with geophysical data in conjunction with in-situ observations of sediment samples showed that the seafloor across the Tornado site survey area was largely homogenous, comprising gravelly sandy mud/muddy sand with cobbles and boulders (Fugro, 2025a). Within the pipeline route corridor, the sediment type observed was gravelly sandy mud/muddy sand with pebbles and sporadic cobles and boulders, and sandy mud/muddy sand with sparse pebbles and cobbles (Fugro, 2025b).

These findings are in line with a previous ROV survey undertaken in the Tornado field in 2009 during the drilling of exploration well 204/13-1/1Z (approximately 1.5 km west of the proposed Tornado drill centre), which recorded a seabed comprised a mix of sand, gravel and occasionally larger pebbles, cobbles and boulders, characteristic of past ice rafting (Jones and Gates, 2010). The presence of soft sediments with varying proportions of cobbles, boulders and gravel were also recorded during the surveys undertaken in the Cambo field area and Rosebank development area (MMT, 2019; Fugro, 2019; Fugro, 2011; Gardline, 2001; Equinor, 2022).

#### 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.

Sediment samples gathered from the Tornado area have been subjected to particle size analysis (PSA). The results of the PSA suggest that in the vicinity of the proposed drill centre the sediment types showed moderate variability; stations (RS_ST11 to RS_ST15) were likely to be dominated by sand (mean 53.20%) or gravel (mean 34.59%); the fines content was generally low (mean 12.21%). Sand content ranged from 17.52% to 52.11%, gravel content ranged from 32.31% to 71.91% and fines content ranged

from 8.06% to 15.57%. Within the pipeline route corridor sediment types showed moderate variability; stations were also likely to be dominated by either sand (mean 51.27%) or gravel (mean 36.29%); the fines content was generally low (mean 12.44%). Sand content ranged from 13.32% to 90.26%; while gravel content ranged from 0.00% to 80.49% (see Table 4.1; Fugro, 2025c; 2025d).

The mean particle size within the vicinity of the proposed drill centre (RS_ST11 to RS_ST15) ranged from 580 µm to 8,519 µm (coarse sand to medium pebble; Wentworth, 1922), with a mean of 3223.5 µm and high variability (RSD 111 %). The mean particle size along the proposed pipeline route ranged from 110 µm to 15987 µm (very fine sand to medium pebble; Wentworth, 1922), with a mean of 2223 µm and high variability (RSD 166 %) (Fugro, 2025c; 2025d).

The samples collected within the vicinity of the proposed drill centre (RS_ST11 to RS_ST15) were all represented by the Folk Classification 'Muddy sandy gravel' (Folk, 1954). The samples collected within the pipeline route corridor were represented by five Folk classifications with 57% of stations classified as 'Muddy sandy gravel', 19% of stations classified as 'Muddy sand', and 14% of stations classified as 'Gravelly muddy sand'. One station (PR_ST01) had a gravel content of 81.49% and was therefore classified as 'Gravel'; the final station (PR_ST20) had a sand content of 90.26% and was therefore classified as 'Sand' (See Table 4.1; Fugro, 2025c; 2025d).

The Gravelly muddy sand sediment type was also common within both the proposed Cambo and Rosebank development areas (MMT, 2019; Equinor, 2022).

### Organic Matter and 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 its 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.

TOC levels recorded at the Tornado site survey area within the vicinity of the proposed drill centre (RS_ST11 to RS_ST15) were low throughout (mean 0.23%) and were also low along the pipeline route corridor (mean 0.21%), reflecting an organically deprived environment considered typical of the region (Fugro, 2025c; 2025d). TOC levels recorded during previous surveys within the region were also relatively low (MMT, 2019; AFEN, 2000; Equinor, 2022).

TOM levels recorded at the Tornado site survey area within the vicinity of the proposed drill centre (RS_ST11 to RS_ST15) were low (mean 1.96%) and were also low within the pipeline route corridor (mean 1.92%), typical of background conditions across the region (Fugro, 2025c; 2025d).

**Table 4.1: Summary of Sediment Characteristics (Fugro, 2025c; 2025d)**

| Station | Depth (m) | Mean Particle Size | | TOM (%) | TOC (%) | Fractional Composition | | | Folk Description |
|---|---|---|---|---|---|---|---|---|---|
| | | µm | Wentworth (1922) Description | | | Gravel (%) | Sand (%) | Fines (%) | |
| **Tornado Site Survey Area** | | | | | | | | | |
| RS_ST01 | 1,045 | 572 | Coarse sand | 1.43 | 0.18 | 34.57 | 51.44 | 13.99 | Muddy sandy gravel |
| RS_ST02 | 1,046 | 684 | Coarse sand | 4.20 | 0.22 | 34.42 | 52.36 | 13.23 | Muddy sandy gravel |
| RS_ST03 | 1,054 | 455 | Medium sand | 1.70 | 0.15 | 32.30 | 47.82 | 19.88 | Muddy sandy gravel |
| RS_ST04 | 1,054 | 1927 | Very coarse sand | 1.72 | 0.19 | 50.53 | 39.32 | 10.15 | Muddy sandy gravel |
| RS_ST05 | 1,057 | 3535 | Granule | 1.67 | 0.16 | 59.62 | 32.22 | 8.16 | Muddy sandy gravel |
| RS_ST06 | 1,069 | 255 | Medium sand | 2.03 | 0.20 | 21.96 | 53.65 | 24.39 | Gravelly muddy sand |
| RS_ST07 | 1,062 | 1792 | Very coarse sand | 1.70 | 0.21 | 52.71 | 36.67 | 10.62 | Muddy sandy gravel |
| RS_ST08 | 1,066 | 7610 | Fine pebble | 1.70 | 0.24 | 82.51 | 16.84 | 0.64 | Gravel |
| RS_ST09 | 1,068 | 3008 | Granule | 1.76 | 0.17 | 62.06 | 30.09 | 7.85 | Muddy sandy gravel |
| RS_ST10 | 1,070 | 585 | Coarse sand | 1.85 | 0.15 | 31.81 | 51.65 | 16.55 | Muddy sandy gravel |
| RS_ST11 | 1,063 | 580 | Coarse sand | 1.80 | 0.17 | 32.31 | 52.11 | 15.57 | Muddy sandy gravel |
| RS_ST12 | 1,060 | 1864 | Very coarse sand | 2.07 | 0.18 | 54.31 | 34.38 | 11.31 | Muddy sandy gravel |
| RS_ST13 | 1,065 | 6978 | Fine pebble | 2.13 | 0.19 | 71.91 | 17.52 | 10.57 | Muddy sandy gravel |
| RS_ST14 | 1,068 | 8519 | Medium pebble | 1.90 | 0.19 | 68.31 | 23.63 | 8.06 | Muddy sandy gravel |
| RS_ST15 | 1,061 | 815 | Coarse sand | 1.92 | 0.40 | 39.15 | 45.32 | 15.53 | Muddy sandy gravel |
| Mean | | 2612 | - | 1.97 | 0.20 | 48.57 | 39.00 | 12.43 | - |
| SD | | 2820 | - | 0.642 | 0.061 | 17.8 | 12.9 | 5.66 | - |
| RSD (%) | | 108 | - | 33 | 30 | 37 | 33 | 46 | - |

| Station | Depth (m) | Mean Particle Size | | TOM (%) | TOC (%) | Fractional Composition | | | Folk Description |
|---|---|---|---|---|---|---|---|---|---|
| | | µm | Wentworth (1922) Description | | | Gravel (%) | Sand (%) | Fines (%) | |
| **Tornado to Tormore Pipeline Route Corridor Survey Area** | | | | | | | | | |
| PR_ST01 | 1,085 | 15987 | Medium pebble | 2.23 | 0.23 | 81.49 | 13.32 | 5.19 | Gravel |
| PR_ST02 | 1,065 | 2466 | Granule | 1.97 | 0.15 | 57.68 | 31.06 | 11.26 | Muddy sandy gravel |
| PR_ST03 | 1,052 | 8272 | Medium pebble | 1.99 | 0.14 | 72.70 | 20.81 | 6.49 | Muddy sandy gravel |
| PR_ST05 | 1,030 | 1955 | Very coarse sand | 2.03 | 0.26 | 57.40 | 29.90 | 12.69 | Muddy sandy gravel |
| PR_ST06 | 1,021 | 970 | Coarse sand | 1.66 | 0.16 | 40.90 | 45.47 | 13.63 | Muddy sandy gravel |
| PR_ST07 | 1,020 | 902 | Coarse sand | 1.92 | 0.18 | 40.78 | 46.24 | 12.98 | Muddy sandy gravel |
| PR_ST09 | 1,038 | 141 | Fine sand | 1.99 | 0.19 | 2.42 | 78.43 | 19.14 | Muddy sand |
| PR_ST10 | 1,018 | 2478 | Granule | 1.92 | 0.25 | 58.48 | 33.64 | 7.88 | Muddy sandy gravel |
| PR_ST12 | 1,010 | 616 | Coarse sand | 1.71 | 0.16 | 34.01 | 50.95 | 15.03 | Muddy sandy gravel |
| PR_ST13 | 1,024 | 1369 | Very coarse sand | 1.83 | 0.18 | 47.85 | 39.64 | 12.50 | Muddy sandy gravel |
| PR_ST14 | 1,023 | 3613 | Granule | 1.99 | 0.16 | 60.56 | 31.35 | 8.09 | Muddy sandy gravel |
| PR_ST15 | 1,012 | 689 | Coarse sand | 1.68 | 0.22 | 35.44 | 52.01 | 12.55 | Muddy sandy gravel |
| PR_ST16 | 982 | 3991 | Granule | 2.02 | 0.06 | 62.26 | 29.92 | 7.82 | Muddy sandy gravel |
| PR_ST17 | 911 | 230 | Fine sand | 1.96 | 0.23 | 13.27 | 71.27 | 15.47 | Gravelly muddy sand |
| PR_ST18 | 869 | 110 | Very fine sand | 2.27 | 0.16 | 3.20 | 75.64 | 21.16 | Muddy sand |
| PR_ST19 | 823 | 112 | Very fine sand | 2.15 | 0.28 | 0.48 | 84.65 | 14.88 | Muddy sand |
| PR_ST20 | 750 | 126 | Fine sand | 1.42 | 0.14 | 0.00 | 90.26 | 9.74 | Sand |
| PR_ST21 | 716 | 533 | Coarse sand | 1.61 | 0.19 | 29.60 | 60.09 | 10.31 | Gravelly muddy sand |
| PR_ST22 | 679 | 126 | Fine sand | 1.98 | 0.23 | 3.05 | 80.86 | 16.09 | Muddy sand |

| Station | Depth (m) | Mean Particle Size | | TOM (%) | TOC (%) | Fractional Composition | | | Folk Description |
|---|---|---|---|---|---|---|---|---|---|
| | | µm | Wentworth (1922) Description | | | Gravel (%) | Sand (%) | Fines (%) | |
| PR_ST23 | 663 | 211 | Fine sand | 2.02 | 0.25 | 14.86 | 67.12 | 18.02 | Gravelly muddy sand |
| PR_ST24 | 622 | 1784 | Very coarse sand | 2.06 | 0.61 | 45.59 | 44.04 | 10.37 | Muddy sandy gravel |
| Mean | | 2223 | - | 1.92 | 0.21 | 36.29 | 51.27 | 12.44 | - |
| SD | | 3700 | - | 0.208 | 0.105 | 25.8 | 22.6 | 4.22 | - |
| RSD (%) | | 166 | - | 11 | 50 | 71 | 44 | 34 | - |
| **Regional Comparisons** | | | | | | | | | |
| AFEN 1996 (AFEN, 2000) | Mean | 262 | - | 1.70 | 0.74 | - | - | - | - |
| | RSD (%) | 50 | - | 20 | 45 | - | - | - | - |

'-' = No value reported

### 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, 2001). A summary of the sediment hydrocarbon concentrations recorded at the Tornado site survey area and within the pipeline route corridor are presented in Table 4.2.

Total hydrocarbon concentrations (THCs) of the sediments recorded in the Tornado survey area within the vicinity of the proposed drill centre (RS_ST11 to RS_ST15) were generally consistently low, ranging from 2.3 $mg.kg^{-1}$ at stations RS_ST11 and RS_ST12 to 3.1 $mg.kg^{-1}$ at station RS_ST14. THCs of the sediments recorded within the Tornado pipeline route corridor were generally consistently low, ranging from 1.6 $mg.kg^{-1}$ at station PR_ST03 to 3.5 $mg.kg^{-1}$ at station PR_ST18. Variability along the pipeline was low (Fugro, 2025c; 2025d). The mean THC values within the vicinity of the proposed drill centre and along the pipeline route were comparable to THC values recorded during previous surveys within the region (AFEN, 2000; MMT, 2019; Gardline, 2001; DTI, 2003; Equinor, 2022).

The carbon preference index (CPI) is used to assess the relative contribution from petrogenic (petroleum-related) and biogenic (natural) sources in hydrocarbon samples. The CPI for the full saturate range ($nC_{12}$ to $nC_{36}$) was fairly consistent within the vicinity of the proposed drill centre (RS_ST11 to RS_ST15), ranging from 1.37 at station RS_ST14 to 1.48 at RS_ST11 and RS_ST15, with an overall mean of 1.43 in the vicinity of the proposed drill centre. The CPI for the full saturate range ($nC_{12}$ to $nC_{36}$) within the pipeline route corridor was fairly consistent, ranging from 1.23 at station PR_ST10 to 1.94 at PR_ST19, with an overall mean of 1.54. These results indicate a minor dominance of biogenic, odd-carbon numbered alkanes which are likely to be mostly allochthonous in origin (i.e. originated at a distance from their present location). The mean CPI value for the full saturate range ($nC_{12}$ to $nC_{36}$) within the proposed Tornado site and along the pipeline route were comparable to or lower than CPI values recorded during previous surveys within the region (AFEN, 2000; MMT, 2019).

Pristane to phytane (types of n-alkane) ratios can also provide information on the relative contribution of biogenic hydrocarbon sources. Pristane is primarily biogenic in origin, whilst phytane is rarely produced biogenically and, in the natural environmental, it is generally absent or only present at low concentrations (McDougall, 2000). A lower pristane to phytane ratio indicates both biogenic and petrogenic sources of n-alkanes, whilst high ratios indicate a dominance of biogenic sources for the n-alkanes. The Tornado site and pipeline route corridor survey found generally high ratios of pristane to phytane, indicating a dominance of the more biogenic pristane, suggesting a general biogenic influence from potential planktonic and terrestrial inputs across the Tornado survey area. This dominance of pristane was comparable to pristane dominance recorded during previous surveys in the region (AFEN, 2000; MMT, 2019).

PAH are largely formed by the incomplete combustion of organic matter. Total US EPA 16 PAH concentrations were moderate to low within the vicinity of the proposed drill centre; ranging from < 12.0 $\mu g.kg^{-1}$ to < 16.0 $\mu g.kg^{-1}$ with a mean of < 14.4 $\mu g.kg^{-1}$ (Fugro, 2025c). Total US EPA 16 PAH concentrations were moderate throughout the Tornado pipeline route corridor survey area; ranging from < 10.8 $\mu g.kg^{-1}$ to < 23.2 $\mu g.kg^{-1}$ with a mean of < 16.2 $\mu g.kg^{-1}$ (Fugro, 2025d). For all the US EPA 16 and alkylated PAH compounds assessed (individual and total), the concentrations reported within the survey area were below the ERL threshold concentrations (OSPAR, 2014). As a result, the PAH concentrations present are unlikely to have an adverse impact on the macrofaunal community.

**Table 4.2: Summary of Seabed Sediment Hydrocarbon Concentrations (Fugro, 2025c; 2025d)**

| Station | Depth (m) | THC ($mg.kg^{-1}$) | Carbon Preference Index Ratio ($nC_{12-36}$) | Pristane / Phytane Ratio | Total US EPA 16 PAHs ($\mu g.kg^{-1}$) |
|---|---|---|---|---|---|
| **Tornado Site Survey Area** | | | | | |
| RS_ST01 | 1,045 | 2.7 | 1.42 | 2.65 | <14.6 |
| RS_ST02 | 1,046 | 3.8 | 1.33 | 1.88 | <13.7 |
| RS_ST03 | 1,054 | 3.7 | 1.39 | 0.80 | <14.0 |
| RS_ST04 | 1,054 | 2.9 | 1.47 | 2.63 | <18.4 |
| RS_ST05 | 1,057 | 2.1 | 1.37 | 1.80 | <11.4 |
| RS_ST06 | 1,069 | 2.0 | 1.41 | 2.22 | <11.3 |
| RS_ST07 | 1,062 | 2.5 | 1.43 | 2.31 | <15.3 |
| RS_ST08 | 1,066 | 2.7 | 1.44 | 2.29 | <19.0 |
| RS_ST09 | 1,068 | 2.7 | 1.41 | 2.76 | <25.3 |
| RS_ST010 | 1,070 | 4.3 | 1.34 | 2.02 | <21.3 |
| RS_ST11 | 1,063 | 2.3 | 1.48 | 2.42 | <15.4 |
| RS_ST12 | 1,060 | 2.3 | 1.42 | 1.99 | <12.0 |
| RS_ST13 | 1,065 | 2.4 | 1.39 | 1.92 | <15.1 |
| RS_ST14 | 1,068 | 2.8 | 1.37 | 2.61 | <13.5 |
| RS_ST15 | 1,061 | 3.1 | 1.48 | 2.39 | <16.0 |
| Mean | | 2.8 | 1.41 | 2.18 | 15.8 |
| SD | | 0.66 | 0.046 | 0.489 | 3.84 |
| RSD (%) | | 23 | 3 | 22 | 24 |
| **Tornado to Tormore Pipeline Route Corridor Survey Area** | | | | | |
| PR_ST01 | 1,085 | 2.6 | 1.39 | 1.82 | <12.7 |
| PR_ST02 | 1,065 | 3.4 | 1.29 | 4.49 | <23.2 |
| PR_ST03 | 1,052 | 1.6 | 1.64 | 2.28 | <10.8 |
| PR_ST05 | 1,030 | 2.0 | 1.61 | 2.58 | <15.4 |
| PR_ST06 | 1,021 | 2.6 | 1.42 | 2.14 | <14.9 |
| PR_ST07 | 1,020 | 2.8 | 1.33 | 2.19 | <13.5 |
| PR_ST09 | 1,038 | 2.8 | 1.51 | 2.42 | <19.2 |
| PR_ST10 | 1,018 | 3.1 | 1.23 | 4.65 | <13.6 |
| PR_ST12 | 1,010 | 2.5 | 1.32 | 2.23 | <12.0 |
| PR_ST13 | 1,024 | 3.1 | 1.46 | 2.24 | <17.5 |
| PR_ST14 | 1,023 | 2.3 | 1.57 | 1.92 | 19.4 |
| PR_ST15 | 1,012 | 3.0 | 1.48 | 2.10 | <14.4 |
| PR_ST16 | 982 | 2.5 | 1.44 | 2.52 | <12.7 |
| PR_ST17 | 911 | 2.2 | 1.44 | 2.57 | <13.1 |
| PR_ST18 | 869 | 3.5 | 1.83 | 2.32 | <16.0 |
| PR_ST19 | 823 | 2.8 | 1.94 | 4.46 | <17.6 |
| PR_ST20 | 750 | 2.0 | 1.76 | 2.40 | <16.8 |
| PR_ST21 | 716 | 2.0 | 1.73 | 2.89 | <17.7 |
| PR_ST22 | 679 | 3.0 | 1.72 | 4.47 | <19.4 |
| PR_ST23 | 663 | 2.7 | 1.57 | 2.82 | <19.6 |
| PR_ST24 | 622 | 1.9 | 1.62 | 2.28 | <21.3 |
| Mean | | 2.6 | 1.54 | 2.75 | 16.2 |
| SD | | 0.51 | 0.187 | 0.914 | 3.34 |
| RSD (%) | | 20 | 12 | 33 | 21 |
| **Regional Comparison** | | | | | |
| AFEN 1996 (AFEN, 2000) | Mean | 2.6 | 1.54 | 2.11 | - |
| | RSD (%) | 36 | 8 | 25 | - |
| Cambo Field Development Survey (MMT, 2019) | Mean | - | 1.58 | 5.06 | 21.88 |
| | SD | - | 0.18 | 2.59 | 13.86 |
| Cambo UKCS 204/10 (Gardline, 2001) | Mean | 2.49 | - | - | - |
| SEA4 (DTI, 2003) | - | 0.8 - 11 | - | - | - |

'-' = No value reported

### Sediment 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).

The biological or ecological effects of metals on organisms has been investigated and researchers have defined the term 'effect range low' (ERL) as the lowest concentration of a metal which produces adverse effects in 10% of the data reviewed. Therefore, metal concentrations below the ERL value are unlikely to produce harmful effects (Fugro, 2025c; 2025d).

Table 4.3 presents a summary of the concentrations of the extractable metals in the sediment samples from a hydrofluoric acid digest. Overall, metal concentrations across the entire Tornado site survey area and along the Tornado pipeline route corridor were consistently low, with many displaying similar patterns of distribution (Table 4.3; Fugro, 2025c; 2025d). No spatial trends in metals concentrations were evident.

The majority of metal concentrations were below their respective ERL values and therefore it is unlikely that detrimental impacts to the benthic communities would occur, shown by the low variability in the composition of the macrofaunal community present at the survey area. An exception to this was the concentrations of chromium and copper which exceeded the ERL values at several stations. However, as a total digest of hydrofluoric acid was used, data may not be representative of the bioavailable content. Concentration of metals are presented as total concentrations rather than bioavailable concentrations, so they account for metals within both the available and unavailable fractions. Therefore, while concentrations may exceed the ERL values, a proportion of this is unlikely to be available for uptake by biota (Fugro, 2025c; 2025d).

The mean concentrations of some metals (barium, chromium, copper, nickel, lead, strontium, vanadium, and zinc) exceeded the AFEN survey mean values (AFEN, 2000). Chromium, copper and vanadium are commonly found in drilling muds. However, the low variation across the survey areas demonstrated that the concentrations present were not localised to the nearby wells and are more likely originating from geogenic sources from basic igneous rocks (Fugro, 2025c; 2025d).

The sediment metals results were also normalised to 5 % aluminium in line with OSPAR reference values. When normalised to 5 % aluminium, OSPAR BAC values were exceeded for chromium copper, and nickel at all stations along the proposed pipeline route and were exceeded for chromium at all stations, copper at 18 stations, and nickel at 20 stations within the site survey area. Concentrations that were higher than the BAC values are considered to be above background but at levels where it can be assumed that little or no risks are posed to the environment and its living resource at the population or community level (Fugro, 2025c; 2025d).

### Comparisons with Regional Survey Data

The historical regional data within the vicinity of the Tornado field used the same analytical techniques as the Tornado survey and showed comparable results. Environmental baseline surveys conducted over the Cambo development area and the proposed Rosebank development area found that concentrations of THC, PAHs and heavy metals were all within background levels for the region, indicating little or no inputs from anthropogenic activity (MMT, 2019; Gardline, 2001).

**Table 4.3: Summary of Sediment Metal Analysis (µg/g dry sediment) (Fugro, 2025c; Fugro, 2025d)**

| Station | Depth (m) | Al | As | Ba | Cd | Cr | Cu | Fe | Hg | Mn | Ni | Pb | Se | Sn | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tornado Site Survey Area** | | | | | | | | | | | | | | | | | |
| RS_ST01 | 1045 | 44500 | 8.4 | 430 | 0.2 | 136 | 41 | 45200 | 0.01 | 1010 | 42.4 | 15 | < 10 | 0.9 | 536 | 186 | 76.6 |
| RS_ST02 | 1046 | 39600 | 8.1 | 353 | 0.2 | 107 | 38.1 | 40800 | 0.03 | 921 | 38.4 | 15.2 | < 10 | < 0.50 | 551 | 165 | 70 |
| RS_ST03 | 1054 | 43700 | 7.6 | 403 | 0.2 | 120 | 38.9 | 43500 | 0.03 | 1040 | 43.5 | 15.9 | < 10 | < 0.50 | 495 | 179 | 74.5 |
| RS_ST04 | 1054 | 42300 | 8.1 | 400 | 0.2 | 128 | 39.6 | 43400 | 0.03 | 1020 | 42.5 | 15.3 | < 10 | < 0.50 | 524 | 183 | 73.8 |
| RS_ST05 | 1057 | 43900 | 7.2 | 418 | 0.2 | 122 | 42.5 | 45800 | 0.03 | 1040 | 42.8 | 15.9 | < 10 | < 0.50 | 536 | 191 | 76.3 |
| RS_ST06 | 1069 | 45300 | 7.7 | 370 | 0.2 | 119 | 39.8 | 44300 | 0.04 | 1010 | 42.1 | 15.7 | < 10 | 0.6 | 545 | 183 | 76.7 |
| RS_ST07 | 1062 | 44300 | 7.6 | 406 | 0.2 | 123 | 41.4 | 45600 | 0.03 | 1040 | 42.9 | 15.1 | < 10 | < 0.50 | 541 | 192 | 75.4 |
| RS_ST08 | 1066 | 45800 | 7.9 | 404 | 0.2 | 125 | 38.7 | 43700 | 0.03 | 980 | 42.1 | 14.5 | < 10 | < 0.50 | 511 | 183 | 78.6 |
| RS_ST09 | 1068 | 45800 | 8.2 | 416 | 0.2 | 126 | 39.7 | 44900 | 0.03 | 988 | 41.4 | 15.1 | < 10 | < 0.50 | 554 | 186 | 71.7 |
| RS_ST010 | 1070 | 47000 | 8.6 | 381 | 0.2 | 124 | 42.3 | 46000 | 0.03 | 1040 | 42.5 | 17.3 | < 10 | < 0.50 | 581 | 187 | 78.4 |
| RS_ST11 | 1063 | 49000 | 7.7 | 359 | 0.2 | 132 | 41.8 | 47500 | 0.02 | 1150 | 46.4 | 12.3 | < 10 | < 0.50 | 531 | 196 | 76.6 |
| RS_ST12 | 1060 | 46100 | 7.7 | 396 | 0.2 | 125 | 39 | 42800 | 0.03 | 952 | 40.5 | 14.2 | < 10 | < 0.50 | 562 | 181 | 72 |
| RS_ST13 | 1065 | 45900 | 7.9 | 367 | 0.1 | 105 | 33.7 | 39500 | 0.03 | 868 | 38.1 | 14.3 | < 10 | < 0.50 | 522 | 157 | 66.9 |
| RS_ST14 | 1068 | 47600 | 7.6 | 388 | 0.2 | 115 | 34.5 | 39900 | 0.03 | 899 | 38.9 | 13.4 | < 10 | < 0.50 | 535 | 168 | 66.1 |
| RS_ST15 | 1061 | 47700 | 7.6 | 492 | 0.1 | 103 | 31.2 | 38000 | 0.02 | 854 | 36.8 | 13.4 | < 10 | < 0.50 | 490 | 152 | 64.2 |
| Mean | | 45200 | 7.90 | 399 | 0.19 | 121 | 38.8 | 43400 | 0.03 | 987 | 41.4 | 14.8 | - | - | 534 | 179 | 73.2 |
| SD | | 2340 | 0.364 | 34.2 | 0.035 | 9.57 | 3.29 | 2730 | 0.0068 | 78.0 | 2.48 | 1.22 | - | - | 24.0 | 12.9 | 4.58 |
| RSD (%) | | 5 | 5 | 9 | 19 | 8 | 8 | 6 | 24 | 8 | 6 | 8 | - | - | 4 | 7 | 6 |
| **Tornado to Tormore Pipeline Route Corridor Survey Area** | | | | | | | | | | | | | | | | | |
| PR_ST01 | 1085 | 43400 | 7 | 388 | 0.1 | 113 | 34.2 | 39000 | 0.02 | 868 | 38.8 | 13.9 | < 10 | 1 | 446 | 159 | 66.7 |
| PR_ST02 | 1065 | 45400 | 7.8 | 428 | 0.2 | 116 | 32.6 | 37900 | 0.02 | 878 | 38.8 | 13.6 | < 10 | < 0.50 | 461 | 153 | 63 |
| PR_ST03 | 1052 | 43600 | 6.8 | 428 | 0.2 | 122 | 31.5 | 36700 | 0.02 | 822 | 38.7 | 12.8 | < 10 | 0.6 | 437 | 153 | 60.6 |
| PR_ST05 | 1030 | 45300 | 6.7 | 371 | 0.1 | 93.3 | 27.9 | 34700 | 0.02 | 730 | 34.9 | 12 | < 10 | 0.6 | 403 | 123 | 56.7 |
| PR_ST06 | 1021 | 44400 | 6.6 | 367 | <0.10 | 77.3 | 22.2 | 30400 | 0.01 | 631 | 30.9 | 10.9 | < 10 | < 0.50 | 322 | 107 | 50 |
| PR_ST07 | 1020 | 41300 | 7.5 | 411 | 0.2 | 121 | 37 | 43500 | 0.03 | 1100 | 42.4 | 14.2 | < 10 | 0.8 | 499 | 173 | 70.7 |
| PR_ST09 | 1038 | 40100 | 7.8 | 413 | 0.2 | 115 | 36.6 | 42900 | 0.03 | 1020 | 40.7 | 16.6 | < 10 | 1 | 520 | 171 | 73.4 |
| PR_ST10 | 1018 | 41000 | 7.8 | 376 | 0.1 | 99.9 | 34 | 41800 | 0.02 | 1020 | 39 | 12.1 | < 10 | < 0.50 | 466 | 162 | 68.3 |
| PR_ST12 | 1010 | 39800 | 7.3 | 387 | 0.2 | 102 | 34.6 | 41000 | 0.03 | 1020 | 38.9 | 13 | < 10 | < 0.50 | 483 | 162 | 67.4 |
| PR_ST13 | 1024 | 41500 | 7.6 | 409 | 0.2 | 110 | 37.6 | 42900 | 0.03 | 1020 | 43.6 | 14.6 | < 10 | < 0.50 | 510 | 168 | 75.4 |

| Station | Depth (m) | Al | As | Ba | Cd | Cr | Cu | Fe | Hg | Mn | Ni | Pb | Se | Sn | Sr | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PR_ST14 | 1023 | 42100 | 7.7 | 413 | 0.2 | 112 | 34.2 | 42200 | 0.03 | 1010 | 39.8 | 14.3 | < 10 | 0.5 | 472 | 166 | 68.9 |
| PR_ST15 | 1012 | 40100 | 7.5 | 457 | 0.2 | 112 | 35.2 | 40200 | 0.03 | 977 | 38.5 | 15.9 | < 10 | < 0.50 | 492 | 164 | 68 |
| PR_ST16 | 982 | 37600 | 8.6 | 403 | 0.2 | 88.9 | 28.6 | 35500 | 0.03 | 886 | 38 | 14.9 | < 10 | < 0.50 | 470 | 131 | 59.2 |
| PR_ST17 | 911 | 38600 | 7.1 | 434 | 0.2 | 93.8 | 33.9 | 38400 | 0.03 | 957 | 37.7 | 16.6 | < 10 | < 0.50 | 509 | 149 | 66.4 |
| PR_ST18 | 869 | 38400 | 7.6 | 528 | 0.2 | 116 | 33 | 41000 | 0.03 | 961 | 38.7 | 15.1 | < 10 | < 0.50 | 468 | 159 | 67.6 |
| PR_ST19 | 823 | 41800 | 8.8 | 398 | 0.2 | 103 | 25.5 | 51400 | 0.03 | 994 | 40.6 | 14.4 | < 10 | 0.6 | 403 | 135 | 66.7 |
| PR_ST20 | 750 | 27600 | 5 | 346 | 0.1 | 65.3 | 14.4 | 23600 | 0.02 | 617 | 25.2 | 13.4 | < 10 | < 0.50 | 396 | 78 | 37.9 |
| PR_ST21 | 716 | 27800 | 5.3 | 342 | 0.1 | 66.4 | 18.4 | 27000 | 0.02 | 512 | 26.1 | 12.2 | < 10 | < 0.50 | 520 | 87.3 | 44.5 |
| PR_ST22 | 679 | 28000 | 6.5 | 327 | 0.1 | 66.1 | 19.5 | 29500 | 0.02 | 591 | 27 | 14.2 | < 10 | < 0.50 | 588 | 93.2 | 47 |
| PR_ST23 | 663 | 34000 | 5.7 | 456 | 0.2 | 80.6 | 21.2 | 30500 | 0.02 | 493 | 32.7 | 12.9 | < 10 | < 0.50 | 530 | 99 | 51.5 |
| PR_ST24 | 622 | 34400 | 7 | 618 | 0.2 | 84 | 24.1 | 32200 | 0.03 | 791 | 36.8 | 14.7 | < 10 | < 0.50 | 559 | 108 | 53.2 |
| Mean | | 38900 | 7.13 | 414 | 0.16 | 98.0 | 29.3 | 37200 | 0.02 | 852 | 36.5 | 13.9 | - | - | 474 | 138 | 61.1 |
| SD | | 5530 | 0.957 | 64.7 | 0.053 | 18.6 | 6.93 | 6590 | 0.006 | 186 | 5.22 | 1.49 | - | - | 60.4 | 30.9 | 10.2 |
| RSD (%) | | 14 | 13 | 16 | 32 | 19 | 24 | 18 | 24 | 22 | 14 | 11 | - | - | 13 | 22 | 17 |
| **Regional Comparison** | | | | | | | | | | | | | | | | | |
| Cambo Field Development (MMT, 2019) | Mean | 29333 | 3.9 | 327.9 | 0.1 | 33.9 | 11.9 | 19508 | 0.0 | 390 | 15.7 | 8.2 | 0.0 | 0.5 | 299.1 | 52.2 | 30.8 |
| | SD | 3950 | 1.3 | 37.2 | 0.1 | 5.9 | 3.1 | 3510 | 0.0 | 70 | 2.3 | 1.0 | 0.0 | 0.3 | 141.1 | 12.0 | 6.9 |
| AFEN 1996 (AFEN, 2000) | Mean | - | - | 333 | < 1 | 44 | 15 | - | - | - | 27 | 6 | - | - | 232 | 53 | 29 |
| | RSD (%) | - | - | 9 | - | 23 | 26 | - | - | - | 16 | 47 | - | - | 13 | 26 | 19 |
| Cambo UKCS 204/10 (Gardline, 2001) | Mean | - | - | 284 | 0 | 51 | 17 | - | - | - | - | 20 | - | - | - | - | 43 |
| SEA4 (DTI, 2003) | - | - | - | 208 - 349 | NC | 10 - 35 | 2 - 39 | - | - | - | - | 3 - 20 | - | - | - | - | 15 - 76 |
| **Reference Levels** | | | | | | | | | | | | | | | | | |
| CEMP Assessment Criteria ERL (OSPAR, 2014) | | - | - | - | 1.20 | 81.0 | 34.0 | - | 0.150 | - | - | 47.0 | - | - | - | - | 150 |
| **Key** | | | | | | | | | | | | | | | | | |
| | Exceeds the reference levels | | | | | | | | | | | | | | | | |
| NC = Not calculated due to values being below the Limit of Detection; '-' = No value reported | | | | | | | | | | | | | | | | | |

### 4.2.4 Hydrography

The WoS area is characterised by persistent, long-period swells, complex current regimes and rapidly changing weather conditions. The deep water over the edge of the continental slope WoS is exposed to a large fetch and strong winds, particularly from the west and southwest. These conditions generate an extreme wave regime in the area, which is more severe than that experienced in the northern North Sea.

In total, five distinct water masses are present in the channel, each of which may be described in relation to their geographical position and vertical distribution in the water column (Figure 4.5).

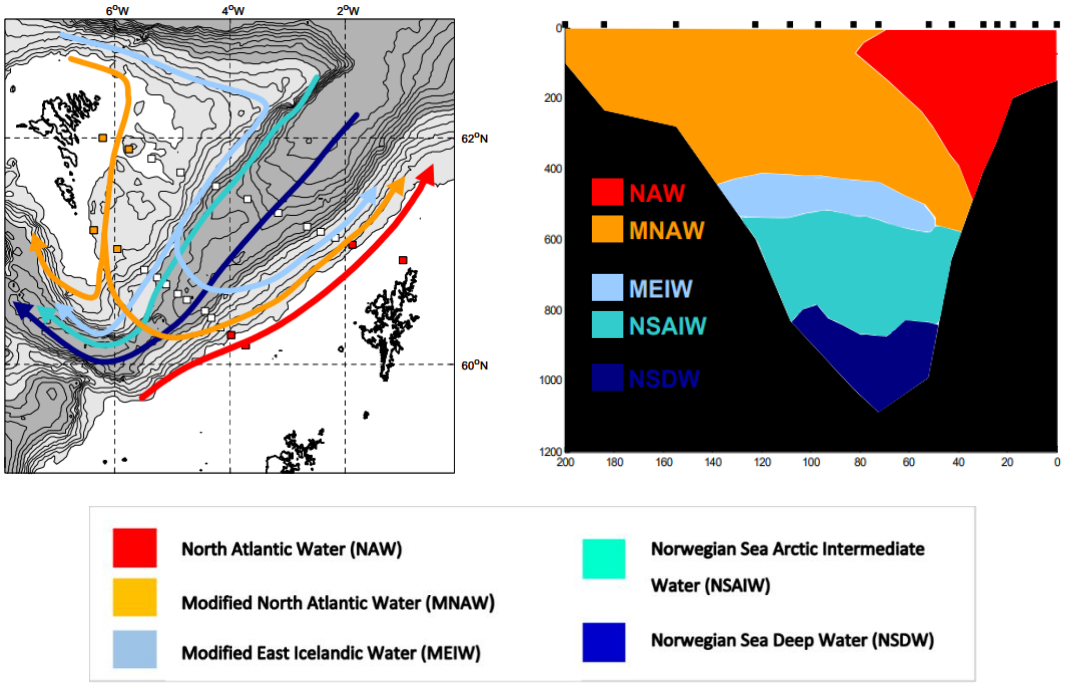



**Figure 4.5: Water Masses and Ocean Current Circulation in the Faroe-Shetland Channel (Hughes and Turrell, 2006)**

Two slow moving deepwater masses originate from Arctic waters and travel southward through the Faroe-Shetland channel towards the Wyville-Thomson Ridge. The Faroe-Shetland Channel bottom waters occur below 800 m on the Faroe shelf side and below 600 m on the Shetland shelf side of the channel, flowing to the southwest along the channel floor. The Norwegian Sea Intermediate Waters occur just above these, at depths of around 600 m to 800 m. This water layer becomes shallower towards the Scottish slope and is often absent from this side of the channel (BEIS, 2022). These dense cold waters flow along the bottom of the channel in a south-westerly direction, while a warmer layer of water moves over the top in the opposite direction from the North Atlantic (Metoc, 2002). This warmer North Atlantic water flows in from the southwest, dividing into northern and southern branches, with the southern branch passing in a north-easterly direction along the continental slope and shelf to the WoS.

The Atlantic intermediate/north Icelandic waters occur from approximately 400 m to 600 m depth. These waters enter the Faroe-Shetland Channel from the north and split to form two flows, with one moving northeast and one southwest along the channel (Turrell et al, 1999). In the region of the proposed Tornado Development, these waters flow in a northeasterly direction.

Two bodies of water from the North Atlantic form the dominant surface currents in the region of the proposed Tornado Development. These surface waters are limited to a depth of around 400 m. North Atlantic waters originate from the south and enter the Faroe-Shetland Channel over the Wyville-Thomson Ridge. These surface waters flow to the northeast through the channel, confined to the eastern (Scottish) slope (Debes, 2000; BEIS, 2022). Modified North Atlantic waters flow to the north around the Faroe Islands, splitting into two currents, one flowing to the west and one to the northeast

along the Faroese side of the Channel. The surface currents originate from more southerly, Atlantic waters and so are relatively warm.

Net flow of surface waters in the Faroe-Shetland Channel is to the northeast. Currents are strongest along the upper continental slope, where they average around 0.3 m/s. The mean velocity of the shelf edge current is approximately 0.4 m/s towards the northeast, and in the lower water mass 0.15 m/s towards the southwest (Saunders, 1990). Measured near-bottom current velocities indicate peak currents over 0.75 m/s on the upper continental slope to the WoS (BEIS, 2022).

A metocean report was undertaken by PhysE Ltd in 2024, to analyse the suitability of existing wind, wave, and current design and operational criteria developed for the Cambo field development (as documented in PhysE, 2018 and updated by Fugro, 2018) in comparison to other sites in the region, namely Tornado (approximately 30 km to the southwest of Cambo), and Tormore (55 km to the east of Cambo), plus the proposed pipeline between the two (PhysE, 2024). It was found that the Cambo design and operational wind and wave criteria (PhysE, 2018) are applicable to Tornado, and that they are conservative - but not excessively so - for use at Tormore. Data from PhysE (2018) and Fugro (2018) has therefore been referenced below.

Analysis of wave height and direction for the Tornado area indicates that waves most frequently originate from the west and southwest (Figure 4.6). Mean significant wave heights were found to be between 1 and 4 m, with the 100-year maximum significant wave height found to be approximately between 32.3 m (PhysE, 2018) and 33 m (Fugro, 2018).

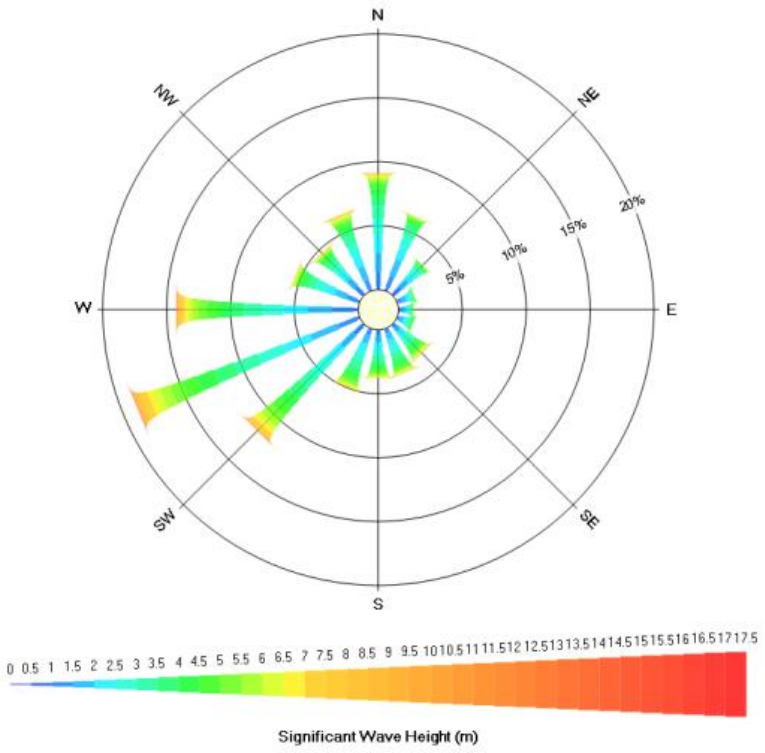



**Figure 4.6: Percentage Occurrence of Total Significant Wave Height and Mean Wave Direction in the Vicinity of Tornado Annually (PhysE, 2018)**

The Faroe-Shetland Channel features a permanent thermocline that marks the boundary between cold Arctic bottom waters and the warmer North Atlantic waters flowing above them, typically at depths of 400 to 600 m (Debes, 2000; SERPENT, 2009a). The temperature of the cold, dense bottom currents generally remains below 0°C, occasionally dipping as low as -1.5°C (Larsen et al., 2016). Above the thermocline, intermediate waters exhibit a rapid temperature increase, fluctuating between 3.0 and 4.5°C (Heath and Jónasdóttir, 1999). Sea surface temperatures in the channel vary seasonally, ranging from a minimum of 5.5°C to a maximum of 11.4°C (Larsen et al., 2016). Additionally, during spring and

summer, a shallower thermocline can form in the surface waters at depths of 20 to 50 metres, depending on prevailing wind conditions (Debes, 2000). Average sea surface temperature in the vicinity of the Tornado Field ranges from between 9.5 and 10°C, and the average near-bed temperature ranges from between 8 and 9°C (NMPi, 2024).

During winter months off the WoS (December to April) the water column is vertically very well mixed, and isotherms and isohalines are almost vertical. Salinity increases in deeper waters (greater than 100 m) and on the outer parts of the shelf the water is of Atlantic origin (greater than 35.2‰) (BEIS, 2022). Annual mean surface salinity in the vicinity of the Tornado Field is 35.2 ppt (NMPi, 2024).

Recent studies indicate that the temperature and salinity of surface waters in the Faroe–Shetland Channel have generally increased over the past two decades (Larsen et al., 2016; OSPAR, 2023). In the deeper layers of the channel, at around 800 m, temperatures have risen since 2000, while salinities have experienced a gradual decline, which is now believed to have stabilised (Larsen et al., 2016).

### 4.2.5 Meteorology

The WoS region has a generally mild, maritime climate resulting from prevailing south-westerly winds and the warming influence of the Atlantic Continental Slope current (DTI, 2003). The area around the proposed Tornado Development experiences frequent low cloud with periods of extensive rain and drizzle. The presence of sea fog is more common in the summer, with gales occurring during the winter months (DTI, 2003).

Although offshore winds around Tornado may blow from any direction, they principally blow from west to south-west (Figure 4.7), with winds of force 5 (8 m/s) or greater reported 70% of the time in winter and 30% of the time in the summer (BEIS, 2022). Mean wind speeds in the area surrounding Tornado were found to be between 7 and 11 m/s.

Stronger winds occur more frequently during the autumn and winter months, with wind speeds occasionally reaching over 34 m/s (Fugro, 2018). The 100-year extreme wind speed, represented as a 3-second gust speed at 10 m above sea level, could be as much as 56.3 m/s (PhysE, 2018).

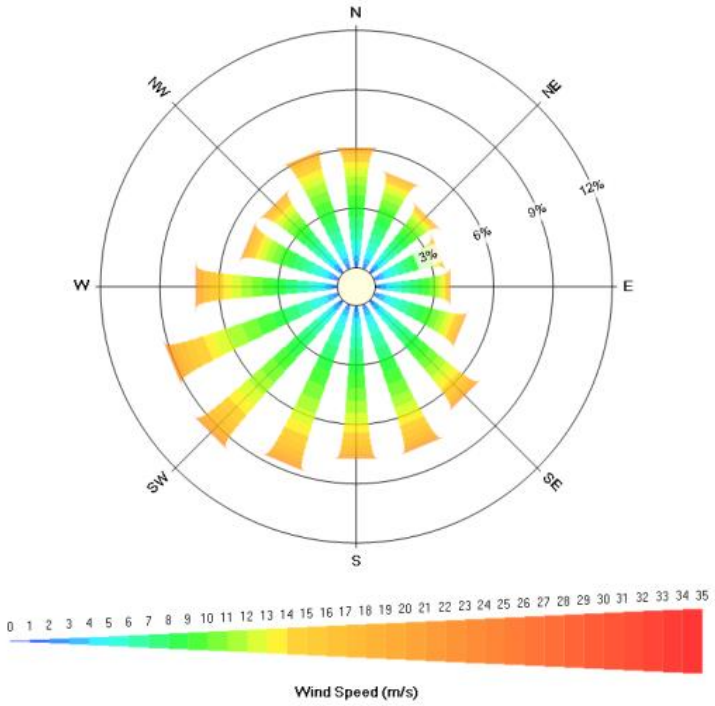



**Figure 4.7: 1 hourly Wind Speed Rose – Annual from Cambo Development Metocean Study (PhysE, 2018)**

### 4.2.6 Climate Change and GHG Emissions

The carbon cycle recycles carbon around the Earth between different reservoirs, which helps regulate global temperatures and make life possible. Over recent decades, however, scientific consensus has confirmed that the Earth's climate is undergoing significant change, largely driven by anthropogenic GHG emissions (IPCC, 2023a; IPCC, 2019a; WMO, 2023; WMO, 2019; UNEP; 2024).

A variety of up-to-date data sources have been examined for this section of the ES to characterise the current state of global GHG emissions in the atmosphere (expressed in carbon dioxide equivalent ($CO_2e$)[1] where available), analyse historical trends, review effects and look at future projections, including:

- Intergovernmental Panel on Climate Change (IPCC) – Sixth Assessment Report 'AR6' (IPCC, 2023b);
- United Nations Environment Programme (UNEP) – Emissions Gap Report 2024 (UNEP, 2024);
- Emissions Database for Global Atmospheric Research (EDGAR) (EDGAR, 2025);
- World Meteorological Organization (WMO) – WMO Greenhouse Gas Bulletin (WMO, 2023);
- National Oceanic and Atmospheric Administration (NOAA) – Global Monitoring Laboratory measurements (Lan et al., 2025);
- Indicators of Global Climate Change 2024 (Forster et al., 2025).

#### Global GHG Emissions – Current Status, Trends and Effects

Since 1850, human activities, including the combustion of fossil fuels, land-use change, and industrial activity have resulted in rapidly increasing concentrations of GHGs in the atmosphere, most notably $CO_2$, methane ($CH_4$) and nitrous oxide ($N_2O$) (Figure 4.8). Global mean concentrations for well-mixed GHGs ($CO_2$, $CH_4$ and $N_2O$) in 2019 correspond to increases of about 47%, 156%, and 23%, respectively, above the levels in 1750 (representative of the pre-industrial era) (high confidence) (IPCC, 2023a). This has unequivocally caused global warming.

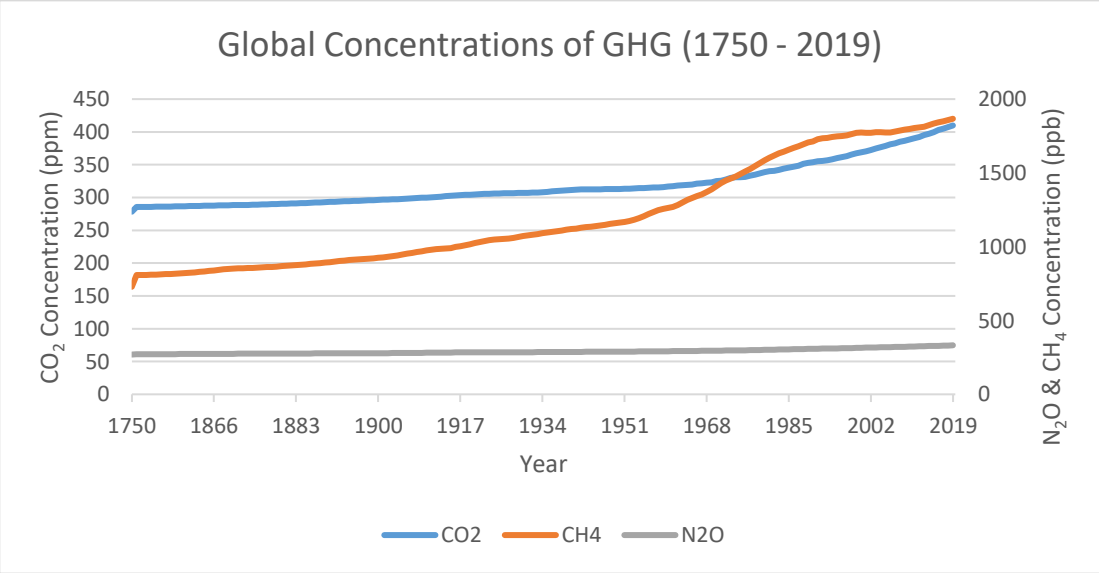



**Figure 4.8: Global GHG Emissions from 1750 to 2019[1]**

[1] Data obtained from IPCC (2023) Working Group 1 (WG1) Sixth Assessment Report (AR6) Annex III Extended Data

[1] $CO_2e$ is a metric used to express the impact of different greenhouse gases in terms of the amount of carbon dioxide that would produce the same global warming effect.

Over the past two decades (2000–2020), $CO_2$ emissions to the atmosphere from the burning of fossil fuels generally have risen year-on-year, starting at 6.8 petagrams (Pg) of carbon[2] per year in 2000 and reaching a maximum of 10.1 Pg of carbon in 2019 (Jacobson, 2023).

Over the period 2014–2023, it is estimated that the annual release rate of GHG emissions into the atmosphere averaged 53.6 ± 5.2 Gt $CO_2e$ per year (Forster et al., 2025), with the latest data from EDGAR (2025) indicating that 53.2 Gt $CO_2e$ was released in 2024 (Figure 4.9; EDGAR, 2025). In 2024, global energy-related GHG emissions reached 42.6 Gt $CO_2e$ (IEA, 2025).

In 2023, global GHG emissions set a new record of ca. 57.1 gigatons (Gt)[3] $CO_2e$ (UNEP, 2024), a 1.3% increase (0.7 $GtCO_2e$) from 2022 levels, with the power sector (i.e. fossil fuel combustion to generate electricity and heat in power plants) the largest global contributor to emissions at 15.1 $GtCO_2e$, followed by transport (8.4 $GtCO_2e$), agriculture (6.5 $GtCO_2e$) and industry (i.e. fossil fuel combustion to drive on-site industrial processes, such as heating furnaces) (6.5 $GtCO_2e$). The 1.3% increase in emissions above 2022 levels, is higher than the average rate in the decade preceding the COVID-19 pandemic (2010–2019), when GHG emissions growth averaged 0.8% per year (UNEP, 2024).

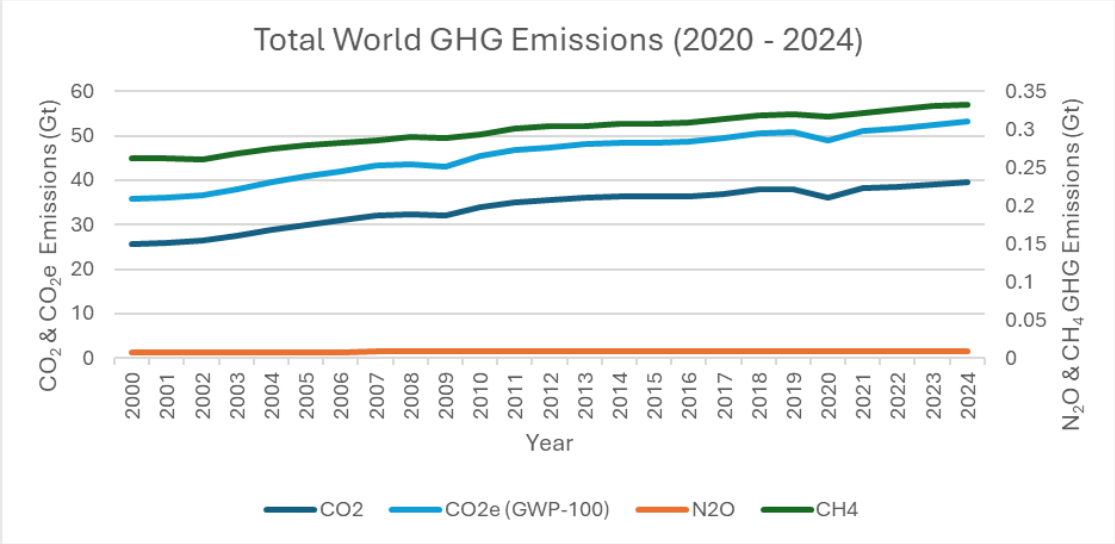



**Figure 4.9: Total Global GHG Emissions by $CO_2$, $N_2O$, $CH_4$ and $CO_2e$ (GWP-100 'AR5')** [1]

[1] Data obtained from EDGAR (2025) GHG total datasets (1974 – 2024), represented to show Gt of GHG, manipulated from base unit of Gg, to show period 2000 – 2024 (the past two decades).

The Global Monitoring Laboratory (GML) of the National Oceanic and Atmospheric Administration (NOAA) measures the atmospheric distribution and trends of $CO_2$, $CH_4$ and $N_2O$. In 2024, global average atmospheric $CO_2$ was 422.79 parts per million (ppm), a new record high, up from 419.36 ppm in 2023. The 3.72 ppm increase during 2024 was the largest one-year increase on record (Lan et al., 2025; Lindsey, 2025). New record highs were also set in 2024 for global average atmospheric $CH_4$ and $N_2O$ at 1,929.85 parts per billion (ppb) and 337.72 ppb, respectively (Lan et al., 2025).

The effects of climate change have been observed both quantitatively, i.e. global mean surface temperature rise, sea level rise, ocean heat content, sea ice extent; and qualitatively, i.e. coral bleaching, extreme weather patterns, seasonal shifting, and migratory species changes (IPCC, 2023a; 2019a; 2019b). Global surface temperature averaged over the decade 2011-2020 was 1.1°C warmer than the 1850-1900 average and the past ten years (2015-2024) were the warmest ten years on record (Met Ocean, 2025). Over the past two decades, the rate of ocean warming has increased to 0.66 ± 0.10 watts per square metre ($W/m^2$), with global mean sea level increasing by 0.20 m between 1901 and 2018 (IPCC, 2023a; IOC-UNESCO, 2024). The ocean has also absorbed enough $CO_2$ to lower its pH by 0.1 units, a 30% increase in acidity (Lindsey, 2025).

[2] One petagram of carbon is equal to one billion metric ton of carbon or 3.67 billion metric tons of $CO_2$.
[3] One gigaton is equivalent to one billion metric tons (1,000,000,000 tons)

### Projected Global GHG Emissions and Possible Future Climate Scenarios

The UNFCCC is an international agreement that commits countries to efforts to stabilise GHG concentrations to prevent dangerous, human-induced climate change. The 'COP' (Conference of the Parties) is the main decision-making body of the UNFCCC. In 2015, COP21 created the Paris Agreement, a global treaty that commits countries to limit global average temperature to well below 2°C above preindustrial levels and pursuing efforts to limit temperature increase to 1.5°C above preindustrial levels. At the heart of the Paris Agreement are NDCs, which embody efforts by each country to reduce national emissions and adapt to the impacts of climate change. Each country, including the UK, must submit a NDC to the UNFCCC secretariat every five years (UNFCCC, 2024).

The Paris Agreement's GST process is designed to evaluate progress on climate action at the global level every five years. The first-ever GST, which concluded at COP28 in December 2023, highlighted that whilst progress has been made since the Paris Agreement — global temperatures are now expected to rise by 2.4-2.6°C by the end of the century, compared to 3.7-4.8°C in 2010 – the world is not on track to limit global warming to 1.5ºC (CCC, 2024). It concluded that to keep 1.5ºC in reach, deep rapid and sustained reductions in global GHG emissions are required (43% by 2030 and 60% by 2035 from 2019 levels, aiming for net zero CO2 by 2050). Records show that 2024 was the first calendar year that the average global temperature exceeded 1.5°C above its pre-industrial level (EU Copernicus, 2025).

The GST process was informed by the IPCC AR6 cycle, completed in July 2023. AR6 defines a core set of five illustrative Shared Socio-economic Pathways (SSP) scenarios combined with Representative Concentration Pathways (RCP) scenarios – SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5. The SSP-RCP scenarios combine baseline socio-economic narratives (the SSPs; SSP1 to SSP5[4]), which incorporate assumptions about future socioeconomic developments (e.g. population growth, economic trends, and technological advancements), with different emissions trajectories informed by the RCP scenarios[5] which impose a level of radiative forcing in 2100, corresponding to a related level of global warming.

Over the life of the Tornado Development (2029 up to 2038), the quantity of global GHGs affecting climate will be subject to both natural and anthropogenic change. In nearly all considered scenarios and modelled pathways, global warming is predicted to continue to increase in the near term (2021–2040) mainly due to increased cumulative $CO_2$ emissions (IPCC, 2023b).

The high and very high GHG emissions scenarios (SSP3-7.0 and SSP5-8.5) have $CO_2$ emissions that roughly double from current levels by 2100 and 2050, respectively. The intermediate GHG emissions scenario (SSP2-4.5) has $CO_2$ emissions remaining around current levels until the middle of the century. The very low and low GHG emissions scenarios (SSP1-1.9 and SSP1-2.6) have $CO_2$ emissions declining to net zero around 2050 and 2070, respectively, followed by varying levels of net negative $CO_2$ emissions (refer to Table 4.4).

[4] Five pathways have been developed by the international scientific community – sustainable development (SSP1), middle-of-the-road development (SSP2), regional rivalry (SSP3), inequality (SSP4) and fossil-fuelled development (SSP5).

[5] RCP scenarios were defined in the IPCC's fifth assessment reporting cycle (AR5) and show how GHG concentrations can affect global temperatures. For example, RCP 8.5 represents a high-emissions pathway, while RCP 2.6 assumes strong mitigation efforts.

**Table 4.4: Shared Socioeconomic Pathways and Changes in Global Surface Temperatures (IPCC, 2023a; 2023b)**

| GHG Emissions Scenario [1] | Description | Change in Global Surface Temperature (°C)[2] Best Estimate [and very likely range] | | | Key Assumptions |
|---|---|---|---|---|---|
| | | Near term (2021 – 2040) | Mid-term (2041 – 2060) | Long-term (2081 – 2100) | |
| SSP1-1.9 (Very Low) | limit warming to 1.5°C (>50%) with no or limited overshoot | 1.5 [1.2 to 1.7] | 1.6 [1.2 to 2.0] | 1.4 [1.0 to 1.8] | Rapid decarbonisation, societies switch to more sustainable practices, inequality falls. Net zero $CO_2$ achieved in ca. 2050. |
| SSP1-2.6 (Low) | limit warming to 2°C (>67%) | 1.5 [1.2 to 1.8] | 1.7 [1.3 to 2.2] | 1.8 [1.3 to 2.4] | Socioeconomic shifts towards sustainability, but reduction in $CO_2$ emissions is slower than SSP1-1.9. Net zero $CO_2$ achieved in ca. 2070. |
| SSP2-4.5 (Intermediate) | limit warming to 3°C (>50%) | 1.5 [1.2 to 1.8] | 2.0 [1.6 to 2.5] | 2-7 [2.1 to 3.5] | Current policies continue. Slow progress toward sustainability and development and income grow unevenly. $CO_2$ emissions hover around current levels before starting to fall mid-century. Net zero $CO_2$ is not achieved by 2100. |
| SSP3-7.0 (High) | limit warming to 4°C (>50%) | 1.5 [1.2 to 1.8] | 2.1 [1.7 to 2.6] | 3.6 [2.8 to 4.6] | Fragmented, high fossil use, inequality. $CO_2$ emissions roughly double from current levels by 2100 |
| SSP5-8.5 (Very High) | exceed warming of 4°C (>50%) | 1.6 [1.3 to 1.9] | 2.4 [1.9 to 3.0] | 4.4 [3.3 to 5.7] | Rapid economic growth without mitigation, fuelled by exploiting fossil fuels and energy-intensive lifestyles. Current $CO_2$ emissions roughly double by 2050. |

[1] Scenarios relate to SSPs + "forcing", where the number refers to the radiative forcing level in W/m² in the year 2100. For example, 'SSP1-1.9' is a scenario that combines SSP1 with 1.9 W/m² radiative forcing in 2100 (RCP1.9)
[2] Temperature differences relative to the average global surface temperature of the period 1850-1900.

Ahead of COP30 (held in November 2025), UNEP published a report (UNEP, 2024) looking at future trends in GHG emissions, with a focus on what is required from NDCs to maintain the possibility of achieving the long-term temperature goal of the Paris Agreement. It predicts that if current policies continue, global emissions will reach 57 $GtCO_2e$ (range: 53–59) in 2030, around 2 $GtCO_2e$ (range: 0–3 $GtCO_2e$) above unconditional NDCs and 5 $GtCO_2e$ (range: 2–9 $GtCO_2e$) above conditional NDCs (refer to Table 4.5).

**Table 4.5: Projected Global Total GHG Emissions in 2030, 2035 and 2050 and Associated Emission Gaps (UNEP, 2024)**

| Scenario [1] | Projected GHG Emissions ($GtCO_2e$) | Estimated Emissions Gap ($GtCO_2e$) | | |
|---|---|---|---|---|
| | Median (and range) | Below 2.0°C | Below 1.8°C | Below 1.5°C |
| **2030** | | | | |
| Current policies | 57 (53–59) | 16 (12–18) | 22 (18–24) | 24 (20–26) |
| Unconditional NDCs | 55 (54–57) | 14 (13–16) | 20 (19–22) | 22 (21–24) |
| Conditional NDCs | 51 (48–55) | 11 (7–14) | 17 (13–20) | 19 (15–22) |
| **2035** | | | | |
| Current policies continued | 57 (44–62) | 21 (9–26) | 30 (18–35) | 32 (20–37) |
| Unconditional NDCs continued | 54 (46–60) | 18 (10–24) | 27 (19–33) | 29 (21–35) |
| Conditional NDCs continued | 51 (43–57) | 15 (8–22) | 24 (17–30) | 26 (19–33) |
| Conditional NDCs + all net zero pledges | 43 (38–49) | 8 (2–13 | 16 (11–22) | 19 (13–24) |
| **2050** | | | | |
| Current policies continued | 56 (25 – 68) | 36 (4–48) | 44 (12–56) | 48 (16–60) |
| Conditional NDCs + all net zero pledges | 19 (6 – 30) | -1 (-14–10) | 7 (-6–18) | 11 (-2–22) |

[1] Scenario Definitions

- Current policies scenario: projects global GHG emissions assuming all currently adopted and implemented policies as of November 2023 are realized and that no additional measures are undertaken. When extended beyond 2030, it assumes a continuation of efforts at a similar level of ambition.
- Unconditional NDC scenarios: projects the GHG emissions assuming full implementation of the most recent NDCs that do not depend on explicit external support (cut-off date: September 2024). When extended beyond 2030, it assumes a continuation of efforts at a similar level of ambition.
- Conditional NDC scenarios: this scenario encompasses the most recent NDC targets for which implementation is contingent on receiving international support, such as finance, technology transfer and/or capacity-building (cut-off date: September 2024). When extended beyond 2030, it assumes a continuation of efforts at a similar level of ambition.

### Remaining Global Carbon Budget

The Global Carbon Project (a Global Research Project of Future Earth and a research partner of the World Climate Research Programme established in 2001) produces an annual Global Carbon Budget (GCB), which tracks the trends in global carbon emissions and sinks and is a key measure of the progress towards the goals of the Paris Agreement. The 2024 GCB projects fossil $CO_2$ emissions of 37.4 Gt $CO_2$[6], up 0.8% from 2023 and concludes that there are no clear signs that the world has reached a peak in fossil $CO_2$ emissions. If current trends continue, from January 2025, the remaining global carbon budget for a 50% likelihood to limit global warming to 1.5°C, 1.7°C and 2°C has respectively been estimated at 235 Gt $CO_2$ (which would be exceeded in 6 years at 2024 emissions levels), 585 Gt $CO_2$ (14 years) and 1110 Gt $CO_2$ (27 years) (Figure 4.10; GCP, 2024). For comparison, for the period 1850–2019, a total of 2,390 ± 240 Gt $CO_2$ has been emitted (IPCC, 2021).

[6] Global fossil $CO_2$ emissions include the cement carbonation sink. Cement carbonation is a process by which concrete absorbs CO2 from the atmosphere, effectively acting as a carbon sink and helping to mitigate climate change.

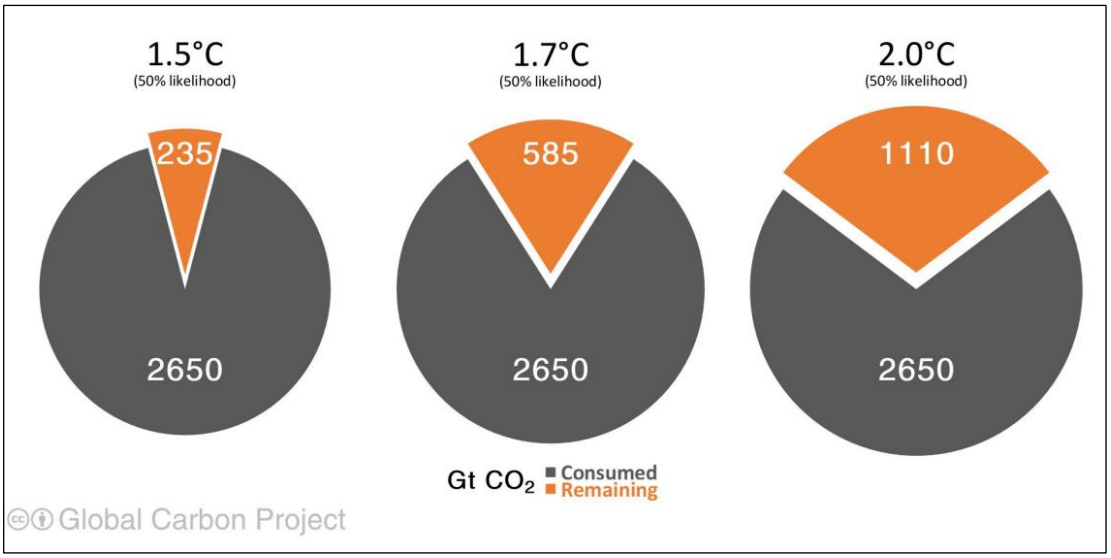



**Figure 4.10: Remaining Carbon Budget (GCP, 2024)**

### UK Carbon Budgets

In the UK, the principal basis for giving effect to the reduction of territorial GHG emissions is through the Climate Change Act 2008, which sets binding carbon budgets and a Net Zero target by 2050 (refer to Section 9.3.2).

## 4.3 Biological Environment

This section describes the species and habitats that have been recorded in the area surrounding the Tornado Field that could be affected by the proposed development. Where relevant, emphasis is placed on the presence of PMFs which are habitats and species that are considered to be nature conservation priorities in Scottish waters either due to being under threat or in decline, or being keystone species which are integral to community function (SNH, 2014; Tyler-Walters *et al.,* 2016). In addition, species or habitats of conservation importance have been identified, including those listed on Annex I or Annex II of the EU Habitats and Birds Directives and the OSPAR List of Threatened and / or Declining Species (OSPAR, 2021).

### 4.3.1 Plankton

Plankton consist of organisms that drift with the ocean currents and can be divided into phytoplankton (plant-like organisms) and zooplankton (animals). The turbulence of the shelf waters brings up nutrients from the depths of the channel making them available for enhanced plankton productivity near to the shelf edge (Reid *et al*., 2003).

During spring, an increase in day length and temperature, coupled with the supply of nutrients released during winter mixing of the water column, results in the rapid growth of the phytoplankton population which is known as the spring diatom bloom. Although the size and timing of this bloom varies from year to year, in the relatively cold waters in the WoS, it generally peaks in May. The phytoplankton bloom is followed by a similar rapid increase in the zooplankton population as they feed on this increased food source. Phytoplankton levels drop as the nutrients in the surface waters become depleted and as a result of zooplankton grazing (Miller & Wheeler, 2012). A secondary phytoplankton bloom occurs in autumn but is less pronounced in the open waters WoS than in the North Sea.

Plankton communities in the Tornado area are greatly influenced by the inflow of Atlantic Ocean water through the Faroe-Shetland Channel (Johns and Wootton, 2003). Phytoplankton assemblages are likely to be a mixture of oceanic and neritic (shallow water or coastal) phytoplankton species (DTI, 2003). Diatoms of the genera *Chaetoceros* and *Thalassiosira*, in addition to dinoflagellates of the genus *Ceratium*, are the dominant phytoplankton taxa in this region of the North East Atlantic (Johns and Wooton, 2003).

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 in the Tornado area includes the larval stages of fish (ichthyoplankton), larval decapods (crustaceans) and echinoderms, as well as copepods and krill (also crustaceans). Zooplankton exhibit a seasonal and geographical variation in abundance and distribution that is closely linked to the over-wintering of animals and food availability. Copepods are the main constituent of the zooplankton WoS (Johns and Wooton, 2003). In addition, the oceanic calanoid copepod *Calanus finmarchicus* plays an important role in the Faroe-Shetland region, directly feeding pelagic fish stocks such as herring and mackerel (Melle *et al*., 2014).

### 4.3.2 Seabed Communities

The benthos refers to the animals (and plants, although plants are generally limited by their light requirements to depths of less than 50 m) associated with 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.

#### Habitat Classification

Data from the European Marine Observation and Data Network (EMODnet) seabed habitats map, indicates that the proposed Tornado Development is located in the European Nature Information System (EUNIS) habitat type 'Upper bathyal mixed sediment' (ME4), with the habitat type 'Upper bathyal mud' (ME6) crossed by the mid-section of the pipeline route (Figure 4.11).

The habitat investigation undertaken for Tornado used a combination of field observations and detailed review of photographic data, along with interpretation of the acquired SSS data to identify and map the habitat types across the survey areas, noting the locations of any observed changes in sediment type and/or associated faunal community (refer to Section 4.1.1).

One habitat type was identified within the Tornado site survey area, described as the EUNIS biotope complex 'Arctic upper bathyal mixed sediment' (ME41). This habitat type was also identified along the proposed pipeline route, with the EUNIS biotope complex 'Arctic upper bathyal mixed sand' (ME51) observed along one section of the proposed pipeline route, approximately 8.3 km in length (Figure 4.11). These sediment types and habitat complexes are commonly encountered in the region (EMODnet, 2024a) and are described below. Note, of the six pipeline transects located within the Faroe-Shetland Sponge Belt NCMPA, the habitat type 'Arctic upper bathyal mixed sediment' (ME41) was observed at three of the transects (PR_TR22 to PR_TR24), with 'Arctic upper bathyal mixed sand' (ME51) observed at the other three transects (PR_TR19 to PR_TR21).

<u>Arctic Upper Bathyal Mixed Sediment (ME41)</u>

Example seabed images of the EUNIS habitat type 'Arctic upper bathyal mixed sediment' (ME41), which were observed on all transects within the site survey area and 23 of the 26 transects along the pipeline route, are presented in Figure 4.12, Figure 4.13 and Figure 4.14. Deep-sea mixed sediment has not been sampled widely for infauna, so little is currently known about infaunal community structure. Epifauna tend to be sparse mobile species (EEA, 2022a).

Epibenthic fauna observed during the survey operations was relatively sparse. The most commonly observed fauna on the seabed photographs and video were brittlestars (Ophiuroidea). Fauna including sponges (Porifera: carnivorous forms: Cladorhizidae including *Asbestopluma sp.* and *Chondrocladia* (*Chondrocladia*) *grandis*; stalked forms including *Stylocordyla borealis*); glass sponges (Hexactinellida), starfish (Asteroidea including *Crossaster squamatus* and *Henricia sp.*) and carnation corals (Malacalcyonacea) anemones (Actiniaria including Halcampidae), tube anemones (*Cerianthus sp.*), feather stars (Crinoidea), sea spider (Pycnogonida including *Colossendeis proboscidea*), tube worms (Polychaeta) and faunal turf (Hydrozoa/Bryozoa) were also widely seen. Other, less regularly observed fauna included marine leech (*Notostomum leave*), tunicates (Ascidiacea), octopus (Octopodoidea), shrimp (Caridea), ribbon worms (Nemertea), possible flatworms (Platyhelminthes), sea snails (Gastropoda), sea mouse (*Aphrodita aculeata*), amphipod (Eusiridae), hydroid (*Corymorpha glacialis*),

starfish (*Pontaster sp.*) and possible bryozoan (*Hornera sp.*). Faunal tracks, tubes and sporadic burrows were also present along some transects (Fugro, 2025a and Fugro, 2025b).

Arctic Upper Bathyal Sand (ME51)

Example seabed images of the EUNIS habitat type 'Arctic Upper Bathyal Sand' (ME51), which were observed on three transects along the pipeline route (PR_TR19, PR_TR20 and PR_TR21), all of which are located within the Faroe-Shetland Sponge Belt NCMPA, are presented in Figure 4.15. Deep-sea sand has not been sampled widely for infauna, so little is currently known about infaunal community structure. Epifauna tend to be sparse mobile species (EEA, 2022b).

The most commonly observed fauna was brittlestars (Ophiuroidea). Other fauna including sponges (Porifera: stalked forms including *Stylocordyla sp.*; carnivorous forms including Cladorhizidae, *Asbestopluma sp.*, *Chondrocladia (Chondrocladia) grandis*; encrusting forms including *Hymedesmia sp.*), glass sponges (Hexactinellida), carnation corals (Malacalcyonacea), starfish (Asteroidea including Halcampidae and *Pontaster sp.*), anemones (Actiniaria) and feather stars (Crinoidea) were also widely seen. Other, less regularly observed fauna included whelk (Buccinoidea), shrimp (Caridea), trachymedusa (*Ptychogastria polaris*), sea pens (*Umbellula sp.* and *Virgularia sp.*), basket star (*Gorgonocephalus sp.*), sea spiders (Pycnogonida incl. *Colossendeis proboscidea*), possible ribbon worms (Nemertea), possible flatworms (Platyhelminthes), faunal turf (Hydrozoa/Bryozoa), tube worms (Polychaeta) and sea snails (Gastropoda) (Fugro, 2025b).

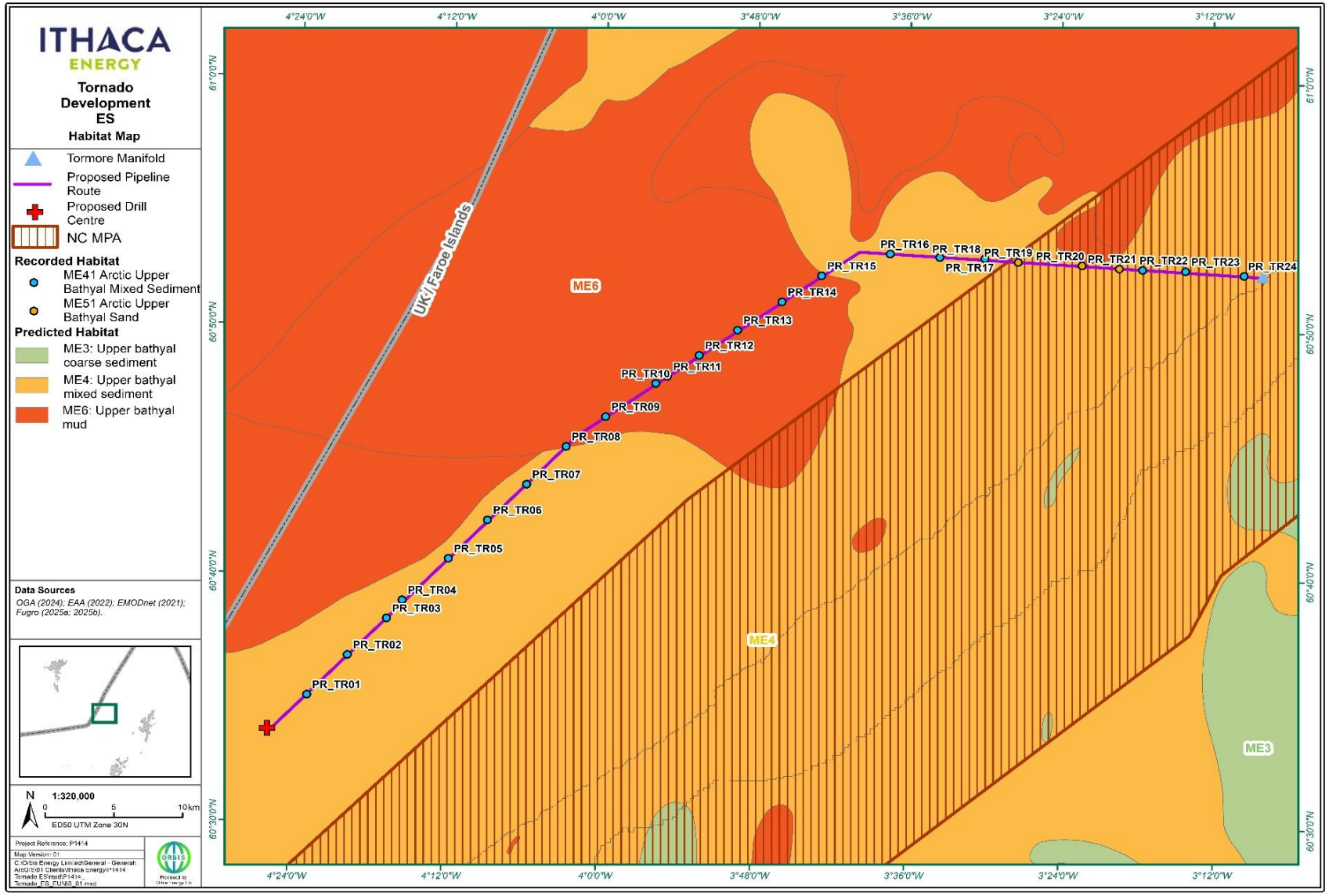
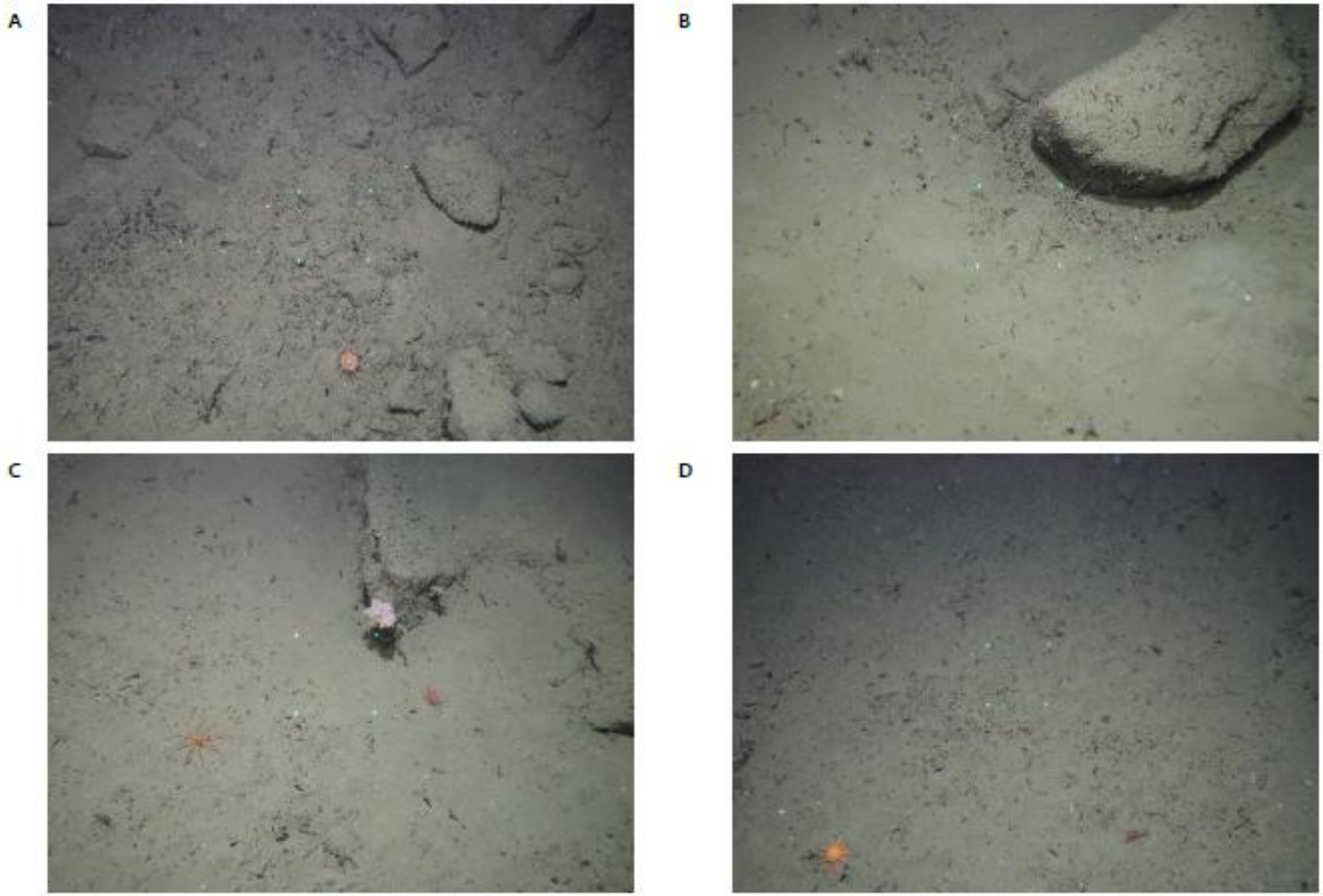



**Figure 4.11: Predicted and Recorded Seabed Habitats in the Vicinity of the Tornado Development (EMODnet, 2021; Fugro, 2025a; 2025b)**




**A: Photograph RS_TR01_14**

Gravelly sandy mud/muddy sand with cobbles and boulders

Brittlestars (Ophiuroidea), anemones (Actiniaria), faunal turf (Hydrozoa/Bryozoa)

**B: Photograph RS_TR05_09**

Gravelly sandy mud/muddy sand with cobbles and a boulder

Brittle stars (Ophiuroidea), faunal turf (Hydrozoa/Bryozoa), faunal tubes

**C: Photograph RS-TR11_06**

Muddy sand with gravel and boulders

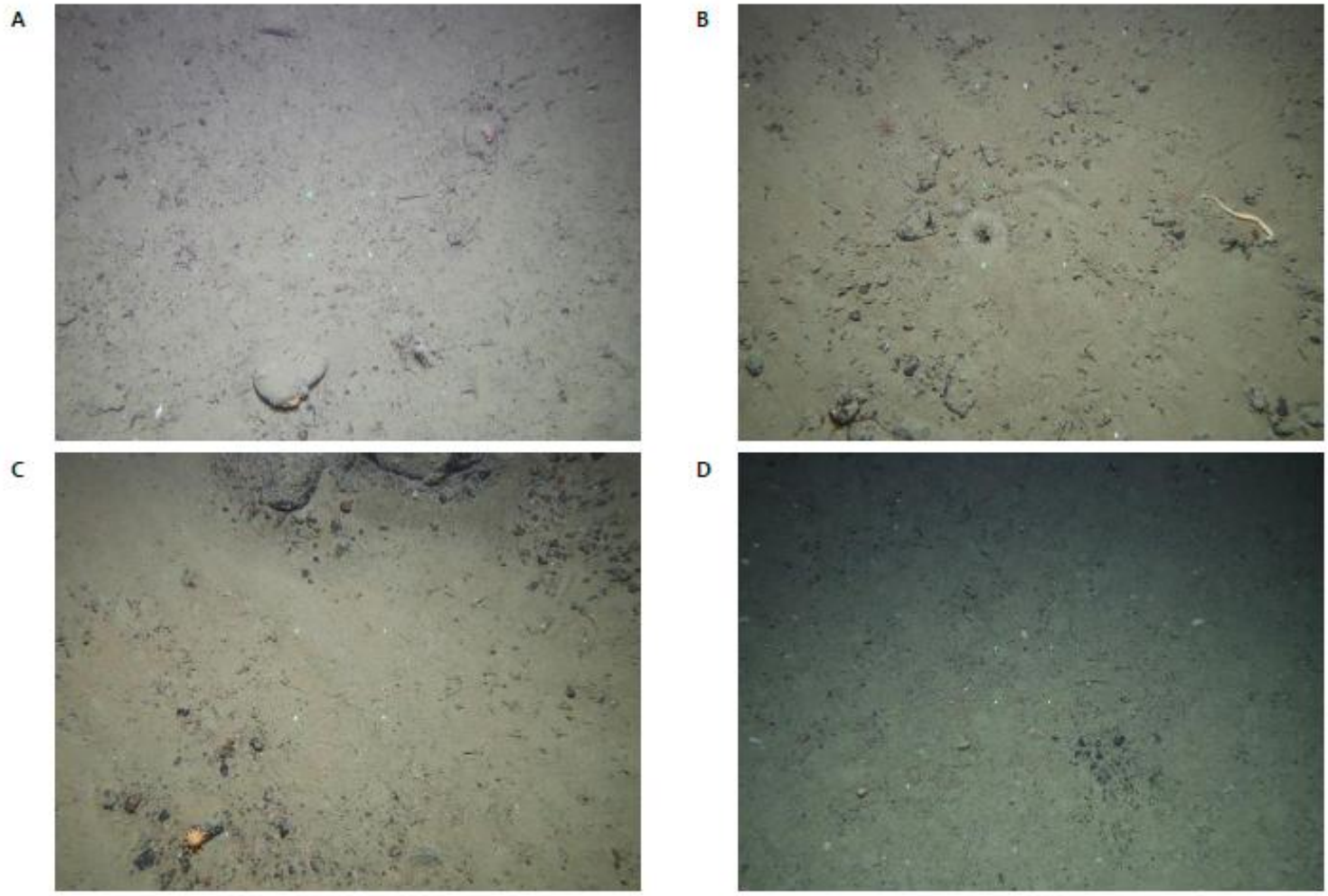
Brittlestars (Ophiuroidea), carnation coral (Malacalcyonacea), anemone (?Halcampidae), sea spider (Pycnogonida), faunal turf (Hydrozoa/Bryozoa), faunal tubes

**D: Photograph RS_TR14_09**

Gravelly sandy mud/muddy sand with cobbles

Brittlestars (Ophiuroidea), starfish (*Crossasster squamatus*), anemone (?Halcampidae)

**Figure 4.12: Example Seabed Images of Arctic Upper Bathyal Mixed Sediment (ME41) within the Site Survey Area (Fugro, 2025a)**




**A: Photograph PR_TR01_10**

Gravelly sandy mud/muddy sand with cobbles and boulders

Carnation coral, (Malacalcyonacea), brittlestars (Ophiuroidea), starfish (*Crossaster squamatus*) and feather star (Crinoidea)

**B: Photograph PR_TR08_15**

Gravelly sandy mud/muddy sand with cobbles

Anemones (Halcampidae), brittlestars (Ophiuroidea), marine leech (*Notostomum laeve*), faunal turf (Hydrozoa/Bryozoa) and faunal burrow and tracks

**C: Photograph PR_TR16_17**

Gravelly sandy mud/muddy sand with cobbles and boulders

Brittlestars (Ophiuroidea), starfish (*Crossaster squamatus*), feather star (Crinoidea) and faunal turf (Hydrozoa/Bryozoa) and tracks

**D: Photograph PR_TR24_19**

Gravelly sandy mud/muddy sand with cobbles

Sponge (Porifera), brittlestars (Ophiuroidea) and faunal tracks

**Figure 4.13: Example Seabed Images of Arctic Upper Bathyal Mixed Sediment (ME41) along the Pipeline Route (Fugro, 2025b)**

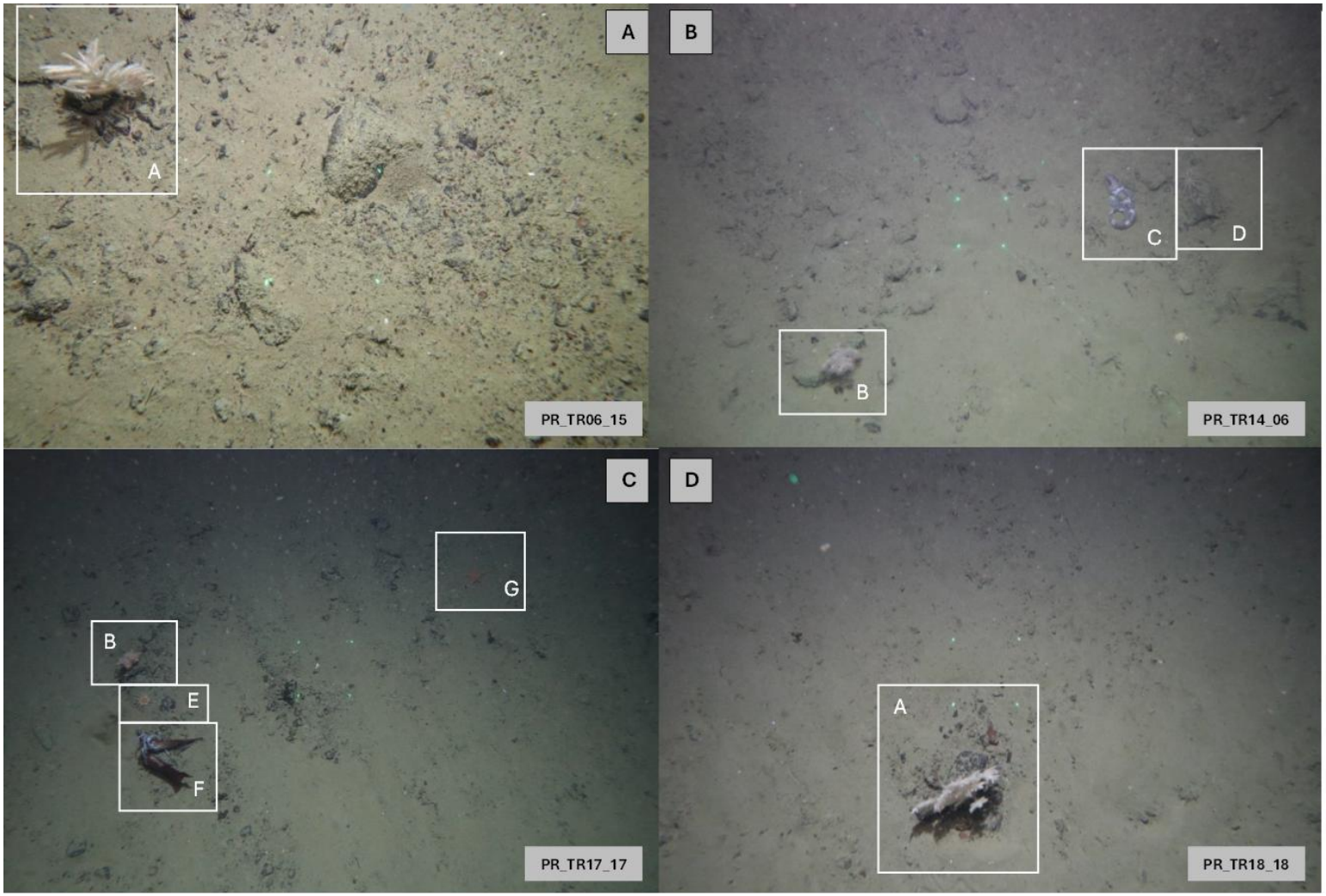
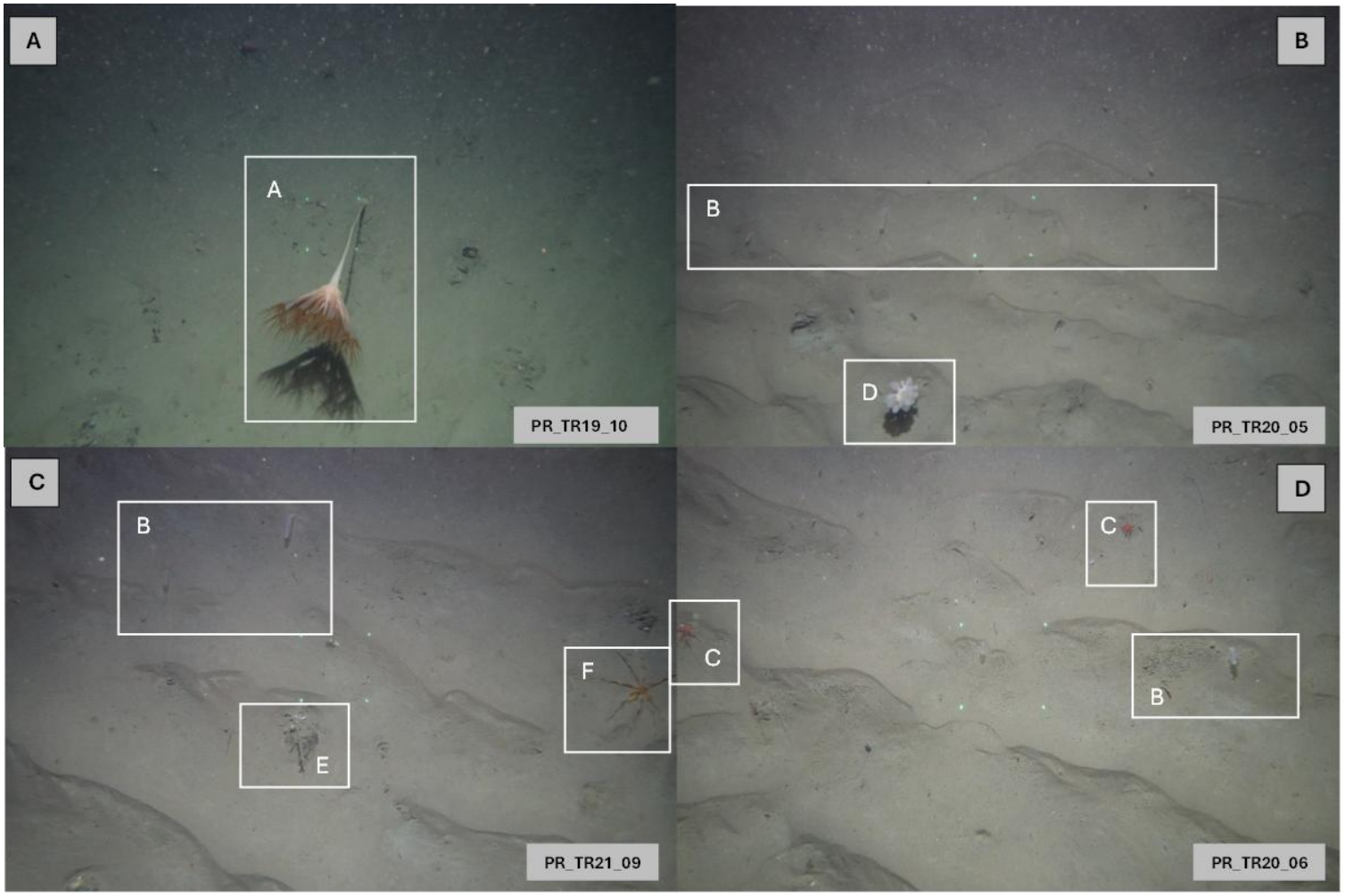



**Figure 4.14: Example Seabed Images of Arctic Upper Bathyal Mixed Sediment (ME41) along the Pipeline Route (Fugro, 2025b)**




**Photograph A**: PR_TR_19_10

Sediment Type: Gravelly sandy mud/muddy sand with cobbles and boulders

A = Sea pen (Umbellula sp.)

**Photograph B**: PR_TR20_05

Sediment Type: Gravelly sandy mud/muddy sand with cobbles and boulders

B = Sea pens (Virgularia sp.)

D = Sponge (Chondrocladia (Chondrocladia) grandis)

**Photograph C**: PR_TR21_09

Sediment Type: Gravelly sandy mud/muddy sand with cobbles and boulders

B = Sea pens (Virgularia sp.)

E = Faunal Turf

F = Sea spider (Pycnogonida possible Colossendeis proboscidea

**Photograph D**: PR_TR20_06

Sediment Type: Gravelly sandy mud/muddy sand with cobbles and boulders

B = Sea pens (Virgularia sp.)

C = Tube Anemones (Cerianthus sp.)

**Figure 4.15: Example Seabed Images of Arctic Upper Bathyal Sand (ME51) along the Pipeline Route (within the Faroe- Shetland Sponge Belt NCMPA) (Fugro, 2025b)**

### Potential Sensitive Habitats and Species

The following potential sensitive habitats and species are known to occur in this region of the WoS:

- Deep-sea Sponge Aggregations;
- Coral gardens;
- Sub-tidal reefs (e.g. biogenic reefs formed by *D. pertusum* and rocky reefs formed from iceberg scour or moraine deposits);
- Sea pens and burrowing megafauna;
- Ocean Quahog (*Arctica islandica*).

The Tornado habitat investigation and environmental baseline survey paid particular attention to establishing whether or not any of the above habitats and/or species occurred within the areas surveyed.

Deep-sea Sponge Aggregations

The habitat 'Deep-sea sponge aggregations' is designated threatened and/or declining by OSPAR and is defined as "aggregations of deep-sea sponges extending over at least 25 m² that are principally composed of sponges from two classes, Hexactinellida and Demospongiae" (OSPAR, 2010a). Additional guidelines suggest that 0.5 to 1 sponge per $m^2$ is equal to approximately 10% coverage of sponge (depending on the sizes of sponges) and thus 10 % coverage of Demospongiae can be expected to qualify as the threatened OSPAR habitat 'Deep-sea sponge aggregations' (Offshore Norge, 2024). Furthermore, a study commissioned by the JNCC, considered sponge communities with an abundance of 'frequent' or more (according to the SACFOR scale) as a potential 'deep-sea sponge aggregation' (Henry & Roberts, 2014a).

Deep sea sponge aggregations are recorded from the northern Scottish slope of the Faroe-Shetland Channel (OSPAR, 2010a) and are usually found in water depths greater than 250 m. The presence of the Faroe-Shetland Sponge Belt NCMPA, in which approximately 18 km of the Tornado pipeline route is located (refer to Section 4.3.6), increases the likelihood for sponge aggregations to occur. The Faroe-Shetland Sponge Belt NCMPA is characterised by iceberg scars in the seabed caused by the scouring action of icebergs during past ice ages. Over time these scars have been partially filled with sediments, creating a mosaic of habitats that can host sponge aggregations (Eggett *et al.*, 2018).

In the Tornado site survey area, the sponge aggregations observed in camera transects or AUV mosaics were sporadic and of low abundance and therefore did not reach the criteria for further assessment (see Figure 4.16; Fugro, 2025a). However, due to observations of demosponges (Figure 4.17), the presence of 'Deep-sea sponge aggregations' was considered along the proposed pipeline route. The assessment found that along two sections of transect PR_TR24, the density of demosponges satisfied the density criteria for the OSPAR threatened and/or declining habitat 'Deep-sea sponge aggregations' (Table 4.6). However, according to Henry and Roberts (2014a) "sponge assemblages should confer a clear functional role for deep-sea sponge communities, e.g. enhanced associated biodiversity, support a distinct associated megafaunal assemblage, ecological symbioses, and/or create habitat for mobile fauna". In the Tornado survey, the faunal assemblages associated with sponges were not different from the surrounding assemblages. Additionally, the areas where sponges satisfied the density criterion did not exceed 25 $m^2$ (14 $m^2$ and 9 $m^2$) and therefore no qualifying criteria were met (Fugro, 2025b). As such, the OSPAR listed Threatened and/or Declining Species and Habitats 'Deep-sea sponge aggregations' was not thought to be present based on the photographic data.

Coral Gardens

Carnation corals (Malacalcyonacea) were recorded throughout the Tornado survey areas, along both the drop-down camera transects and AUV lines (see examples in Figure 4.16 and Figure 4.17). Carnation corals potentially contribute to coral gardens within the United Kingdom (UK) (Henry & Roberts, 2014b); however, the occurrence of carnation corals was sporadic, with only single individuals recorded. The presence of carnation corals therefore did not warrant a full coral garden assessment due to the sporadic distribution and low abundance (Fugro, 2025a and Fugro, 2025b).

**Table 4.6: Deep Sea Sponge Aggregation Assessment (Fugro, 2025b)**

| Transect | Section | Section Length (m) | Sponge Density ($m^2$) | Glass Sponge Density ($m^2$) | Associated Fauna | Area Observed ($m^2$) | Qualifying Criteria Satisfied | | | Overall Assessment |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Density | Habitat | Ecological Function | |
| PR_TR24 | 1 | 40.2 | < 1 | < 1 | - | > 25 $m^2$ | X | X | X | Not present |
| | 2 | 7.6 | 1.4 | < 1 | Carnation coral (Malacalcyonacea), anemones (Actiniaria), brittlestars (Ophiuroidea), hagfish (*Myxine glutinosa*) | > 25 $m^2$ | ✓ | X | X | Not present (< 25 $m^2$) |
| | 3 | 5.3 | <1 | < 1 | - | > 25 $m^2$ | X | X | X | Not present |
| | 4 | 4.8 | 5.3 | < 1 | Carnation coral (Malacalcyonacea), anemones (Actiniaria), brittlestars (Ophiuroidea), starfish (Asteroidea incl. *Crossaster squamatus*) | > 25 $m^2$ | ✓ | X | X | Not present (< 25 $m^2$) |
| | 5 | 24.5 | < 1 | < 1 | - | > 25 $m^2$ | X | X | X | Not present |
| | 6 | 28.8 | < 1 | < 1 | - | > 25 $m^2$ | X | X | X | Not present |
| Confidence Key: | | | | | | | | | | |
| Low | | | | | Medium | | | High | | |

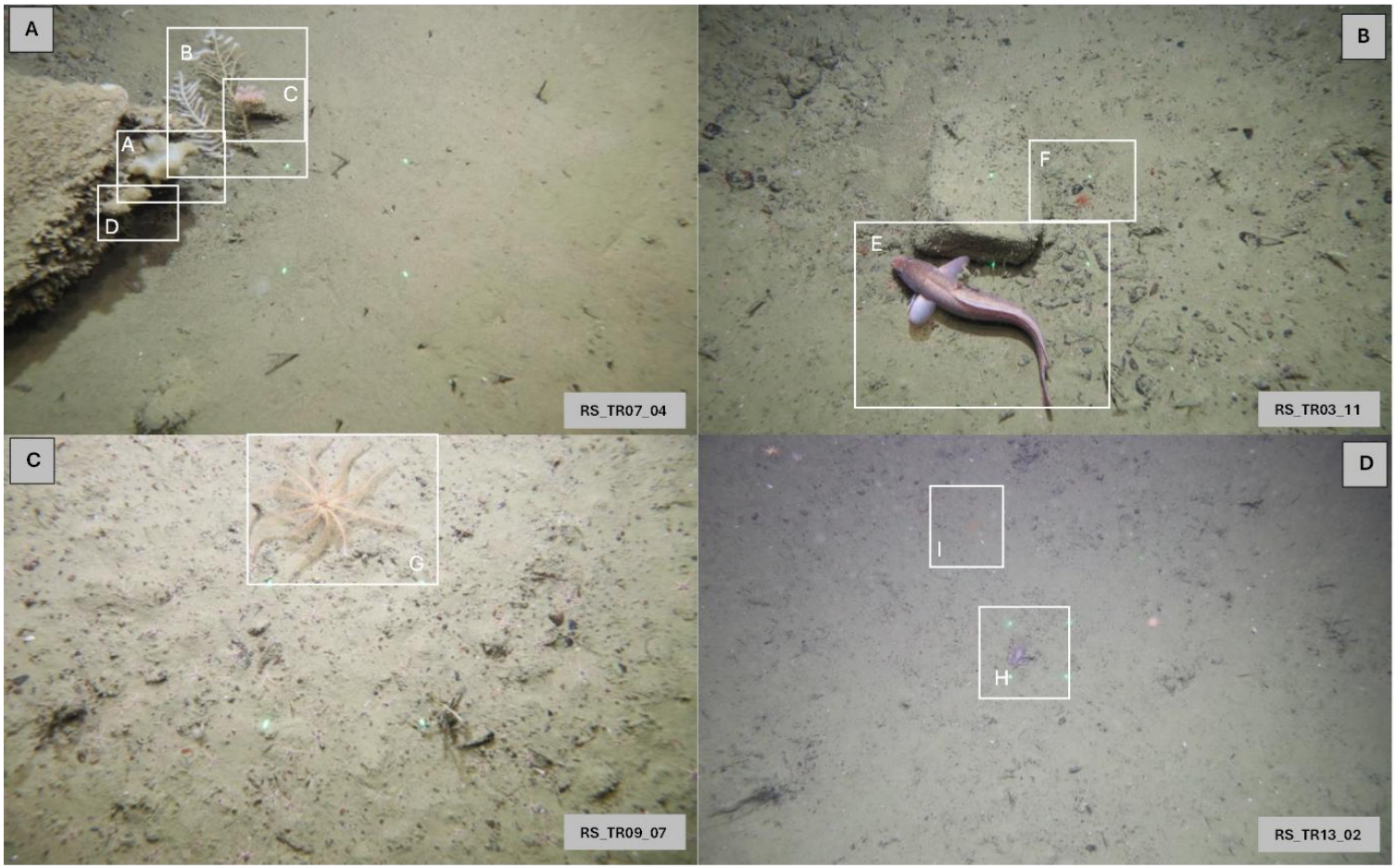
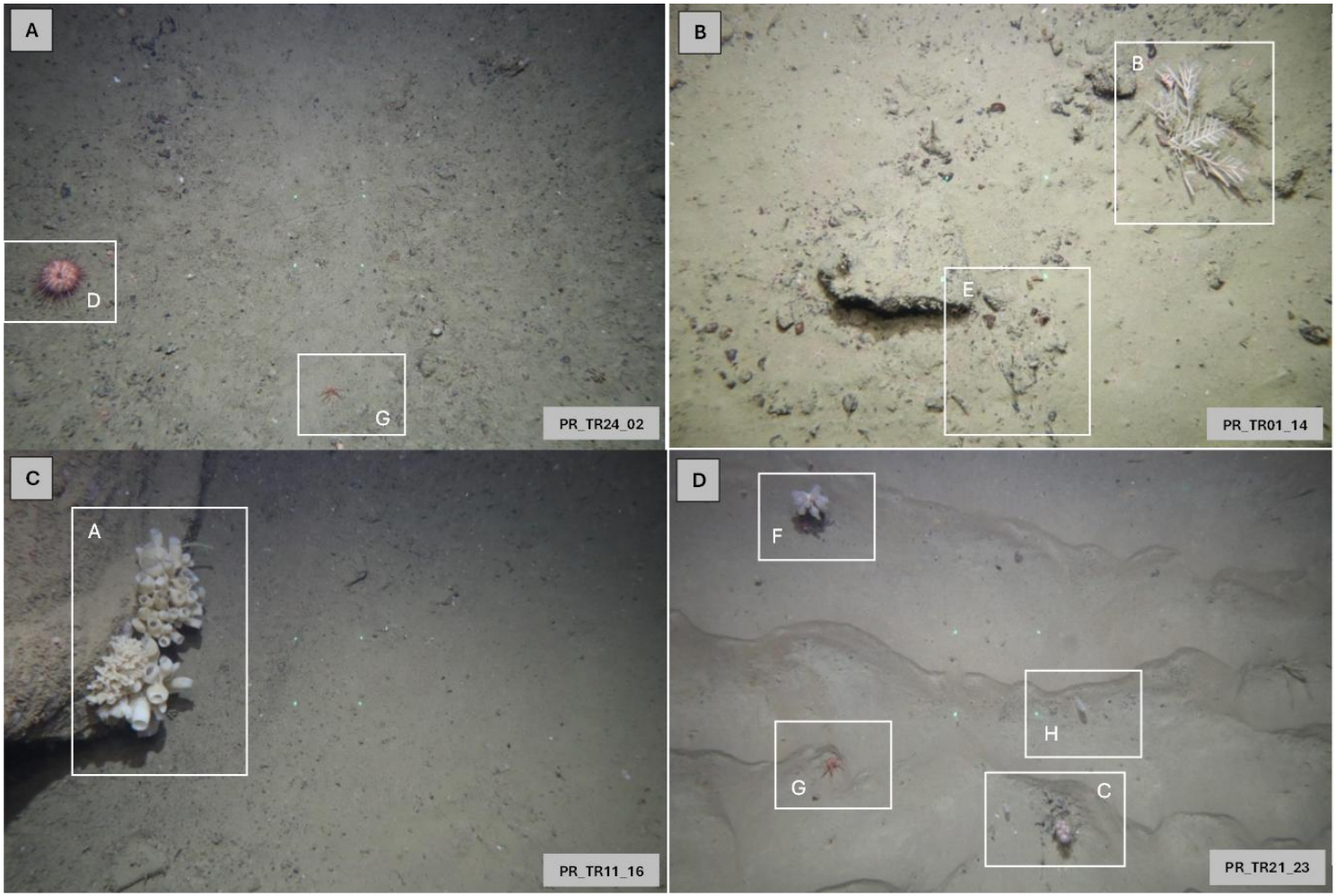



**Figure 4.16: Seabed Communities within the Tornado Site Survey Area (Fugro, 2025a)**




**Photograph A**: PR_TR24_02

Sediment Type: Gravelly sandy mud/muddy sand with cobbles and boulders

D = Sea urchin (Echinoidea)

G = Tube anemones (?Halcampidae)

**Photograph B**: PR_TR01_14

Sediment Type: Gravelly sandy mud/muddy sand with cobbles and boulders

B = Sponge (Stylocordyla sp.)

E = Brittlestars

**Photograph C**: PR_TR11_16

Sediment Type: Gravelly sandy mud/muddy sand with cobbles and boulders

A = Glass sponge (Hexactinellid)

**Photograph D**: PR_TR21_23

Sediment Type: Gravelly sandy mud/muddy sand with cobbles and boulders

C = Carnation coral (Malacalcyonacea)

F = Sponge (Chondrocladia (Chondrocladia) grandis)

G = Tube anemones (Cerianthus sp.)

H = Sea pens (Virgularia sp.)

**Figure 4.17: Seabed Communities within the Tornado Pipeline Route Survey Area (Fugro, 2025b)**

Annex I Reef

Stony reefs are defined by the Habitats Directive as comprising 'areas of boulders (>256mm diameter) or cobbles (64mm – 256mm diameter) which arise from the seafloor and provide suitable substratum for the attachment of algae and/or animal species' (Irving, 2009).

Areas of cobbles and boulders were observed throughout the Tornado survey areas and were further assessed for the potential to be categorised as Annex I stony reef, specifically stony reefs (Golding et al., 2020), using the Irving (2009) stony reef protocol.

Table 4.7 presents the Irving (2009) criteria of 'reefiness' for stony reef habitat assessments, adopted for this study, which requires that areas of potential stony reef habitat must have an area of more than 25 $m^2$ to be classified as reef, with area of features of interest taken into account during initial selection of the transect locations.

Table 4.8 presents the stony reef matrix used to assess the overall 'reefiness' of an area.

**Table 4.7: Measures of 'reefiness' for stony reef habitat (after Irving, 2009)**

| Characteristic | Resemblance to a 'Stony Reef' | | | |
|---|---|---|---|---|
| | Not a Reef | Low | Medium | High |
| **Composition**<br>Diameter of cobbles/boulders being greater than 64 mm.<br>Percentage cover relates to a minimum area of 25 $m^2$.<br>The 'composition' characteristic also includes 'patchiness'. | < 10% | 10 – 40 % | 40 -95 % | > 95 % |
| **Elevation**<br>Minimum height (64 mm) relates to minimum size constituent cobbles.<br>This characteristic could also include 'distinctness' from the surrounding seafloor.<br>Note that two units (mm and m) are used. | Flat seafloor | < 64 mm | 64 mm – 5 m | > 5 m |
| **Extent** | < 25 $m^2$ | > 25 $m^2$ | | |
| **Biota** | Dominated by infauna species | - | - | > 80 % of species present composed of epifaunal species |
| Notes: When determining whether an area of the seafloor should be considered as Annex I stony reef, if a 'low' is scored in any of the four characteristics (composition, elevation, extent, or biota), then a strong justification would be required for this area to be considered as contributing to the Marine Natura site network of qualifying reefs in terms of the EU Habitats Directive. Adapted from Irving (2009) | | | | |

**Table 4.8: Stony Reef Matrix**

| Reef Structure | Composition (% of Seafloor Comprised of Cobbles/Boulders) | | | | Biota |
|---|---|---|---|---|---|
| **Elevation** | **< 10** | **10 – 40** | **40 -95** | **> 95** | |
| Flat seafloor | Not a Reef | Not a Reef | Not a Reef | Not a Reef | Infauna dominated |
| < 64 mm | Not a Reef | Low | Low | Low | - |
| 64 mm – 5 m | Not a Reef | Low | Medium | Medium | - |
| > 5 m | Not a Reef | Low | Medium | High | > 80 % |
| Notes: Full reef assessment not applicable of areas of cobble and/or boulders with an extent of < 25 $m^2$, which would be classified as 'Not a Reef | | | | | |

The cobbles and boulders within the Tornado survey areas were predominantly low-lying and embedded in the sediment (elevation less than < 64 mm), with the visible surfaces of hard substrate covered with a layer of soft sediment. As the majority of the cobbles and boulders within the survey areas covered less than 10 % of the visible seafloor, these areas were classified as 'not a reef' (Fugro, 2025a; Fugro, 2025b).

Along sections of two transects within the site survey area (RS_TR05 and RS_TR07, located approximately 1.7 km east and 0.6 km east respectively of the proposed drill centre), aggregated cobbles and boulders were observed from the photographic data meeting the composition (10 % to 40 % cover cobbles and boulders, and < 80 % biota) and elevation (< 64 mm) criteria, but not the area criteria (> 25 m2). However, upon review of SSS data, it was possible to extrapolate the potential area of 'Reef' that transects RS_TR05 and RS_TR07 cross, which measured approximately 72 m2 and 45 m2, respectively. Therefore, there is potential for the Annex I habitat 'Reefs', specifically stony reefs, to be present within the site survey area. Figure 4.15 shows the stony reef assessment and potential reef extents for transects RS_TR05 and RS_TR07, overlaid on SSS. No further potential areas of potential 'stony reef' were observed within the site survey area when AUV photomosaics were reviewed in conjunction with SSS data (Fugro, 2025a).

Along sections of 13 transects within the proposed pipeline route corridor, aggregated cobbles and boulders were observed meeting the composition and elevation criteria and were classified as 'low reef'. However, the areas of the 'low reef' observed from the photographic data along 12 of these transects did not exceed 25 $m^2$ and did not satisfy the area criteria for 'Reefs'. Only one patch along transect PR_TR15 was observed from the photographic data to exceed 25 $m^2$ and was thus classed as 'low reef'.

Patches of 'medium' stony reef meeting the composition and elevation criteria were observed along sections of four transects (PR_TR01, PR_TR09, PR_TR11 and PR_TR22), but the size of these areas observed from the photographic data did not exceed 25 $m^2$.

Upon a review of the SSS data and AUV mosaics, it was possible to extrapolate potential areas of 'Reef' along six transects (PR_TR01, PR_TR11, PR_TR15, PR_TR18, PR_TR22 and PR_TR24) within the proposed pipeline route corridor, identifying an additional eight patches of >25 $m^2$ of 'low' or 'medium' reef as follows:

- Along transect PR_TR01 the extrapolated area associated with a section classified as 'medium reef' measured 115 $m^2$.
- Along transect PR_TR11, one large area was extrapolated from SSS data, measuring 6,996 $m^2$. Sections of transect PR_TR11 intersecting this area of potential reef were classified as 'low' or 'medium' reef. While boulders were present along the corresponding section of the AUV mosaic, these sections were classed as 'not a reef'.
- Along transect PR_TR15 two areas of potential reef were extrapolated from SSS data, measuring 175 $m^2$ and 296 $m^2$, and corresponded with sections of 'low reef' identified from photographic data.
- Along transect PR_TR18 one area was extrapolated measuring 40 $m^2$, corresponding with a section of 'low reef' identified from photographic data.
- Two areas were extrapolated along transect PR_TR22, one measuring 44 $m^2$ and corresponding with a section classified as 'low reef', and the other measuring 217 $m^2$ corresponding with a section classified as 'low' and 'medium' reef. Upon review of the AUV mosaics, one area measuring 47 $m^2$ was identified along transect PR_TR22 and part of the area identified from SSS measuring 217 $m^2$. While in the stony reef assessment, from the video data, parts of this area were classed as 'not a reef', when the AUV photo mosaic overlapping the transect was considered, the percentage coverage and elevation of the entire area met the criteria to be classed as 'low reef' (Figure 4.19). These differences were due to the limited area visible in the drop-down video footage, and the camera passing over a small section with a lower percentage cover of cobbles and boulders.

- One area along transect PR_TR24 was extrapolated along the area classified as 'low reef' from photographic data and measured 85 $m^2$.

Figure 4.20 shows the stony reef assessment and potential reef extents for transects along the proposed pipeline route (PR_TR01, PR_TR11, PR_TR15, PR_TR18, PR_TR22 and PR_TR24), overlaid on SSS.

The epifaunal assemblage associated with the 'low reef' and 'medium reef' areas within the survey areas was sparse, comparable to the areas of cobbles and boulders classified as 'not a reef', and included anemones (Actiniaria), sponges (Porifera: carnivorous forms: Cladorhizidae including *Chondrocladia (Chondrocladia) grandis*; glass sponges Hexactinellida), carnation corals (Malalcyonacea), starfish (Asteroidea incl. *Crossaster squamatus*) and faunal turf (Hydrozoa/Bryozoa).

Table 4.9 presents a summary of the results of the stony reef assessment along the transects where sections of 'low reef' and 'medium reef' were present. It should be noted that, 'when determining whether an area of the seafloor should be considered as Annex I stony reef, if a 'low' is scored in any of the four characteristics (composition, elevation, extent or biota), then a strong justification would be required for this area to be considered as contributing to the Marine Natura site network of qualifying reefs in terms of the EU Habitats Directive' (Irving, 2009). In this instance, composition and elevation were low, with percentage cover of biota < 10 %, and no differences in epifauna were observed when compared with areas classified as 'not a reef'. Therefore, it is unlikely that the areas of 'low' stony reef were representative of Annex I 'Reef' habitat. In addition, the areas characteristic of 'medium' stony reef were of such small areas (<25 $m^2$) that these are also unlikely to be representative of Annex I reef, based on the Irving, 2009 criteria.

**Table 4.9: Stony reef assessment along transects where sections of 'low reef' and above were present (Fugro, 2025a; Fugro, 2025b)**

| Transect | Video Coordinates [1] | | Length (m) | Area Observed (m²) | Sediment Description | Stony Reef Characteristics | | | Overall Reefiness Matrix |
|---|---|---|---|---|---|---|---|---|---|
| | Easting | Northing | | | | Composition (% cover of cobbles & boulders) | Elevation | Biota (%) | |
| **Tornado Site Survey Area** | | | | | | | | | |
| RS_TR05 | 423 519.29 | 6715 142.86 | 84 | 164 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | - | Not a Reef |
| | 423 461.28 | 6 715 081.69 | | | | | | | |
| | 423 461.28 | 6 715 081.69 | 3 | 7 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 – 40 | < 64 | < 10 | Low |
| | 423 458.18 | 6 715 080.42 | | | | | | | |
| | 423 458.18 | 6 715 080.42 | 25 | 49 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | - | Note a Reef |
| | 423 435.67 | 6 715 068.89 | | | | | | | |
| RS_TR07 | 422 370.16 | 6715 198.67 | 40 | 68 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | - | Not a Reef |
| | 422 330.81 | 6 715 195.07 | | | | | | | |
| | 422 330.81 | 6 715 195.07 | 5 | 8 | Gravelly sandy mud/muddy sand with cobbles and boulders | | < 64 | < 10 | Low |
| | 422 326.31 | 6 715 194.40 | | | | | | | |
| | 422 326.31 | 6 715 194.40 | 38 | 66 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | - | Not a Reef |
| | 422 288.28 | 6 715 193.11 | | | | | | | |
| **Tornado Pipeline Route Survey Area** | | | | | | | | | |
| PR_TR_CPT_19_1 | 449 675.96 | 6 741 103.67 | 64 | 88 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 449 622.72 | 6 741 067.49 | | | | | | | |
| | 449 622.72 | 6 741 067.49 | 9 | 12 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 - 40 | < 64 | < 10 | Low |
| | 449 616.03 | 6 741 062.16 | | | | | | | |
| | 449 616.03 | 6 741 062.16 | 44 | 61 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 449 578.19 | 6 741 039.52 | | | | | | | |
| PR_TR01 | 424 443.64 | 6 717 550.03 | 47 | 107 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 424 473.81 | 6 717 513.74 | | | | | | | |
| | 424 473.81 | 6 717 513.74 | 2 | 4 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 - 40 | < 64 | < 10 | Low |
| | 424 475.28 | 6 717 512.72 | | | | | | | |
| | 424 475.28 | 6 717 512.72 | 21 | 48 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 424 491.36 | 6 717 499.18 | | | | | | | |
| | 424 491.36 | 6 717 499.18 | 9 | 20 | Gravelly sandy mud/muddy sand with cobbles and boulders | 40 - 95 | 64 - 5 | < 10 | Medium |
| | 424 498.48 | 6 717 493.95 | | | | | | | |
| | 424 498.48 | 6 717 493.95 | 32 | 73 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 424 528.03 | 6 717 481.59 | | | | | | | |

| Transect | Video Coordinates [1] | | Length (m) | Area Observed ($m^2$) | Sediment Description | Stony Reef Characteristics | | | Overall Reefiness Matrix |
|---|---|---|---|---|---|---|---|---|---|
| | Easting | Northing | | | | Composition (% cover of cobbles & boulders) | Elevation | Biota (%) | |
| PR_TR02 | 427 422.75 | 6 720 537.70 | 2 | 4 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 – 40 | 64 - 5 | < 10 | Low |
| | 427 422.47 | 6 720 536.04 | | | | | | | |
| | 427 422.47 | 6 720 536.04 | 32 | 75 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | Flat Seabed | < 10 | Not a Reef |
| | 427 410.64 | 6 720 505.99 | | | | | | | |
| | 427 410.64 | 6 720 505.99 | 80 | 188 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 427 368.94 | 6 720 437.25 | | | | | | | |
| PR_TR03 | 430 176.65 | 6 723 264.68 | 7 | 13 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 430 172.69 | 6 723 258.44 | | | | | | | |
| | 430 172.69 | 6 723 258.44 | 3 | 5 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 – 40 | < 64 | < 10 | Low |
| | 430 170.95 | 6 723 256.04 | | | | | | | |
| | 430 170.95 | 6 723 256.04 | 33 | 60 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 430 153.43 | 6 723 228.19 | | | | | | | |
| | 430 149.51 | 6 723 218.73 | 59 | 106 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 430 167.08 | 6 723 162.80 | | | | | | | |
| PR_TR06 | 437 367.14 | 6 730 494.12 | 10 | 18 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 437 359.79 | 6 730 500.25 | | | | | | | |
| | 437 359.79 | 6 730 500.25 | 3 | 5 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | 64 - 5 | < 10 | Not a Reef |
| | 437 358.48 | 6 730 502.56 | | | | | | | |
| | 437 358.48 | 6 730 502.56 | 69 | 131 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 437 332.37 | 6 730 566.54 | | | | | | | |
| | 437 332.37 | 6 730 566.54 | 2 | 4 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 – 40 | < 64 | < 10 | Low |
| | 437 330.66 | 6 730 568.05 | | | | | | | |
| | 437 329.07 | 6 730 570.48 | 13 | 26 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 437 319.49 | 6 730 579.97 | | | | | | | |
| PR_TR09 | 445 833.13 | 6 738 270.81 | 42 | 68 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 445 802.43 | 6 738 241.72 | | | | | | | |
| | 445 802.43 | 6 738 241.72 | 6 | 10 | Gravelly sandy mud/muddy sand with cobbles and boulders | 40 - 95 | 64 - 5 | < 10 | Medium |
| | 445 799.02 | 6 738 236.82 | | | | | | | |
| | 445 799.02 | 6 738 236.82 | 54 | 87 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 445 754.53 | 6 738 206.91 | | | | | | | |

| Transect | Video Coordinates [1] | | Length (m) | Area Observed ($m^2$) | Sediment Description | Stony Reef Characteristics | | | Overall Reefiness Matrix |
|---|---|---|---|---|---|---|---|---|---|
| | Easting | Northing | | | | Composition (% cover of cobbles & boulders) | Elevation | Biota (%) | |
| PR_TR10 | 449 387.68 | 6 740 671.34 | 68 | 165 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 449 377.57 | 6 740 738.26 | | | | | | | |
| | 449 377.57 | 6 740 738.26 | 2 | 5 | Gravelly sandy mud/muddy sand with cobbles and boulders | 40 - 95 | < 64 | < 10 | Low |
| | 449 376.54 | 6 740 740.00 | | | | | | | |
| | 449 376.54 | 6 740 740.00 | 37 | 91 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 449 369.58 | 6 740 776.61 | | | | | | | |
| | 449 371.64 | 6 740 777.52 | 11 | 28 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 449 368.84 | 6 740 788.56 | | | | | | | |
| PR_TR10_1 | 449 243.10 | 6 740 847.66 | 52 | 91 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 449 288.16 | 6 740 872.82 | | | | | | | |
| | 449 288.16 | 6 740 872.82 | 3 | 5 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 – 40 | < 64 | < 10 | Low |
| | 449 290.66 | 6 740 873.61 | | | | | | | |
| | 449 290.66 | 6 740 873.61 | 58 | 102 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 449 343.81 | 6 740 896.41 | | | | | | | |
| PR_TR11 | 450 303.70 | 6 741 320.62 | 115 | 178 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 450 208.50 | 6 741 256.19 | | | | | | | |
| | 450 208.50 | 6 741 256.19 | 8 | 13 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 450 202.73 | 6 741 250.37 | | | | | | | |
| | 450 202.73 | 6 741 250.37 | 11 | 17 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 – 40 | 64 - 5 | < 10 | Low |
| | 450 192.82 | 6 741 246.20 | | | | | | | |
| | 450 192.82 | 6 741 246.20 | 22 | 34 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 450 174.74 | 6 741 233.20 | | | | | | | |
| | 450 174.74 | 6 741 233.20 | 6 | 10 | Gravelly sandy mud/muddy sand with cobbles and boulders | 40 - 95 | 64 - 5 | < 10 | Medium |
| | 450 169.21 | 6 741 230.41 | | | | | | | |
| | 450 169.21 | 6 741 230.41 | 10 | 15 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 450 160.73 | 6 741 225.56 | | | | | | | |
| PR_TR15 | 461 237.81 | 6 748 842.06 | 41 | 111 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 461 216.21 | 6 748 806.65 | | | | | | | |
| | 461 216.21 | 6 748 806.65 | 15 | 39 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 – 40 | 64 -5 | < 10 | Low |
| | 461 212.12 | 6 748 792.49 | | | | | | | |
| | 461 212.12 | 6 748 792.49 | 12 | 33 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 461 211.31 | 6 748 780.02 | | | | | | | |

| Transect | Video Coordinates [1] | | Length (m) | Area Observed ($m^2$) | Sediment Description | Stony Reef Characteristics | | | Overall Reefiness Matrix |
|---|---|---|---|---|---|---|---|---|---|
| | Easting | Northing | | | | Composition (% cover of cobbles & boulders) | Elevation | Biota (%) | |
| | 461 211.31 | 6 748 780.02 | 7 | 19 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 – 40 | 64 – 5 | < 10 | Low |
| | 461 211.62 | 6 748 773.02 | | | | | | | |
| | 461 211.62 | 6 748 773.02 | 39 | 104 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 461 211.22 | 6 748 733.97 | | | | | | | |
| PR_TR17 | 469 681.77 | 6 750 173.43 | 53 | 145 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 469 644.45 | 6 750 135.39 | | | | | | | |
| | 469 644.45 | 6 750 135.39 | 2 | 5 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 – 40 | < 64 | < 10 | Low |
| | 469 643.40 | 6 750 134.01 | | | | | | | |
| | 469 643.40 | 6 750 134.01 | 81 | 220 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 469 576.18 | 6 750 088.88 | | | | | | | |
| PR_TR18 | 472 881.93 | 6 750 077.77 | 38 | 53 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 472 864.10 | 6 750 043.94 | | | | | | | |
| | 472 864.10 | 6 750 043.94 | 4 | 6 | Gravelly sandy mud/muddy sand with cobbles and boulders | 40 – 95 | < 64 | < 10 | Low |
| | 472 861.76 | 6 750 040.36 | | | | | | | |
| | 472 861.76 | 6 750 040.36 | 86 | 119 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 472 797.22 | 6 749 983.23 | | | | | | | |
| PR_TR22 | 484 101.68 | 6 749 175.46 | 46 | 64 | Small scale rippled sand with gravel, pebbles and cobbles | < 10 | < 64 | < 10 | Not a Reef |
| | 484 072.21 | 6 749 140.20 | | | | | | | |
| | 484 072.21 | 6 749 140.20 | 3 | 5 | Small scale rippled sand with gravel, pebbles and cobbles | 40 – 95 | 64 – 5 | < 10 | Medium |
| | 484 069.83 | 6 749 137.87 | | | | | | | |
| | 484 069.83 | 6 749 137.87 | 3 | 4 | Small scale rippled sand with gravel, pebbles and cobbles | 10 – 40 | < 64 | < 10 | Low |
| | 484 069.02 | 6 749 135.18 | | | | | | | |
| | 484 069.02 | 6 749 135.18 | 23 | 31 | Small scale rippled sand with gravel, pebbles and cobbles | < 10 | < 64 | < 10 | Not a Reef |
| | 484 057.02 | 6 749 116.04 | | | | | | | |
| | 484 057.02 | 6 749 116.04 | 8 | 11 | Small scale rippled sand with gravel, pebbles and cobbles | 10 - 40 | 64 – 5 | < 10 | Low |
| | 484 054.21 | 6 749 108.87 | | | | | | | |
| | 484 054.21 | 6 749 108.87 | 7 | 10 | Small scale rippled sand with gravel, pebbles and cobbles | < 10 | < 64 | < 10 | Not a Reef |
| | 484 050.00 | 6 749 102.74 | | | | | | | |
| | 484 050.00 | 6 749 102.74 | 3 | 4 | Small scale rippled sand with gravel, pebbles and cobbles | 40 – 95 | 64 - 5 | < 10 | Medium |
| | 484 049.55 | 6 749 099.52 | | | | | | | |
| | 484 049.55 | 6 749 099.52 | 15 | 21 | Small scale rippled sand with gravel, pebbles and cobbles | < 10 | < 64 | < 10 | Not a Reef |
| | 484 042.96 | 6 749 086.23 | | | | | | | |

| Transect | Video Coordinates [1] | | Length (m) | Area Observed ($m^2$) | Sediment Description | Stony Reef Characteristics | | | Overall Reefiness Matrix |
|---|---|---|---|---|---|---|---|---|---|
| | Easting | Northing | | | | Composition (% cover of cobbles & boulders) | Elevation | Biota (%) | |
| PR_TR24 | 491 383.19 | 6 748 760.00 | 40 | 74 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 491 348.89 | 6 748 739.01 | | | | | | | |
| | 491 348.89 | 6 748 739.01 | 8 | 14 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 – 40 | < 64 | < 10 | Low |
| | 491 344.05 | 6 748 733.17 | | | | | | | |
| | 491 344.05 | 6 748 733.17 | 5 | 10 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 491 341.27 | 6 748 728.69 | | | | | | | |
| | 491 341.27 | 6 748 728.69 | 5 | 9 | Gravelly sandy mud/muddy sand with cobbles and boulders | 10 - 40 | < 64 | < 10 | Low |
| | 491 339.44 | 6 748 724.27 | | | | | | | |
| | 491 339.44 | 6 748 724.27 | 24 | 45 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 491 329.75 | 6 748 701.78 | | | | | | | |
| | 491 325.49 | 6 748 695.61 | 29 | 53 | Gravelly sandy mud/muddy sand with cobbles and boulders | < 10 | < 64 | < 10 | Not a Reef |
| | 491 304.57 | 6 748 675.76 | | | | | | | |

| Stony Reef Assessment Key | | |
|---|---|---|
| Not a Reef | Low Reef | Medium |

[1] Geodetics Parameters: ED50, UTM Zone 30N, CM 3° W [m]

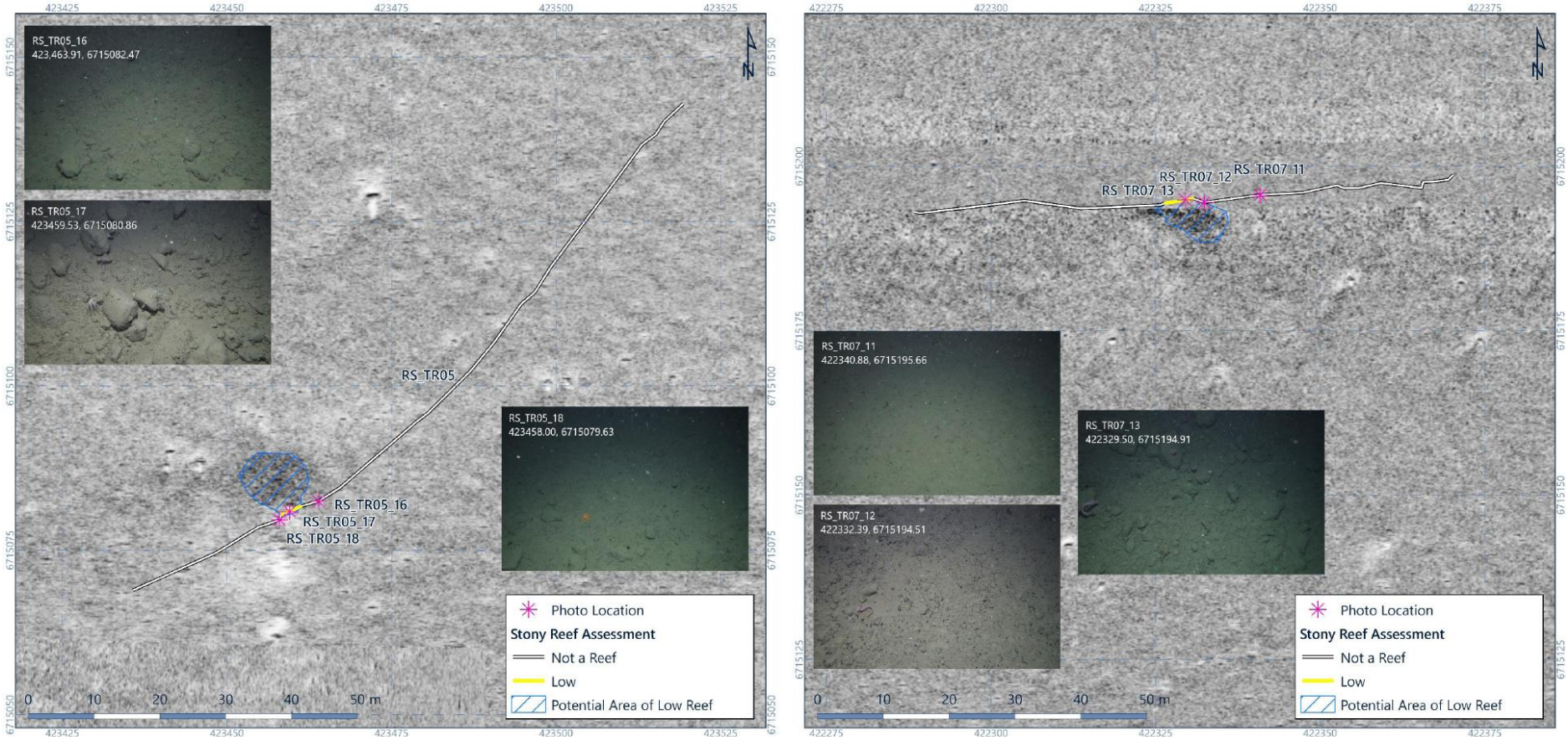



**Figure 4.18: Stony reef assessment and potential reef extents for transects RS_TR05 and RS_TR07, overlaid on SSS, Tornado Site Survey Area (Fugro, 2025a)**

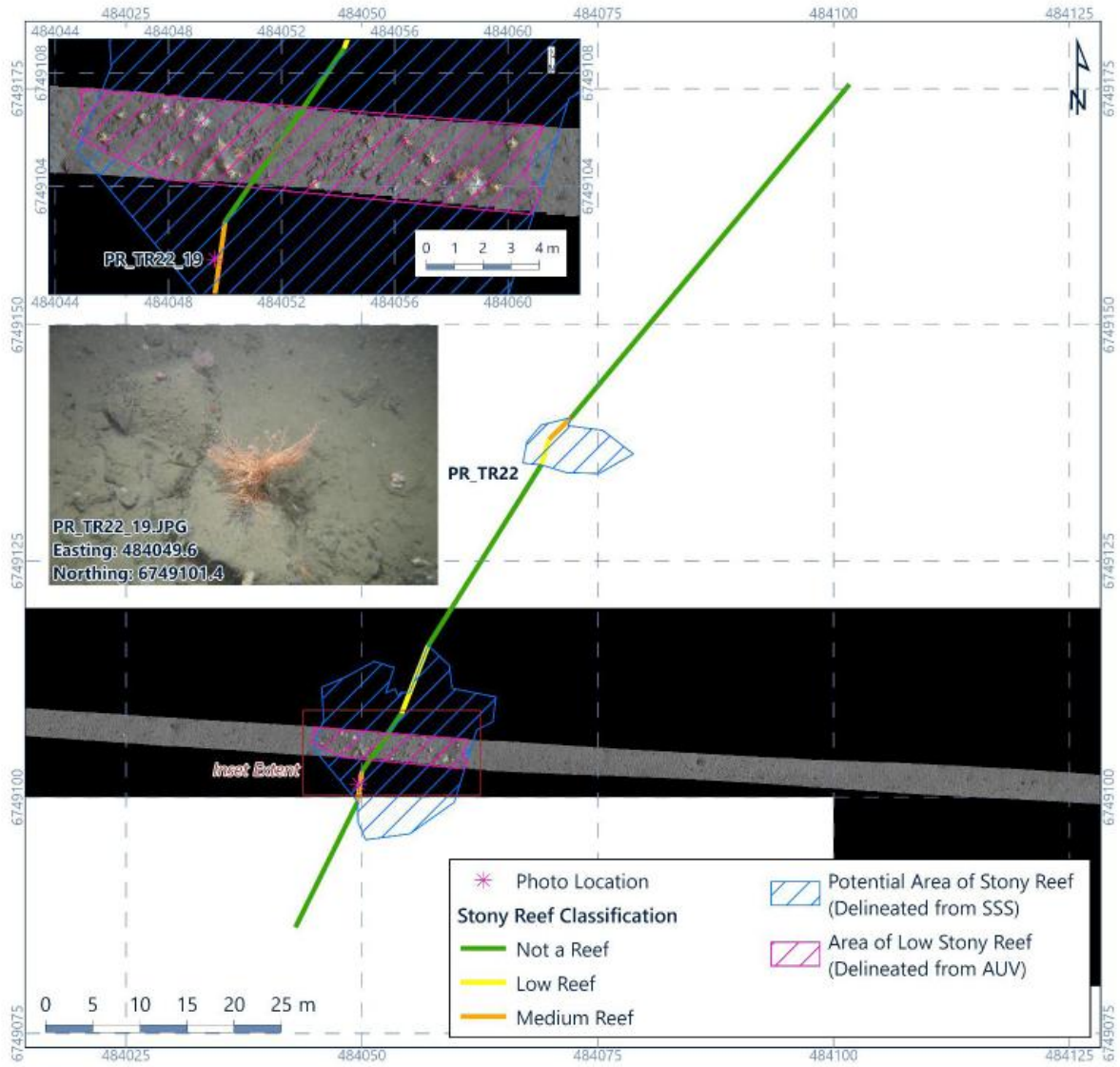



**Figure 4.19: Stony reef assessment and potential reef extents along transect PR_TR22 overlain on AUV mosaic, Tornado Pipeline Route Survey (Fugro, 2025b)**

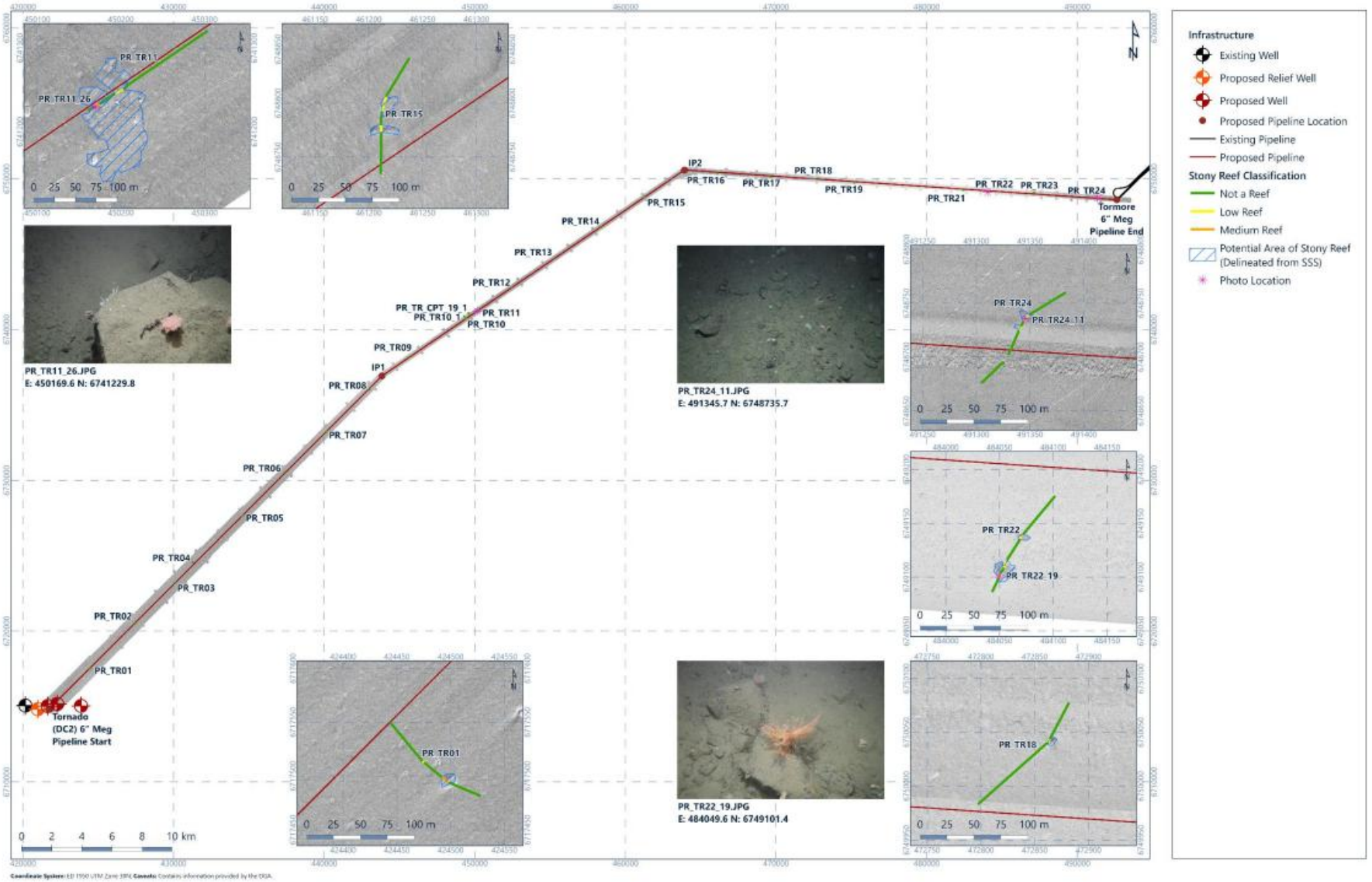



**Figure 4.20: Stony reef assessment and potential reef extents overlain on side scan sonar, Tornado Pipeline Route Survey (Fugro, 2025b)**

Ocean Quahog (*Arctica islandica*)

Ocean quahog (*Arctica islandica*) is listed as a PMF in Scottish waters and is listed as an OSPAR Threatened and/or Declining species. This species of bivalve mollusc is long-lived with a slow growth rate and is generally found partially buried in sandy and muddy sediments.

Ocean quahog is recorded as inhabiting the Faroe-Shetland Sponge Belt, WoS (JNCC, 2014); however, no individuals were recorded in the macrofauna data at the proposed Tornado drill centre or within the pipeline route corridor survey, no potential relict shells were observed along the video transects and no live individuals or their distinctive siphons were noted during analysis of video footage and still photographs from the survey areas (Fugro, 2025a; 2025b).

In addition, no ocean quahog specimens were observed on camera or recorded in the macrofauna data within the vicinity of the Cambo and Rosebank development areas (MMT, 2019; Equinor, 2022). It is therefore unlikely that *Arctica islandica* are present within the Tornado Development area.

Sea pens and burrowing megafauna

Sporadic burrows were observed along transects and AUV lines within the Tornado site survey area, but in conjunction with the sediment type and size of the area where burrows were observed, were not considered to be present in sufficient numbers to warrant a full 'Sea pens and burrowing megafauna' (OSPAR, 2010b) assessment. No sea pens were observed along the environmental survey transects or AUV lines within the site survey area. Along the proposed pipeline route, sea pens and burrows were present, but did not warrant a full assessment due to the sporadic distribution and low abundance (Fugro, 2025b). Therefore, 'Sea pens and burrowing megafauna' were not thought to be present within the Tornado survey areas.

Other Potential Sensitive Habitats and Species

The Tornado habitat assessment survey along the proposed pipeline route (Fugro, 2025b) found that the EUNIS level 3 habitat types 'Arctic upper bathyal mixed sediment' (ME41) and 'Arctic upper bathyal sand' (ME51) are encompassed within the PMF 'Offshore subtidal sands and gravels'. Arctic bathyal sediments are the component biotope of 'Offshore subtidal sands and gravels', which is a designated priority habitat within Scottish waters (Tyler-Walters *et al*., 2016). However, 'Arctic upper bathyal mixed sediment' (ME41) and 'Arctic upper bathyal sand' (ME51) are not included in the United Kingdom Biodiversity Action Plan (UK BAP) priority habitat 'Subtidal sands and gravels' (BRIG, 2011).

No other Annex I habitats, Annex II species, OSPAR listed as threatened and/or declining habitats or species, UK Biodiversity Action Plan (BAP) priority habitats and species or PMF habitats or species were observed within the Tornado survey areas (Fugro, 2025a; Fugro, 2025b).

### Benthic Infaunal Communities

The proposed Tornado site survey area showed a generally high species richness, with similar species dominating throughout. Macrofaunal analysis was carried out on 30 grab samples obtained at fifteen environmental stations within the Tornado site survey area (see Figure 4.1 in Section 4.1.1).

A total of 7,577 individuals from the samples taken from within the Tornado site survey area were analysed. Overall, 165 taxa were recorded; the taxa consisted of 52 annelid species, which dominated the community, accounting for 61.7% of the total individuals. There were 74 species of arthropods recorded (26.6% of the total individuals), 32 species of molluscs (6.8% of the total individuals), and 2 species of echinoderms (4.3% of total individuals). The other phyla (Cnidaria, Hemichordata, Platyhelminthes and Nemertea) were represented by 5 species, accounting for 0.6% of the total individuals. The most abundant taxa from the Tornado site survey area are listed in Table 4.10 (Fugro, 2025c).

**Table 4.10: Summary of Macrofaunal Analysis for the Tornado Site Survey (Fugro, 2025c)**

| Phylum | Tornado Survey [1] | | | |
|---|---|---|---|---|
| | Number of Taxa | Composition of Taxa (%) | Abundance | Composition of Individuals (%) |
| Annelida | 52 | 31.5 | 4,853 | 61.7 |
| Arthropoda | 74 | 44.8 | 1,921 | 26.6 |
| Mollusca | 32 | 19.4 | 469 | 6.8 |
| Echinodermata | 2 | 1.2 | 300 | 4.3 |
| Other [2] | 5 | 3.0 | 39 | 0.6 |
| **Total** | **165** | **100** | **7,582** | **100** |

[1] Tornado site survey sampled using a 0.5 mm mesh sieve;
[2] Other phyla included Cnidaria, Hemichordata, Platyhelminthes and Nemertea

The species identified during the Tornado site survey were ranked in terms of dominance, ranking the taxa has made it possible to examine which were consistently dominant throughout the survey area. Annelids dominated within the infaunal community, making up six of the top ten ranked species. The five most dominant species were the annelids *Notoproctus* (Type B), followed by *Notoproctus* (Type A), *Proclea graffii*, *Nephasoma (Nephasoma) lilljeborgi* and *Paramphinome jeffreysii* all with a frequency of presence across all stations of 100%.

Table 4.11 lists the rank dominance and abundance of taxa recorded during the Tornado site survey. By ranking the taxa recorded at each station in terms of density and summing the rank scores for all stations to assign an overall rank abundance and dominance for each taxon, it is possible to examine which taxa were consistently abundant as well as dominant throughout the survey area. The pattern of rank abundance and rank dominance were relatively consistent in the survey suggesting that the majority of the macrofaunal community structure was similar across the survey area, with only subtle differences in abundance of certain taxa observed throughout the site (Fugro, 2025c).

**Table 4.11: Overall Taxon Dominance Ranking within the Tornado Site Survey Area (Top 10 Taxa) (Fugro, 2025c)**

| Species / Taxon | Phylum | Tornado Site Survey [1] | | | |
|---|---|---|---|---|---|
| | | Rank Dominance | Frequency (%) | Rank Abundance | Mean Station Abundance (0.2 $m^2$) |
| *Notoproctus* (Type B) | Annelida | 1 | 100 | 1 | 90 |
| *Notoproctus* (Type A) | Annelida | 2 | 100 | 2 | 53 |
| *Proclea graffii* | Annelida | 3 | 100 | 3 | 27 |
| *Nephasoma (Nephasoma) lilljeborgi* | Annelida | 4 | 100 | 4 | 26 |
| *Paramphinome jeffreysii* | Annelida | 7 | 100 | 5 | 20 |
| *Myriochele* | Annelida | 6 | 100 | 6 | 20 |
| *Ophiocten gracilis* | Echinodermata | 9 | 93.3 | 7 | 19 |
| *Pseudosphyrapus* | Arthropoda | 5 | 100 | 8 | 18 |

| Species / Taxon | Phylum | Tornado Site Survey [1] | | | |
|---|---|---|---|---|---|
| | | Rank Dominance | Frequency (%) | Rank Abundance | Mean Station Abundance (0.2 $m^2$) |
| *Typhlotanais* | Arthropoda | 8 | 100 | 9 | 18 |
| *Spectrarcturus hystrix* | Arthropoda | 10 | 100 | 10 | 11 |

[1] Tornado site survey sampled using a 0.5 mm mesh sieve

The proposed Tornado pipeline route corridor survey area showed a good to high species diversity throughout the surveyed area, with similar species dominating throughout. Macrofaunal analysis was carried out on 42 grab samples obtained at 21 environmental stations within the Tornado pipeline route corridor survey area (see Figure 4.2 in Section 4.1.1).

A total of 10,420 individuals from the samples taken from within the pipeline route corridor survey area were analysed. Overall, 204 taxa were recorded; the taxa consisted of 76 annelid species, which dominated the community, accounting for 62.3% of the total individuals. There were 87 species of arthropods recorded (23.9% of the total individuals), 31 species of molluscs (10.5% of the total individuals), and 4 species of echinoderms (2.1% of total individuals). The other phyla (Cnidaria, Chordata, Platyhelminthes and Nemertea) were represented by 6 species, accounting for 1.2% of the total individuals. The most abundant taxa from the Tornado pipeline route corridor survey are listed in Table 4.12 (Fugro, 2025d).

**Table 4.12: Summary of Macrofaunal Analysis for the Tornado Pipeline Route Corridor Survey (Fugro, 2025d)**

| Phylum | Tornado Survey [1] | | | |
|---|---|---|---|---|
| | Number of Taxa | Composition of Taxa (%) | Abundance | Composition of Individuals (%) |
| Annelida | 76 | 37.3 | 6,491 | 62.3 |
| Arthropoda | 87 | 42.6 | 2,488 | 23.9 |
| Mollusca | 31 | 15.2 | 1,095 | 10.5 |
| Echinodermata | 4 | 2.0 | 223 | 2.1 |
| Other [2] | 6 | 2.9 | 123 | 1.2 |
| **Total** | **204** | **100** | **10,420** | **100** |

[1] Tornado pipeline route corridor survey sampled using a 0.5 mm mesh sieve;
[2] Other phyla included Cnidaria, Chordata, Platyhelminthes and Nemertea

The species identified during the Tornado pipeline route corridor survey were ranked in terms of dominance, ranking the taxa has made it possible to examine which were consistently dominant throughout the survey area. Annelids dominated within the infaunal community, making up six of the top ten ranked species. The two most dominant species were the annelids *Nephasoma (Nephasoma) lilljeborgi*, followed by *Paramphinome jeffreysii both* with a frequency of presence across all stations of 100%. The third most dominant taxon was the Annelid *Notoproctus* (Type A), with a frequency of presence of 85.7%. The Molluscs *Yoldiella nana* and *Yoldiella propinqua* were the fourth and fifth most dominant species with a frequency of presence of 100% and 95.2% respectively.

Table 4.13 lists the rank dominance and abundance of taxa recorded during the Tornado pipeline route corridor survey. By ranking the taxa recorded at each station in terms of density and summing the rank scores for all stations to assign an overall rank abundance and dominance for each taxon, it is possible to examine which taxa were consistently abundant as well as dominant throughout the survey area. The pattern of rank abundance and rank dominance were relatively consistent in the survey suggesting

that the majority of the macrofaunal community structure was similar across the survey area, with only subtle differences in abundance of certain taxa observed throughout the site (Fugro, 2025d).

**Table 4.13: Overall Taxon Dominance Ranking with the Tornado Pipeline Route Corridor Survey Area (Top 10 Taxa) (Fugro, 2025d)**

| Species / Taxon | Phylum | Tornado Pipeline Survey [1] | | | |
|---|---|---|---|---|---|
| | | Rank Dominance | Frequency (%) | Rank Abundance | Mean Station Abundance (0.2 $m^2$) |
| *Nephasoma (Nephasoma) lilljeborgi* | Annelida | 1 | 100 | 3 | 34 |
| *Paramphinome jeffreysii* | Annelida | 2 | 100 | 1 | 76 |
| *Notoproctus (Type A)* | Annelida | 3 | 85.7 | 2 | 42 |
| *Yoldiella nana* | Mollusca | 4 | 100 | 10 | 12 |
| *Yoldiella propinqua* | Mollusca | 5 | 95.2 | 16 | 10 |
| *Pseudosphyrapus* | Arthropoda | 6 | 95.2 | 6 | 17 |
| *Glycera capitata* | Annelida | 7 | 100 | 17 | 8 |
| *Chaetozone* | Annelida | 8 | 100 | 8 | 13 |
| *Byblis* | Arthropoda | 9 | 95.2 | 14 | 10 |
| *Galathowenia* | Annelida | 10 | 100 | 13 | 10 |

[1] Tornado pipeline route corridor survey sampled using a 0.5 mm mesh sieve

Primary and Univariate Analysis

Overall, the number of species identified during the Tornado site survey was relatively consistent throughout the area. There was limited variation in the number of species per station, with numbers ranging from 34 to 79 species. The number of individuals was more variable, with numbers ranging from 145 to 435 across the stations. Diversity across the Tornado site survey area correlated with the fine fractions in the sediment; however, no other correlations between the sediment fractions or metals and the macrofaunal community statistics were present (Fugro, 2025c).

Diversity was high across the Tornado site survey area and indices showed low variability, with very similar values across stations. Additionally, evenness values, a diversity index measuring how close in numbers each species in an area are, are between 0-1 with values closer to one demonstrating high species evenness with less variation in communities between species (Fugro, 2025c).

The number of species identified during the Tornado pipeline route corridor survey was also relatively consistent throughout the area. There was limited variation in the number of species per station, with numbers ranging from 56 to 87 species. The number of individuals was more variable, with numbers ranging from 302 to 733 across the stations. The variation in number of individuals and species across the Tornado pipeline route corridor survey area correlated with the depth profile. This variation was most prevalent around the north-east end of the route, corresponding to the shallowest depths, indicating that differences were mainly driven by depth and sediment characteristics. A positive correlation between the gravel fractions and the Shannon-Wiener diversity index was identified; however, no other correlations between the sediment fractions and the macrofaunal community statistics were present (Fugro, 2025d).

Diversity indices additionally showed low variability within the Tornado pipeline route corridor survey area, with values very similar value across stations. Additionally, evenness values, a diversity index

measuring how close in numbers each species in an area are, are between 0-1 with values closer to one demonstrating less variation in communities between species (Fugro, 2025d).

Multivariate Analysis

For the Tornado site survey stations, similarity profile (SIMPROF) analysis, which analyses the contribution of each species to the observed similarity between samples, identified two main clusters which were significantly different with two ungrouped stations. The area within the vicinity of the proposed drill centre (RS_ST11 to RS_ST15) fell into both identified clusters. The two clusters appeared to differentiate primarily due to the greater abundances of the brittlestar *Ophiocten gracilis*, as well as small scale variations of arthropods, molluscs and annelids, including some in the top ten most abundant taxa such as *Notoproctus* (Type A). Two ungrouped stations were identified; RS_ST02 displayed a higher abundance of polychaete species including *P. jeffreysii*, whereas RS_ST07 displayed higher abundances of arthropod species, such as *Ischyrocerus*, and *Ericthonius* (Fugro, 2025c).

The clusters and the stations they encompass are summarised below:

- Cluster A – (RS_ST01, RS_ST03 to RS_ST05, RS_ST08 to RS_ST11, and RS_ST13 to RS_ST15) grouped together with at least 67.7% similarity to each other;
- Cluster B – (RS_ST06 and RS_ST12) grouped together with at least 65.6% similarity to each other;
- Ungrouped station RS_ST02 grouped to Cluster A with 65.8 % and Cluster B with 54.4% similarity;
- Ungrouped station RS_ST07 grouped to Cluster A with 65.2% and Cluster B 61.8% similarity.

Correlations tests were carried out to assess whether the observed differences in community composition within the site survey area were a result of any relationships between the biological community and environmental parameters. Tests between species diversity and PSD, and species diversity and fines content showed that there was a significant correlation between the data sets, which was to be expected considering the variability in species type and sediment variability throughout the sampling stations. Further tests were carried out between the species diversity values and separate subsets of hydrocarbon and metal concentrations which showed no relationship between species diversity and metals or hydrocarbons within the sediment (Fugro, 2025c).

The differences observed between the clusters were largely due to the variability in the most dominant taxa including the polychaetes *Notoproctus* (Type A), and *P. jeffreysii*, as well as the echinoderm *Ophiocten gracilis*. The difference between the ungrouped stations were driven by the higher abundance of certain species of annelids including *P. jeffreysii* and multiple arthropods species including *Ischyrocerus*, *Typhlotanais*, and *Ericthonius*. These differences were most likely driven by variations within the sediments, with many of these taxa commonly associated with epifauna attached to cobbles and pebbles. No apparent spatial patterns were observed in the dominant taxa throughout the site survey area (Fugro, 2025c).

For the Tornado pipeline route corridor survey stations, SIMPROF analysis, identified six main clusters which were significantly different. As with univariate analysis, multivariate analysis of sample data indicates that there was variability in the abundance of dominant taxa, including *Notoproctus* (Type A and B) and *P. jeffreysii*. The investigation of faunal similarities also showed some spatial patterns in the dominant taxa along the survey route. Stations to the north-east of the route (cluster C and cluster F) showed clear differences in similarity to all other clusters. This was mainly due to the high variability in abundance of the annelid species, *P. jeffreysii*.

The clusters and the stations they encompass are as follows:

- Cluster A – (PR_ST02, PR_ST03, PR_ST05, PR_ST06, PR_ST10, PR_ST12, PR_ST14, and PR_ST15) grouped together with at least 63.3% similarity to each other;
- Cluster B – (PR_ST01, PR_ST07, PR_ST09, and PR_ST16) grouped together with at least 67.1% similarity to each other;

- Cluster C – (PR_ST20, PR_ST21, and PR_ST22) grouped together with at least a 70.8% similarity to each other;
- Cluster D – (PR_ST17 and PR_ST18) grouped together with at least a 72.1% similarity to each other;
- Cluster E – (PR_ST13 and PR_ST19) grouped together with at least a 60.4% similarity to each other;
- Cluster F - (PR_ST23 and PR_ST24) grouped together with at least a 62.1% similarity to each other.

Correlations tests were carried out to assess whether the observed differences in community composition within the pipeline route corridor survey area were a result of any relationships between the biological community and environmental parameters. Tests between species diversity and PSD, and species diversity and depth showed that there was a significant correlation between the data sets, which was to be expected considering the variability in species type a shallower stations and sediment variability throughout the sampling stations. Further tests were carried out between the species diversity values and separate subsets of hydrocarbon and metal concentrations which showed significant positive relationship between species diversity and the aluminium, chromium and iron concentrations within the sediment. There were no significant relationships between species diversity and hydrocarbon concentrations (Fugro, 2025d).

Clusters appeared to differentiate due to the varying abundance of annelid species across the survey area. Clusters with stations in shallow waters present at the northern end of the pipeline route were shown to be dissimilar to all other clusters present and the key difference in the communities here was driven by high variation in abundance of *Paramphinome jeffreysii*, and *Notoproctus* (Type A and B) (Fugro, 2025d).

Comparisons with Other Regional Surveys

The macrofauna community recorded within the Tornado site survey area and pipeline route corridor is broadly similar to that identified from previous surveys undertaken in the wider WoS region. The AFEN regional survey and proposed Rosebank development area was characterised by a community with high diversity and species evenness (AFEN, 2000). The community diversity within the Cambo development area was also high; the annelid *Paramphinome jeffreysii* was the most abundant species, with 102 individuals, which occurred in 50% of the samples. This was followed by annelid *Nephasoma* sp., species from the Nemetoda phylum and the echinoderm *Ophiura robusta (*MMT,2019*)*.

### 4.3.3 Fish and Shellfish

#### Distribution of Adult Populations

Fish are separated into pelagic species, which occur in shoals swimming in mid-levels of the water, typically making extensive seasonal movements or migrations between sea areas and demersal species, which live on or near the seabed.

The dominant mesopelagic species (inhabiting waters between 200-1,000 m) along the west coast of the UK are thought to be the lantern-fish (*Notoscopelus kroyeri*) and the pearlside (*Maurolicus muelleri*) (BEIS, 2022).

Beyond 500 m in depth, water temperatures decline rapidly as warm Atlantic water meets with cold Norwegian Sea water. The sharp temperature gradient supports an atypical fish assemblage dominated by cold water species such as Arctic skate (*Amblyraja hyperborea*), roughhead grenadier (*Macrourus berglax)*, blue ling (*Molva dypterygia*), tusk (*Brosme brosme*), redfish (*Sebastes norvegicus*) and Greenland halibut (*Reinhardtius hippoglossoides*) (Gordon, 2003). Dulvey et al. (2008) have documented that cold water species such as monkfish (*Lophius piscatorius*) and megrim (*Lepidorhombus whiffiagoni*) are moving into deeper waters as a result of ocean warming, which has increased their numbers in waters deeper than 500 m.

Below 1,000 m (i.e. at the proposed Tornado drill centre location), bottom temperatures are generally less than 0°C and the water mass present is confluent with cold Norwegian Sea water. This deep-water

environment supports less demersal fish species which are commercially exploited (Gordon et al, 1994). There are limited surveys of the deeper areas (>1,000 m), but it has been revealed that a sparse cold water fauna occupies these depths, which includes Arctic skate, rockling (*Gaidropsarus* sp.), Greenland halibut and deepwater species of eelpout (*Lycodes esmarkii*) (SERPENT, 2009a, 2009b; Jones and Gates, 2010; DTI, 2003).

Fish observed during the Tornado surveys conducted in 2024, included rockling, sculpin (*Cottunculus microps*), eelpout (*Lycodes* sp. including *Lycodes esmarkii*), hagfish (*Myxine glutinosa*) and other unidentified fish (Osteichthyes) (Fugro, 2024a; Fugro, 2024b).

A number of shellfish species are also present in the waters of the WoS, although not in the deep waters of the proposed Tornado Development area. Crabs and lobsters are generally confined to inshore rocky areas whilst the commercially valuable crustacean *Nephrops norvegicus* (or langoustine) and scallops have a more offshore distribution. *Nephrops* are the most important shellfish species in the Scottish continental shelf and slope down to depths of 600 m (BEIS, 2022).

### Spawning and Nursery Grounds

The North-East Atlantic and North Sea is split into a statistical grid called International Council for the Exploration of the Sea (ICES) Rectangles in order to map statistical information about the area. The proposed Tornado drill centre and approximately 33.4 km of the proposed pipeline route down to a water depth of ca. 1,074 m is located within ICES Rectangle 50E5, with the remainder of the pipeline route (approximately 50.9 km) to the Tormore manifold is located within ICES Rectangle 50E6.

The waters of ICES Rectangles 50E5 and 50E6 act as a spawning area for blue whiting (*Micromesistius potassou*) and Norway pout (*Trisopterus esmarkii*), although these areas do not directly overlap with the proposed Tornado Development area (see Table 4.14 and Figure 4.21; Coull *et al*., 1998; Ellis *et al*., 2012). Both blue whiting and 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, 2021). The spawning grounds of these species can therefore cover extensive areas, leaving them less vulnerable to disturbance from point sources (BEIS, 2022).

The waters of ICES Rectangles 50E5 and 50E6 also act as a nursery ground for blue whiting (high intensity), ling (*Molva molva*), mackerel (*Scomber scombrus)* and Norway pout (see Table 4.14 and Figure 4.21; Coull *et al*., 1998; Ellis *et al*., 2012). However, only nursery grounds for blue whiting completely overlap the proposed Tornado Development area, with nursery grounds for ling partially overlapping the proposed pipeline route at the Tormore end.

**Table 4.14: Fish Spawning and Nursery Species within the Proposed Tornado Development Area (ICES Rectangles 50E5 and 50E6) (Coull *et al.,* 1998; Ellis *et al.,* 2012)**

| Species | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blue Whiting | N | N | N | N | N | N | N | N | N | N | N | N |
| Ling | N | N | N | N | N | N | N | N | N | N | N | N |
| Mackerel | N | N | N | N | N | N | N | N | N | N | N | N |
| Norway Pout | N | N | N | N | N | N | N | N | N | N | N | N |

**Key**
N = High intensity nursery as per Ellis *et al*., 2012

| | | | | | |
|---|---|---|---|---|---|
| | Spawning | | Peak Spawning | N | Nursery |

Herring tends to deposit their sticky eggs on coarse sand and gravel, although spawning may also take place in the open sea, as long as waters are well-mixed, and temperature and salinity tolerance are wide (DECC, 2016). Historically, herring spawned in the spring to the northwest and west of Shetland, while autumn spawning took place primarily to the east of the Northern Isles (Frost and Diele, 2022). Active spawning grounds are now considered limited to the autumn months when there is an abundance of yolk-sac larvae between Shetland and Orkney (Frost and Diele, 2022). However, the closest mapped herring spawning area to the proposed Tornado Development area is located approximately 67 km southeast of the Tormore manifold (Coull et al., 1998; Ellis et al., 2012). The proposed Tornado Development area is additionally not an area of high importance to juvenile herring

spawning (Aires et al., 2014). As such, the proposed Tornado Development area is likely to not be suitable for herring spawning.

Known spawning grounds for other species, such as Arctic skate, halibut, Greenland halibut, roughhead grenadier, blue ling, tusk, monkfish and redfish have been recorded in the wider region surrounding the proposed Tornado Development area. Many of these species have slow growth rates, late onset of sexual maturity and low fecundity, making them vulnerable to over-exploitation.

Adult monkfish make seasonal migrations to winter deepwater spawning grounds, with spawning occurring at depths between 150 m to 900 m during November to April (Hislop et al., 2001). Monkfish eggs are released in a large ribbon of jelly which float on the surface, hatching during February to April (Priede, 2018). Studies have found that blue ling form spawning aggregations at depths between 500 m to 1,100 m (Large et al., 2010). This is along the continental slope northwest of Scotland during February to June, peaking in March and May (Large et al., 2010). Halibut form seasonal spawning aggregations at depths of 700 m to 1,000 m during January to April, with spawning grounds identified to the south of the Faroe Islands. Greenland halibut spawning occurs on the continental slope at 450 m to 1,100 m depth during November to January, with juvenile halibut living in shallower inshore nursery grounds for the first years and gradually migrating to deeper waters (Haug, 1990).

In addition to the mapping of spawning and nursery grounds of key commercial fish species, spatial modelling of the probability of the occurrence of aggregations of 0 group fish species (i.e. fish in the first year of their life) and / or larval stages is also available. This has provisionally identified the spatial distribution of sensitive life stages of commercial fish species (in line with mapping from Coull *et al.,* 1998 and Ellis *et al*., 2012) that could be affected by offshore oil and gas operations (Aires *et al*., 2014). However, the spatial modelling indicates that the proposed Tornado Development area is not considered to be of high importance to juvenile fish species in their first year of development. Of the species mapped, there is only a low probability of 0 group aggregations of blue whiting, whiting (*Merlangius merlangus*), sprat (*Sprattus sprattus*), sole (*Solea solea*), plaice (*Pleuronectes platessa*), Norway pout, mackerel, horse mackerel (*Trachurus trachurus*), herring, hake (*Merluccius merluccius*), haddock, cod, and anglerfish (*Lophius piscatorius*), with aggregations limited to the in shallower waters at the Tormore end of the pipeline route (Figure 4.22 and Figure 4.23) (Aires *et al.,* 2014).

Species that are listed as PMF in Scottish waters include blue whiting, Norway pout, ling, Greenland halibut, halibut, mackerel, herring, whiting, horse mackerel, blue ling , cod and anglerfish (NatureScot, 2020; Tyler-Walters et al., 2016) but are listed as ‘Least Concern’ on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2024).

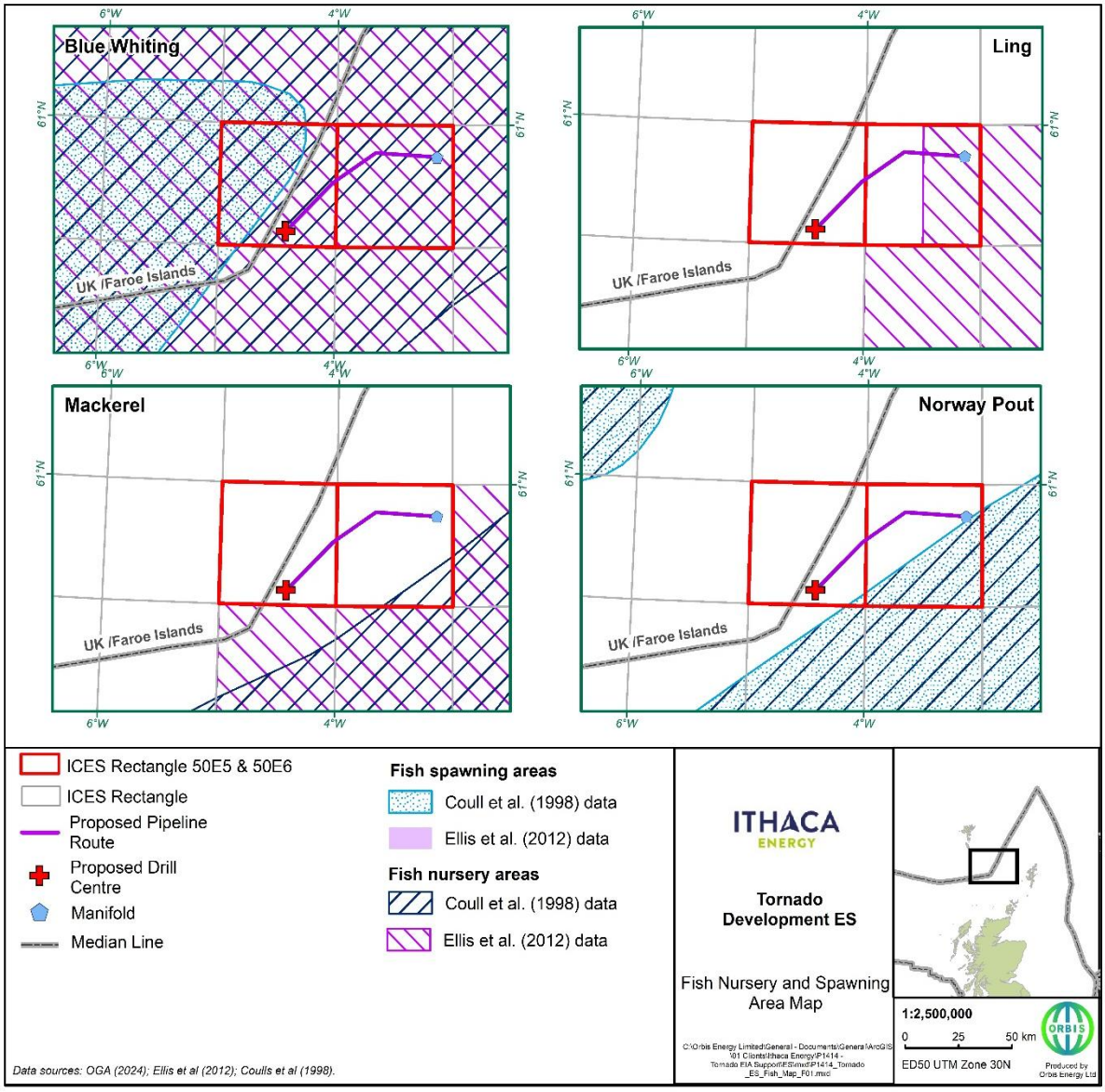



**Figure 4.21: Fish Spawning and Nursery Areas across the Proposed Tornado Development Area**

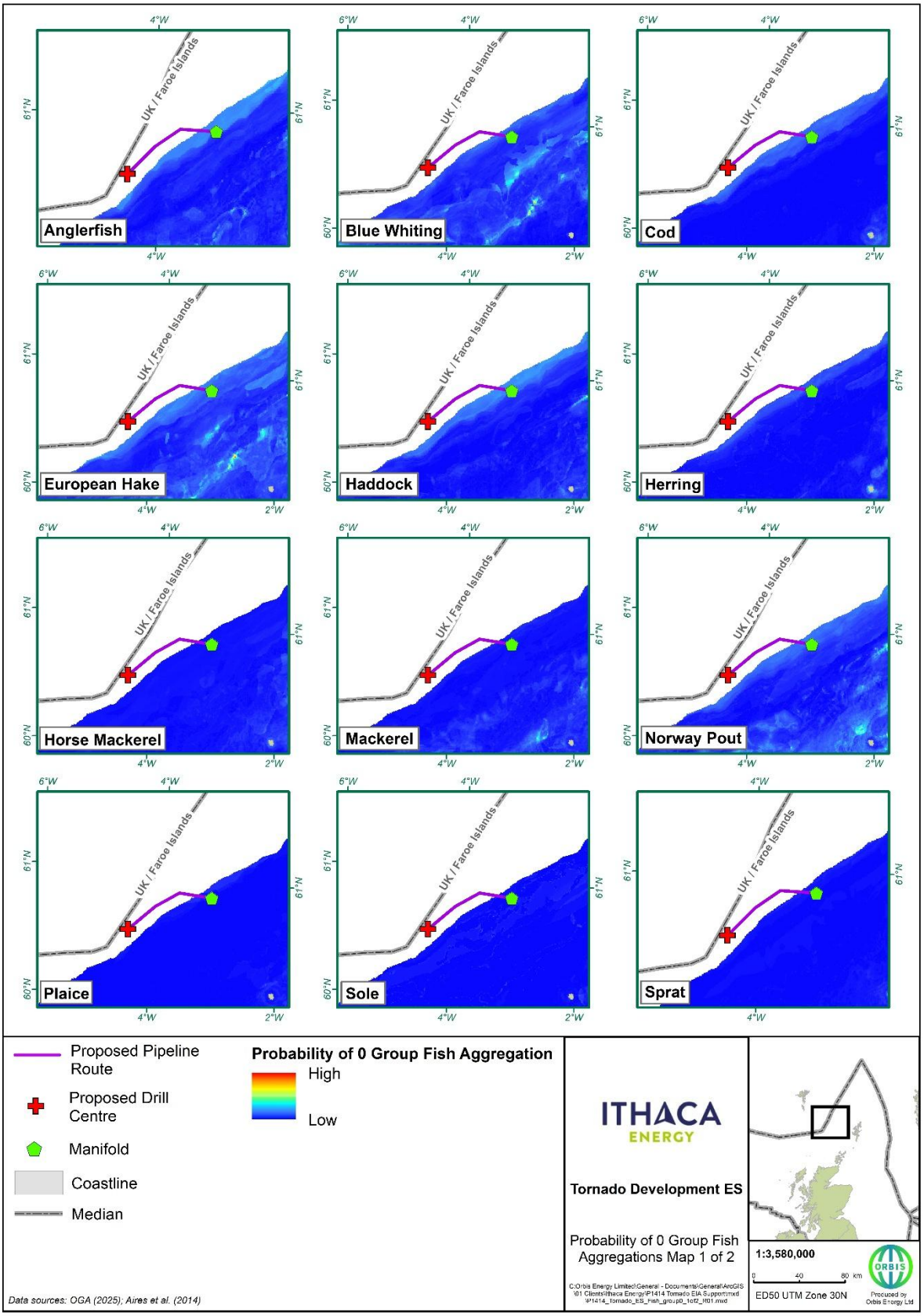



**Figure 4.22: Probability of 0 Group Fish Aggregations in the Vicinity of the Tornado Development Area**

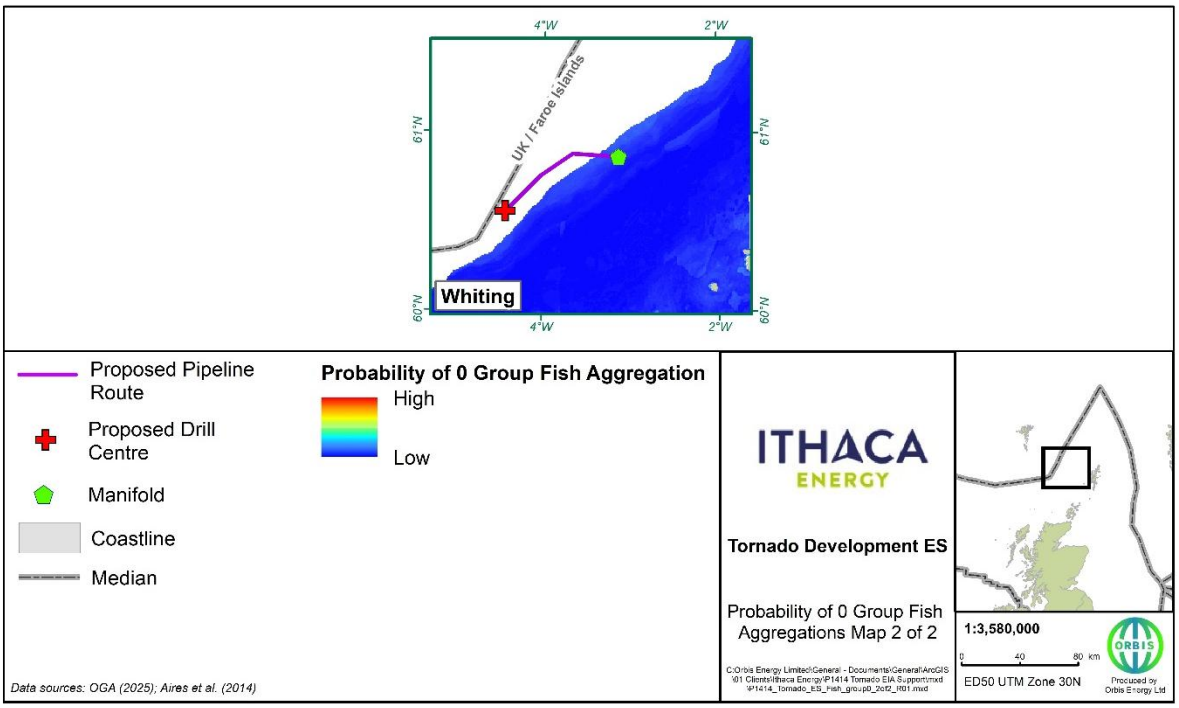



**Figure 4.23: Probability of 0 Group Fish Aggregations in the Vicinity of the Tornado Development Area**

### Migratory Species

Regarding migratory species, tagging studies have shown that Atlantic salmon (*Salmo salar*) from the southwest UK and Ireland inhabit the surface waters and shelf edge current of the Faroe-Shetland Channel, during migrations northwards to the Norwegian Sea and the coastal waters of Greenland (Malcolm et al., 2010). These tagging studies retrieved 167 post-smolt salmon in five trawls in surface waters of the Faroe-Shetland Channel, where the densities captured suggested that post-smolt salmon form schools in the open sea (Shelton et al., 1997).

Not much is known in how the common eel (*Anguilla Anguilla*) uses the WoS waters during migration between UK rivers and the Sargasso Sea (Malcolm et al., 2010). However, it is presumed that juvenile stages arrive in waters WoS and the Western Isles in September each year, being larvae when they reach west of the continental shelf and being slightly larger glass eels by the time they reach shelf waters (Tesch, 2003).

### 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 that have been recorded WoS at various times throughout the year, and therefore may be present in the vicinity of the proposed Tornado Development area, are listed in Table 4.15.

**Table 4.15: List of Elasmobranch Species Likely to be found in the Tornado Development Area (Ellis *et al.,* 2004; Baxter *et al.,* 2011)**

| Common Name | Scientific Name | Depth Range (metres) | Global IUCN Status [1] | European IUCN Status[1] |
|---|---|---|---|---|
| Porbeagle shark | *Lamna nasus* | 200 - 700 [2] | Vulnerable | Critically Endangered |
| Portuguese dogfish | *Centroscymnus coelolepis* | 400 - 2,700 [3] | Near Threatened | Endangered |
| Spurdog (spiny dogfish) | *Squalus acanthias* | 15 - 528 | Vulnerable | Endangered |
| Leafscale Gulper Shark | *Centrophorus squamosus* | 145 – 2,400 [4] | Endangered | Endangered |
| Arctic Skate | *Amblyraja hyperborea* | 250 – 2,500 | Least Concern | Least Concern |
| Basking Shark | *Cetorhinus maximus* | 80 – 1,264 [5] | Endangered | Endangered |

[1] Status as of April 2025
[2] Sometimes found in shallower water close inshore (Baxter *et al*., 2011)
[3] Recorded in commercial fisheries catches in the vicinity of the proposed Tornado Development (Baxter *et al.,* 2011)
[4] Depth ranges taken from Priede (2018)
[5] Depth ranges taken from Gore *et al.* (2008)

In addition to the porbeagle shark, other pelagic shark species known to occur in the Faroe-Shetland Channel include blue sharks (*Prionace glauca*), which follow the North Atlantic Drift through the Faroe-Shetland Channel towards the Norwegian Sea (Kohler et al., 2002) and thresher sharks (*Alopias vulpinus*), although this species has only been recorded in low numbers (Muus and Dahlstrøm, 1985). The leafscale gulper shark (*Centrophorus squamosus*) occupies a very wide depth range, from 145 to 2,400 m (Priede, 2018). It can be found on the continental shelf rarely above depths of 1000m. It is found off the far west and north-west coasts of Scotland. (Baxter *et al*., 2011).

The basking shark (*Cetorhinus maximus*) is a filter-feeding elasmobranch which is widely distributed throughout the waters of the UK west coast, including the Faroe-Shetland Channel. Basking shark sightings are most frequent between April and September (Chambers and Solandt, 2005; Witt et al., 2012) when they move inshore to feed. However, in winter months, basking shark use deep-water areas off the shelf edge west of the British Isles, exploiting mesopelagic zooplankton populations, specifically calanoid copepods overwintering at depths down to 1,200 m (Sims et al., 2003; Gore et al., 2008). All the species listed above are of most concern due to their unfavourable conservation status apart from Arctic skate (IUCN, 2024). In addition, spurdog, leafscale gulper shark and porbeagle shark are listed on the OSPAR list of threatened and/or declining species (OSPAR, 2021) and spurdog, basking shark, and porbeagle shark are listed as a PMF in Scotland (NatureScot, 2020).

### Cephalopods

There are a number of cephalopod species found in the waters around the British Isles, among the most frequently recorded species within the Faroe-Shetland Channel are the long-finned squid, the short-finned squid and spoonarm octopuses (BEIS, 2022). Collins *et al*. (2001) lists 29 species as occurring in waters ranging from 150 to 4,850 m in the northeast Atlantic, with deepwater octopuses widespread throughout the deep, cold waters of the North Atlantic, down to depths of 2,500 m.

Cephalopods are short-lived molluscs, characterised by rapid growth rates, and are important predators and prey in oceanic and coastal environments. The Faroe-Shetland Channel is a known habitat and migration route for whales (refer to Section 4.3.5) many of which rely partly or exclusively on cephalopods for food. The long-finned squid is the main cephalopod species of economic importance within the Faroe-Shetland Channel (Pierce *et al*., 2003). Short-finned squid are known to contribute toward the diet of seabirds (Pierce *et al*., 2003) while bobtail squid are frequently recorded

in the diet of porpoises. Many oceanic squid species occur in the diets of sperm whales (*Physeter macrocephalus)*, northern bottlenose whales (*Hyperoodon ampullatus)* and Cuvier's beaked whales (*Ziphius cavirostris)* (Santos *et al*., 1999; 2001a, 2001b; 2002).

### 4.3.4 Seabirds

#### Offshore Distribution and Abundance

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). Scotland holds internationally important numbers of 24 species of breeding seabirds (Baxter *et al*., 2011), as well as providing habitat for a number of overwintering or passage seabird species, and the coastal waters around the Shetland Islands hold vulnerable concentrations of seabirds all year round.

In the Faroe-Shetland Channel and up the continental slope and shelf, seabirds found are likely to originate mainly from major colonies in the Faroe Islands, Shetland and Orkney and breeding areas further afield such as Iceland and Norway. The offshore areas are too far for most seabirds to visit during the breeding season and seabirds are more likely to be found offshore in late summer and autumn on passage to wintering grounds, or in spring on route to breeding colonies. Although breeding season visits are likely to be few, the Faroe-Shetland Channel and continental shelf is within the foraging range for some of the highly pelagic species, such as northern fulmar (*Fulmarus glacialis)*, the most abundant seabird species in this area. Based on the mean maximum foraging ranges taken from Woodward *et al.,* 2019, other species which may forage in the vicinity of the Tornado Development area during the breeding season, include great skua (*Stercorarius skua*), black-legged kittiwake (*Rissa tridactyla*) (156.1±144.5 km), Atlantic puffin (*Fratercula arctica*) (137.1±128.3 km), northern gannet (*Morus bassanus*) (315.2±194.2 km) and Leach's storm petrel (*Oceanodroma leucorhoa*) (see Table 4.16 for further details).

**Table 4.16: Seabirds Potentially Foraging in the Proposed Tornado Development Area during the Breeding Bird Season (Woodward *et al.,* 2019)**

| Species | Mean Max+1SD Foraging Range (km) | Originating SPA / Ramsar | Type of Feeder |
|---|---|---|---|
| Leach's storm petrel (*Oceanodroma leucorhoa*) | - | Ramna Stacks and Gruney, Foula, Mousa | Surface |
| Great skua (*Catharacta skua*) | 443.3 ± 487.9 | Ronas Hill - North Roe and Tingon, Hermaness, Saxa Vord and Valla Field, Fetlar, Seas off Foula, Foula, Noss | Surface |
| Gannet (*Morus bassanus*) | 315.2 ± 194.2 | Hermaness, Saxa Vord and Valla Field, Noss | Diver |
| Puffin (*Fratercula arctica*) | 137.1 ± 128 | Hermaness, Saxa Vord and Valla Field, Seas off Foula, Foula | Surface / Diver |
| Fulmar (*Fulmarus glacialis*) | 542.3 ± 657.9 | Hermaness, Saxa Vord and Valla Field, Seas off Foula | Diver / Surface |
| Kittiwake (*Rissa tridactyla*) | 156.1 ± 144.5 | Hermaness, Saxa Vord and Valla Field | Surface |

Waggitt *et al.* 2019 analysed seabird survey data in the North-East Atlantic between 1980 and 2018 using Species Distribution Models (SDM) to produce seabird distribution maps. Prediction distributions for January and July were produced to show variation between the coolest and warmest months. Results suggest the Faroe-Shetland Channel is an important feature for some seabird species. In particular, black-legged kittiwake, storm petrel, northern gannet and northern fulmar in summer are predicted to be found in comparatively high densities within the Channel compared to the surrounding areas, whereas during the winter months, black-legged kittiwake and northern fulmar are predicted to be found in comparatively higher densities within the Channel. Of the species studied, northern fulmar

is found in the highest densities within the Faroe-Shetland Channel, up to 3.1 animals per km$^2$ during the winter (Waggitt *et al*., 2019).

The European Seabirds at Sea (ESAS) database is the most complete and longstanding dataset detailing the distribution of seabirds at sea, compiling a range of boat and transect data over a period of 29 years. The data predicts a density of less than 5 seabirds per km$^2$ during the breeding season (March – September), increasing to a predicted density of less than 14 seabirds per km$^2$ in winter (November – March). Largely consistent with the findings of Waggitt *et al.* 2019, the most abundant species present in the vicinity of the proposed Tornado Development area are fulmar and Atlantic puffin (*Fratercula arctica*) during the breeding season, fulmar and black-legged kittiwake (*Rissa tridactyla*) over winter, and guillemot (*Uria aalge*) during the post-breeding dispersal period (JNCC, 2019; Kober *et al*., 2010).

Of note is that the Seas off Foula Special Protection Area (SPA) is located approximately 49 km to the south of the Tormore manifold location and 69 km southeast of the proposed Tornado drill centre location (refer to Section 4.3.6). This site protects important feeding grounds for seabirds breeding on Foula and beyond, including the largest marine aggregation of great skua in the UK.

The JNCC prepares the latest analysed trends in abundance, productivity, demographic parameters, and diet of breeding seabirds, from the Seabird Monitoring Programme (JNCC, 2023). This data provides at-a-glance UK population trends as a percentage of change in breeding numbers from complete censuses. From the year 2015 to 2021, 25 species were monitored, and there is confidence in the trends of 21 of these species, with 11 of these 21 having declined in population since the 1998-2002 census. Species with declining population trends include Arctic skua (-66%), common gull (-49%), black- legged kittiwake (-42%), northern fulmar (-35%), and great black- backed gull (-40%). Breeding seabird numbers of some species have shown a long-term decline, probably as a result of a shortage of key prey species such as sandeel associated with changes in oceanographic conditions (BEIS, 2022). This is further exacerbated by fish stock depletion by commercial fisheries, meaning there's not enough food to go around during the important breeding season. In contrast, seabird species with increasing population trends include great skua (+14%), razorbill (+18%) and northern gannet (+38%). Species that remained stable (change within +/- 10%) include common guillemot, common tern, and sandwich tern (JNCC, 2023).

Five new species have been added to the UK Birds of Conservation Concern (BoCC) 'Red' list, indicating they are now at significant risk of local extinction. These species include Leach's storm-petrels, common gulls, great black-backed gulls, Arctic terns, and great skuas. They join the previously listed kittiwakes, herring gulls, roseate terns, Arctic skuas, and puffins, all of which are also highly threatened. Research comparing the Seabird 2000 consensus with the Seabirds Count (Burnell et al., 2023) has revealed substantial declines in bird populations across the UK. Noteworthy decreases include a 52% drop in common gulls, a 79% decline in Leach's storm-petrels, and a 43% reduction in great black-backed gulls. Britain and Ireland account for 64% to 67% of the global population of great skuas. However, the outbreak of Highly Pathogenic Avian Influenza (HPAI) has led to a 76% decline in the 2023 colony count—representing 83% of the UK Seabirds Count population—resulting in the reclassification of great skuas from the BoCC 'Amber' to 'Red' list. The effects of HPAI have also contributed to a 7% and 25% decline in the breeding populations of herring gulls and lesser black-backed gulls, respectively, at selected natural nesting sites, based on pre- and post-HPAI counts (Tremlett et al., 2024). The impact of HPAI on their winter populations, however, remains uncertain.

Note that there are no bird species identified as PMFs in Scottish waters as they are protected under the EU Birds Directive (NatureScot, 2020; Tyler-Waters *et al*., 2016). However, the black guillemot (*Cepphus grille*) is listed as a NCMPA 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 (BEIS, 2022). The species has a short mean maximum foraging range of 4.8±4.3 km (Woodward *et al.,* 2019) and, as such, it is unlikely to be found in the vicinity of the proposed Tornado Development area.

### Seabird Sensitivity to Oiling

Seabird sensitivity to oiling varies considerably throughout the year and is dependent on a variety of factors, including time spent on the water, total biogeographical population, reliance on the marine

environment and potential rate of population recovery (BEIS, 2022). The Seabird Oil Sensitivity Index (SOSI) (Webb *et al*., 2016) combines seabird data collected between 1995 and 2015 and individual seabird species index values to create a single measure of seabird sensitivity to oil pollution. An assessment of the median SOSI scores for the proposed Tornado Development area indicates that the sensitivity of seabirds to oil varies across the year. SOSI scores within the UKCS Blocks of Interest vary between medium (4) to low (5) in January, February, March, April and June, high (3) to low (5) in May, low (5) in July, August and December, extremely high (1) to low (5) in September and October and very high (2) to low (5) in November (Table 4.17; Webb *et al*., 2016).

**Table 4.17: Seabird Sensitivity to Oiling within the Proposed Tornado Development Area and Surrounding UKCS Blocks**

| Block | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 212/30 | 5 | 5 | 5 | 5 | 5 | 3 | 4 | 5 | 1 | 5 | 5 | 5 |
| 213/26 | 5 | 3 | 3 | 4 | 5 | 5 | 4 | 5 | 2 | 2 | 5 | 5 |
| 213/27 | 5 | 3 | 3 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 | 5 |
| 213/28 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 213/29 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 1 | 5 | 5 |
| 213/30 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 214/26 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 204/4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 1 | 5 | 5 | 5 |
| 204/5 | 5 | 5 | 5 | 5 | 4 | 4 | 5 | 5 | 1 | 5 | 5 | 5 |
| **205/1** | **5** | **5** | **4** | **4** | **3** | **5** | **5** | **5** | **3** | **5** | **5** | **5** |
| **205/2** | **5** | **5** | **5** | **5** | **4** | **5** | **5** | **5** | **5** | **5** | **5** | **5** |
| **205/3** | **5** | **5** | **5** | **5** | **4** | **5** | **5** | **5** | **5** | **1** | **5** | **5** |
| **205/4** | **5** | **5** | **5** | **5** | **4** | **5** | **5** | **5** | **5** | **2** | **5** | **5** |
| **205/5** | **5** | **5** | **5** | **4** | **5** | **5** | **5** | **5** | **5** | **5** | **5** | **5** |
| 206/1 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 204/8 | 5 | 5 | 5 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| **204/9** | **5** | **5** | **5** | **4** | **5** | **5** | **5** | **5** | **2** | **5** | **2** | **5** |
| **204/10** | **5** | **5** | **4** | **4** | **5** | **4** | **5** | **5** | **1** | **5** | **5** | **5** |
| **205/6** | **5** | **5** | **5** | **4** | **4** | **5** | **5** | **5** | **3** | **5** | **5** | **5** |
| 205/7 | 5 | 3 | 3 | 4 | 3 | 5 | 5 | 5 | 5 | 4 | 5 | 5 |
| 205/8 | 5 | 3 | 3 | 5 | 3 | 5 | 5 | 5 | 5 | 3 | 5 | 5 |
| 205/9 | 5 | 2 | 2 | 5 | 4 | 5 | 5 | 5 | 5 | 3 | 5 | 5 |
| 205/10 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 206/6 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 204/12 | 4 | 4 | 5 | 4 | 3 | 3 | 5 | 5 | 5 | 5 | 5 | 5 |
| **204/13** | **4** | **4** | **5** | **4** | **4** | **5** | **5** | **5** | **5** | **5** | **5** | **5** |
| **204/14** | **5** | **4** | **5** | **4** | **4** | **5** | **5** | **5** | **5** | **5** | **3** | **5** |
| 204/15 | 5 | 5 | 5 | 4 | 5 | 4 | 5 | 5 | 5 | 5 | 2 | 5 |
| 205/11 | 5 | 5 | 5 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 3 | 5 |
| 205/12 | 5 | 4 | 4 | 4 | 4 | 5 | 5 | 4 | 5 | 3 | 5 | 5 |
| 204/17 | 4 | 4 | 5 | 5 | 3 | 3 | 3 | 4 | 5 | 3 | 5 | 5 |
| 204/18 | 4 | 4 | 5 | 5 | 4 | 3 | 5 | 4 | 5 | 5 | 5 | 5 |
| 204/19 | 5 | 4 | 5 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 2 | 5 |
| 204/20 | 5 | 5 | 5 | 4 | 5 | 4 | 5 | 5 | 5 | 5 | 2 | 5 |

Key: 1 = Extremely High; 2 = Very High; 3 = High; 4 = Medium; 5 = Low; N = No Data.
SOSI sensitivity category in red and underlined indicates an indirect assessment of SOSI scores, in light of coverage gaps.
Row in bold and dark grey indicates the location of the proposed Tornado Development area.

#### Wildfowl and Waders

The Shetland Islands coastline is of particular importance during the spring and autumn for migratory waterfowl. The variety of habitats within the coastal areas adjacent to the proposed Tornado Development area, means that species assemblages vary significantly with exposure to the coastline and the substratum type. Smaller waders such as the dunlin (*Calidris alpina*), are generally confined to sheltered muddy shores around estuaries, whilst sandy, more exposed shorelines support species such as knot (*Calidris canutus*) and oystercatcher (*Haematopus longirostris*) (DTI, 2005).

Whilst relatively less important for migratory waders and wildfowl than other key areas of Scotland, the Shetland Islands also support internationally important populations of eider (*Somateria spectabilis*) which moult on Shetland between August and September and overwinter from November to March (SOTEAG, 2015). Other important species include the great northern diver (*Gavia immer*), the largest population of Slavonian grebe (*Podiceps auritus*) in Great Britain (SOTEAG, 2015), pink-footed goose (*Anser brachyrhynchus*) and mute swan (*Cygnus olor*) which overwinter or migrate to these areas (DTI, 2005; SSMEI, 2010). The Shetland Islands are also a major habitat for the whimbrel (*Numenius phaeopus*) and support up to 95% of Britain's breeding population (Massey, 2016).

### 4.3.5 Marine Mammals

The waters between the Faroe Islands and Shetland support a rich and diverse population of cetaceans (whales, dolphins and porpoise) and pinnipeds (seals), particularly in comparison to the North Sea region where a low diversity and abundance of species is found. In addition, the coast and islands of western Scotland are particularly important for otters (NatureScot, 2021).

#### Cetaceans

The waters of the Faroe-Shetland Channel support important and diverse populations of cetaceans. The confluence of ocean currents results in strong upwelling of deeper waters rich in nutrients, in turn attracting higher trophic levels including zooplankton and fish, enabling several species to live in the area throughout the year. Certain species are resident in the shallower waters of the shelf where they feed all year round such as the minke whale (*Balaenoptera acutorostrata*) the smallest of the larger filter feeding whales, white-beaked dolphins (*Lagenorhynchus albirostris*) and harbour porpoises (*Phocoena phocoena*) (Reid *et al.,* 2003). White-sided dolphins (*Lagenorhynchus acutus*) and larger species such as killer whales (*Orcinus orca*) and long-finned pilot whales (*Globicephala melas*) preferentially inhabit the deeper waters beyond the continental shelf (Reid *et al.,* 2003).

Other cetaceans, including blue (*Balaenoptera musculus*), fin (*Balaenoptera physalus*), sei (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), sperm (*Physeter macrocephalus*), right (*Eubalaena* spp.) and northern bottlenose whales (*Hyperoodon ampullatus*), are thought to use the Faroe-Shetland Channel as a migratory pathway, moving through the area to summer feeding grounds in the north, before returning to more southern overwintering and breeding grounds (JNCC, 2014b).

Resident Species

Several species of cetacean are resident (may be present throughout the year) WoS, where their distribution is governed primarily by water depth and availability of food resources. In the relatively shallow waters of the continental shelf, minke whales, white-beaked dolphins, and harbour porpoises feed year round (Reid *et al.,* 2003). These species all feed on a variety of fish species, particularly gadoids, herring and sandeels (Reid *et al.,* 2003; SNH, 2009). The Risso's dolphin has also been recorded in these shelf waters, although in fewer numbers, feeding on mainly octopus with some cuttlefish and squid (Reid *et al*., 2003). The distribution and abundance of these year round inhabitants of the continental shelf waters, and their movements in the vicinity of the proposed Tornado Development area, is summarised in Table 4.18.

The distribution of resident cetaceans, which favour the deep water of the Faroe-Shetland Channel, is also summarised in Table 4.18. Both long-finned pilot whales and Atlantic white-sided dolphins feed on a variety of squid and fish species. They tend to occur in deep water areas beyond the shelf edge, where their prey is more abundant. Killer whales have a very varied diet, feeding on fish, squid, seals, birds and other cetaceans, and have been observed in a range of water depths as a result. However, in the WoS area, sightings suggest that they are primarily concentrated in the deep slope waters to the north.

While favouring deeper waters, both white-sided dolphins and killer whales have been observed over shelf waters, and in the vicinity of the proposed Tornado Development (Reid *et al*., 2003).

**Table 4.18: Distribution of Whales, Dolphins and Porpoises in the Waters WoS**

| Species | Abundance and Distribution |
|---|---|
| **Year-Round Inhabitants of the Shelf Waters** | |
| Harbour porpoise | Sightings of harbour porpoises are generally confined to shallow shelf waters, although individuals have occasionally been recorded in the deep water between Shetland and the Faroe Islands. |
| White-beaked dolphin | This species is abundant and widely distributed on the continental shelf to the WoS and Orkney. Although present year-round, most observations are between June and October (Reid *et al*., 2003). While they have been observed in the proposed Tornado Development area, sightings are more numerous off the north and west coasts of mainland Scotland. |
| Risso's dolphin | Although this species is often regarded preferring deeper offshore waters, most sightings around Scotland and the northern Scottish Isles have occurred over the continental shelf, in water depths of less than 200 m (Pollock *et al.,* 2000). The majority of sightings have been recorded around the Outer Hebrides, although small numbers have also been seen off Orkney and Shetland. There have been no recorded sightings within the vicinity of the proposed Tornado Development area, although low to moderate numbers have been observed within the wider area. |
| Minke whale | This species is widely distributed throughout UK waters. Most sightings occur within the 200 m depth contour, indicating the inshore nature of this species. Sightings are most frequent around the Western Isles, with few records in the proposed Tornado Development area. Although this species occurs year round, most sightings are between June and August. While usually seen individually or in pairs, they may aggregate into groups of 10 to 15 individuals (Reid *et al*., 2003). |
| Common Dolphin | Common dolphin are occasional summer visitors of the Faroe-Shetland Channel. It is thought that their presence in the Channel results from following squid, their preferred food source. |
| **Year-Round Inhabitants of the Deeper Waters** | |
| Atlantic white-sided dolphin | This species is frequently observed in groups numbering in the tens to hundreds and is one of the most abundant species found in the WoS area. This species has an offshore distribution, and is observed along the shelf edge and into waters deeper than 1,000 metres. While they are found in these deep water areas year round, groups are frequently recorded in continental shelf waters during the summer months (Pollock *et al*., 2000). |
| Killer whale | Killer whales are distributed over both the continental shelf and in the deep offshore waters, with the main concentration of sightings occurring over the slope north and north west of Shetland (Stone, 1998; Pollock *et al.,* 2000). The majority of the sightings have been in the wider area surrounding the proposed Tornado Development. Although killer whales occur year round, sightings increase during the early summer months. The majority of sightings in the UK have been of individuals or groups of less than eight animals. |
| Long-finned pilot whale | Most pilot whale sightings occur along shelf slope north of Scotland, with the highest abundance in the deeper waters of the Faroe-Shetland Channel (Pollock *et al.,* 2000). These whales only occasionally venture into continental shelf waters, with very few sightings on the shelf in the WoS area. Their diet of deep water squid influences this distribution. Pilot whales often occur in large pods, although surveys to the north and west of Scotland recorded an average group size of just over ten (Reid *et al*., 2003). |

| Species | Abundance and Distribution |
|---|---|
| Northern Bottlenose whale | The northern bottlenose whale has been recorded through much of the Faroe-Shetland Channel, with the channel representing an important part of their habitat. However, within the proposed Tornado Development area sightings are low. The species are thought to migrate north through the channel during spring and then returning in the autumn. |

Migratory Species

With the exception of the smaller minke whale, the large baleen whales are not thought to be year-round residents of the Faroe-Shetland Channel, but instead use it as a migratory pathway. These whales move into these colder temperate waters to feed in summer. While some remain within the channel over summer, others travel onto polar areas further north, before returning to lower latitude overwintering and breeding grounds in autumn (BEIS, 2022). Baleen whales differ from toothed whales (odontocetes) as they have baleen plates through which they filter feed zooplankton, particularly krill and other small pelagic prey, and their distribution is often related to oceanographic features such as fronts, upwellings, and associated areas in which prey availability is high.

Visual surveys have confirmed the presence of large baleen whales, at least in small numbers, during the summer months (Pollock *et al*., 2000). This seasonal occurrence may however, be misrepresented by the uneven distribution of survey effort across the year. Limited passive acoustic monitoring of cetacean vocalisations has suggested that blue, fin and humpback whales also occur in spring and autumn, with at least some individuals remaining throughout the year (Charif and Clark, 2000). However, there is currently insufficient data to give a reliable indication of the abundance or seasonal distribution of these whales within the Faroe-Shetland Channel.

On the basis of survey sightings and acoustic detections, Table 4.19 attempts to summarise the occurrence of large baleen whales within the Faroe-Shetland Channel. Blue, fin, humpback and sei whales are all considered to be open water species, favouring deep water areas. Almost all sightings of these whales have been recorded either over or beyond the shelf break (Pollock *et al*., 2000), concentrated along the 1,000 m depth contour. It is, therefore, possible that any of these whales may appear within the vicinity of the Tornado drill centre location and pipeline within water depths of over 1,000 m.

Although sperm whales are a toothed whale species, they also use the Faroe-Shetland Channel as a migratory pathway. It is believed that only males migrate into these colder temperate waters to feed, before returning to warmer areas to breed. As a result, sightings increase between July and December, although evidence suggests that some individuals may remain year-round.

**Table 4.19: Distribution of Large Migratory Baleen Whales within the Deepwater of the Faroe-Shetland Channel**

| Species | Abundance and Distribution |
|---|---|
| Blue whale | Blue whales are thought to breed in tropical waters during the winter months and then migrate to colder temperate and polar waters to feed in summer. Whaling records indicate that small numbers of blue whales regularly pass to west of the UK and Ireland in the deep waters off the continental shelf. Although there have been no recorded sightings of the blue whale to the WoS (Reid *et al.,* 2003), acoustic monitoring has shown individuals to occur in the deep water of the channel during autumn and spring (Charif and Clark, 2000). |
| Fin whale | Fin whales use the Faroese shelf edge as a migratory channel, spending the summer months at high latitudes before returning to overwintering grounds. Fin whales are generally observed in deep water areas and are not expected in the vicinity of the proposed Tornado Development (Swift *et al*., 2002). WoS, peak numbers have been observed in July and August (Reid *et al*., 2003). However, acoustic monitoring has suggested that at least some individuals may be resident year-round (Charif and Clark, 2000). |

| Species | Abundance and Distribution |
|---|---|
| Humpback whale | The humpback whale occurs globally, favouring waters over and along the edges of continental shelves. In winter they breed in tropical waters, while spending summer in temperate and polar waters. These whales have been sighted in the deep water in the WoS area, although infrequently and in very small numbers (Pollock *et al.,* 2000). Although acoustic surveys have detected humpbacks over winter and in early spring (Charif and Clark, 2000), visual observations during seismic surveys have occurred during the summer months (PFML, 2016). |
| Sei whale | Sei whales migrate between summer feeding grounds off the Faroe Islands, Shetland and Norway, and lower latitude overwintering grounds. They are thought to reach Scottish waters between April and July, leaving during late August and September. They are considered to be pelagic deep water species, with most observations concentrated in the deep water to the southeast of the Faroe Islands (Pollock *et al.,* 2000). However, occasional sightings do occur in shallow waters off Shetland (Reid *et al*., 2003). |

Beaked whales are a group of toothed whales which favour deep, oceanic waters, often far from shore. As such their ecology and distribution is not fully understood. It is known that they tend to occupy waters of intermediate depth, over sloping seabeds, and have often been reported to prefer areas of complex seabed topography, such as submarine canyons, shelf-edges and escarpments (MacLeod, 2005). Each species, however, may occupy its own niche within this generalised beaked whale habitat, based upon its own habitat preferences, including water depths, water temperatures and prey types. Sightings and strandings data have shown these whales occur within the Faroe-Shetland Channel, with almost all sightings records beyond the 1,000 m depth contour; however, rare observations have also been recorded from coastal waters of the Hebrides, Orkney, Shetland and the northern North Sea (Aguilar de Soto *et al.,* 2016 cited in DECC, 2016). Therefore, beaked whales may be present in the vicinity of the proposed Tornado Development area but are unlikely to be present in significant numbers.

Recorded Sightings

The relative abundance of the most common species of cetaceans in this area of the North Sea can be derived from data obtained during the Small Cetacean Abundance of the North Sea (SCANS-IV) aerial and ship-based surveys. This project identified the abundance of cetacean species within predefined sectors of the North Sea and North-East Atlantic. The proposed Tornado drill centre location is not covered by the SCANS data, but approximately 10 km of the proposed Tornado pipeline route at the Tormore end is situated within SCANS-IV Block CS-K in which harbour porpoise, minke whale, Risso's dolphin and white-beaked dolphin have been recorded (see Table 4.20; Gilles *et al*., 2023). It should be noted that although density estimates are shown in Table 4.20, they are only an example of what densities could be encountered in the area due to the wide-scale nature of the SCANS-IV survey and the fact the data was mainly collected between June and August, and partially between September and October in 2022.

**Table 4.20: Estimated Abundance and Density of Cetaceans in UK Waters from the SCANS IV Survey (Gilles et al., 2023)**

| Species | SCANS-IV Block 'CS-K' | | Total (Aerial Survey Blocks) | |
|---|---|---|---|---|
| | Abundance | Density [1] | Abundance | Density [1] |
| Harbour Porpoise | 11,357 | 0.2813 | 409,244 | 0.2789 |
| Risso's Dolphin | 1,519 | 0.0376 | 13,854 | 0.0094 |
| White-Beaked Dolphin | 5,460 | 0.1352 | 67,138 | 0.0458 |
| Minke Whale | 467 | 0.0116 | 12,417 | 0.0085 |

[1] Density is the number of animals per km$^2$

As the SCANS-IV survey area encompasses a relatively large geographical area and is therefore unlikely to accurately reflect the abundance and densities of cetaceans which may be present within the vicinity of the proposed survey area, data from the JNCC Atlas of Cetacean Distribution in north-west European Waters has also been used to give a more localised indication of the seasonal distribution of cetaceans.

Data from the Cetaceans Atlas (Reid *et al.,* 2003) also records sightings of harbour porpoise, minke whale, white-beaked dolphin, Risso's dolphin, killer whale, pilot whale and the white-sided dolphin in the vicinity of the proposed Tornado Development area during various times of the year (see Table 4.21), although generally only in low densities. However it should be noted that cetaceans move considerable distances and therefore there are many difficulties with accurately recording their abundance and distribution.

**Table 4.21: Cetacean Sightings in the Vicinity of the Proposed Tornado Development Area (Reid *et al.,* 2003)**

| Species | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Harbour porpoise | | | | | | | | | | | | |
| Killer whale | | | | | | | | | | | | |
| Pilot whale | | | | | | | | | | | | |
| 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 (1 – 10) | Very Low (0 – 1) | No sightings |
|---|---|---|---|---|

During the Tornado geophysical survey undertaken by Fugro between June to July 2024, a total of 24 marine mammals were sighted during visual observations. The highest number of individuals spotted during the survey was the long finned pilot whale, with a pod of 70 individuals spotted on two separate occasions. Other species sighted during the survey included; Atlantic white-sided dolphin, minke whale, fin whale and Sei whale, alongside other unidentified species (Fugro, 2024c).

Management Units for Cetaceans

The UK Statutory Nature Conservation Bodies (SNCBs) have published Management Units (MUs) for the seven most common cetacean species in UK waters (bottlenose dolphin, common dolphin, harbour porpoise, minke whale, Risso's dolphin, white-beaked dolphin and white-sided dolphin). The boundaries of the MUs for each species are primarily defined by the presence of known populations, with divisions proposed on the basis of ecological evidence and / or divisions used for the management of human activities. MUs provide an indication of the spatial scales at which impacts of plans and projects need to be assessed for the key cetacean species in UK waters (IAMMWG, 2022). The MUs of relevance to the proposed Tornado Development area, along with the corresponding abundance of animals within these units, are presented in Table 4.22. Note, the proposed Tornado drill centre location is situated outside of the MU boundaries, but part of the proposed pipeline route crosses into the MUs. In addition, the Tornado drill centre is situated close to the boundary of the West Scotland MU for harbour porpoises and the Oceanic Waters MU for bottlenose dolphins.

**Table 4.22: Marine Mammal Management Units for Cetaceans in UK Waters (IAMMWG, 2022)**

| Species | Management Unit (MU) | Abundance in MU | Abundance in UK part of MU | Density [1] |
|---|---|---|---|---|
| Harbour porpoise | North Sea (678,206 km$^2$) | 346,601 | 159,632 | 0.511 |
| | West Scotland (343,035 km$^2$) | 28,936 | 24,305 | 0.084 |
| Bottlenose dolphin | Greater North Sea (639,886 km$^2$) | 2,022 | 1,885 | 0.003 |
| | Oceanic Waters (559,408 km$^2$) | 70,429 | 1,299 | 0.126 |
| Risso's dolphin | Celtic and Greater North Seas (1,560,875 km$^2$) | 12,262 | 8,687 | 0.007 |
| Common dolphin | | 102,656 | 57,417 | 0.065 |
| Minke whale | | 20,118 | 10,288 | 0.012 |
| White-beaked dolphin | | 43,951 | 34,025 | 0.028 |
| White-sided dolphin | | 18,128 | 12,293 | 0.011 |

[1] Density (individuals per km$^2$) was calculated using the total area of the MU and the abundance of animals within that MU

All cetaceans (whales, dolphins, and porpoises) are listed as European Protected Species (EPS) under Annex IV of the Habitats Directive. Harbour porpoise is also listed on the OSPAR List of Threatened and/or Declining Species (OSPAR, 2021) and harbour porpoise and bottlenose dolphin are listed under Annex II of the Habitats Directive. In addition, harbour porpoise, bottlenose dolphin, Risso's dolphin, minke whale, Atlantic white- sided dolphin, fin whale, northern bottlenose whale, sperm whale, white beaked dolphin, killer whale and long- finned pilot whale are listed as PMFs (NatureScot, 2020). All species mentioned are regarded as being of Least Concern in terms of their population threats (IUCN, 2024). Note, there are no marine protected areas designated for the protection of cetaceans in the vicinity of the proposed Tornado Development area.

Of the cetacean species mentioned, there has been a change in overall conservation status from favourable to unknown since 2013. This is due to the implementation of a more robust assessment methodology, supported by updated EU Commission guidance, which requires consideration of population trends in setting the Favourable Reference Population (FRP) value. However, this requires a higher number of UK population estimates over time than are currently available, resulting in the unknown conclusion (BEIS, 2022).

### Seals

Two species of seal (pinniped) are resident in Scottish waters, the grey seal (*Halichoerus grypus*) and the harbour, or common, seal (*Phoca vitulina*). These animals are most frequently found in coastal waters less than 200 m deep and are present in internationally important numbers around the Shetland Islands (BEIS, 2022). Grey and harbour seals are both listed under Annex II of the EU Habitats Directive, requiring the designation of SACs in order to protect these species. In addition, harbour and grey seals are protected under the Conservation of Seals Act 1970 (from 0 - 12 nautical miles from the coast) and both the harbour and grey seal are listed as PMFs to aid in their conservation in Scottish waters (NatureScot, 2020; Tyler-Walters *et al*., 2016).

Grey Seals

Approximately 80% of the UK population of grey seals breeds in Scotland, largely in the Hebrides and Orkney (SCOS, 2022a). 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 (BEIS, 2022). Grey seals utilise outlying islands and remote coastlines as moulting, pupping and haul-out sites. The Orkney Islands support the second largest

breeding colony for grey seals in the UK at the Faray and Holm of Faray Islands in the northern part of Orkney, located approximately 170 km to the south east of the proposed Tornado drill centre location.

Around the Scottish Continental Shelf region, studies have shown that grey seals tend to utilise much of the coastal shelf seas, with greatest activity around Orkney, Shetland, North Rona, the north mainland and west and south of the Outer Hebrides; activity in these areas represents some of the highest in UK waters (Jones *et al*., 2015; BEIS, 2022). However, grey seals were rarely sighted in waters near the shelf edge during JNCC surveys of seabird and marine mammal distribution (Pollock *et al*., 2000).

Grey seals spend a high proportion of their time ashore during their annual moult (December to April) and during the breeding (autumn) and pupping seasons. The majority of grey seals in west Scotland pup between September and late November (SCOS, 2022a). Satellite tracking has shown that grey seals may forage up to several hundred kilometres offshore, although most foraging probably occurs within 100 km of their haul out site (SCOS, 2022a). Individual seals based at a particular haul-out site will also often make repeated trips to the same locations offshore (SCOS, 2022a). The closets pupping site to the proposed Tornado Development area is at Uyea on the northwest coast of the Shetland Island, located approximately 124 km to the southeast of the Tormore manifold location (NMPi, 2024).

Studies using UK seal population estimates indicate the at-sea distribution of grey seals towards the Tormore end of the proposed pipeline route is very low (less than 0.001% per 25 square kilometres). At-sea distribution in the remainder of the proposed Tornado Development area is extremely low (0.00% per 25 km$^2$) (Figure 4.25; Carter *et al.,* 2022).

Studies using Shetland Isles seal population estimates also indicate the at-sea distribution of grey seals towards the Tormore end of the proposed pipeline route is very low (ca. 0.000054% per 25 square kilometres), while the at-sea distribution data does not cover the remainder of the proposed Tornado Development (Figure 4.25; Carter et al., 2022).

Harbour Seals

The UK is home to approximately 32% of the European population of harbour seals, with Scotland holding approximately 85% of the UK harbour seal population (SCOS, 2022a). Harbour seals are widespread around the west coast of Scotland, throughout the Hebrides and around Shetland and Orkney (SCOS, 2021; BEIS 2022), although since 2001, harbour seal counts have declined in Shetland, Orkney and along the north and east coasts of Scotland (Lonergan et al., 2007; Thompson et al., 2013) while counts in the West Scotland SMU appear to have increased (SCOS, 2022a).

Harbour seal haul out, breeding and moulting sites are typically situated in sheltered estuaries and on sandbanks, but they also utilise rocky areas. Harbour seal populations on Shetland are concentrated along the Yell Sound coast, St Magnus Bay and on the island of Mousa (Duck, 1997; JNCC, 2025) and the Yell Sound Coast SAC, partly designated for the protection of harbour seal, is located approximately 106 km south east of the Tormore manifold.

Harbour seals spend a high proportion of time ashore during the pupping and moulting seasons from June to August (Hammond *et al.,* 2001). Satellite tagging studies have observed that foraging trips around Orkney and Shetland are generally within 40 - 50 km of haul out sites; some foraging trips of over 100 km were recorded (SCOS, 2005; SCOS, 2014). Longer trips (further than 200 km) were also observed, but these were between haul out sites on Orkney and Shetland rather than to offshore foraging areas.

As with grey seals, harbour seals were rarely sighted in deeper waters near the shelf edge during coordinated JNCC surveys (Pollock *et al.,* 2000). Studies using UK seal population estimates indicate the at-sea distribution of harbour seals towards the Tormore end of the proposed pipeline route is very low (less than 0.001% per 25 square kilometres). At-sea distribution in the remainder of the proposed Tornado Development area is extremely low (0.00% per 25 km$^2$) (Figure 4.25; Carter *et al.,* 2022).

Studies using Shetland Isles seal population estimates also indicate the at-sea distribution of harbour seals towards the Tormore end of the proposed pipeline route is very low (ca. 0.000054% per 25 square kilometres), while the at-sea distribution data does not cover the remainder of the proposed Tornado Development (Figure 4.25; Carter et al., 2022).

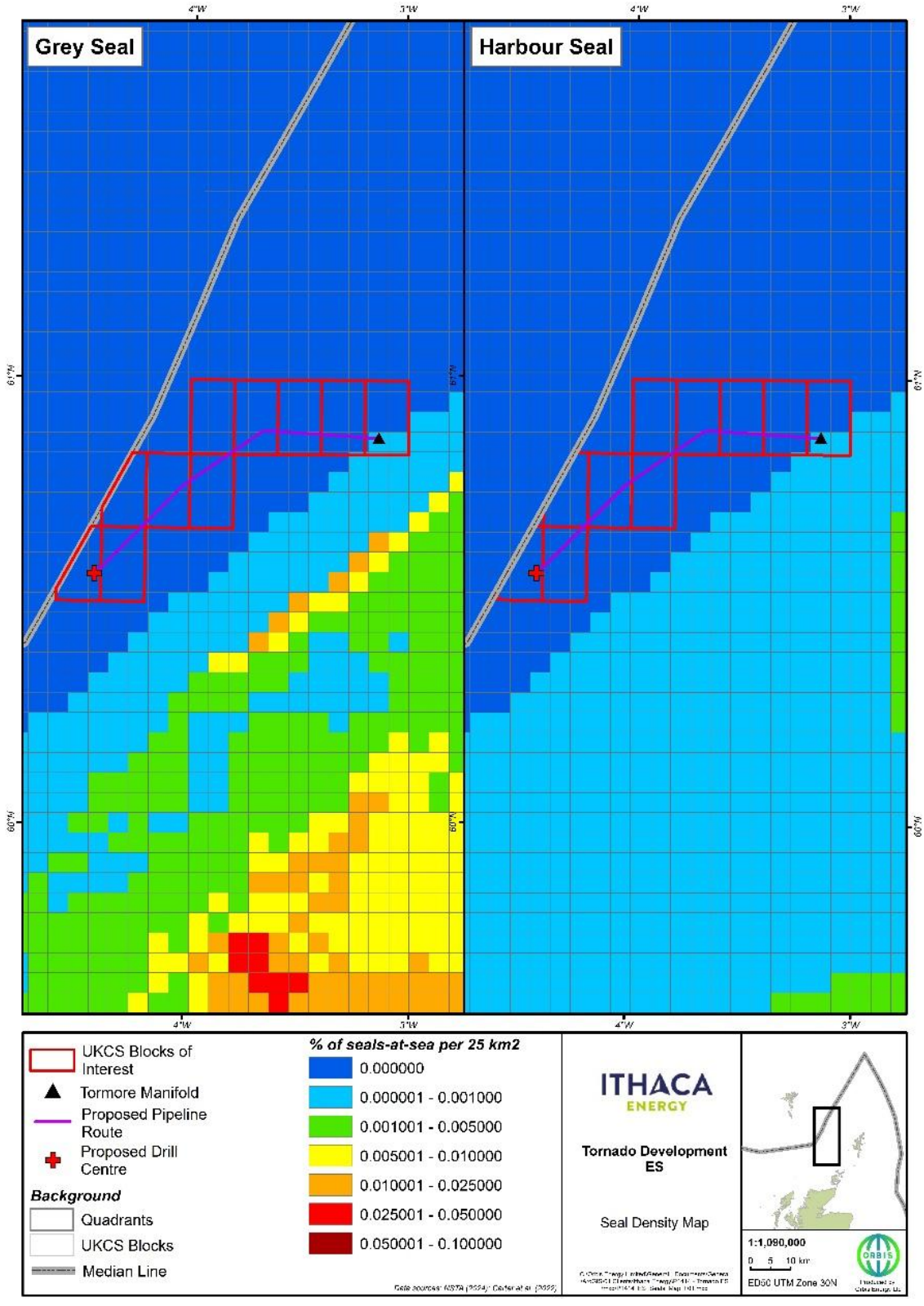



**Figure 4.24: Estimated Grey and Harbour Seal Relative Density (percentage of the population) around the Proposed Tornado Development using UK seal counts**

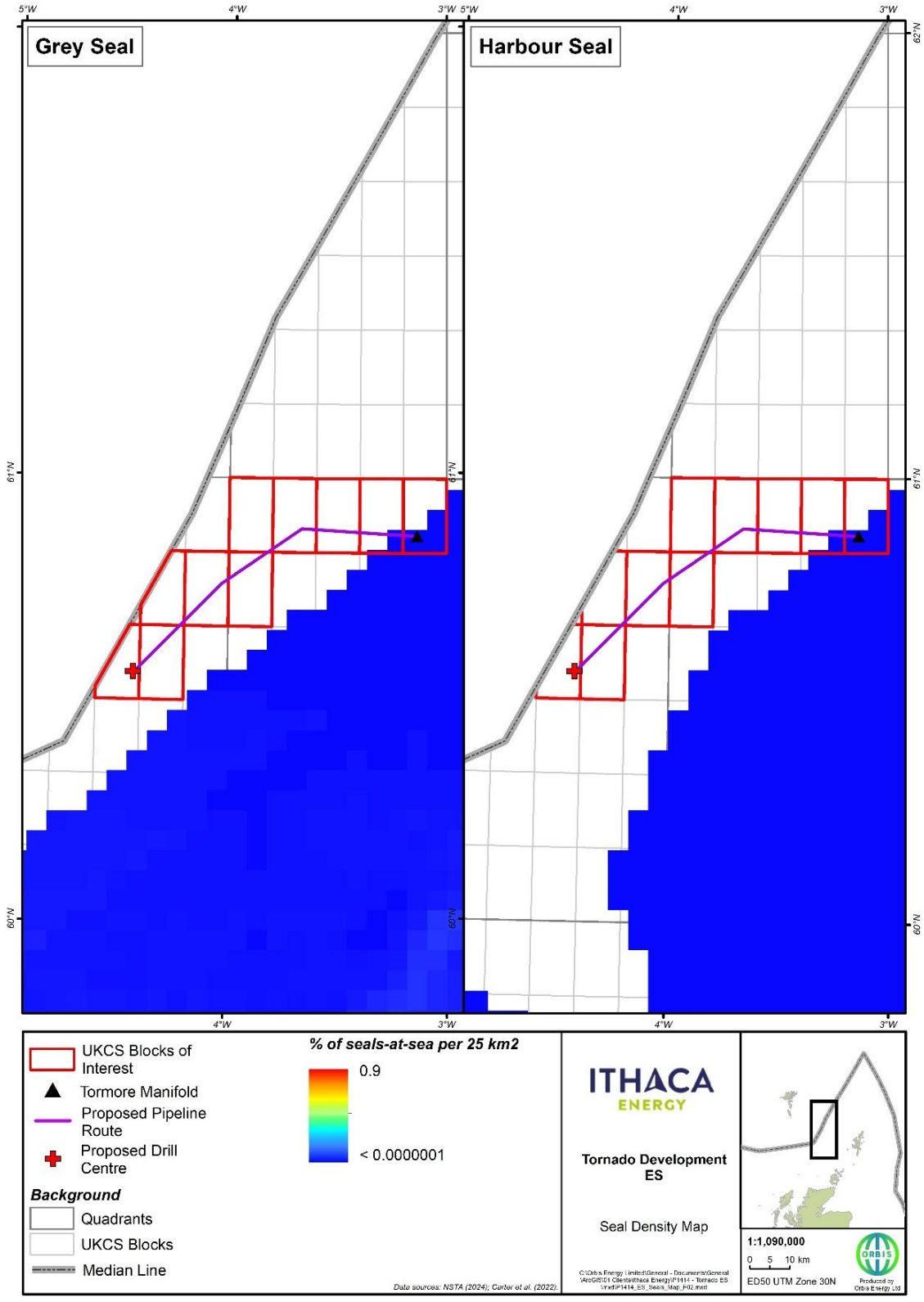



**Figure 4.25: Estimated Grey and Harbour Seal Relative Density (percentage of the population) around the Proposed Tornado Development using Shetland Isles seal count**

Management Units for Seals

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 Tornado Development area is however not located within a MU. The closest MU is the Shetland MU which is located approximately 39 km east of the Tormore manifold at the closest point. Table 4.23 lists the seal count and estimated populations within this unit.

**Table 4.23: Estimates of Seal Abundance in the Relevant MU (IAMMWG, 2013)**

| Species | Management Unit | Seal Count | Estimated Population Size [1] | Survey Year |
|---|---|---|---|---|
| Grey seal | Shetland | 1,536 | 5,100 | 2009 |
| Harbour seal | Shetland | 3,039 | - | 2009 |

[1] 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.

In the UK, recent demographic changes (increases in most grey seal populations and declines in some harbour seal populations) could potentially be linked in some way to climate-mediated changes in food supply, however, other factors (depletion of food resources from fishing, recovery from epizootics, interspecific competition, density dependent effects) may be more important (BEIS, 2022).

#### Otters

The otter (*Lutra lutra*) is a semi-aquatic mammal, which occurs in both inland freshwater and coastal waters (JNCC, 2017a). The Scottish population comprises a high proportion of coastal-dwelling individuals that feed almost exclusively in the sea. The coast and islands of western Scotland are particularly important for this species (SNH, 2021). However, otters do not venture far offshore as while they utilise shallow inshore marine areas for feeding, they also require freshwater for bathing and terrestrial areas for resting and breeding (JNCC, 2017a).

Otters are listed as an EPS under Annex IV of the Habitats Directive and are listed under Annex II of the Habitats Directive. Otters are also listed as a PMF in Scottish terrestrial waters (NatureScot, 2020; Tyler-Walters *et al*., 2016) and are listed as 'Near Threatened' in terms of their population threats and global conservation status (IUCN, 2024).

### 4.3.6 Marine Protected Areas

The location of MPAs (including designations such as NCMPA, Special Areas of Conservation (SAC), SPAs, RAMSARs) in the WoS region in relation to the proposed Tornado Development are illustrated in Figure 4.26. Those MPAs in closest proximity to the proposed Tornado Development include:

- Faroe- Shetland Sponge Belt NCMPA, crossed by approximately 18 km of proposed Tornado pipeline route;
- Seas off Foula SPA, located approximately 49 km south of the Tormore manifold;
- West Shetland Shelf NCMPA, located approximately 78 km south of the proposed Tornado drill centre location;
- North-east Faroe-Shetland Channel NCMPA, located approximately 92 km to the northeast of the Tormore manifold;
- North-west Orkney NCMPA, located approximately 108 km to the southeast of the proposed Tornado drill centre location.

The protected features and conservation objectives of these MPAs are discussed below.

In addition, the IUCN's Marine Mammal Protected Areas Task Force (MMPATF) has designated one Important Marine Mammal Area (IMMA) approximately 29 km west from the proposed Tornado Development area. IMMAs are defined as discrete portions of habitat, important to marine mammal species, that have the potential to be delineated and managed for conservation. They are not legal designations but independent, peer-reviewed assessments based on criteria supported by data. This

creates a possibility that in the future a legally designated MPA may exist within the vicinity of the proposed Tornado Development area (IUCN MMPATF, 2025).

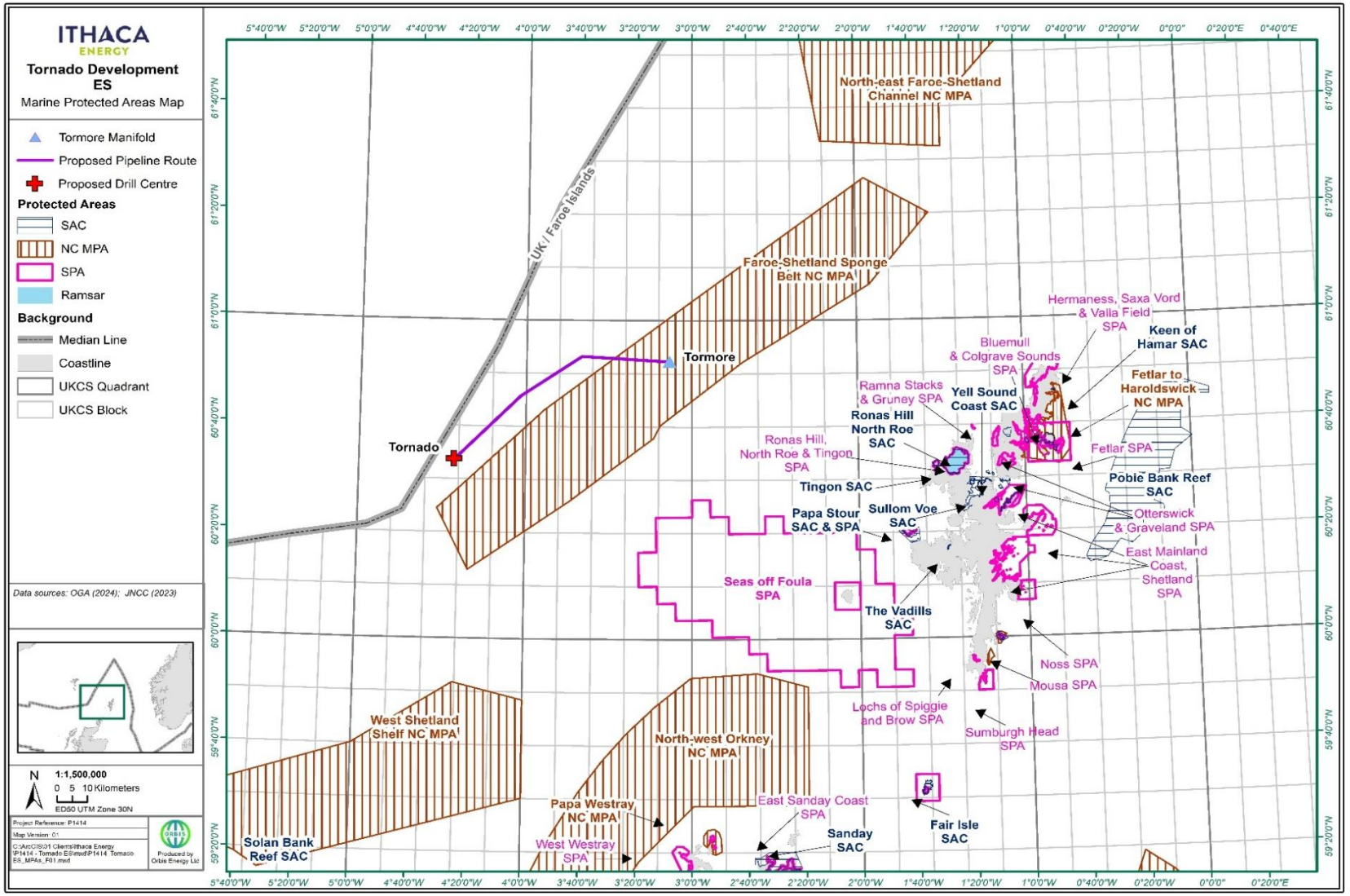



**Figure 4.26: Marine Protected Areas in the Vicinity of the Proposed Tornado Development**

### Faroe-Shetland Sponge Belt NCMPA

Approximately 18 km of the proposed Tornado pipeline route lies within the Faroe-Shetland Sponge Belt NCMPA. This NCMPA is designated for the protection of nine features of conservation interest:

- Deep sea sponge aggregations;
- Ocean quahog (*Arctica islandica*) aggregations;
- Atlantic and Arctic influenced offshore subtidal sand and gravel habitats;
- An area of the Faroe-Shetland Channel continental slope; and
- Five geodiversity (geomorphological) features representative of the West Shetland Margin paleo-depositional system and the West Shetland Margin Contourite Deposits key geodiversity areas (JNCC, 2014a).

Figure 4.27 illustrates the boundary of the Faroe-Shetland Sponge Belt NCMPA and associated protected feature data in relation to the proposed Tornado pipeline route.

The conservation objectives for the Faroe-Shetland Sponge Belt NCMPA (JNCC, 2018) are that the protected features listed above:

- so far as already in favourable condition, remain in such condition; and
- so far as not already in favourable condition, be brought into such condition, and remain in such condition.

With respect to **Deep-sea sponge aggregations** and **Offshore subtidal sands and gravels**, this means that:

- Extent is stable or increasing; and
- Structures and functions, quality, and the composition of characteristic biological communities (which includes a reference to the diversity and abundance of marine fauna forming part of or inhabiting each habitat) are such as to ensure they remain in a condition which are healthy and not deteriorating.

With respect to the **Ocean quahog (*Arctica islandica*) aggregations**, this means that the quality and quantity of its habitat and the composition of its population are such that they ensure that the population is maintained in numbers which enable it to thrive.

With respect to the **Continental slope channels, Iceberg plough marks, Prograding wedges, Slide deposits, Sand wave fields and Sediment wave fields** representative of the West Shetland Margin Paleo-Depositional System and West Shetland Margin Contourite Deposits Key Geodiversity Areas, this means that:

- Their extent, component elements and integrity are maintained;
- Their structure and functioning are unimpaired; and
- Their surfaces remain sufficiently unobscured for the purposes of determining whether the points noted above are satisfied.

With respect to the area of the Faroe-Shetland Channel **Continental slope** protected as a large-scale feature, this means that:

- Its extent, distribution and structure is maintained;
- Its function is maintained so as to ensure that it continues to support its characteristic biological communities (which includes a reference to the diversity of any species associated with the large-scale feature) and their use of the site for, but not restricted to, feeding, courtship, spawning, or use as nursery grounds; and
- The processes supporting it are maintained.

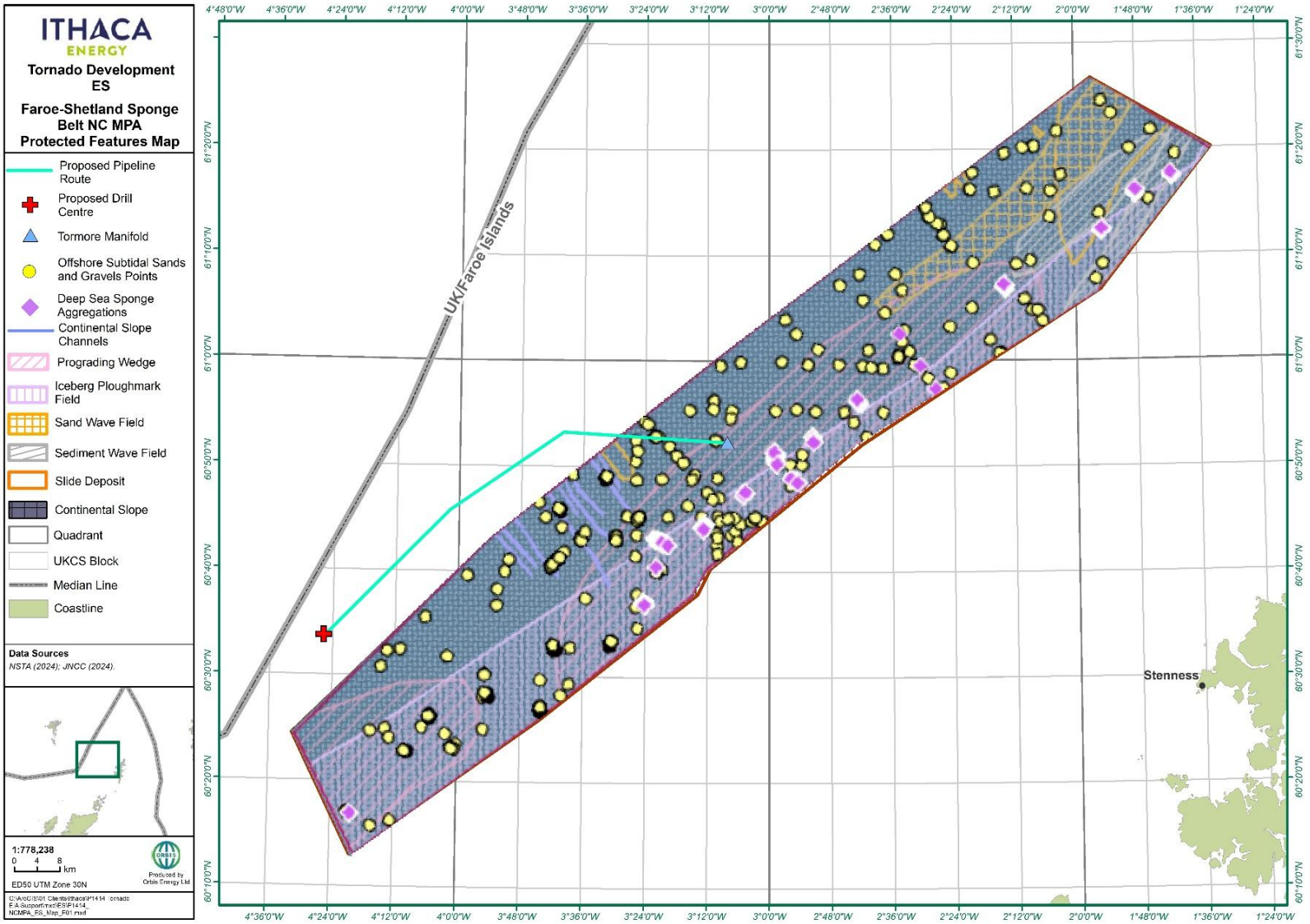


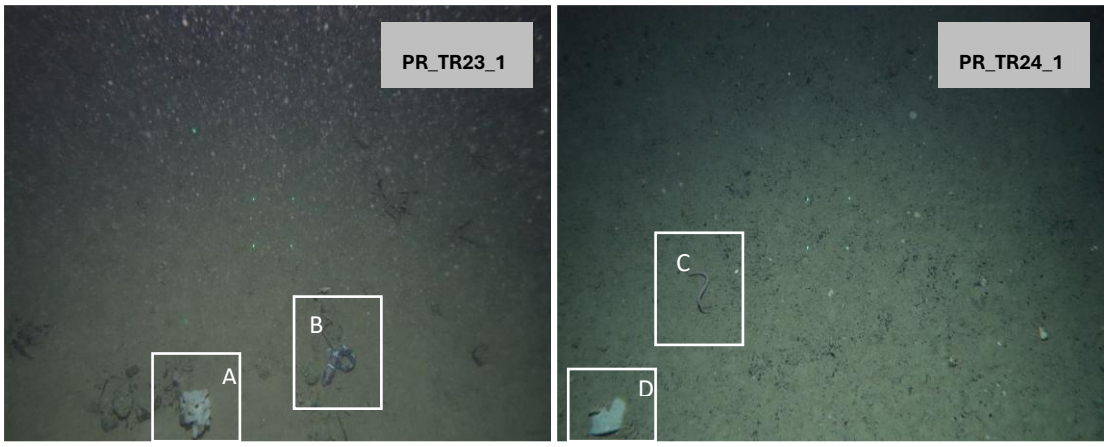

**Figure 4.27: Faroe-Shetland Sponge Belt NCMPA Protected Features**

All protected features of the NCMPA are in an unfavourable condition and need to be recovered to favourable condition. The exception to this is the area of the Faroe-Shetland Channel continental slope protected as an example of a large-scale feature, which is already in a favourable condition (JNCC, 2020).

The Tornado habitat assessment survey along the proposed pipeline route (Fugro, 2025b) found that the EUNIS habitat types 'Arctic upper bathyal mixed sediment' (ME41) and 'Arctic upper bathyal sand' (ME51) are encompassed within the PMF 'Offshore subtidal sands and gravels', but are not included within the UK BAP priority habitat 'Subtidal sands and gravels' (BRIG, 2011).

The route survey also investigated if there were possible plough marks along the proposed pipeline route particularly along transect PR_TR16 (see Figure 4.2 in Section 4.1.1). However, no evidence of such plough marks were found during the survey operations.

Within the Faroe- Shetland Sponge Belt NCMPA, sponge species such as Porifera and glass sponge species such as Hexactinellid were observed along transects PR_TR23 and PR_TR24 (Fugro, 2025b; Figure 4.28). Other species observed along the transects within the NCMPA (PR_TR19, PR_TR20, PR_TR21, PR_TR22, PR_TR23 and PR_TR24) are discussed within Section 4.3.2 and can be seen within Figure 4.15 and Figure 4.17.




Key: Sediment Type: Gravelly sandy mud/muddy sand with cobbles and boulders

A = Glass Sponge (Hexactinellid); B = Eel pout (*Lycodes esmarkii*); C = Hagfish (*Myxine glutinosa*); D = Sponge (Porifera)

**Figure 4.28: Seabed Images from pipeline transects within the Faroe-Shetland Sponge Belt NC MPA (Fugro, 2025b)**

Deep sea sponge aggregations provide shelter for a diverse faunal assemblage and an elevated substratum to allow filter and suspension feeders to extend into the water column to feed (JNCC, 2014a). The Faroe-Shetland Sponge Belt NCMPA is entirely located beyond the shelf break in waters deeper than 400 m. The sponge communities present are believed to be restricted to between 400 - 600 m on the slope where a combination of seabed type and a plentiful supply of nutrients are ideal for the establishment of deep sea sponges (Tangye *et al*., 2022). They have, however, also been reported at depths up to 1,300 m (Bett and Rice, 1992). Within the NCMPA, the boreal ostur aggregation is formed by massive sponges including, *Geodia barretti*, *G. macandrewi*, *G. atlantica* and *G. phlegraei* (Henry and Roberts, 2014). The flabellate chalice sponge (*Phakellia ventilabrum*) was also observed during the survey of the NCMPA in 2012 and other erect sponges, as well as yellow and white encrusting sponges, are known to be present in the aggregation (Howell *et al.,* 2010). However, as noted in Section 4.3.2, no deep-sea sponge aggregations meeting the OSPAR threatened and/or declining habitat criteria were observed during the Tornado surveys (Fugro, 2025a; 2025b).

The ocean quahog is a large burrowing bivalve and is considered to be the longest living mollusc, with one individual reported as being over 500 years in age (Tyler-Walters *et al*., 2016). Ocean quahog has been found in a range of sediments, from coarse clean sand to muddy sand in a range of depths typically from 4 m to 482 m deep, but most commonly between 10 m to 280 m (Thorarinsdóttir and Einarsson, 1996; Sabatini *et al*., 2008; OSPAR, 2009a; Tyler-Walters and Sabatini, 2017). Ocean quahog is thought to have a high sensitivity to physical loss of habitat (Tyler-Walters and Sabatini, 2017), therefore, it is

important to conserve the extent and distribution of supporting habitats to provide the best chance of any potential settlement for new recruits and to retain existing individuals. However, as noted in Section 4.3.2, no individuals were recorded in the macrofauna data at Tornado, no potential relict shells were observed along video transects and no live individuals or their distinctive siphons were noted during analysis of video footage and still photographs from the survey area (Fugro, 2025a; 2025b; 2025c; 2025d).

The interaction between hydrographic processes and the continental slope may enhance feeding conditions through the aggregation of principle prey items (e.g. squid, herring, blue whiting and krill) for several species of cetacean, including sperm whale, minke whale, killer whale, fin whale, long-finned pilot whale and Atlantic white-sided dolphin (Stone, 1998; Weir *et al.,* 2001; Swift *et al.,* 2002; Macleod, 2004; Macleod *et al.,* 2006). In addition, the topography of the Faroe-Shetland Channel continental slope and wider channel is thought to be of functional significance as a migratory pathway/corridor for several cetacean species (refer to Section 4.3.5 for further details).

### Seas off Foula SPA

The Seas off Foula SPA is located approximately 49 km to the south of the Tormore manifold and covers the waters around and to the north west of the Isle of Foula, 15 km west of mainland Shetland. Seabirds breeding on Foula are already protected on land and in the waters immediately surrounding the island by the existing Foula SPA. The Seas off Foula SPA therefore provides additional protection for seabirds in the area by ensuring that the adjacent marine foraging habitat and the prey on which seabirds depend are equally protected (JNCC, 2025).

Specifically, the SPA protects the following migratory seabird species that forage at sea: great skua (breeding and non-breeding); assemblage of breeding seabirds; assemblage of seabirds, non-breeding; including northern fulmar (breeding and non-breeding); Arctic skua (breeding); common guillemot (breeding and non-breeding) and Atlantic puffin (breeding). The seaward boundary of the site is based on the extent of the sea area around Foula that holds at least 1 % of the biogeographic population of great skua on a regular basis (see Figure 4.29), however, all of the qualifying seabird species are found throughout the entire extent of the Seas off Foula SPA (JNCC, 2016). The conservation objectives for this site are:

- Avoid significant mortality, injury and disturbance of the qualifying features, so that the distribution of the species and ability to use the site are maintained in the long-term;
- Maintain the habitats and food resources of the qualifying features in favourable condition.

Studies suggest that the site, at least in its southern extent (Coull *et al*., 1998; Ellis *et al.,* 2012), overlaps with spawning and nursery grounds of sandeels. Sandeels are an important prey resource for many seabird species, particularly in the Seas off Foula SPA, the maintenance of both sandeel habitat and associated populations is important in order to ensure the ability of the site to support the qualifying species in the long-term (JNCC, 2016).

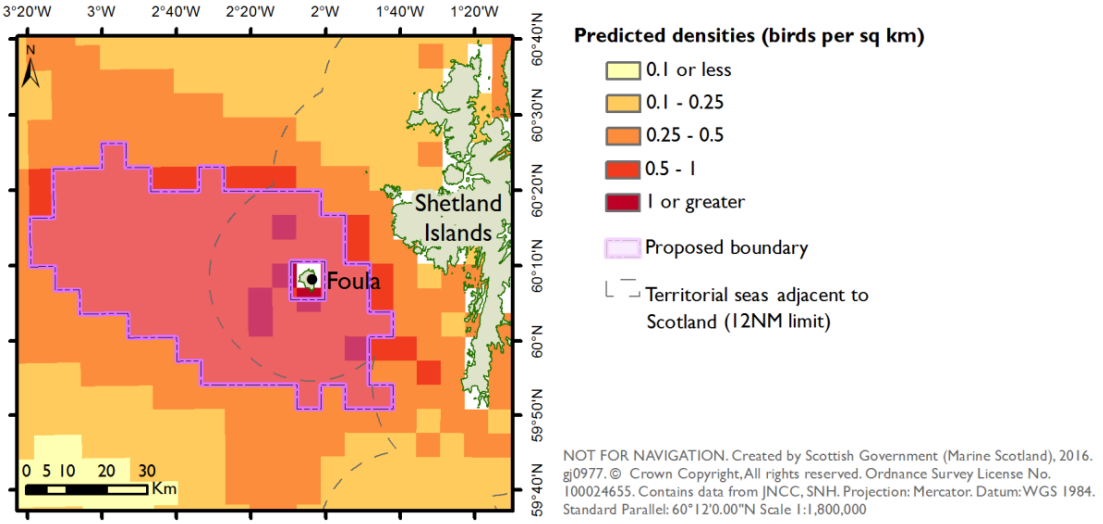



**Figure 4.29: Predicted at Sea Densities of Great Skua and the Boundary of Seas off Foula (JNCC, 2016)**

### West Shetland Shelf NCMPA

The West Shetland Shelf NCMPA is located approximately 78 km to the south of the proposed Tornado drill centre location. The site has been designated for the protection of the wide variety of sand and gravel habitats present in the area, providing an important example of the northern extent of their range on the continental shelf in Scottish seas. Although a relatively common habitat in Scottish seas, the range of different types of sand and gravel habitats present within the MPA support a particularly rich diversity of wildlife. On the surface anemones, cup sponges (*Axinella infundibuloformis*) and several types of crustaceans including hermit crabs and squat lobster (*Munida rugosa*) can be found living between small rocks, whilst urchins and starfish (such as *Porania pulvillus* and *Asterias rubens*) are typical fauna living on the surface of sandier sediments. Bryozoans and encrusting sponges are often found growing on the surface of cobbles and pebbles. Sea snails and bivalves, such as scallops, keel worms and sand mason worms (*Lanice conchilega*), are adapted to living buried in the sand to avoid predators. The conservation objectives for the West Shetland Shelf NCMPA are that the protected feature (Offshore subtidal sands and gravels) so far as already in favourable condition, remain in such condition; and so far, as not already in favourable condition, be brought into such condition, and remain in such condition.

### North-east Faroe-Shetland Channel NCMPA

The North-east Faroe-Shetland Channel NCMPA is located approximately 92 km to the northeast of the Tomore manifold. The NCMPA has been designated for the protection of deep-sea sponge aggregations, offshore deep-sea muds, offshore subtidal sands and gravels, continental slope and features representative of the West Shetland Margin Palaeo-depositional, Miller Slide and Pilot Whale Diapirs Key Geodiversity Areas. The site covers a large proportion of the north-eastern reaches of the Faroe-Shetland Channel in Scottish waters. The continental slope contributes to funnelling oceans currents which bring food and nutrients which support a wide diversity of life in the region. The slope additionally acts as corridor for migratory marine mammals including the fin whale and sperm whale, as described in Section 4.3.5 (JNCC, 2025). The conservation objectives for the North-East Faroe-Shetland Channel NCMPA are that the protected features so far as already in favourable condition, remain in such condition; and so far, as not already in favourable condition, be brought into such condition, and remain in such condition.

### North-west Orkney NCMPA

The North-west Orkney NCMPA is located approximately 108 km to the southeast of the proposed Tornado drill centre location. The NCMPA is a shallow area lying to the north and west of the Orkney Isles on the Scottish continental shelf. The area is considered important as an export ground for sandeels – a type of burrowing fish that forms a critical component of many North Sea food webs. The area is characterised by a mixed ground type (areas of rough substrate within the areas of sediment) which make it suitable for sandeel colonisation. This may also account for the patchiness of the larval distribution. The NCMPA plays an important role in supporting wider populations of sandeels in Scottish waters. Specifically, newly hatched sandeel larvae from this region are exported by currents to sandeel grounds around Shetland and the Moray Firth. The NCMPA also includes protection for geomorphological features representative of the Fair Isle Strait Marine Process Bedforms Key Geodiversity Area. These shelf tidal bedform features such as the sediment wave fields, sand wave fields and sandbanks, are active and are maintained under a specific range of tidal current conditions. The conservation objectives for the North-west Orkney NCMPA are that the protected features (Sandeels, sand banks, sand wave fields and sediment wave fields) so far as already in favourable condition, remain in such condition; and so far, as not already in favourable condition, be brought into such condition, and remain in such condition.

### Coastal MPAs

The Shetland Islands possess a highly indented coastline with sheltered inlets as well as very exposed headlands. The resulting habitats are therefore highly heterogeneous and include extensive stretches of exposed cliffs and rocky shorelines with long, narrow inlets (known locally as voes) extending several kilometres inland. Sandy shorelines are rare and are largely restricted to sheltered embayments. In

some of the sheltered areas, small lagoons have become impounded behind shingle or gravel sand bars providing habitats such as salt marsh (BEIS, 2022).

Coastal MPAs situated along the coastline adjacent to the proposed Tornado Development area include:

- **Ronas Hill - North Roe and Tingon SPA and Ramsar site** located approximately 94 km south east of the Tormore manifold. This site qualifies under Article 4.1 and Article 4.2 of the Birds Directive by supporting populations of European importance of red-throated diver and merlin (JNCC, 2025). Although not qualifying features, the site also provides habitat for harbour seal and otter. The conservation objectives for this site are:
  1. To avoid deterioration of the habitats of the qualifying species or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained;
  2. To ensure for the qualifying species that the following are maintained in the long term:
     a. Population of the species as a viable component of the site.
     b. Distribution of the species within site.
     c. Distribution and extent of habitats supporting the species.
     d. Structure, function and supporting processes of habitats supporting the species.
     e. No significant disturbance of the species.

- **Papa Stour SPA and SAC** located 96 km south east of the Tormore manifold. This site qualifies under Article 4.1 and Article 4.2 of the Birds Directive by supporting populations of European importance (refer to Section 4.3.4; JNCC, 2021d). This site is also designated as an SAC due to the presence of Annex I reefs and submerged or partially submerged sea caves (JNCC, 2025). The conservation objectives for the SPA are:
  1. To avoid deterioration of the habitats of the qualifying species or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained;
  2. To ensure for the qualifying species that the following are maintained in the long term:
     a. Population of the species as a viable component of the site;
     b. Distribution of the species within site;
     c. Distribution and extent of habitats supporting the species;
     d. Structure, function and supporting processes of habitats supporting the species;
     e. No significant disturbance of the species.

  The conservation objectives for the SAC are:

  1. To avoid deterioration of the qualifying thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to achieving favourable conservation status for each of the qualifying interests.
  2. To ensure for the qualifying habitats that the following are maintained in the long term:
     a. Extent of the habitat on site:
     b. Distribution of the habitat within site
     c. Structure and function of the habitat
     d. Processes supporting the habitat
     e. Distribution of typical species of the habitat
     f. Viability of typical species as components of the habitat
     g. No significant disturbance of typical species of the habitat

- **Ramna Stacks and Gruney SPA** located 103 km south east of the Tormore manifold. This site qualifies under Article 4.1 by supporting populations of Leach's petrel in the breeding season. The conservation objectives for this site are:
  1. To avoid deterioration of the habitats of the qualifying species or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained;
  2. To ensure for the qualifying species that the following are maintained in the long term:
     a. Population of the species as a viable component of the site.
     b. Distribution of the species within site.
     c. Distribution and extent of habitats supporting the species.
     d. Structure, function and supporting processes of habitats supporting the species.
     e. No significant disturbance of the species.

# 4.4 Human Environment

## 4.4.1 Commercial Fisheries

### Prohibited Trawling Area

In 2016, the EU adopted Regulation (EU) 2016/2336, called the "Deep-sea Access Regulation", which came into force in 2017 and prohibits all bottom trawling below 800 m in EU waters. Following the UK's departure from the EU, the adopted legislation has been converted and preserved in UK law, binding UK fisheries to the depth limit. The location of the prohibited trawling area in relation to the proposed Tornado Development area is illustrated in Figure 4.30, with the proposed Tornado drill centre and majority of the proposed pipeline route (ca. 65.8 km) located in water depths greater than 800 m. Fishing activity is therefore more likely to be concentrated at the Tormore end of the pipeline route, where water depths are shallower. However, the Scottish government has recently introduced fisheries management measures, through The Offshore Fishing (Prohibition of Fishing Methods) (Scotland) Order 2025, in 20 MPAs within the Scottish offshore region, including the Faroe-Shetland Sponge Belt NCMPA. These measures came into effect on 16th October 2025. The management measures for the Faroe-Shetland Sponge Belt NCMPA include zoned closure to demersal gear (mobile and static) fishing practices, as illustrated in Figure 4.30 (Scottish Government, 2025). The proposed Tornado pipeline route cross through the northern zone for a distance of ca. 13 km, where the use of demersal mobile gear is prohibited. As such, only ca. 5 km of the entire proposed pipeline route would potentially be exposed to demersal mobile fishing gear interaction, noting that a 500 m length of this section is located within the existing Tormore 500 m safety exclusion zone.

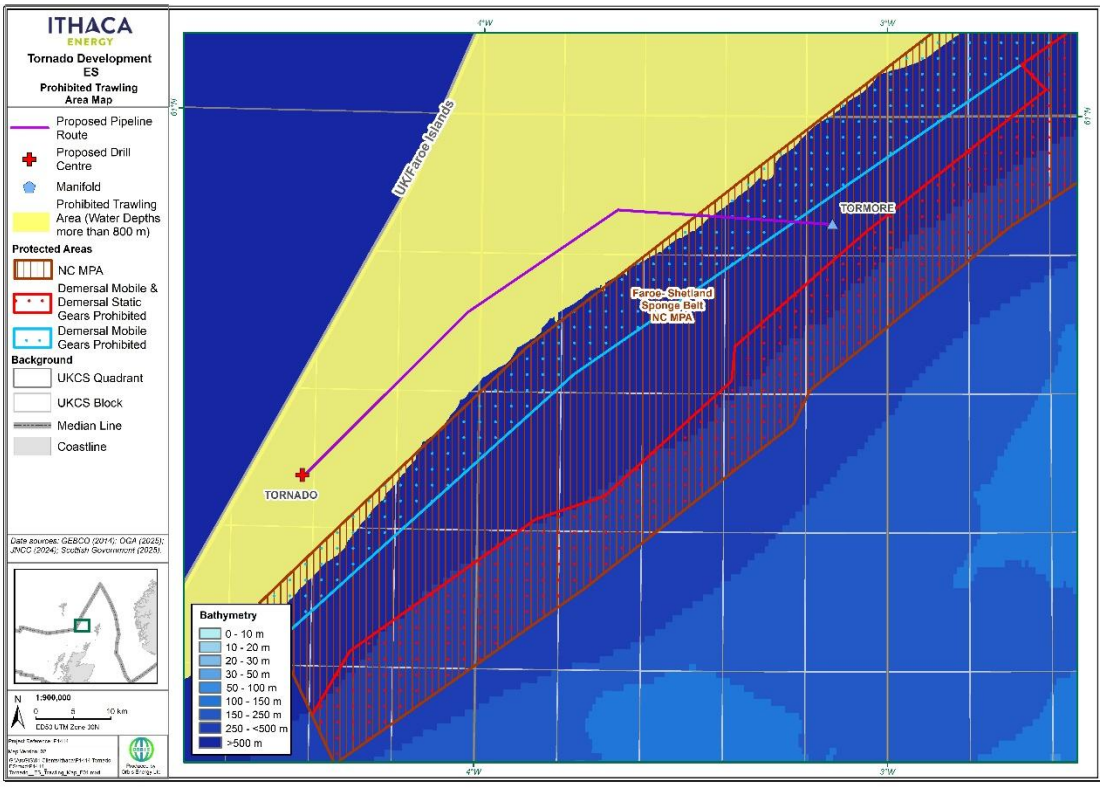



**Figure 4.30: Prohibited Trawling Areas surrounding the Tornado Development**

### Fishing Intensity Study

A detailed fishing intensity study (Xodus, 2024) has been conducted for the proposed Tornado Development to characterise and quantify fishing activity over a 10 year period between 2014 to 2024 within 500 m of the proposed pipeline route and within a wider 5 nautical miles (nm) study area.

The study found that both fishing vessel presence and fishing activity (assumed from assessing vessels travelling 5 knots or less) is low across the 5 nm and 500 m study areas. In total, 517,998 AIS records

were received and processed over the 10 year period between 2014 and 2024, which were associated with 673 unique vessels and processed into 11,602 individual track lines. During the 2014 installation of Laggan Tormore facilities, several fishing vessels were employed as guard vessels. These vessels were excluded from the overall analysis, meaning this resulted in the removal of 12 unique vessels and 126 AIS derived track lines within the 5 nm study area and 10 unique vessels and 23 AIS derived track lines within the 500 m study area for 2014. With the exclusion of the fishing vessels employed as guard vessels, the total number of track lines observed in the 5 nm and 500 m study areas was 1,400 and 685, respectively. The number of individual vessels observed in the 5 nm and 500 m study areas was 359 and 249, respectively. The ten most frequently occurring fishing vessels within the 500 m study area, which account for 25% of all track lines, were all foreign vessels (a mix of Faroese, French, Russian and Dutch vessels) (Xodus, 2024).

Whilst there is yearly fluctuation within both the 5 nm and 500 m study areas, a gradual liner increase in track line counts is observed between 2014 and 2023. The year with the highest count within the 5 nm study area was 2023, where 202 individual track lines were observed, accounting for 14.4% of the total number of track lines across all years. The year with the highest track line count within the 500 m study area was 2020, where 95 individual tracks were observed, accounting for 13.9% of the total number of track lines across all years, however 2023 did observe the second highest yearly track line count of 92 (or 13.4%) (Xodus, 2024).

Figure 4.31 shows track lines and associated track line grid cell densities within the 5 nm study and wider region. Generally, fishing vessel activity is restricted to shallower waters less than 650 m in depth with the highest densities observed along the 250 m bathymetric contour. There is also a higher presence of fishing vessels west of the UK Exclusive Economic Zone (EEZ) boundary. Fishing vessel activity is low across the entire proposed pipeline route and the 5 nm study area where no more than 40 track lines are observed within a 0.5 $km^2$ grid cell area. The highest levels of fishing vessel presence in the 5 nm study area are around Tormore facilities or the north-eastern end and an area of the 5 nm study area to the south-west that crosses the UK EEZ boundary. Along the pipeline route the highest densities are observed between approximately KP 15 to KP 30 where a maximum of 40 track lines are observed within a 0.5 $km^2$ grid cell area. The density pattern here suggests that vessels are crossing the proposed pipeline route, transiting in a north-westerly, south-easterly direction (Xodus, 2024).

The main fishing method (gear type) occurring both in the 5 nm study area and along the pipeline is trawling, specifically demersal (bottom) otter trawling. AIS records show that trawlers account for approximately 70% all fishing vessel activity both in terms of track line counts and time spent travelling 5 knots or less within the 5 nm and 500 m study areas. Whilst some fluctuation is observed, trawler presence remains consistent across the 10-year period. Other prevalent fishing methods include Scottish seines and longlines, with the former accounting for nearly a quarter of all track lines in the 5 nm study, but only recording one track line in the 500 m study area during the 10-year study period (Xodus, 2024).

VMS data and aggregated ICES spatial data layers corroborates the findings from the AIS data both in terms of spatial and temporal variability of fishing vessel presence and specific gear types and fishing methods occurring within the 5 nm and 500 m study areas. This can be seen in Figure 4.32 which provides the yearly average of fishing intensity (time spent fishing) for a 10-year period between 2010 and 2020 aggregated into ICES sub-rectangles of approximately 15 $km^2$. Of the four main benthic fishing methods, only otter trawl activity is recorded in the 5 nm study area, which is restricted to the Tormore end, where up to one day of effort was recorded per sub-rectangle. The wider distribution of otter trawl activity occurs to the south east of the 5 nm study area in water depths less than 700 m and with the highest intensities between 200 m and 300 m (Xodus, 2024).

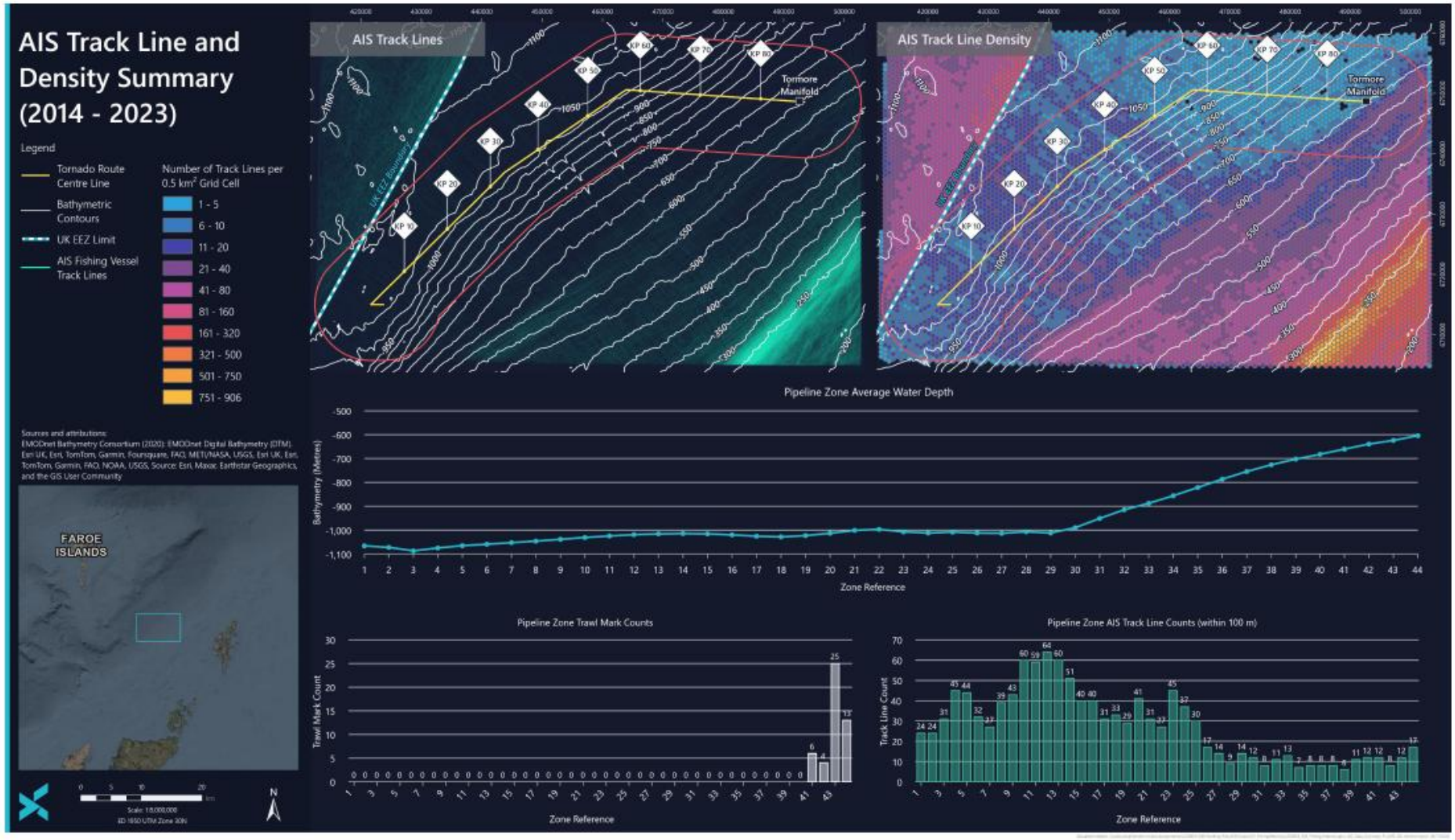



**Figure 4.31: AIS track line and density summary for the 10-year period between 2014 and 2023 (Xodus, 2024)**

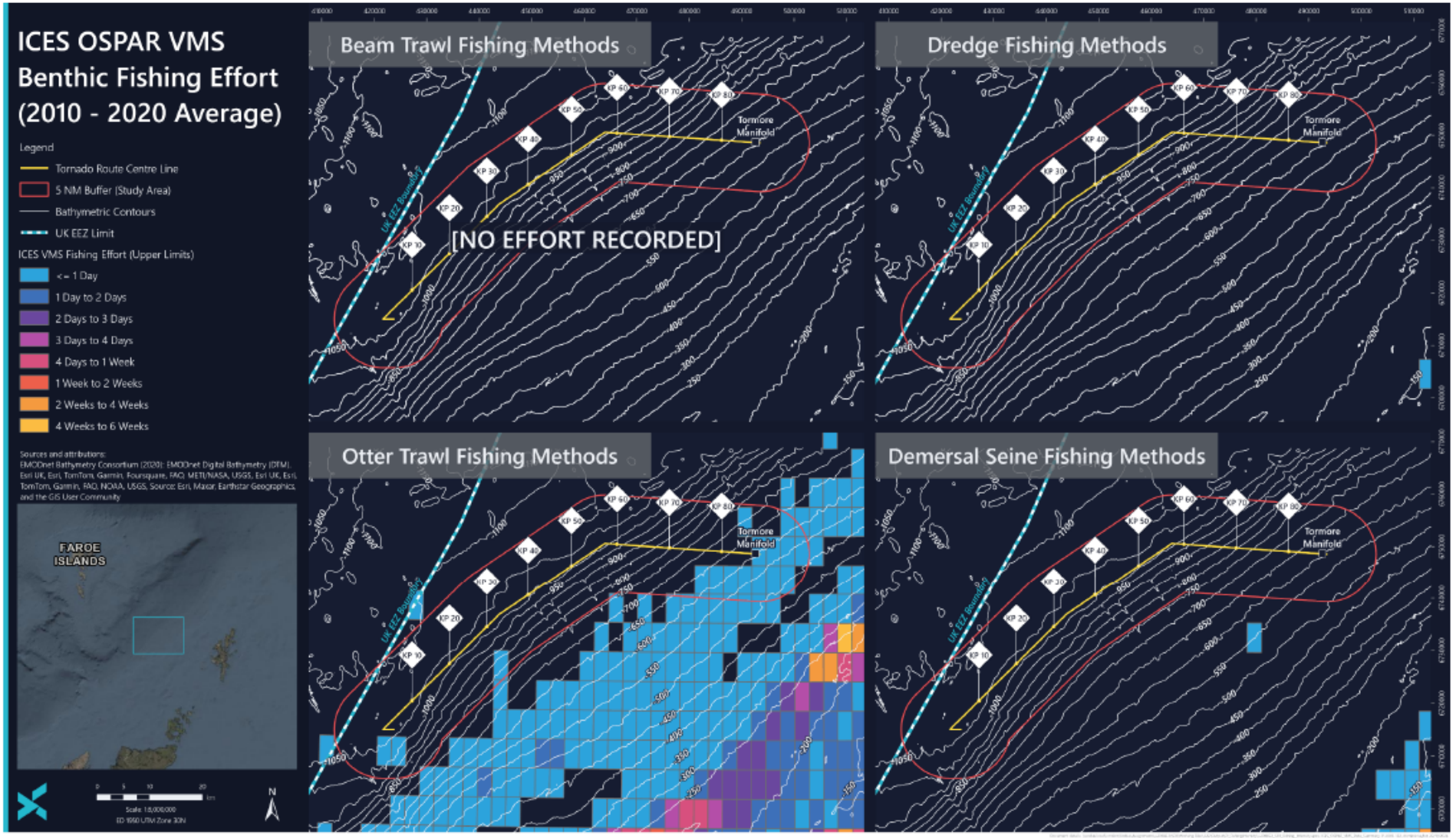



**Figure 4.32: ICES OSPAR VMS Benthic Fishing Effort between 2010 - 2020 (Xodus, 2024)**

### Fisheries Landings Data

Scottish Government's Marine Directorate (SGMD) provides landings data, including the live weight (tonnes) and sales value (£) of sea fish by UK vessels into the UK and abroad, and landings into the UK by foreign vessels by ICES rectangles. Each ICES rectangle measures 30 nm by 30 nm, although it is important to note that fishing activity may not be uniformly distributed over the whole area of the ICES rectangle.

The proposed Tornado drill centre and approximately 33.4 km of the proposed pipeline route down to a water depth of ca. 1,074 m is located within ICES Rectangle 50E5, with the remainder of the pipeline route to the Tormore manifold (a length of approximately 50.9 km) located within ICES Rectangle 50E6. However, SGMD data is only available for Rectangle 50E6, with disclosive / no data available within ICES Rectangle 50E5 due to inactivity of vessels within the area.

Table 4.24 and Table 4.26 summarises monthly fisheries landings data (live weight and sales value, respectively) from ICES Rectangle 50E6 over a ten year period from 2014 to 2024. Across the ten year period, the mean live weight landings fluctuate, but were highest in October at an average of 47.23 tonnes and lowest in February at an average of 7.1 tonnes. Whereas, the mean sales value also fluctuates, but were highest on average in June at £77,469.86, and lowest on average in November at ££15,010.62.

Table 4.25 and Table 4.27 summarises the fisheries landings data (live weight and sales value, respectively), from ICES Rectangle 50E6 for a ten year period from 2014 to 2024 by species type. It can be seen from this that demersal fisheries dominate the landings data from ICES Rectangles 50E6, with hake, halibut (Greenland) and saithe the greatest components of the fishery (see Table 4.28 and Table 4.29). The total live weight and sales value fluctuates over the ten year period, with the highest values recorded in 2022 at 695.87 tonnes and £1,416,280.02 respectively and lowest values recorded in 2021 at 184.38 tonnes and £291,155.16 respectively.

In comparison to the surrounding areas the value and tonnage of landings from ICES Rectangle 50E6 is lower compared to the ICES Rectangle blocks adjacent to the south east, which are in shallow waters closer to the Shetland Islands (NMPi, 2024).

**Table 4.24: Total Monthly Fishing Landings (by live weight) by Vessels between 2014 and 2024 within ICES Rectangles 50E6 (Marine Scotland, 2016; Marine Scotland, 2021; SG-MD, 2025)**

| Month | 50E6 - Fishing Landings (tonnes) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | Mean |
| Jan | D | - | 75.15 | - | D | 31.07 | D | D | D | 3.35 | 15.6 | **11.38** |
| Feb | D | D | D | D | 31.06 | D | D | 17.97 | 18.89 | D | 10.15 | **7.1** |
| Mar | D | - | - | D | 29.58 | 57.40 | 168.62 | D | D | 11.92 | 10.58 | **25.28** |
| Apr | D | D | 60.86 | D | 83.72 | D | D | D | 76.73 | 21.98 | 10.17 | **23.04** |
| May | D | 102.30 | D | 65.27 | 110.91 | 107.43 | 13.80 | D | 71.35 | 33.11 | 12.1 | **46.93** |
| Jun | D | D | 86.32 | 53.48 | D | 10.10 | D | D | 112.22 | 62.25 | 58.32 | **34.79** |
| Jul | D | D | D | D | D | D | 17.24 | 28.27 | 21.82 | 64.14 | 49.46 | **16.45** |
| Aug | D | 40.82 | D | D | D | D | 75.07 | 42.19 | 92.16 | 36.34 | 46.81 | **30.31** |
| Sept | D | D | D | D | 22.96 | 68.90 | 33.62 | 21.28 | 78.86 | 38.85 | D | **24.04** |
| Oct | D | D | D | D | 88.60 | 37.27 | 266.45 | D | 84.58 | 23.47 | 19.19 | **47.23** |
| Nov | D | D | D | D | D | 33.43 | 13.35 | - | D | 56.26 | 13.48 | **10.59** |
| Dec | D | D | D | 59.39 | 20.90 | D | 11.33 | 9.86 | 83.00 | 38.47 | 40.77 | **23.97** |

**Note**: Total Monthly fishing landings (tonnes) by Vessels: '-' = no data, 'D' = Disclosive data (indicating very low effort).

**Table 4.25: Weight of landings (by species type) for ICES Rectangle 50E6 between 2013 and 2023 (Marine Scotland, 2016; Marine Scotland, 2021; SG-MD, 2025)**

| Species | 50E6 - Fishing Landings (tonnes) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
| Demersal | 223.41 | 257.62 | 372.62 | 272.66 | 477.97 | 418.12 | 687.17 | 182.17 | 694.94 | 393.28 | 316.41 |
| Pelagic | - | - | - | 1.48 | 1.02 | 0.05 | 0.16 | - | - | - | - |
| Shellfish | 1.24 | 0.30 | 0.19 | 0.57 | 0.24 | 0.66 | 0.98 | 2.21 | 0.93 | 2.22 | 0.63 |
| **Total** | **224.65** | **257.92** | **372.81** | **274.71** | **479.23** | **418.83** | **689.16** | **184.38** | **695.87** | **395.50** | **317.04** |

**Note**: Weight of landings (by species type): '-' = no data.

**Table 4.26: Total Monthly Fishing Landings (by value) by Vessels between 2014 and 2024 within ICES Rectangle 50E6 (Marine Scotland, 2016; Marine Scotland, 2021; SG-MD, 2025)**

| Month | 50E6 - Fishing Landings (value) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | Mean |
| Jan | D | - | £281,243.92 | - | D | £108,745.54 | D | D | D | £9,504.98 | £41,185.33 | **£40,061.80** |
| Feb | D | D | D | D | £88,208.04 | D | D | £30,602.17 | £54,239.37 | D | £12,413.48 | **£16,860.28** |
| Mar | D | - | - | D | £59,480.91 | £61,861.41 | £31,963.99 | D | D | £33,808.56 | £23,221.22 | **£19,121.46** |
| Apr | D | D | £71,340.51 | D | £115,599.08 | D | D | D | £121,763.67 | £45,979.40 | £11,427.78 | **£33,282.77** |
| May | D | £126,144.87 | D | £140,569.10 | £107,206.25 | £137,579.88 | £12,539.81 | D | £168,511.53 | £78,601.09 | £31,035.86 | **£72,926.22** |
| Jun | D | D | £186,742.35 | £134,179.81 | D | £19,262.30 | D | D | £234,179.16 | £142,595.00 | £135,209.81 | **£77,469.86** |
| Jul | D | D | D | D | D | D | £29,639.82 | £40,391.81 | £30,591.75 | £54,757.54 | £72,796.63 | **£20,743.41** |
| Aug | D | £80,473.46 | D | D | D | D | £132,952.29 | £54,457.37 | £116,618.95 | £46,088.24 | £53,989.52 | **£44,052.71** |
| Sept | D | D | D | D | £28,464.47 | £113,079.29 | £60,716.69 | £37,143.40 | £112,806.52 | £64,659.78 | D | **£37,897.29** |
| Oct | D | D | D | D | £134,065.73 | £87,674.48 | £112,073.67 | D | £201,517.87 | £42,903.60 | £25,703.77 | **£54,903.56** |
| Nov | D | D | D | D | D | £66,010.82 | £20,463.01 | - | D | £49,837.81 | £28,805.16 | **£15,010.62** |
| Dec | D | D | D | £144,569.73 | £43,464.52 | D | £12,413.33 | £21,137.31 | £203,282.94 | £31,155.39 | £67,931.46 | **£47,632.24** |

**Note**: Total Monthly fishing landings (£) by Vessels: '-' = no data, 'D' = Disclosive data (indicating very low effort).

**Table 4.27: Value of landings (by species type) for ICES Rectangle 50E6 between 2014 and 2024 (Marine Scotland, 2016; Marine Scotland, 2021; SG-MD, 2025)**

| Species | 50E6 - Fishing Landings (value) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
| Demersal | £359,937.5 | £610,466.11 | £838,740.14 | £601,975.54 | £829,495.42 | £720,648.87 | £603,745.80 | £287,186.86 | £1,412,015.61 | £604,172.95 | £553,361.80 |
| Pelagic | - | - | - | £591.52 | £454.93 | £18.32 | £111.00 | - | - | - | - |
| Shellfish | £1,075.67 | £3,366.14 | £774.12 | £1,846.81 | £1,085.46 | £2,245.85 | £2,139.51 | £3,968.30 | £4,264.41 | £7,910.00 | £1,696.93 |
| **Total** | **£361,013.17** | **£613,832.25** | **£839,514.26** | **£604,413.87** | **£831,035.81** | **£732,353.17** | **£605,996.31** | **£291,155.16** | **£1,416,280.02** | **£612,082.95** | **£555,013.73** |

**Note**: Value of landings (by species type): '-' = no data.

**Table 4.28: Total Catch Composition by Weight (tonnes) between 2014 and 2024 within ICES Rectangle 50E6 (Marine Scotland, 2016; Marine Scotland, 2021; SGMD, 2025)**

| Number | Average Quantity (tonnes) | Species |
|---|---|---|
| 1 | 128.28 | Saithe |
| 2 | 84.41 | Hake |
| 3 | 57.48 | Halibut - Greenland |
| 4 | 41.70 | Ling |
| 5 | 32.12 | Monks or Anglers |
| 6 | 15.27 | Redfishes |
| 7 | 8.79 | Haddock |
| 8 | 8.46 | Cod |
| 9 | 5.05 | Spurdog |
| 10 | 3.95 | Torsk (Tusk) |

**Table 4.29: Total Catch Composition by Value (£) between 2014 and 2024 within ICES Rectangle 50E6 (Marine Scotland, 2016; Marine Scotland, 2021; SGMD, 2025)**

| Number | Average Value (£) | Species |
|---|---|---|
| 1 | £213,521.61 | Hake |
| 2 | £147,656.13 | Halibut (Greenland) |
| 3 | £99,120.31 | Saithe |
| 4 | £88,608.82 | Monks or Anglers |
| 5 | £50,941.81 | Ling |
| 6 | £21,285.59 | Cod |
| 7 | £18,804.90 | Redfishes |
| 8 | £11,878.36 | Haddock |
| 9 | £8,716.46 | Megrim |
| 10 | £3,571.24 | Blue Ling |

#### Aquaculture

Aquaculture is a prominent industry along the west coast of the Shetland Islands (Baxter *et al.,* 2011). Shetland continues to make a significant contribution to Scotland's growing aquaculture industry. Over 30,000 tonnes of salmon are harvested on Shetland, equating to 25% of Scotland's total production volumes, and valued at over £150 million. While Scotland's mussel sector is dominated by Shetland producers with over 6,500 tonnes of mussels grown in Shetland, accounting for 81% of Scottish mussel production (Seafood Shetland, 2025). The closest aquaculture area to the Tornado Development is the Hamnavoe shellfish aquaculture site, located approximately 95 km to the south east of the Tornado Development at the Tormore manifold end, which farms mussels (NMPi, 2024).

A number of Shellfish Water Protected Areas have been established surrounding the coasts of Shetland and Orkney, with each area having environmental objectives as part of the river basin management planning process (NMPi, 2024). The closest Shellfish Waters Protected Area to the proposed Tornado Development area is the Ronas Voe Area located approximately 96 km southeast of the Tormore manifold (NMPi, 2024).

Aquaculture is also widespread in the Faroe Islands, with fish and fish products making up almost 95% of the total export income and 20% of the total Faroese gross national product. Alongside wild capture fisheries, aquaculture has become an important Faroese industry. Atlantic salmon dominates production, with some small production of seaweed (ICES CIEM, 2023).

### 4.4.2 Shipping

Shipping activity in the waters WoS are relatively low when compared with parts of the English Channel and North Sea (BEIS, 2022).

Commercial traffic is likely to include vessels en-route to/from SVT and vessels in transit across the Atlantic; these include containers, ferries and cruise liner traffic. The wide expanse of water, combined with overall low vessel traffic, result in reduced vessel congestion (BEIS, 2022).

Shipping activity in the proposed Tornado Development area is considered to be very low to negligible (OGA, 2016). Figure 4.33 illustrates shipping densities in the vicinity of the proposed Tornado Development area, which indicates that the highest densities in the area are found at existing oil and gas infrastructure likely to be associated with oil and gas supply and support vessels (EMODnet, 2024b).

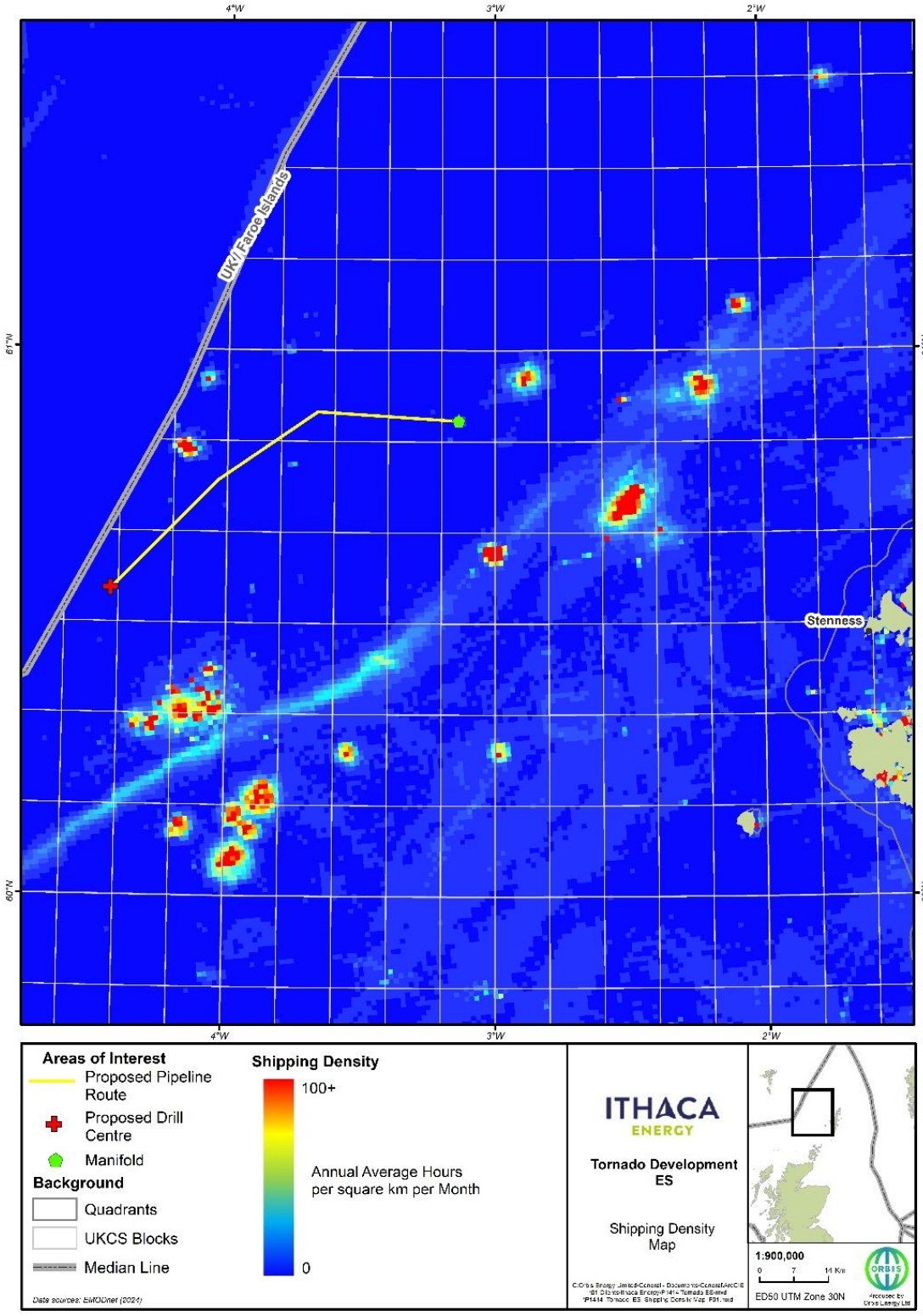



**Figure 4.33: Shipping Density in the Vicinity of the Proposed Tornado Development**

### 4.4.3 Offshore Energy and Submarine Cables

The closest producing fields to the proposed Tornado drill centre location are the Alligin, Loyal and Schiehallion oil fields (operated by BP), developed through the Glen Lyon FPSO, which is located approximately 30 km southeast of the Tornado drill centre. The Foinaven field is not operational. The closest producing field to the proposed Tornado pipeline route, with the exception of the Tormore field, is the Laggan condensate field (operated by TotalEnergies E&P UK Limited) located approximately 7.5 km to the northeast of Tormore. The Clair Ridge and Clair Phase One platforms (operated by BP), are located approximately 38 km southeast of the proposed Tornado pipeline route at the Tormore manifold end and approximately 105 km northeast of the Tornado drill centre (Figure 4.34; NSTA, 2024b).

No pipelines currently cross the proposed Tornado Development area, with the closest active pipelines being those associated with the Tormore and Laggan development (operated by TotalEnergies E&P UK Limited) (NSTA, 2024b). However, the proposed Tornado pipeline route will cross the proposed Rosebank gas export pipeline, which will form part of Equinor's proposed Rosebank field development, at a point approximately 13.5 km west of the Tormore manifold. The Rosebank field development is currently undergoing reapproval following a court ruling in January 2025. Nevertheless, installation work at Rosebank commenced in 2025, therefore it is expected that the Rosebank pipeline will be installed ahead of the Tornado pipeline.

The proposed Tornado pipeline route also crosses the Farice (active) telecommunications cable, at a point approximately 5.5 km west of the Tormore manifold and the Shefa-2 Seg 7 (active) cable, at a point approximately 28 km west of the Tormore manifold (Figure 4.34; KIS-ORCA, 2025).

The majority of the proposed Tornado Development (ca. 65 km of the pipeline route) is located within Innovation and Targeted Oil and Gas (INTOG) area WoS-a, representing an area targeting oil and gas decarbonisation or for generating offshore wind projects of > 100 MW. However, there are no INTOG offshore wind projects or carbon capture and storage sites within the vicinity of the proposed Tornado Development (Crown Estate Scotland, 2024). The closest offshore windfarm to the proposed Tornado Development is the West of Orkney Wind Farm, currently in the planning stage, which would be located approximately 165 km south of the proposed Tornado drill centre location (Crown Estate Scotland, 2024).

### 4.4.4 Dredging and Disposal Activity

There are no commercial or capital dredging activities undertaken, neither are there any sites licenced for disposal of dredged material within the vicinity of the proposed Tornado Development area (Crown Estate Scotland, 2024).

### 4.4.5 Military Activity

There are no military practise and exercise areas in the vicinity of the proposed Tornado Development area (NMPi, 2024). However, licence conditions have been applied to UKCS Blocks 205/1, 205/2, 205/3, 205/4, 205/5 and 205/6 (all of which form part of the pipeline route) on behalf of the Ministry of Defence (MoD) as they lie within MoD training ranges. The licence condition stipulates that the MoD must be consulted 12 weeks in advance of placement of any installation (fixed or floating) related to oil and gas activity within the blocks (OGA, 2019).

### 4.4.6 Wrecks

There are no wrecks designated as historic Marine Protected Areas (hMPAs), scheduled monuments or war graves within the vicinity of the proposed Tornado Development area (UKHO, 2024; NMPi, 2024). One wreck has been recorded approximately 5 km south of KP 72 along the proposed Tornado pipeline route; the Eclipse FV sunk by U-45 on 1st July 1917, however, this wreck was not observed during the 2024 survey operations.

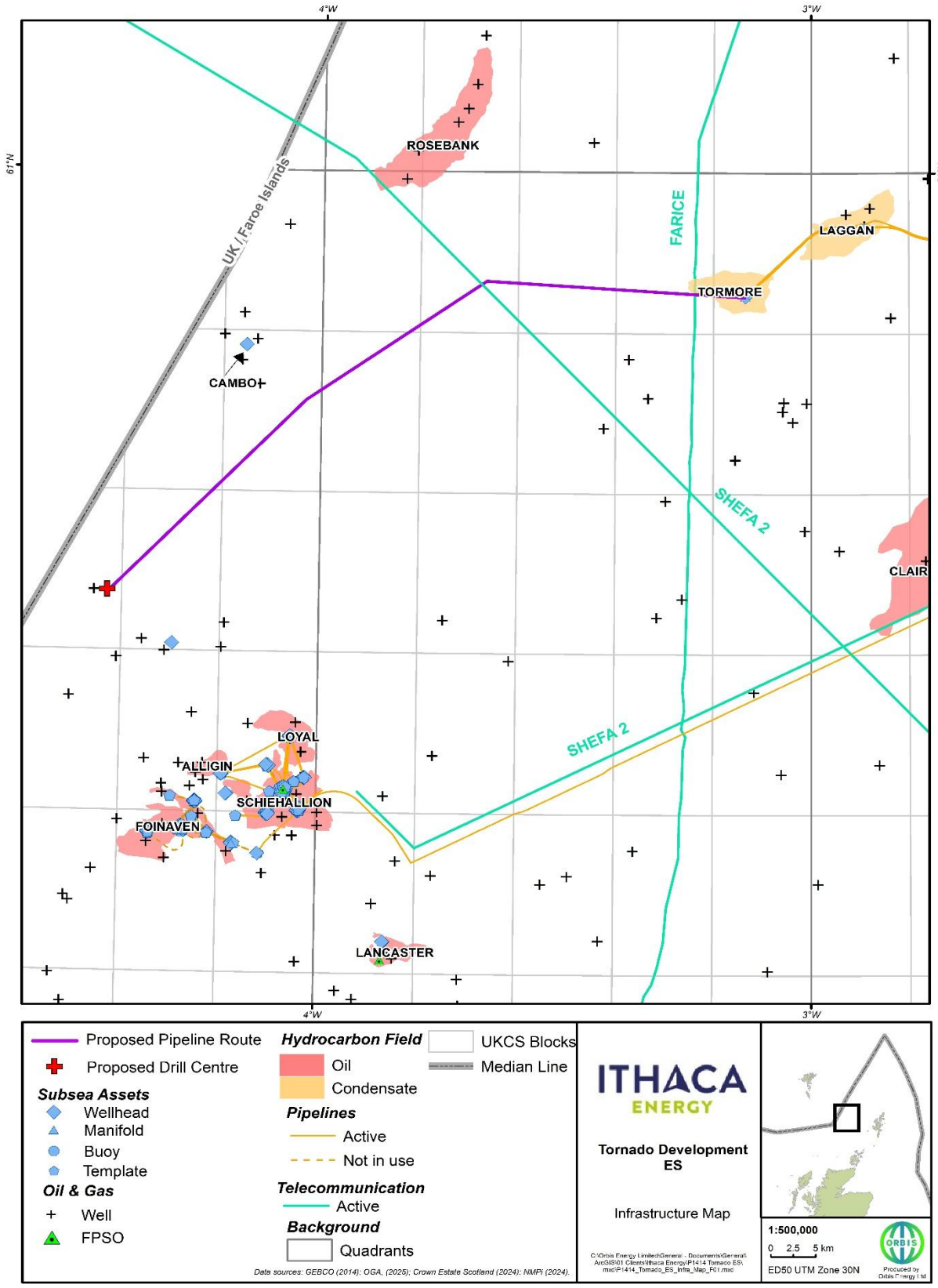



**Figure 4.34: Infrastructure in the Vicinity of the Proposed Tornado Development**

### 4.4.7 Tourism and Leisure

In general, tourism and leisure activities are focused along the coastline and nearshore water of the Shetland Islands, inshore of the proposed Tornado Development area. Coastal tourism activities include wildlife watching for birds, otters, cetaceans and pinnipeds, as well as recreational and sport fishing activities. Scuba diving is also popular due to the extensive rocky shores and kelp beds which support a diverse assemblage of species (DTI, 2005; Visit Shetland, 2021). However, tourism and leisure activities are relatively small contributors to Shetland's economy, which are dominated by oil and gas activities including the Sullom Voe oil and gas terminal, alongside the Shetland Gas Plant. Further sectors that contribute towards Shetland's economy is the seafood industry which is worth approximately £300 million and other industries such as aquaculture (HIE, 2025).

### 4.4.8 Natural Disasters

There are natural features of the environment in the Tornado Development area that could pose a risk to the Project, including the possible effects of climate change, and particularly those events that could result in a hydrocarbon spill.

The Faroe-Shetland Channel and continental shelf areas can be exposed to significant weather conditions, with strong winds exceeding 14 m/s occurring through the year but most frequently during the winter months. These strong winds are associated with significant wave conditions (refer to Section 4.2.4).

Historical records show that seismic activity in the North Sea is concentrated between the Fladen Ground and the waters offshore of Norway, and within the Dogger Bank area. An epicentre of small magnitude has been recorded on the continental slope WoS, with the most recent earthquake recorded 180 km east of Lerwick in Shetland, measuring a 2.8 magnitude (BGS, 2025). It is considered that earthquakes with magnitude of 4 or higher may require special structural design and are of concern for oil and gas activities. In the North Sea, the expected frequency of occurrence for a magnitude 4 natural seismic event is approximately every two years and a magnitude 5 natural seismic event every 14 years (BGS, 2001). However, within the vicinity of the Tornado field and the Faroe-Shetland Channel, seismic activity is largely non-existent, being mainly limited to the north of Shetland, towards the Møre Basin-Viking Graben area, where the highest recorded local magnitude is 3.1.

Slope instabilities generated by earthquakes have been recorded to the north-west of Shetland, however the seismicity and seismic hazard are low in this area. The Faroe-Shetland Channel displays landslides and debris flows, such as in the AFEN slide located 95 km north-west of Shetland where submarine mass movements occurred during the Holocene (BEIS, 2022).

# 5 Assessment Methodology

## 5.1 Introduction

The method used in this ES to determine if there are any likely significant effects of the proposed Tornado Development (the Project) on the environment, is described in this section and follows EIA good practice guidance (e.g. EC, 2017; CIEEM, 2018; SNH and HES, 2018; IEMA, 2016).

The process commences with the identification of Project activities (or aspects) that could impact environmental and socio-economic receptors, with consideration given to both planned (routine) activities and unplanned (accidental) events.

The terms “impact” and “effect” have different definitions in EIA and one drives the other. Impacts are defined as changes to the environment as a direct result of Project activities. Effects are defined as the consequences of those impacts upon receptors.

The type of impacts which could occur from the Project are categorised as follows:

- **Direct:** resulting from a direct interaction between a planned or unplanned Project activity and a receptor;
- **Indirect:** occurring as a consequence of a direct impact and may arise as a result of a complex pathway and be experienced at a later time or spatially removed from the direct impact;
- **In-combination:** arising from different activities within the Project resulting in several impacts on the same receptor or where different receptors are adversely affected to the detriment of the entire ecosystem;
- **Cumulative:** resulting from incremental changes caused by other past, present or reasonably foreseeable projects/proposals together with the Project itself.
- **Transboundary:** extending beyond the boundaries of the UKCS (i.e. impacting on other countries).

The nature, duration, scale and frequency of these impacts can be described as adverse or positive, short-, medium- or long-term, temporary or permanent, localised or widespread, one-off, intermittent or continuous.

Impacts that could potentially result in significant effects have been subject to detailed assessment based on best available scientific evidence and professional judgement so that, where possible, measures can be taken to prevent, reduce or offset what might otherwise be significant adverse effects on the environment through design evolution or operational mitigation measures.

Residual effects are those that are predicted to remain assuming the successful implementation of the identified mitigation measures and have been reviewed by Ithaca to confirm that the Project complies with environmental regulations and does not adversely impact Marine Planning policies and objectives (refer to Appendix A).

## 5.2 Stakeholder Engagement

In October 2024, as part of the informal stakeholder engagement process, Ithaca issued a Scoping Report to key stakeholders. The Scoping Report provided an overview of the Project and the impacts to be assessed in the ES, with stakeholders invited to comment on the Project and scope of the ES. The feedback received and how the issues raised have been considered during the EIA process, where applicable, and addressed in this ES are detailed in Table 5.1.

**Table 5.1: Summary of Key Issues Raised during the Stakeholder Engagement Process**

| Organisation | Comments Raised | Considered by the Project / Addressed in ES |
|---|---|---|
| OPRED | Confirmed that an option select will need to be presented on how the pipeline will be laid and protected along the proposed route. | Section 2.4.2<br>Section 3.4.4 |
| | Advised that the assessment of presence of deep-sea sponges and presence of rocky reefs follows the Henry & Roberts methods and that an assessment of the presence of Annex 1 reefs for both biogenic and geogenic reefs also needs to be conducted. | Section 4.3.2 |
| | Recommended including pictorial evidence of nursery/spawning grounds, based on the references, when describing the fish baseline. | Section 4.3.3 |
| | Advised that designated sites impact assessment should include Feature Activity Sensitivity Tool (FeAST) against the protected features of each designated site. In terms of the impacts on protected features such as the Faroe Shetland Sponge Belt NCMPA, an assessment of cumulative impacts on the features along with other pressures in the sponge belt must be included. The impact assessment also needs to include all phases of the project (construction/operation/decom). | Section 7 |
| | Advised that the 'Potentially Significant Aspects Subject to Detailed Assessment' should be expanded to include transboundary effects, cumulative effects and waste. Impacts should be presented in terms of the construction phase, the operation and maintenance phase and the decommissioning phase. | Sections 6 to 12 |
| | With regards to Net Zero:<br>• Provide information on how the project fits in with the appropriate policies such as (but not limited to) Energy White Paper, North Sea Transition deal, Net Zero Strategy, Carbon budgets, Climate Change Act, OGA SE11 and Ithaca's own corporate Net Zero policy;<br>• Explain how the selected field development concept minimises emissions;<br>• Identify what flaring and venting will be associated with the project and how this aligns to Net Zero goals<br>• If produced water is generated how will this be managed in terms of energy consumption;<br>• Explain how rig selection minimises emissions;<br>• Explain how emissions will be minimised during well clean-up and well testing;<br>• Identify what measures will be put in place to reduce emissions from construction operations, (e.g. energy efficiency measures for vessels);<br>• Identify what the operational energy requirements are and where this will be provided from over the lifetime of the field and how this has been selected in terms of emissions reductions. | Section 2.2.6<br>Section 9 |

| Organisation | Comments Raised | Considered by the Project / Addressed in ES |
|---|---|---|
| JNCC | Advised to limit impacts to Faroe-Shetland Sponge Belt NCMPA by minimising the amount of hard substrate material used and selecting least impactful route on site of the NCMPA. Recommended to separate out impacts to within and outside of the NCMPA for clarity. | Section 2.4<br>Section 7 |
| | Ensure that sufficient information is included within the ES so that a Habitats Regulations Assessment can take place. As part of pipeline route is within NCMPA, effects should be assessed under Section 126 of the Marine and Coastal Access Act (2009). Information should be provided to enable consideration of how the features of the NCMPA may be affected by the pressures of the proposed operations including information on the sensitivity (including recoverability) of the features to the identified pressures. It is additionally important that the proposed operations are contextualised alongside other projects and impacts that will be occurring within the NCMPA. | Section 7 |
| | Recommended including a diagram indicating the surveyed area in the context of the proposed activities, and to identify any sample points or the location of photographic evidence. | Section 4.1 |
| | Would expect to see detailed commentary on stabilisation operations to be included in the ES in order to understand the potential nature conservation impacts, including:<br>• Location of deposit sites<br>• Size / grade of rock to be used<br>• Tonnage / volume to be used<br>• Contingency tonnage / volume to be used<br>• Method of delivery to the seabed<br>• Footprint of rock<br>• Assessment of the impact<br>• Expected fate of deposit after end of production, i.e. will it be left in situ or recovered. | Section 3.4<br>Section 3.6<br>Section 7 |
| | Recommended that the proposed operations are assessed alongside approved developments under construction, approved developments that have not yet commenced construction, developments submitted for approval but not yet approved, as well as any other significant development for which some realistic figures are available within the Cumulative and In-Combination Assessments. | Sections 6 to 11 |

| Organisation | Comments Raised | Considered by the Project / Addressed in ES |
|---|---|---|
| SFF | Regarding pipeline burial, concerns over mud berms have been raised previously due to pipeline trenching operations. Advised that appropriate embedded mitigations are to be in place to eliminate any safety risk for fishermen. | Section 6.3 |
| | Advised that rock placement be carried out to industry standards, in respect of size of rock and rock berm profile (1:3) followed by an overtrawl sweep. | Section 3.4<br>Section 6.3 |
| | Raised concerns with regards to protection materials such as concrete mattresses and rock bags when used in open water (<800 m water depths). This can be a snagging hazard for fishing vessel gear. Recommend that any mattresses installed in open waters are subjected to a covering of rock dump. | Section 3.4<br>Section 6.3 |
| | Recommended that the relocation of boulders is avoided as much as possible. If boulder relocation is unavoidable, it is recommended that new locations / coordinates are recorded and provided to fishermen. Note: Fishermen require geographical readings to a decimal of a minute format (3 decimal places) in WGS84 datum. | Section 3.4<br>Section 6.3 |
| | Identified 'Commercial Fisheries' as a receptor of 'Seabed Disturbance', as laying of concrete mattresses and pipeline crossings would have an impact on commercial fisheries. | Risk to commercial fisheries is addressed in Section 6 |
| | Recommended that fisheries data sources used within the ES Baseline Chapter cover a 10 year period, to account for fisheries that have temporary ceased due to Brexit from 2016 onwards). | Section 4.4.1 |
| | Requested that a thorough assessment is made to establish if herring spawning is taking place along the proposed pipeline route. If herring spawning is taking place, it is proposed that any construction and decommissioning activities are undertaken outwith the spawning and nursery grounds of the relevant fish and shellfish species in the project area. In addition, if herring spawning does exist along the proposed pipeline route, SFF is of the view that any activities on herring spawning habitat should be prohibited based on the 'ICES Advice on fishing opportunities, catch, and effort Greater North Sea ecoregion' published 31 May 2024. | Section 4.3.3 |
| | Proposed that the following embedded mitigation measures are considered to eliminate any risk of snagging to fishermen and mitigate any disruptions to the fishing industry during the project lifespan:<br>• Issue Notice to Mariners with sufficient time ahead of any construction and decommission works.<br>• Comply with the ColReg to mitigate risk of collision with fishing vessels.<br>• Remove all development related subsea infrastructure (including drill cuttings) during decommissioning period followed by over-trawl sweep to make sure the project area is safe for fishing operations to resume. | Section 6.3 |

## 5.3 Identification of Environmental Impacts

In order to identify the environmental impacts which could arise from the Tornado Development, an ENVID workshop was undertaken by Ithaca and the EIA team. The purpose of the ENVID was to identify potentially significant aspects requiring detailed assessment in the ES, along with any project specific mitigation measures for consideration. The results of the ENVID workshop are documented in the ENVID Registers provided in Appendix B.

### 5.3.1 Aspects Subject to Further Assessment

Ithaca has determined that the aspects listed in Table 5.2 could potentially result in significant environmental effects. A comprehensive assessment has therefore been undertaken for these aspects, using the significance criteria defined in Section 5.3, the results of which are documented in Sections 6 to 12 of the ES.

**Table 5.2: Aspects Subject to Further Assessment**

| Assessment Topic | Potentially Significant Aspects | Receptors | ES Section |
|---|---|---|---|
| Physical Presence | • Presence of DP MODU and vessels during drilling, installation, inspection, maintenance and decommissioning activities<br>• Ongoing presence of subsea infrastructure and protection material | Shipping, Commercial Fisheries | Section 6 |
| Seabed Disturbance | • Installation (and subsequent removal) of CAN-ductors<br>• Discharge of WBM cuttings and excess cement on the seabed<br>• Pipeline prelay boulder clearance by pick and grab or boulder clearance plough<br>• Laying of production pipeline on the seabed<br>• Trenching and burial / protection of MEG pipeline and control umbilical in water depths <800m<br>• Installation of tie-in spools, jumpers and electrical flying leads at Tornado<br>• Installation of PLEMs and FLET structures and associated temporary initiation anchors and wet storing of subsea equipment / workbaskets<br>• Use of Glass Fibre Reinforced Polymer (GRP) structures and rock protection at Tormore<br>• Pipeline and cable crossing construction / pipeline corridor preparation (rock carpet) / structure foundation preparation (rock carpet)<br>• Deposit of additional rock on the pipelines to rectify free spans and interaction with fishing gear | Water Quality, Seabed Sediments, Benthic Communities, Fish, Marine Protected Areas | Section 7 |
| Underwater Noise Emissions | • Use of seismic sources during the Vertical Seismic Profile (VSP) survey | Fish, Marine Mammals, Seabirds | Section 8 |

| Assessment Topic | Potentially Significant Aspects | Receptors | ES Section |
|---|---|---|---|
| GHG Emissions | • Fuel burnt for power generation on the MODU, vessels and helicopters during drilling, installation, inspection, maintenance and decommissioning activities<br>• Flaring of hydrocarbons during well test and clean-up operations<br>• Incremental atmospheric emissions at the SGP as a result of Tornado coming online<br>• Further refining, transportation and distribution of Tornado gas and condensate once it leaves the SGP, but prior to end use of sold products;<br>• End use emissions from burning the extracted hydrocarbons | Climate | Section 9 |
| Marine Discharges | • Discharge of WBM cuttings at the sea surface<br>• Discharge of payzone cuttings<br>• Discharge of residual hydrocarbons when conducting well clean-up and testing operations and during pipeline dewatering<br>• Discharge of drilling, cementing, completion and rig chemicals during drilling operations<br>• Discharge of chemicals during hook-up and commissioning of subsea infrastructure, including commissioning and preservation fluids<br>• Discharge of water-based hydraulic fluid for subsea valve activation during production operations (open loop control system) and maintenance activities<br>• Discharge of chemicals or hydrocarbons during subsea intervention activities and decommissioning operations | Water Quality, Plankton, Fish, Benthic Communities | Section 10 |
| Accidental Releases | • Well blowout (releasing large quantities of condensate and gas) in the event of a loss of well control<br>• MODU or vessel collision (loss of diesel inventory)<br>• Pipeline rupture and subsequent release of hydrocarbons to sea<br>• Large release of gas due to loss of gas pipeline inventory | Water Quality, Seabed Sediments, Plankton, Benthic Communities, Fish and Shellfish, Seabirds, Marine Mammals, Marine Protected Areas, Shipping, Commercial Fishing, Tourism and Leisure, Air Quality, Climate | Section 11 |
| Waste Management | • Onshore disposal of general operational solid waste (non-hazardous & hazardous). | Population and Human Health | Section 12 |

[1] Note, waste management was scoped out of assessment during the ENVID workshop; however, in response to feedback from OPRED during the Scoping phase, information on Ithaca's waste management strategy for the Tornado Development has been provided in Section 12 of this ES.

### 5.3.2 Aspects Scoped Out of Assessment

A number of aspects were not considered to result in significant environmental effects and were scoped out from further assessment. A justification for this is provided in Table 5.3.

**Table 5.3: Aspects Scoped out of Further Assessment**

| Topic | Aspect | Receptors | Justification / Control Measures |
|---|---|---|---|
| Physical Presence | Presence of CAN-ductors (prior to commencement of drilling operations) | Commercial Fishing | A Screening Direction and Consent to Locate will be in place prior to installation of CAN-ductors. There is an EU-wide ban on bottom trawling at depth >800m. Given the water depth at Tornado (ca. 1,060m) trawling activity is not expected and it is unlikely that snagging will occur. |
| | Presence of MODU and vessels | Marine Mammals, Seabirds | The physical presence of the DP MODU and vessels has the potential to disturb or displace seabirds. However, the temporary presence of a small number of vessels is unlikely to result in significant disturbance or displacement of seabirds from the area and alternative foraging habitat is available in the surrounding area. The risk of injury to marine mammals from collision with the MODU or a vessel is low as they will be travelling below the speed threshold where most lethal and serious injuries occur (Laist et al., 2001; Neilson et al., 2012). |
| | Artificial light emitted from the MODU and vessels | Seabirds | Metocean conditions will drive operations to target summer weather (when hours of darkness are shorter). Tornado is also remote from sensitive seabed breeding areas on the coast. |
| Physical Presence | Presence of wellheads during life of the field | Commercial Fisheries | Wellheads will be located within a 500 m safety zone and will be marked as hazards on Navigational charts and entered into the FishSafe system. There is an EU-wide ban on bottom trawling at depth >800m. Given the water depth at Tornado (ca. 1,060m) trawling activity is not expected and it is unlikely that snagging will occur. |
| Seabed Disturbance | Inspection, maintenance and repair of subsea infrastructure | Water Quality, Seabed Sediments, Benthic Communities, Fish, Marine Protected Areas | The subsea equipment is designed for the field life time such that no maintenance is required. Any disturbance to the seabed resulting from the repair of subsea infrastructure, if required, would be small scale and localised. |
| Underwater Noise Emissions | Use of propellers / DP thrusters on MODU and vessels including general noise and vibration of equipment whilst operating | Fish, Marine Mammals, Seabirds | Noise and vibration may cause localised, temporary changes in the distribution of sensitive marine fauna in the immediate vicinity of the MODU / vessel. However, the limited temporal scale of vessel use during the Tornado Development means any changes would be small-scale and would not result in population level effects (refer to Section 8 for further justification). Scheduling will minimise MODU / vessel offshore durations. Operational and maintenance |
| | Operation of equipment on MODU | | |

| Topic | Aspect | Receptors | Justification / Control Measures |
|---|---|---|---|
| | (e.g. rotating machinery) | | procedures will aim to optimise the efficiency of equipment. |
| Airborne Noise Emissions | Well Testing | Seabirds | Well testing operations will be of a short duration. Helicopter movements will be optimised by careful planning. Any impacts to seabirds from airborne noise emissions will therefore be short term, limited to temporary disturbance and/or displacement from foraging areas. Alternative foraging habitat is available to seabirds in the wider area. |
| | Use of helicopters | | |
| Atmospheric Emissions | Fuel burnt for power generation on the MODU, vessels and helicopters during drilling, installation, inspection, maintenance and decommissioning activities | Air Quality | The release of contaminants such as particulates, 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. However, given the open and dynamic metocean environment in the WoS region, it is anticipated that any pollutants released into the air from the temporary offshore operations associated with the Tornado Development will disperse rapidly under most conditions to levels approaching background within a few tens of metres of their source. As such, although there could be a short-term deterioration in local air quality, the magnitude of impact will be Negligible.<br>Onshore, emissions to air from the SGP (operated by TotalEnergies E&P UK Limited) are required to meet strict environmental standards in accordance with permits issued by SEPA under the Pollution Prevention and Control (Scotland) Regulations 2012. No significant impacts on air quality are therefore predicted from the incremental atmospheric emissions that will be produced at the SGP due to the Tornado Development coming online. |
| | Flaring of hydrocarbons during well test and clean-up operations | | |
| | Incremental atmospheric emissions at the SGP as a result of Tornado coming online | | |
| Marine Discharges | Routine discharges to sea (grey/blackwater, food waste) from MODU and vessels | Water Quality, Plankton, Fish, Seabirds, Marine Mammals | Waste water and food waste will be disposed of in accordance with the requirements of the MARPOL convention and UK regulations. |
| | Discharge of ballast water (potential for introduction of alien species) from MODU and vessels | | MODU and vessels will comply with the IMO Ballast Water Management Convention. |
| | Oily water discharges from deck drainage on MODU | | Deck drainage water will be sampled prior to discharge to ensure the oil in water concentration is <40 mg/l. An Oil Discharge Permit will also be in place. |
| Accidental Events | Subsea control system failure resulting in a minor release of hydraulic / control fluid to sea | Water Quality, Plankton, Fish & Shellfish, Seabirds, Marine | Any impacts on water quality and marine fauna will be localised and temporary. Appropriate maintenance, and pre-use checks on hydraulic equipment and ROVs will be undertaken. |

| Topic | Aspect | Receptors | Justification / Control Measures |
|---|---|---|---|
| Accidental Events | Small release of hydrocarbons / chemicals to sea (e.g. from drains, bunkering operations etc.) during drilling, installation and commissioning activities | Mammals, Marine Protected Areas | Any impacts on water quality and marine fauna from a small release of hydrocarbons / chemicals to sea will be localised and temporary. MODU / vessels are designed and will be managed and maintained to prevent spills. Crews will be adequately trained, and regular exercises will be held. Bunkering procedures will be put in place. All releases to sea of oil and offshore chemicals that occur during offshore oil and gas activities will be immediately reported to the regulator (via a PON1). |
| | Dropped objects resulting in unplanned disturbance to seabed | Oil and Gas, Commercial Fishing | Dropped objects may pose a risk to subsea infrastructure or present a snagging risk to trawlers. However, any dropped objects will be immediately reported to the regulator (via a PON2) 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. Subsea infrastructure will be designed for dropped objects as applicable. |
| Use of Resources | Resource use during drilling, installation, inspection, maintenance and decommissioning activities | Population and Human Health | The use of natural resources will be minimised, as far as practicable. Subsea structures will be designed with consideration to decommissioning. Decommissioned structures will be recovered and recycled onshore. |
| Natural Disasters | Some natural disasters could increase the risk of a major pollution event occurring at the Tornado field. For example, an earthquake could lead to damage to the subsea infrastructure and potential loss of well control | Water Quality, Seabed Sediments, Plankton, Benthic Communities, Fish and Shellfish, Seabirds, Marine Mammals, Marine Protected Areas, Shipping, Commercial Fishing, Tourism and Leisure, Air Quality, Climate, Population and Human Health | The probability of an earthquake of sufficient magnitude occurring on the UKCS impacting seabed infrastructure is extremely rare. Climate change effects, such as sea level change and extreme weather events, are not considered to significantly alter the range of effects considered. |

## 5.4 Significance Evaluation

This section describes the criteria used in this ES for determining the likely significance of effects on the environment to ensure the assessment process is as transparent and consistent as possible. Where uncertainty exists, this has been acknowledged in the assessment text in Sections 6 to 11.

### 5.4.1 Planned Events

For planned activities, the significance of environmental effects has been evaluated by considering the **sensitivity** of the receptor affected in combination with the **magnitude** of impact that is likely to arise, having regard to:

- The magnitude and spatial extent of the impact (geographical area and size of the population likely to be affected)
- The nature of the impact
- The transboundary nature of the impact
- The intensity and complexity of the impact
- The probability of the impact
- The expected onset, duration, frequency and reversibility of the impact
- The cumulation of the impact with the impact of other existing and / or approved projects and / or projects not yet approved, but that Ithaca is aware of
- The possibility of effectively reducing the impact

#### Sensitivity Criteria

Sensitivity is a function of the value of the receptor (a measure of its importance, rarity and worth), its capacity to accommodate change when a pressure is applied (resistance or tolerance), and its subsequent recoverability (resilience). The criteria presented in Table 5.4 has been used as a guide to determine the sensitivity of receptors.

**Table 5.4: Determining Sensitivity**

| | | Resistance and Resilience | | | |
|---|---|---|---|---|---|
| | | ***Very High*** | ***High*** | ***Medium*** | ***Low*** |
| **Value** | ***Low*** | Low | Low | Medium | Medium |
| | ***Medium*** | Low | Medium | Medium | High |
| | ***High*** | Low | Medium | High | Very High |
| | ***Very High*** | Medium | High | Very High | Very High |

| **Definitions:** | |
|---|---|
| **Resistance (Tolerance) and Resilience (Recovery)** | |
| Very High: | Highly adaptive and resilient to pressure. High recoverability in the short-term. |
| High: | Some tolerance / capacity to accommodate pressure.<br>High recoverability in the medium-term. |
| Medium: | Limited tolerance / capacity to accommodate pressure.<br>Recoverability is slow and/or costly. |
| Low: | Very limited or no tolerance / capacity to accommodate pressure.<br>Recovery is unlikely or not possible. |
| **Value** | |
| Very High: | Very high value and/or of international importance. |
| High: | High value and/or of national importance. |
| Medium: | Moderate value and/or of regional importance. |
| Low: | Low value and/or of local importance. |

### Magnitude of Impact Criteria

The magnitude of impact considers the characteristics of the change that is likely to arise (e.g. a function of the spatial extent, duration, reversibility and likelihood of occurrence of the impact) and can be adverse or positive. Where it is not possible to quantify impacts, a qualitative assessment has been carried out, based on best available scientific evidence and professional judgement. The criteria presented in Table 5.5 has been used as a guide to define the magnitude of impact.

**Table 5.5: Determining Magnitude of Impact** [1]

| Magnitude | Definition |
|---|---|
| Substantial | Widespread long-term change in baseline environmental conditions, with poor potential for recovery.<br>Impact may be one-off, intermittent or continuous and/or experienced over a very wide area (i.e. international in nature).<br>Impact will result in environmental quality standards or threshold criteria being routinely exceeded.<br>The Project's GHG emissions are not compatible with international climate agreements and emissions reduction pathways that aim to hold the global average temperature to well under 2°C. The Project is not aligned with UK sector-specific Net Zero strategies and reduction trajectories. |
| Major | Widespread medium to long-term, but reversible change in baseline environmental conditions.<br>Impact may be one-off, intermittent or continuous and/or experienced over a wide area (i.e. national in scale).<br>Impact is likely to result in exceedance of environmental quality standards or threshold criteria.<br>The Project's GHG emissions are not compatible with international climate agreements and emission reduction pathways that aim to hold the global average temperature to well under 2°C. The Project is only partially aligned with the requirements of UK sector-specific Net Zero strategies and reduction trajectories. |
| Moderate | Medium-term, temporary change in baseline environmental conditions or longer-term changes in areas surrounding the immediate footprint of the Project.<br>Impact may be one-off, intermittent or continuous and/or regional in scale (i.e. beyond the area surrounding the Project site to the wider region).<br>Impact could result in one-off exceedance of environmental quality standards or threshold criteria.<br>The Project's GHG emissions are consistent with international climate agreements and emission reduction pathways that aim to hold the global average temperature to well under 2°C. The Project is not fully aligned with the requirements of UK sector-specific Net Zero strategies and reduction trajectories. |
| Minor | Short-term, temporary change in baseline environmental conditions or localised longer-term changes within the footprint of the Project.<br>Impact may be one-off, intermittent and/or localised in scale.<br>Impact would not result in exceedance of environmental quality standards or threshold criteria.<br>The Project's GHG emissions are consistent with international climate agreements and emission reduction pathways that aim to hold the global average temperature to well under 2°C. The Project is aligned with the requirements of UK sector-specific Net Zero strategies and reduction trajectories. |

| Magnitude | Definition |
|---|---|
| Negligible | Immeasurable or undetectable changes (i.e. within the range of normal natural variation).<br>The Project's GHG emissions are consistent with international climate agreements and emissions reduction pathways, which aim to restrict global temperature to under 1.5°C above pre-industrial levels. The Project goes beyond the requirements of UK sector-specific Net Zero strategies and reduction trajectories. |

[1] Further detail on how the magnitude of impact of the proposed Tornado Development's GHG emissions on the global climate has been determined in this Assessment is provided in Section 9.6.2.

### Significance of Effects

The overall significance of an effect has been determined by cross referencing the sensitivity of the receptor with the magnitude of impact, using the matrix shown in Table 5.6.

**Table 5.6: Significance Evaluation Matrix (Planned Activities)**

| | | Magnitude of Impact | | | | |
|---|---|---|---|---|---|---|
| | | Negligible | Minor | Moderate | Major | Substantial |
| Receptor Sensitivity | Low | Negligible | Minor | Minor | Minor | Minor/ Moderate [1] |
| | Medium | Negligible | Minor | Minor | Moderate | Moderate/ Major [1] |
| | High | Negligible | Minor | Moderate | Major | Major |
| | Very High | Negligible | Minor/ Moderate [1] | Moderate/ Major [1] | Major | Major |

[1] The choice of significance level is based upon professional judgement and has been justified in the assessment text.

Effects classed as **Major** or **Moderate** are considered to be "significant" in EIA terms and therefore mitigation measures are required to be identified in order to prevent, reduce or offset adverse significant effects or enhance positive effects. The overall significance of the effect is then re-evaluated, taking the mitigation measures into consideration, to determine the residual effect utilising the methodology outlined above.

Effects classed as **Minor** are not considered to be significant and are usually controlled through good industry practice.

Effects classed as **Negligible** are also not considered to be significant.

## 5.4.2 Unplanned Events

For unplanned events, such as accidental hydrocarbon releases, significance has been determined using a risk assessment approach, where the likelihood (probability) of the unplanned event occurring is considered against the consequence (significance of effect) if the event was to occur.

The consequence (significance of effect) has been determined using the methodology for planned events as described in Section 5.3.1 above. The likelihood of an unplanned event occurring has been determined using the criteria presented in Table 5.7 as a guide.

**Table 5.7: Determining Likelihood of Occurrence**

| Likelihood | Definition |
|---|---|
| Extremely Rare | Event is extremely unlikely to occur during the Project, given good industry practice. Frequency of event: 1 x $10^{-4}$. |
| Rare | Event is very unlikely to occur during the Project, given good industry practice. Frequency of event: 1 x $10^{-3}$. |
| Unlikely | Event is unlikely to occur during the Project, given good industry practice. Frequency of event: 1 x $10^{-2}$. |
| Possible | Event could occur during the Project, based on industry data. Frequency of event: 1 x $10^{-1}$. |
| Likely | Event is likely to occur at least once during the Project. Frequency of event: > 1 |

A risk category (low, medium or high) has then been assigned to the unplanned event using the matrix shown in Table 5.8.

**Table 5.8: Significance Evaluation Matrix (Unplanned Events)**

| | | Consequence (Significance of Effect) [1] | | | |
|---|---|---|---|---|---|
| | | Negligible | Minor | Moderate | Major |
| Likelihood of Event | Extremely Rare | LOW | LOW | MEDIUM | MEDIUM |
| | Rare | LOW | LOW | MEDIUM | MEDIUM |
| | Unlikely | LOW | LOW | MEDIUM | HIGH |
| | Possible | LOW | MEDIUM | MEDIUM | HIGH |
| | Likely | LOW | MEDIUM | HIGH | HIGH |

[1] The consequence (significance of effect) has been determined using the methodology for planned events as described in Section 5.3.1.

**High** risk events are considered to be "significant" in EIA terms and are unacceptable.

**Medium** risk events are also considered to be "significant" in EIA terms, unless it can be demonstrated that the risk has been reduced to as low as reasonably practicable (ALARP) through mitigation, control measures and good industry practice.

**Low** risk events are not considered to be "significant" in EIA terms, but should still be controlled through good industry practice.

# 6 Physical Presence

## 6.1 Introduction

The temporary presence of the MODU and vessels and the long term presence of the Tornado subsea infrastructure once installed have the potential to obstruct or exclude other sea users. This section therefore assesses the potentially significant impacts on other sea users, namely shipping and commercial fisheries, which could arise from:

- The presence of the DP MODU and vessels during drilling, installation, inspection and maintenance and decommissioning activities;
- Ongoing presence of subsea infrastructure and protection material.

## 6.2 Assessment of Impacts

### 6.2.1 Shipping

Shipping densities within the WoS region are low compared to the North Sea. The majority of vessels in the vicinity of the Tornado Development area are likely to be supply and support vessels associated with oil and gas activities (refer to Section 4.4.2).

The Tornado Development has the potential to interact with shipping through the temporary presence of the MODU and vessels resulting in increased vessel traffic and collision risk. Shipping may also be excluded from areas of sea, potentially resulting in increased steaming times.

The greatest increase in vessel presence in the Development area will be during drilling operations, installation of subsea infrastructure and, following cessation of production, during decommissioning operations. However, any discernible increase in vessel presence in the area will be temporary in nature.

A 500 m safety zone, patrolled by an ERRV equipped with an AIS and/or ARPA, will be in place around the MODU for the duration of the proposed drilling operations (up to 85 days per well), which will minimise the potential for collision risk between the MODU and third-party vessels. Notwithstanding this, a Vessel Traffic Survey will be undertaken by Ithaca to inform the Consent to Locate (CtL) permit application, required under Part 4a of the Energy Act 2008 to site the MODU at Tornado. If necessary, a Collision Risk Assessment may also be undertaken.

During the installation phase of the Tornado Development, a number of DP vessels will be on location for a period of around six months, with metocean conditions likely to drive operations to be conducted in the summer weather window. In the year prior to this, a CSV will be on location at the Tornado drill centre location for around 5 days to install the CAN-ductors and a ROVSV may be operating along the proposed pipeline route for around 40 days conducting boulder clearance work. The main navigational hazard during the installation phase will be associated with the installation of the pipelines and control umbilical. However, vessels will be moving along the pipeline route, and therefore, will not be in any one area for any significant length of time. Notifications to other sea users will be issued via Notices to Mariners and Kingfisher Bulletin to communicate the location of the works. Following installation, the pipelines and control umbilical will be subject to routine inspections and maintenance, although vessel requirements for this will be minimal.

During decommissioning, it is anticipated that DP vessels will be used to either fully or partially remove the subsea infrastructure, with the wells plugged and abandoned. Any potential impacts to shipping as a result of decommissioning operations will therefore be similar to those described above for drilling and installation operations.

The sensitivity of shipping to displacement as result of the Tornado Development is therefore considered to be **Low**. The receptor is of regional importance, classed as Medium value, but resistance and resilience is Very High as there is ample sea room for shipping to re-route or avoid the Tornado Development location, as necessary, particularly as the density of traffic transiting through the area is low. The magnitude of impact is predicted to be **Minor** as any impact will be localised and temporary in nature. Effects on shipping from the physical presence of the DP MODU and vessels during drilling,

installation, inspection and maintenance and decommissioning activities, are therefore assessed as **Minor** and not significant. Mitigation measures are proposed in Section 6.3 to ensure that good industry practice is followed.

### 6.2.2 Commercial Fishing

Fishing activity in the Tornado Development area is low, with effort concentrated in the shallower water at the Tormore end of the pipeline route, noting that a 500 m safety exclusion zone exists around Tormore. The main fishing method (gear type) occurring in the wider area is trawling, specifically demersal (bottom) otter trawling, with hake and halibut (Greenland) the greatest components of the fishery.

As discussed in Section 4.4.1, there is a ban on the use of all bottom trawling below 800 m depth in UK waters and under The Offshore Fishing (Prohibition of Fishing Methods) (Scotland) Order 2025 mobile demersal fishing gear is currently prohibited within the northern zone of the Faroe-Shetland Sponge Belt NCMPA. The proposed Tornado drill centre and the majority of the proposed pipeline route (ca. 68 km) are located in water depths greater than 800 m. In addition, ca. 18 km of the proposed pipeline route crosses through the northern zone of the NCMPA.

Given the above, no specific overtrawlable protection will be installed around the Tornado wellheads or the other structures at the Tornado field as the likelihood of fishing interaction is sufficiently low. However, for the purposes of this ES, it is assumed that as a worst case overtrawlable protection will be required at depths less than 800 m, i.e. not taking credit for The Offshore Fishing (Prohibition of Fishing Methods) (Scotland) Order 2025 that came into effect on the 16th October 2025 (refer to Section 3.4). The assessment of pipeline protection requirements is still ongoing.

During the proposed drilling operations, the presence of the MODU and support vessels has the potential to interact with commercial fishing vessels through displacement. As described above, while the MODU is on location, a 500 m safety exclusion zone will be in place, which will be patrolled by an ERRV. Although the 500 m safety zone around the MODU will be temporary, Ithaca will apply for a 500 m safety zone to be in place around the subsea infrastructure at the Tornado drill centre post installation. Fishing vessels will therefore be excluded from an area of 0.8 $km^2$ throughout the life of the field. However, as demersal trawling is prohibited within water depths greater than 800 m, this exclusion is only relevant to vessels operating other types of gear (e.g. Scottish seines). The risk of snagging at the Tornado drill centre location is very low as there is no demersal trawling over the area, therefore the wellheads and subsea structures do not require protection from fishing interaction.

The presence of installation vessels for the pipelines and control umbilical may also temporarily displace fishing vessels. This would be in the immediate vicinity of the installation vessels that will be travelling along the proposed pipeline route. Therefore, the nature of displacement will be transient and highly localised.

Once installed the pipelines and control umbilical may pose a snagging risk to fishing gear, such as nets. Fishing gear can become trapped on subsea infrastructure, resulting in loss of fishing gear or potentially posing a threat to the safety of the fishing vessel and crew, or damage the asset. The production pipeline will be surface laid and will remain exposed on the seabed as it will be designed to resist fishing interaction loads. The requirement for protective measures for the MEG pipeline and control umbilical will depend on the findings of ongoing studies assessing the intensity of fishing activity and the potential for damage. As noted above, for the purposes of this ES, it is assumed that the MEG pipeline and control umbilical may require protection from fishing interaction in water depths less than 800 m. The MEG pipeline and control umbilical will be either trenched and backfilled or surface laid with overtrawlable rock protection laid on top of the lines (refer to Section 3.4.4 for further details). If the MEG pipeline is piggybacked onto the surface laid production pipeline, both lines would require protection in water depths less than 800 m, which would be achieved by a single rock berm. Seabed topography could also necessitate the installation of pre-lay rock along some sections of the route due to the presence of seabed features such as boulders, depressions and mounds.

During pipeline installation, the risk of snagging will be greatest after pipelay, prior to installation protection. To minimise this risk, two guard vessels will be used to patrol the length of the lines in water

depths less than 800 m, a length of approximately 16 km at the Tormore end of the route, whilst installation activities are ongoing.

Prior to pipelay activities commencing, there may also be a requirement to remove boulders (>0.5 m) from the lay corridors for each line and relocate these to the edges of the installation corridor. In the event this is required, the as-left position of any relocated boulders would be recorded.

In water depths less than 800 m, if the pipelines and umbilical are trenched using a pipeline plough, trenching berms could be formed by cohesive clay sediments, which are most likely to generate resistance to fishing gear (Rouse et al., 2020). The sediments along the proposed pipeline route are dominated by either sand or gravel, with the fines content generally low (refer to Section 4.2.3). Sandy sediments are expected to provide little resistance to demersal towed gear which is likely to be able to pull through the sediment and wash out. Notwithstanding this, Ithaca will liaise with the Scottish Fishermen's Federation (SFF) following the results of post lay surveys to ensure that if mud berms are present, they do not represent a safety risk for fishermen.

Towards the Tormore end of the pipeline route, two cables (Farice and Shefa-2 Seg 7) and one pipeline (Rosebank) cross the installation corridor. In order to reduce snagging risks, these crossings will be designed to be overtrawable, as described in Section 3.4.4.

Once the lines have been installed, there is the potential for free spans to arise, presenting a snagging risk to demersal fishing gear. A final survey will be undertaken of the infrastructure prior to the installation vessels leaving the field to confirm location and as-built status. During the life of the field, external inspection of the lines, will take place through a combination of ROV/AUV and towed sonar, at a frequency determined by ongoing risk assessment. Any free spans recorded that present a potential hazard to legal fishing activities will be suitably rectified.

At the tie-in to Tormore, the DP vessels used to install the Tornado subsea structures will be operating within an existing 500 m safety exclusion zone. Therefore, there will be no additional loss of access to fishing grounds as a result of the Tornado Development. The existing safety zone also minimises any potential snagging risk, however, the subsea structures and protection material will be designed to be overtrawlable.

Given the water depths over the Tornado Development area, the MODU and vessels used during drilling, installation, inspection and maintenance and decommissioning activities will use DP to maintain position, and therefore, there will be no anchoring required for these vessels, with no potential for anchor mounds to present a snagging risk.

Following cessation of production, it is anticipated that DP vessels will be used to either fully or partially remove the Tornado subsea infrastructure, with the wells plugged and abandoned. Any potential impacts to commercial fishing as a result of decommissioning activities will therefore be similar to those described above for drilling and installation operations. Any infrastructure or protection material (e.g. rock) left in situ, will be surveyed for potential snagging risks and mitigated accordingly.

Given the above, the sensitivity of commercial fishing to displacement is considered to be **Low.** Fishing activity is low throughout the Tornado Development area, with bottom trawling prohibited in water depths greater than 800m and the use of mobile demersal fishing gear is currently prohibited within the northern section of the Faroe-Shetland Sponge Belt NCMPA (refer to Section 4.4.1). The receptor is of regional importance, classed as Medium value, but resistance and resilience is Very High as fishing vessels are able to switch to alternative fishing grounds. The magnitude of impact is predicted to be **Minor**, restricted to the Tornado Development area, with the risk of snagging considered to be low. In the long term, fishing vessels will only be prevented from entering an area of 0.8 $km^2$ at the Tornado drill centre location. Effects on commercial fishing from physical presence are therefore **Minor** and not significant. Mitigation measures are proposed in Section 6.3 to ensure that good industry practice is followed.

## 6.3 Mitigation Measures

Impacts to other sea users from the physical presence of the MODU and vessels and the long term presence of the Tornado subsea infrastructure will be minimised by the implementation of the following mitigation measures:

- 500 m safety exclusion zone will be designated around the MODU and a dedicated ERRV, equipped with AIS and/or ARPA will be present during the drilling operations to monitor movements of other vessels in the area and prevent them entering the exclusion zone.
- A Vessel Traffic Survey and, if necessary, a Collision Risk Assessment, will be prepared to support the CtL permit applications required to site the MODU and subsea infrastructure at the Tornado Development location and all vessels will comply with the International Regulations for Preventing Collisions at Sea (COLREG).
- Information on the location of the MODU, 500m safety zone, subsea infrastructure and vessel operations will be communicated to other sea users via the United Kingdom Hydrographic Office (UKHO), MCA, FishSAFE, Kingfisher Information Services, Notices to Mariners and Radio Navigation Warnings.
- Ithaca will continue to consult with SFF during the detailed design phase and planning process for the subsea infrastructure installation activities. A Fisheries Liaison Officer (FLO) will be appointed to maintain good communication with local fisheries and co-ordinate activities, particularly during installation of the pipelines and umbilical.
- During installation operations, the number of vessels and length of time they are required on site will be reduced as far as practicable through careful planning.
- Where water depths are less than 800 m, subject to fishing intensity and damage tolerability studies, the MEG pipeline and control umbilical may require protection from fishing interaction. In this instance, up to two guard vessels will be on location for the period between the MEG pipeline and umbilical being laid on the surface of the seabed and the lines being trenched and backfilled or protected by rock. The rock berm profile will be overtrawlable.
- Where boulders (>0.5 m) are required to be removed from the pipeline lay corridors, the as-left position of any relocated boulders will be recorded and reported via Kingfisher.
- Following pipeline trenching operations, Ithaca will liaise with the SFF to review any safety risks for the fishermen from mud berms being left behind and discuss potential mitigation.
- A 500 m safety zone will be in place around the subsea infrastructure at the Tornado drill centre location.
- At the Tormore tie-in location, the subsea structures and protection material will be designed to be overtrawlable.
- During the life of the field, external inspection of the pipelines and control umbilical will take place at a frequency determined by ongoing risk assessment. Any free spans recorded that present a potential hazard to legal fishing activity will be suitably rectified.

## 6.4 Residual Effects

In summary, no significant residual effects on other sea users are predicted as a result of the physical presence of the presence of the DP MODU and vessels during drilling, installation, inspection and maintenance and decommissioning activities or the long-term presence of the Tornado subsea infrastructure and associated protection material. There is adequate sea room for shipping to re-route or avoid the Tornado location, as necessary, particularly given the low density of vessel traffic in the area. Fishing vessels may be temporarily displaced from the Tornado Development area during the drilling and installation phases, with an area of 0.8 $km^2$ at the Tornado drill centre location lost for the life of the field development. This is considered to be a very small area in comparison to the alternative fishing grounds available in the wider WoS area. In addition, fishing activity in the Tornado Development area is low, with bottom trawling prohibited in water depths greater than 800 m and the use of mobile demersal fishing gear is currently prohibited within the northern section of the Faroe-Shetland Sponge Belt NCMPA. As such, the risk of snagging is low, with overtrawlable protection only utilised as part of the Development at depths less than 800 m, along approximately 20% of the length of the entire pipeline route.

## 6.5 Transboundary Impacts

The Tornado field is located approximately 6.5 km to the south east of the UK/Faroe median line. Although fishing activity in the Tornado Development area is low, foreign vessels are known to fish in the wider region (refer to Section 4.4.1). Information on the location of the MODU, 500m safety zone, subsea infrastructure and vessel operations will be communicated to international fishing organisations, with known vessels working in the area. The area which will be lost to fisheries for the life of the Tornado field (0.8 $km^2$ at the drill centre location) represents a small fraction of the total sea available. Furthermore, non-UK fishing vessels will be made aware of the Tornado Development through adequate charting of infrastructure. On this basis it is considered that there will be no significant transboundary impacts on other sea users.

## 6.6 Cumulative Impacts

The closest producing fields to the proposed Tornado drill centre location are the Alligin, Loyal and Schiehallion oil fields (operated by BP), developed through the Glen Lyon FPSO, which is located approximately 30 km southeast of the Tornado drill centre. The Clair Ridge and Clair Phase One platforms (operated by BP), are located approximately 38 km southeast of the proposed Tornado pipeline route at the Tormore manifold end (refer to Section 4.4.3). In addition, the proposed Tornado drill centre is located approximately 32 km from the proposed Cambo development and 63 km from the proposed Rosebank development. Note, there are no existing or proposed renewable energy projects in the vicinity of the Tornado Development area.

The other oil and gas developments in the area will utilise vessels which have the potential to act cumulatively in increasing vessel collision risk. However, as the proposed Tornado Development area is located within the open sea and increased vessel traffic will be temporary, limited to the drilling, installation, inspection and maintenance and decommissioning activities, it should not act in combination with any other development to increase collision risk.

Given the low levels of fishing effort recorded in the Tornado Development area and the temporary nature of the drilling, installation, inspection and maintenance and decommissioning activities, it is considered that there will be no significant cumulative impact on commercial fishing. Long term loss of access is restricted to an area totalling 0.8 $km^2$ at the Tornado drill centre location for the life of the field development. This is very small in comparison to the fishing grounds available in the wider WoS area, particularly as bottom trawling is prohibited in water depths greater than 800 m. In addition, in waters depths less than 800 m, the Tornado infrastructure and protection material will be designed to be overtrawlable. A significant cumulative increase in snagging risk with other oil and gas development in the area is therefore not anticipated.

# 7 Seabed Disturbance

## 7.1 Introduction

This section discusses the potentially significant environmental impacts on seabed sediments, seabed communities and fish arising from:

- Potential installation of CAN-ductors, wellheads and parking-CANS for Xmas tree storage;
- Discharge of Water-Based Mud (WBM) cuttings and excess cement to the seabed;
- Pipeline pre-lay boulder clearance;
- Production pipeline laydown on the seabed;
- Trenching and burial / protection of the Monoethylene Glycol (MEG) pipeline and control umbilical in water depths <800m;
- Installation of tie-in spools, jumpers and electrical flying leads at Tornado and Tormore;
- Installation of Pipeline End Manifolds (PLEMs), Umbilical End Terminal (UET) structures and Flowline End Terminal (FLET) structures and associated temporary initiation anchors and wet storing of subsea equipment / workbaskets;
- Use of Glass Fibre Reinforced Polymer (GRP) structures and rock protection at Tormore;
- Pipeline and cable crossing construction / pipeline corridor preparation (rock carpet) / structure foundation preparation (rock carpet);
- Deposit of additional rock on the pipelines to rectify free spans and mitigate against interaction with fishing gear.

## 7.2 Quantification of Impact Area

### 7.2.1 Discharge of Drill Cuttings and Cement

#### WBM Cuttings

For the purpose of the ES, conventional drilling with WBM has been assumed for the Tornado wells (refer to Section 2.3.5). As described in Section 3.3.5, the two top-hole sections (42" x 36" and 26") for the three Tornado wells will be drilled riserless, with seawater and frequent bentonite “sweeps” passed down the well to clean out the hole. Cuttings from these top-hole sections will be discharged directly from the wellbore at the seabed. Cuttings from the top-hole sections will be discharged directly from the wellbore at the seabed and will form a pile in the immediate vicinity of the Tornado drill centre locations. An environmental riser will be installed following the drilling of the 26" section, for the deeper 17½, 12¼" and 8½" (underreamed to 12¼") sections. The WBM and cuttings returned to the Mobile Offshore Drilling Unit (MODU) from the deeper well sections will pass through shale shakers, with the separated cuttings passed through a cleaning system and discharged to sea from the MODU just below the sea surface. In case unexpected issues are expected when drilling, Ithaca has also added a contingency re-spud of the tophole section and contingency 26”, 17½, 12¼" and 8½" (underreamed to 12¼") sidetracks to the longest well profile (W3) to represent a worst case scenario in terms of the total amount of WBM cuttings that might be discharged.

The overall combined amount of WBM cuttings discharged in the event all three wells are drilled is 5,274,310 kilograms (kg) (5,275 tonnes), which reduces to 3,143,520 kg (3,144 tonnes) if all wells are drilled with CAN-ductors.

In the event Low Toxicity Oil-Based Mud (LTOBM) is used to drill the well, due to the remote location of Tornado and harsh environment, the LTOBM cuttings will be returned to the MODU where they will be processed by a thermal cuttings treatment unit before being discharged. This minimises the requirement for drilling waste to be shipped to shore for treatment and disposal.

Simulations of these drilling releases in relation to the Tornado site have been completed using the three-dimensional dispersion model (MUDMAP) by RPS on behalf of Ithaca. Ten years (2010 to 2019 (inclusive)) of Hybrid Coordinate Ocean Model (HYCOM) current data and HYDROMAP tidal data was generated. The current data is suitably long enough to be indicative of interannual variability in ocean currents. As the spud date may vary, 50 simulations were modelled for each release location with varying start dates to assess a range of current conditions. Results from these simulations were overlaid to identify the maximum thicknesses on the seabed in each grid cell.

As a conservative measure, a thickness of 0.1 millimetres (mm) was employed as the minimum reporting threshold (or above the natural levels) for this study. Thresholds of 1-10 mm and above 10 mm were then used to define low and high exposure levels, respectively. The thresholds are supported by studies from Trannum et al. (2009) which found a significant decrease in species count, abundance of individuals, and biomass of marine animals with deposited cuttings 3-24 mm. Furthermore, a study by Kjeilen-Eilertsen et al. (2004) reports that depositional thicknesses greater than 9.6 mm are likely to cause smothering impacts on benthic ecosystems, including corals. It is also worth noting that a study by Smit et al. (2008) established that a thickness threshold of greater than 6.5 mm would be needed before potential harm to benthic macrofauna occur.

Figure 7.1 presents the maximum thicknesses in each grid cell from all 150 simulations to define the potential exposure from the discharge of WBM cuttings and muds during the modelled operational period. The drill cuttings and muds predominantly settled along the south-west to north-east, coinciding with the dominant current directions at the release location.

The maximum bottom deposition thicknesses of >2 metres (m) for all release locations were predicted to occur within the immediate vicinity of the near-bottom discharges (within 20 m). Note, this predicted maximum thickness is a conservative reported thickness as slumping of the localised deposited material immediately adjacent to the discharge is not accounted for (RPS, 2025a).

Table 7.1 summarises the combined total area of coverage and the maximum distances for each thickness threshold from all three release locations.

Based on the assessment of all 150 simulations, the maximum distances from the release locations to the edge of the minimum reporting threshold of 0.1 mm, and the low (≥1 mm) and high (≥10 mm) exposure thresholds is predicted to be 2.6 kilometres (km), 1.5 km, and 0.2 km respectively. Additionally, the total area of coverage for the minimum reporting threshold for bottom deposition of 0.1 mm, the low and high exposure thresholds are predicted to be 4.1 kilometres squared ($km^2$), 1.9 $km^2$ and 0.06 $km^2$, respectively (RPS, 2025a).

**Table 7.1: WBM Scenario - Combined predicted areas of coverage and maximum distances from all three release locations, N1, W1 and W3, to each reporting threshold based on the results of all 150 simulations. (RPS, 2025a)**

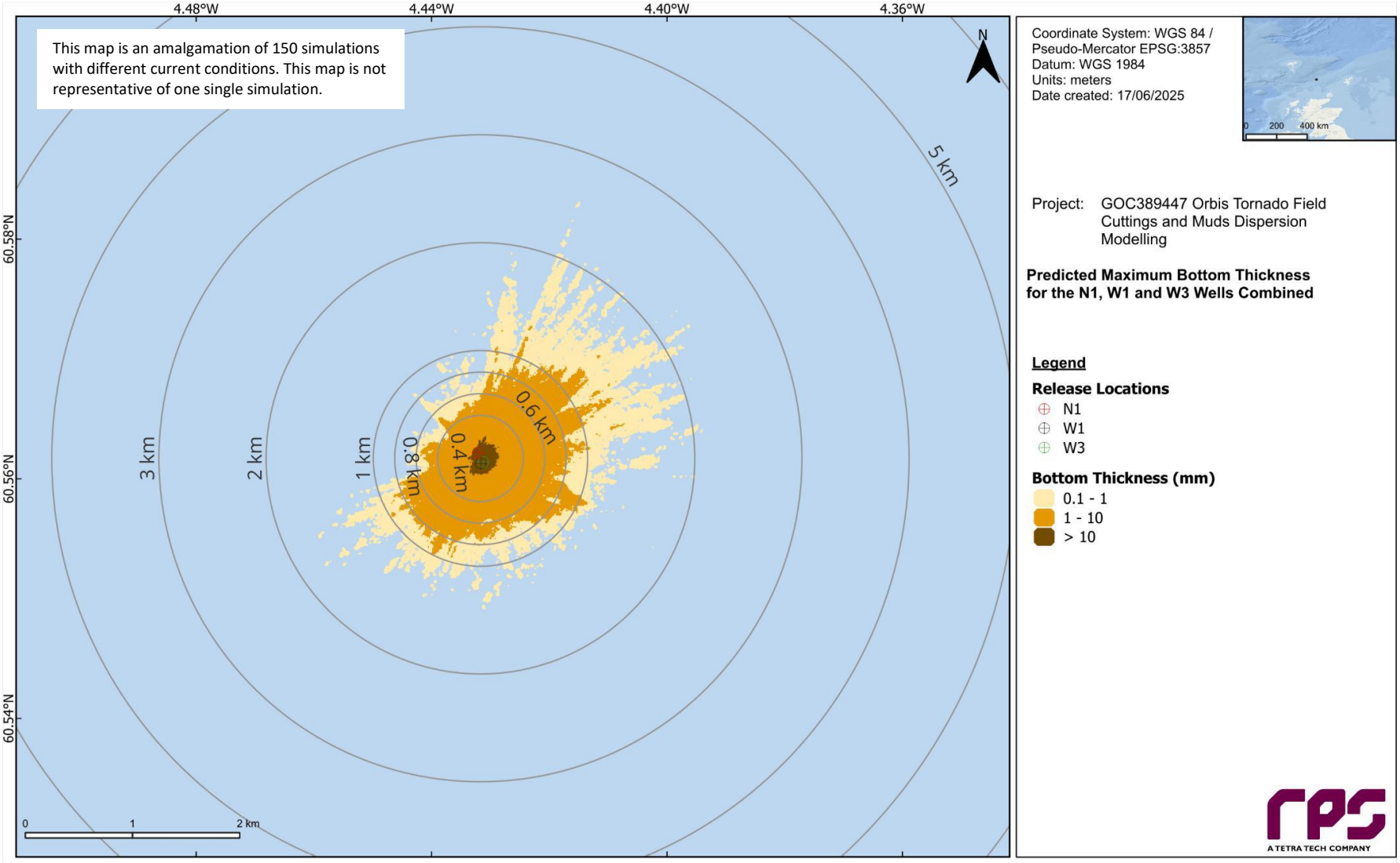
| Reporting Criteria | Total area of coverage ($km^2$) | Maximum distance (km) from the release locations |
|---|---|---|
| ≥0.1 mm (minimum threshold) | 4.1 | 2.6 |
| ≥1 mm (low threshold) | 1.9 | 1.5 |
| ≥10 mm (high exposure) | 0.06 | 0.2 |

As noted in Section 2.5.3, preliminary drill cuttings and muds dispersion modelling was also run for the LTOBM scenario. The LTOBM scenario resulted in similar sediment thickness over a smaller area than the WBM scenario (sediments at a thickness exceeding the minimum reporting threshold (≥0.1 mm) out to a distance of 2.6 km). Therefore, a summary of the combined predicted areas of coverage and maximum distances resulting from all three release locations, N1, W1 and W3, has been provided in Table 7.2, for comparison. However, overall the modelling results indicate that the total area of coverage and maximum distance from the release location is greatest in the WBM scenario.

**Table 7.2: LTOBM Scenario - Combined predicted areas of coverage and maximum distances from all three release locations, N1, W1 and W3, to each reporting threshold based on the results of all 150 simulations. (RPS, 2025c)**

| Reporting Criteria | Total area of coverage ($km^2$) | Maximum distance (km) from the release locations |
|---|---|---|
| ≥0.1 mm (minimum threshold) | 3.1 | 2.6 |
| ≥1 mm (low threshold) | 1.4 | 1.3 |
| ≥10 mm (high exposure) | 0.06 | 0.2 |

**Figure 7.1: Combined predicted maximum bottom thicknesses from the discharge of WBM drill cuttings and muds at all three release locations, N1, W1 and W3. Results are based on 150 simulations (RPS, 2025a)**



#### Cement

The pumping of cement slurry onto the seabed will result in the creation of a cement patio surrounding each of the wells. Assuming uniform spread radially from the centre of the well, it is estimated that the radial spread of cement will be within 14.2 m of each well where the conductor is cemented into the top hole section of the well versus within 10.3 m of each well if a CAN-ductor is used, noting that the overspill from the CAN-ductor is ejected from one point onto the seabed so will not circle the CAN-ductor. Therefore, the worst case total seabed footprint per well could be up to 633 metres squared ($m^2$) (0.0006 $km^2$) (refer to Section 3.3.5 for further detail). The cement patios will be formed within the footprint of the area where cuttings will be deposited.

### 7.2.2 Installation of the Pipelines and Umbilical

Tornado production fluids will be exported via a new 16-inch circa (ca.) 86 km pipeline to the existing Tormore FLET structure for entry into the L-T pipeline system. A dedicated 4-inch ca. 86 km MEG pipeline will be extended from the Tormore MEG FLET to Tornado. The electro-hydraulic controls for Tornado will be provided by extending the existing L-T system from the Tormore manifold to Tornado by means of a dedicated ca. 86 km steel tube control umbilical. Given the water depth, all installation vessels will use DP to maintain position, therefore there will be no anchoring required for these vessels.

For the purposes of this ES, it is assumed that the pipelines and umbilical are to be designed for fishing interaction in water depths shallower than 800 m as the worst-case scenario. The pipelines and umbilical route can therefore be divided into two distinct sections as described in Table 7.3, each with a different installation method (distances are rounded to the nearest kilometre for clarity) (refer to Section 3.4.4).

**Table 7.3: Sections of the Pipeline / Umbilical Route from Tornado to Tormore**

| Section of Route | Kilometre Point (from Tornado) | Main Installation Method |
|---|---|---|
| 1 | KP0 - KP 68 | Surface lay of production pipeline, MEG pipeline [1] and umbilical, with no post-lay protection (water depth is >800 m)<br>Potential for numerous boulders requiring boulder removal<br>Rock stabilisation may be required to correct freespans |
| 2 | KP68 - KP86 [2] | Production pipeline surface laid with no post-lay protection<br>Protection required for MEG pipeline [1] and umbilical (water depth is <800m)<br>Potential for numerous boulders requiring boulder removal<br>Trenching and/or post lay rock installation for the MEG pipeline and umbilical<br>Rock stabilisation may be required to correct freespans |

[1] Alternative option exists to piggyback the MEG pipeline onto production pipeline, which may require rock protection of the production and piggy-back lines in water depths less than 800 m water (refer to Section 2.4.2)
[2] The entirety of Section 2 of the pipelines and umbilicals is located within the Faroe-Shetland Sponge Belt NCMPA

#### Worst Case Total Seabed Footprint

Table 7.4 provides a description of the worst-case estimate of potential permanent seabed impact (i.e. the introduction of a permanent hard substrate footprint on the seabed) from installation of the production pipeline, MEG pipeline and control umbilical, based on the assumptions described in Section 3.4.4. Table 7.5 provides a description of the worst-case estimate of temporary disturbance to the seabed from installation of the production pipeline, MEG pipeline and control umbilical, based on the assumptions described in Section 3.4.4. As a very conservative worst case, the totals from both of these tables will be assessed. However, the use of some options (e.g. trenching) will remove the requirement for other options (e.g. use of a pre-lay rock carpet). Therefore, the assessment of both values, while necessary to take into account all options, is a highly conservative approach.

The total worst case permanent seabed disturbance area from pipeline and umbilical installation and protection is equal to ca. 484,648 $m^2$ (0.485 $km^2$). The total worst case temporary seabed disturbance area from pipeline and umbilical installation and protection is equal to ca. 6,327,000 $m^2$ (6.33 $km^2$).

**Table 7.4: Estimate (Worst Case) of the Area of Seabed to be Directly (Permanently) Impacted by the Production Pipeline, MEG Pipeline and Control Umbilical**

| Element | Length of Pipeline Corridor | Parameters and Assumptions for Worst Case Scenario | Worst Case Footprint [1, 2] | |
|---|---|---|---|---|
| | | | ($m^2$) | ($km^2$) |
| Section 1<br>KP0 –ca. KP68<br>Water depth<br>> 800m | 68 km | Footprint for the production pipeline, MEG pipeline and umbilical is based upon the products being surface laid on the seabed with pre lay rock carpets installed. | 134,896 [1] | 0.135 [1] |
| Section 2<br>ca. KP68 – KP86<br>Water depth<br>< 800m | 18 km | Footprint for production pipeline and MEG pipeline is based upon the two products being installed together via piggyback system and both products protected by a single post lay rock berm. Footprint for umbilical is based upon the product installed on its own and protected by its own post lay rock berm. | 341,280 [3] | 0.341 [3] |
| Pipeline / Cable crossings | - | Footprint for production pipeline and MEG pipeline is based upon the two products being installed together via piggyback system, laid onto a preinstalled rock carpet, and then protected by a post lay rock berm. Footprint for umbilical is based upon the product being installed on its own onto a preinstalled rock carpet and then protected by a post lay rock berm. | 8,472 | 0.008 |
| | | **Total:** | **484,648** | **0.485** |

[1] Footprints of products individually surface laid on the seabed in Section 1 is 42,160 $m^2$. Footprint of the pre lay rock carpets in Section one is 92,736 $m^2$ (including 20% contingency). Total footprint is 134,896 $m^2$.
[2] Includes 20% contingency added to the sub-total of the seabed footprint resulting from rock placement due to the pre-FEED maturity of the engineering.
[3] For footprint dimensions of post lay rock in Section two refer to Section 3.3.4.

**Table 7.5: Estimate (Worst Case) of the Area of Seabed to be Temporarily Impacted by the Production Pipeline, MEG Pipeline and Control Umbilical**

| Element | Length of Pipeline Corridor | Parameters and Assumptions for Worst Case Scenario | Worst Case Footprint | |
|---|---|---|---|---|
| | | | ($m^2$) | ($km^2$) |
| Section 1 KP 0 – ca. KP 68 Water depth > 800m | 68 km | The maximum corridor of temporary disturbance in section one of the route is 65 m. Footprint for the Production Pipeline, MEG pipeline and umbilical is based upon the products being surface laid on the seabed within a 60 m installation corridor. An additional 5 m corridor is required adjacent to the installation corridor due to the potential for bolder relocation. Includes Temporary laydown areas. [1] [2] | 4,518,500 | 4.52 |
| Section 2 ca. KP 68 – KP 86 Water depth < 800m | 18 km | The maximum corridor of temporary disturbance in section 2 of the route is 50 m. This is based upon a +/- 10m installation corridor for each product and a trencher with a width of 10 m. A 5 m corridor for boulder relocation from the lay routes, adjacent to each individual installation corridors (3 x 5m) has been included. Includes Temporary laydown areas. [1] [2] | 1,808,500 | 1.81 |
| | | **Total:** | **6,327,000** | **6.33** |

[1] Includes temporary laydown area of 62,500 $m^2$ required for UETs – based upon 10 off areas 250 m x 250 m
[2] Includes temporary laydown area of 36,000 $m^2$ required for initiation anchors – based upon 1 off initiation wire used for both MEG and Production pipelines. Initiation wire length of 1,800 m and a 20m wide corridor.

### 7.2.3 Installation of Subsea Infrastructure at Tornado

The total seabed footprint caused by the installation of seabed infrastructure at the proposed Tornado drill centre is summarised in Table 7.6. In total, the loss of available seabed associated with the installation of these structures is estimated to be 5648.5 $m^2$ (0.0057 $km^2$) (refer to Section 3.4.2).

**Table 7.6: Estimated Area of Seabed Occupied by Subsea Infrastructure at Tornado Drill Centre**

| Subsea Item | Number | Assumptions | Quantity of Rock to be Deposited (te) | Total Seabed Footprint | |
|---|---|---|---|---|---|
| | | | | ($m^2$) | $km^2$ |
| CAN-ductor / wellhead [1] | 3 | 6 m (diameter) | - | 84.9 | 0.00008 |
| CAN-parking unit | 2 | 6 m (diameter) | - | 56.6 | 0.00006 |
| Tornado manifold | 1 | 21 m (L) x 15 m (W) | - | 315 | 0.0003 |
| FLET (and prelay rock carpet) | 2 | 53 m (L) x 46 m (W) [2] | 13,516 | 4,876 | 0.0049 |
| UET | 1 | 6 m (L) x 6 m (W) | - | 36 | 0.00004 |

| Subsea Item | Number | Assumptions | Quantity of Rock to be Deposited (te) | Total Seabed Footprint | |
|---|---|---|---|---|---|
| | | | | ($m^2$) | $km^2$ |
| Tie-in Spools and Flying Leads | 6 | Lines will be surface laid with no requirement for protection. Maximum combined line length is 560 m with width of lay corridor assumed to be 0.5 m | - | 280 | 0.0003 |
| **Total Seabed Footprint at Tornado Drill Centre** | | | **13,516** | **5,648.5** | **0.0056** |

[1] Xmas trees will be located on top of the CAN-ductors.
[2] Dimensions of the prelay rock carpet, which is installed for each FLET.

### 7.2.4 Installation of Subsea Infrastructure at Tormore

The total seabed footprint caused by the installation of seabed infrastructure at the Tormore manifold is summarised in Table 7.7. In total, the loss of available seabed associated with the installation of these structures is estimated to be 36,962 $m^2$ (0.037 $km^2$) (refer to Section 3.4.3).

**Table 7.7: Estimated Area of Seabed Occupied by Subsea Infrastructure Installation at Tormore**

| Subsea Item | Number | Assumptions | Quantity of Rock to be Deposited (te) | Total Seabed Footprint | |
|---|---|---|---|---|---|
| | | | | ($m^2$) | $km^2$ |
| Tornado PLEM | 1 | 30 m (L) x 20 m (W) | - | 600 | 0.00060 |
| UET | 1 | 6 m (L) x 6 m (W) | - | 36 | 0.00004 |
| FLET (and prelay rock carpet) | 2 | 53 m (L) x 46 m (W) [1] | 13,516 | 4,876 | 0.0049 |
| Tie-in Spools, Flying Leads and Jumper | 7 | Lines will be surface laid and protected by GRP structures (worst case). The dimensions of each GRP (inc. rock) are ca. 17 m (W) x 15 m (L). The maximum combined line length of the lines is 1,550 m. [2] | 23,870 | 26,350 | 0.02635 |
| Protection Transition at FLET | N/A | An overlap of GRP cover and rock may exist for a transition length of circa 150 m on each line. The width of seabed impacted by the rock and GRP for each line is 17 m. | 4,620 | 5,100 | 0.00510 |
| **Total Seabed Footprint at Tormore** | | | **42,006** | **36,962** | **0.037** |

[1] Dimensions of the prelay rock carpet, which is installed for each FLET.
[2] The disturbance area is based upon installation of the GRP structures and adjacent rock berms but does not consider additional temporary disturbance which could occur during any the deconstruction activities of the existing GRP structures and adjacent rock berms. The temporary disturbance area for the deconstruction activities of the existing GRP structures and adjacent rock berms is estimated to be ca. 4,000 $m^2$ (40m (W) x 100m (L))

### 7.2.5 Estimated Total Seabed Disturbance Area

Table 7.8 summarises the worst case total area of seabed that could be disturbed as a result of the Tornado Development. Areas of seabed subject to temporary disturbance will begin to recover on completion of the operations as discussed in Section 7.3. In contrast long term impacts to the seabed are associated with infrastructure that will be in place for the duration of the Tornado Development (ca. 6 to 10 years) and permanent impacts will arise if the infrastructure (e.g. pipelines, umbilical and associated protection/stabilisation material) remain in situ following decommissioning.

The estimated worst case total temporary area of seabed disturbed from the Tornado Development is 8,231,000 $m^2$ (8.24 $km^2$). The worst case total area of seabed disturbed in the long term / permanently by the subsea structures, protection / stabilisation material and installation of the pipelines and umbilical for the life of the Tornado Development is estimated to be 529,157.5$m^2$ (0.53 $km^2$).

**Table 7.8: Estimated Extent of Seabed Disturbed from the Tornado Development (Assessing the Worst Case Options)**

| Aspect | Assumptions | Estimated Area of Seabed Disturbance (Worst Case) | | | |
|---|---|---|---|---|---|
| | | Temporary Impacts | | Long Term / Permanent Impacts | |
| | | $m^2$ | $km^2$ | $m^2$ | $km^2$ |
| Drill Cuttings and Cement (Section 7.2.1) | • The majority of drill cuttings, will be deposited out to a maximum distance of 1.5 km from the release location, aligned with the direction of the current<br>• There will be a formation of a cement patio surrounding the wellbores: 633 $m^2$ per well (1,899 $m^2$ in total) resulting in long term impact. | 1,900,000 | 1.9 | 1,899 | 0.0019 |
| Installation of the Pipelines and Umbilical (Section 7.2.2)[1] | • See Table 7.4 and Table 7.5 (includes the areas of disturbance for the temporary laydown areas) | 6,327,000 | 6.33 | 484,648 | 0.485 |
| Installation of Subsea Infrastructure at Tornado (Section 7.2.3) | • Installation of CAN-ductors, Wellheads and parking-CANS: 141.5 $m^2$<br>• Installation of Manifold, UETs and FLETs (including pre-lay rock carpet for FLETs): 5,227 $m^2$<br>• Installation of tie-in spools, flying leads and jumpers: 280 $m^2$ | - | - | 5,648.5 | 0.0056 |
| Installation of Subsea Infrastructure at Tormore (Section 7.2.5) | • Installation of Manifolds, UETs and FLETs (including pre-lay rock carpet for FLETs): 5,512 $m^2$<br>• Installation of tie-in spools, flying leads and jumpers (protected by GRP structures): 26,350 $m^2$<br>• Protection Transition at FLET using GRP structures: 5,100 $m^2$<br>• Deconstruction of existing GRP structures: 4,000 $m^2$ | 4,000 | 0.004 | 36,962 | 0.037 |
| | **Total** | **8,231,000** | **8.24** | **529,157.5** | **0.53** |

[1] The long term impacts caused by the installation of the pipelines and umbilicals are considered permanent due to the assumption that pipelines and associated protection / stabilisation material will remain in situ following decommissioning operations.

## 7.3 Assessment of Impacts

### 7.3.1 Discharge of Drill Cuttings, Muds and Cement

As discussed in Section 7.2.1, as a worst case, it has been assumed that the WBM cutting discharged from the Tornado wells (5,274,310 kg (5,275 tonnes) for all three wells) have the potential to be deposited within an area of up to 1.9 $km^2$ surrounding all three wells (based on a threshold for bottom deposition of ≥1 mm)(RPS, 2025a). A high exposure level of WBM cuttings (based on a threshold for bottom deposition of ≥10 mm) are likely to be deposited within an area of 0.06 $km^2$ (RPS, 2025a). Any cement discharged at the seabed during cementing operations will also be deposited within this area.

Research has shown that 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 (e.g. Cranmer, 1988, Neff et al. 1989, Hyland et al. 1994, Daan & Mulder, 1996). The main components of WBM are naturally occurring products (e.g. barite 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 (Pose Little or No Risk to the marine environment). Barium (Ba) in the form of barite is a weighting material used to increase the density of drilling muds and can contain measurable concentration of heavy metals as impurities, including cadmium, chromium, copper, lead, mercury, and zinc (NRC, 1983; McLeese et al., 1987). As a result of this, Ba in the seabed sediment can be used as an indication of previous drilling activities.

The proposed Tornado Development area has been subject to historic drilling activity. The Tornado field was discovered by the OMV operated well 204/13-1 in 2009, and appraised by side-track well, 204/13-1Z. These wells are located approximately 1.5 km to the west of the proposed Tornado drill centre. Therefore, there could be some historical contamination of the sediments in the area from previous drilling operations. Within the Tornado site survey area, barium levels were found to be above background levels for the West of Shetland (WoS) recorded during the Atlantic Frontier Environmental Network (AFEN) survey (mean at RS_ST11 to RS_ST15 was 400.4 µg/g), indicating some evidence of drilling related contamination (Refer to Section 4.2.3; Fugro, 2025c; AFEN, 2000).

As part of the operations at the Rosebank North well (213/27-3Z), drilled approximately 66 km to the northeast of the proposed Tornado drill centre, detailed Remotely Operated Vehicle (ROV) monitoring was conducted around the well location, both pre- and immediately post-drilling. This was carried out in 2009 by SERPENT project of the National Oceanography Centre, Southampton (NOCS) in order to assess the effects of such discharges on local benthic communities, particularly larger seabed organisms known as megafauna. The water depth, seabed and hydrographic characteristics are largely consistent with the proposed Tornado location, therefore the observations of the SERPENT study at the Rosebank location can be used as a reference point for the cuttings modelling for the proposed Tornado well (Siccar Point Energy, 2021).

Post drilling monitoring of the seabed around the Rosebank well observed that at least partial coverage of drill cuttings extended to approximately 80 m to 90 m in all directions. The seabed within 40 m of the well site was characterised by a uniform coverage of drill cuttings material with no visual evidence of the natural seabed, although the depth of coverage was not recorded. At distances between 40 m and 90 m from the well, areas of darker sediment`patches' were identified, interspersed between the natural sediments. Deposited material was observed at greater distances (over 100 m) to the southwest of the well, which coincided with the estimated net current movement in the area (SERPENT, 2009). However, generally at distances beyond 100 m, no visible evidence of drill cuttings deposition was observed (Siccar Point Energy, 2021).

The SERPENT research conducted in Block 213/27 has been collated with observations of nine other ROV surveys at drilling sites in the Faroe-Shetland Channel and Norwegian sea as part of a 5 year monitoring programme. Water depths at these sites varied between approximately 400 m and 1,750 m. Although there was some variation between sites, generally speaking, at distances greater than 100 m from the drilling location cuttings deposition was very thin and some of the natural seabed was visible; at distances greater than 200 m there was almost no evidence of discharge (Siccar Point Energy, 2021). This aligns with the results of the cuttings modelling; sediment thickness over the high exposure

threshold is predicted to occur out to 0.2 km (200 m) following drilling activity at all three wells (RPS, 2025a).

### Seabed Sediments

Temporary Impact

The seabed sediments at the Tornado drill centre were interpreted to be represented by the Folk Classification 'muddy sandy gravel'. The discharge of drill cuttings and muds from the Tornado Development wells will initially alter the seabed topography and sediment structure of a small area close to the wells (1.9 $km^2$ surrounding all three wells). The material deposited will be a mixture mostly of cuttings (rock fragments and sediment removed from the well) of various sizes and drilling mud including particles of barite (barium sulphate) and bentonite, a mineral clay. It is feasible that changes in sediment particle size characteristics could affect the suitability of the seabed for re-colonisation by species normally characteristic of the area, although it is anticipated that the sediments will return to their original composition under the influence of seabed currents and natural sedimentation.

Surface hole cuttings mounds in the majority of the WoS area will be dispersed, typically over a time scale of 1 – 10 years, mainly through the re-suspension and bedload transport due to tidal, storm and surge induced currents. Near seabed current velocities and sediment mobility in the WoS area appear generally sufficient to prevent detectable local accumulation of cuttings (Wynn et al., 2002).

The sensitivity of seabed sediments to the discharge of drill cuttings and muds as a result of the Tornado Development wells is therefore considered to be **Low**. The receptor is of local importance for sediment type, classed as Low value, and the overall resistance and resilience is High as seabed currents are likely to prevent local accumulations of cuttings or piles from persisting. The magnitude of impact is predicted to be **Minor** as the disturbance to seabed sediments will be localised to the Tornado drill centre location. Effects on seabed sediments from the discharge of drill cuttings, muds and cement are therefore assessed as **Minor** and not significant.

Long Term Impact

The formation of cement patios surrounding each well will result in the loss of sandy and gravelly sediment habitat from the area, and the introduction of novel hard substrata. In the worst case, the total area of long-term sandy and gravelly sediment habitat loss is estimated to amount to approximately 0.0019 $km^2$ permanently. This area is small in comparison to the area of similar habitat available across the wider area.

In summary, the sensitivity of seabed sediments to the permanent disturbance from the formation of cement patios around each well as a result of the Tornado Development is considered to be **Medium** in the vicinity of the proposed Tornado Development. The receptor is of local importance for sediment type, classed as Low value, but the overall resistance and resilience is Low, as there will be a permanent change to the habitat type. The magnitude of impact, however, is considered to be **Negligible** given the small worst case area (0.0019 $km^2$) which will be impacted compared to the available sandy and gravelly sediment habitat type. Effects on seabed sediments from the formation of cement patios are therefore assessed as **Negligible** and not significant, particularly as the impacted sediment is characteristic of the wider area.

### Benthic Communities

Temporary Impact

The accumulation of WBM drill cuttings and mud at the Tornado drill centre is likely to change the benthic community in the immediate area by burying some animals and impairing the feeding and respiration of others. It is expected that the communities in the immediate vicinity of the well will be lost, and that increased concentrations of suspended particles near the seabed may also impair respiratory and feeding processes, inducing metabolic stress and reducing growth and survival rates. Filter feeding organisms (for example, hydroids and bryozoans) that rely on suspended particles as a source of food are likely to be more vulnerable to the impacts of the drilling operations than the scavengers that rely on the deposition of suspended material. The net result therefore is likely to be a reduction in species diversity and production and a change in the species composition of the community, predicted to be within ca. 200 m of the three wellheads (RPS, 2025a). However, as the

main impact is purely physical, it is anticipated that the sediment communities will begin to recover once the drilling operations have ceased. Re-colonisation 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.

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).

For example, a comprehensive desk study of the composition, environmental fates and biological effects of WBM cuttings and muds was prepared on behalf of the Petroleum Environmental Research Forum and the 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).

Daan and Mulder (1993) investigated the possible environmental effects of discharges of WBM cuttings from a single well site and reported there to be no short term adverse effects on the benthic community due to the presence of cuttings. A follow up study was carried out a year later which also revealed no adverse effects on the benthic community, and further indicated that there was no change to the sediment characteristics after 1 m distance from the discharge point.

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, 120 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 wellheads, 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 and the North Sea 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; Neff, 2010).

The habitats and species present at the proposed Tornado drill centre are typical of the WoS region. Annelids dominated within the infaunal community, making up six of the top 10 ranked species (Fugro, 2025c). The most abundant species was the polychaete *Notoproctus* (Type A and B). The next most dominant taxon was the polychaete *Proclea graffii*. Common components of the epifauna included Echinodermata (Asteroidea, Crinoidea and Ophiuroidea), Porifera (Cladorhizidae, Hexactinellida and stalked sponges), Arthropoda (Pycnogonida), Cnidaria (Malacalcyonacea and Actiniaria), Annelida (Polychaeta), Hydrozoa and Bryozoa.

In the Tornado site survey area, some sponge aggregations were observed in camera transects or Autonomous Underwater Vehicle (AUV) mosaics, but were sporadic and of low abundance and therefore did not reach the criteria for further assessment (refer to Section 4.3.2). In addition, no coral gardens, or sea pens and burrowing megafauna within the vicinity of the proposed Tornado drill centre.

The Tornado drill centre is, however, situated in an area identified as having the potential for Annex I 'stony reef' habitats. Research has shown that stony reefs have a limited tolerance to direct physical pressures, with recovery not expected for an extended period. The closest stony reefs were recorded 0.6 km and 1.7 km respectively from the proposed well locations, thus it is unlikely the discharge of cuttings, mud and cement will affect these recorded reefs (refer to Section 4.3.2). As discussed in Section 7.2.1, it is likely that the majority high exposure thickness of WBM cuttings discharged from the drilling rig (> 10 mm) will be distributed within an area out to a maximum distance of ca. 200 m from the release locations, aligned with the northeasterly current direction. The remainder of the WBM

cuttings particles at a low exposure thickness (>1 mm) will travel up to around 1.5 km from the release locations, but due to the orientation of the cuttings pile, are unlikely to affect the stony reef habitats identified.

Ocean quahog (*Arctica islandica*) were also not recorded during the Tornado survey, but there are mapped instances of the species occurring in the area and therefore it is possible they could be present. Ocean quahog burrow into the sediment, they use a short inhalant siphon which sits above the sediment surface for feeding and respiration (Taylor, 1976). Data taken from the Feature Activity Sensitivity Tool (FeAST) indicates that high rates of siltation may adversely affect ocean quahog, with the species having no tolerance and low recovery to the pressure and therefore a high sensitivity (Tillin et al. 2010; Marine Scotland, 2013). As such, there is a possibility that ocean quahog could be impacted by siltation caused by the discharge of cuttings, muds and cement.

In summary, the sensitivity of seabed communities to the discharge of drill cuttings and muds as a result of the Tornado Development is considered to be **Low**. The receptors are of national importance and are of High value, and the overall resistance and resilience is Very High as recoverability is expected in the short term. The magnitude of impact is predicted to be **Minor**; there will only be a temporary change to the baseline conditions, predicted to occur in the short to medium term, with any changes occurring within close proximity to the Tornado drill centre. Effects on seabed communities from the discharge of drill cuttings, muds and cement are therefore assessed as **Minor** and not significant.

Long Term Impact

The seabed beneath the cement patios will be compacted. The sessile epifauna, and a proportion of the infauna (animals that burrow into the sediment or form tubes within it) such as polychaete worms in the direct footprint area of the cement patios will be lost from compression and abrasion. However, the consequences for most species in context to the wider region are expected to be short-lived as most of the smaller sedentary species (such as polychaete worms) have short lifecycles and high reproductive rates (Tillin and Tyler-Walters, 2014). Annelids dominated within the infaunal community, making up six of the top 10 ranked species within the Tornado site survey area. The most abundant species within the Tornado site survey area was the annelida Notoproctus (Type B). The second and third most dominant taxa were the Notoproctus (Type A) and Proclea graffii (Fugro, 2025c).

The physical presence of the cement patios will introduce a new stable hard substrata to the area and over time a new rocky substrate habitat will become established. Seabed animals within the direct footprint of the cement will be damaged, displaced or smothered resulting in the mortality and loss of individuals of species but the material itself could, over time, function as reef habitat providing additional attachment sites for the indigenous sessile communities, such as sponges, as well as refugia for mobile epibenthos such as *Munida* sp. (squat lobster) or fish. Ultimately this new seabed feature is expected to be colonised by the same types of mobile and encrusting epifaunal animals already present on cobbles and boulders in the wider WoS area.

On the whole, epifaunal coverage was found to be generally high in richness across the Tornado site survey area. Overall, 165 taxa were recorded; the taxa consisted of 52 annelid species, which dominated the community, accounting for 61.7% of the total individuals. There were 74 species of arthropods recorded (26.6% of the total individuals), 32 species of molluscs (6.8% of the total individuals), and 2 species of echinoderms (4.3% of total individuals). The other phyla (Cnidaria, Hemichordata, Platyhelminthes and Nemertea) were represented by 5 species, accounting for 0.6% of the total individuals (Fugro, 2025c). Therefore, it is possible that the introduction of a stable hard substrata within the Tornado Development area could encourage colonisation by similar species. Colonisation of cement patios on the seabed will be slowed by any biocides included within the cement recipe.

The habitat assessment results for Tornado highlighted the presence of the European Nature Information System (EUNIS) biotope complex 'Arctic upper bathyal mixed sediment' (ME41) within the Tornado site survey area. (Refer to Section 4.3.2). This habitat type is encompassed within the Priority Marine Feature (PMF) 'Offshore subtidal sands and gravels'. Arctic bathyal sediments are the component biotope of 'Offshore subtidal sands and gravels', which is a designated priority habitat within Scottish waters (Tyler-Walters et al., 2016). However 'Arctic upper bathyal mixed sediment'

(ME41) is not included in the UK Biodiversity Action Plan (BAP) priority habitat 'Subtidal sands and gravels' (BRIG, 2011).

This habitat type is characterized by mobile pebbles and cobbles; pressures that lead to penetration and disturbance could damage associated species through abrasion and by overturning surfaces could result in the smothering of fauna or reductions in respiration, feeding efficiency or fertilization of gametes in the water column. This habitat type is, however, likely to be exposed to at least seasonal movement of substrata and this movement and scour maintains these biotopes by preventing species that require more stable habitats from colonizing and developing stable populations.

As previously mentioned, the Tornado field is situated in an area identified as having the potential for Annex I 'stony reef' habitats. Stony reefs have a limited tolerance to direct physical impact, with recovery not expected for an extended period. A stony reef assessment (after Irving, 2009) for the Tornado site survey area found two occurrences of 'Low Reef' in terms of overall reefiness (structure vs epifaunal cover vs epifauna). These comprised single occurrences on each of the two transects approximately 1.7 km west and 0.6 km west of the proposed Tornado drill centre location. There were no occurrences of 'Medium Reef' or 'High Reef', with all other ground-truthing data indicating areas with no cobbles and boulders or were classified as 'Not a Reef' (Fugro, 2025a; Fugro, 2025b). The cement patio will only extend 14.2 m radially from each well and thus it is unlikely that these incidences of 'Low Reef' will be affected.

As mentioned above, deep sea sponge aggregations are recorded around the Faroe-Shetland Channel (OSPAR, 2010a). In the Tornado site survey area, the sponge aggregations observed were sporadic and of low abundance and therefore did not reach the criteria for further assessment (Fugro, 2025a). In terms of impacts associated with the formation of the cement patios, based on information from FEAST (Marine Scotland, 2013) deep-sea assemblages are considered to have high sensitivity to physical changes to the seabed and direct damage, displacement and disturbance from direct physical impact on the sponges (mainly trawling but also other activities). However due to the limited aggregations of deep sea sponges recorded within the proposed development area, and the limited extent of the area affected, the formation of these cement patios is unlikely to cause direct mortality to deep sea sponges.

Ocean quahog (*Arctica islandica*) has also been reported to inhabit the wider region surrounding the proposed Tornado Development. More specifically the Faroe-Shetland Sponge Belt Nature Conservation Marine Protected Area (NCMPA), located ca. 8 km from the proposed Tornado drill centre, is designated for the conservation of *A. islandica*. However, no individuals were recorded in the macrofauna data at the proposed Tornado drill centre, no potential relict shells were observed along the video transects and no live individuals or their distinctive siphons were noted during analysis of video footage and still photographs from the survey areas (Fugro, 2025a; 2025b). The introduction of a new stable hard substrata to the area will cause a direct reduction in suitable seabed habitat that could support ocean quahog, with Tillin et al. (2010) reporting the species as having a high sensitivity to physical change to another seabed habitat type.

Overall, the formation of the cement patios from the Tornado Development is very small and localised (confirmed to an area of ca. 0.0019 $km^2$ in the worst case) and, whilst it will represent a change to the benthic environment locally it is not expected to cause any widespread changes to the marine life present in the area.

In summary, the sensitivity of seabed communities to long term impacts from the formation of the cement patios as a result of the Tornado Development is considered to be **Very High** as the habitats and species present are typical of this area. The receptors are of national importance and are of High value, and the overall resistance and resilience is Low as there will be a permanent change to the habitat type. The magnitude of impact is predicted to be **Minor** as although the impact will last the duration of the Tornado Development it will be restricted to a very small area (0.0019 $km^2$). Effects on seabed communities from the formation of cement patios are therefore assessed as **Minor** and not significant, given that any change to the benthic environment will be local and is not expected to cause any widespread changes to the marine life present in the area.

### Fish and Shellfish

As discussed in Section 4.3.3, a number of fish species are known to use the waters in the vicinity of the Tornado Development location, and some use the area as a spawning and / or nursery ground. The International Council for the Exploration of the Seas (ICES) Rectangle 50E5, within which the Tornado drill centre is located, has been identified as a potential spawning ground for blue whiting. ICES Rectangle 50E5 also acts as a nursery area for blue whiting (high intensity) and Norway pout.

Temporary Impact

Exposure to increased turbidity caused by the proposed operations may reduce the visual acuity of fish utilising the area potentially affecting foraging behaviour (Bakke et al., 2013). Fish may also be temporarily displaced from their spawning and nursery areas due to the settlement of drill cuttings and muds on the seabed. However, given the localised area of impact and the mobile nature of the species, any displaced fish are likely to find foraging opportunities, as well as suitable spawning and nursery areas in adjacent locations.

It should be noted that benthic spawners, such as sandeels and herring are particularly vulnerable to seabed disturbance, with egg development and hatching success vulnerable to the effects of smothering (DTI, 2001). A number of studies have been conducted on the effects of sedimentation on fish egg development of commercially valuable fish species, particularly in relation to dredging operations. Results are variable with some demonstrating mortality of fish eggs when smothered by even a thin veneer of sediment (DOER, 2000) and other studies showing no significant effects on fish egg and larval development and mortality (Auld and Schubel, 1978; Kiørboe et al., 1981). However, the species present within the vicinity of the Tornado drill centre do not fall into the category of benthic spawners.

In summary, the sensitivity of fish to the discharge of drill cuttings and muds as a result of the Tornado Development is considered to be **Low**. The species present are typical of the wider area in this region of the WoS, although blue whiting, ling, mackerel and Norway pout, are listed as PMFs in Scottish waters, whereby this designation should seek to protect these features (refer to Section 4.3.3) and, as such, are of High value, but the overall resistance and resilience is Very High as recoverability is expected in the short term. The magnitude of impact is predicted to be **Negligible** with immeasurable changes in the baseline environment pertaining to fish species; any changes will occur within close proximity to the Tornado drill centre and fish species are mobile. Effects on fish from the discharge of drill cuttings, muds and cement are therefore assessed as **Negligible** and not significant.

Long Term Impact

The physical presence of the cement patios on the seabed will provide a new stable hard substrata, resulting in the long term loss of seabed habitat within an area of ca. 0.0019 $km^2$. However, the spawning and nursery grounds within which the Tornado Development area is located are part of wider spawning and nursery grounds and, as such, is not considered to be a key habitat for these fish species. As discussed in Section 4.3.3, ICES Rectangle 50E5 has been identified as a potential spawning ground for blue whiting and Norway pout.

In summary, the sensitivity of spawning fish to the long term disturbance as a result of the formation of the cement patios as a result of the Tornado Development is considered to be **Low** as the species present are typical of the wider area. The species present are typical of the wider area in this region of the WoS, although blue whiting and Norway pout, are listed as PMFs in Scottish waters, whereby this designation should seek to protect these features (refer to Section 4.3.3) and, as such, are of High value, but the overall resistance and resilience is Very High as recoverability is expected in the short term. The magnitude of impact is predicted to be **Negligible** with immeasurable changes in the baseline environment. Effects on spawning fish from the formation of cement patios are therefore assessed as **Negligible** and not significant.

### 7.3.2 Installation of Subsea Infrastructure

#### Water Quality

There is a potential that the installation of the subsea infrastructure in depths less than 800 m that is required for the proposed Tornado Development could result in a reduction of water quality. This could arise from the resuspension of sediment during the installation of the production pipeline, MEG pipeline and control umbilical leading to increased turbidity and a higher concentration of contaminated sediments in the water column. The greatest amount of sediment resuspension will take place during the potential trench and burial operations in waters less than 800 m in depth.

Suspended sediment is not expected to persist within the water column beyond a day following the completion of subsea infrastructure installation activities (Dale et al., 2011; Black and Parry, 1999). In addition, although the concentrations of chromium and copper exceeded the Effects Range Low (ERL) values at several stations along the pipeline route and within the vicinity of the Tornado drill centre, the concentration of the metals were presented as total concentrations rather than bioavailable concentrations. Therefore, while the concentrations exceeded the ERL values, a proportion of this is unlikely to be available for uptake by biota. The heavy metal concentrations along the pipeline route and within the vicinity of the Tornado drill centre were also similar to background levels (refer to Section 4.2.3) In summary, the resuspension of sediments arising from the installation of subsea infrastructure is unlikely to result in high turbidity for a prolonged period or a significant concentration of contaminants entering the water column.

The sensitivity of water quality to the increase turbidity as a result of the Tornado Development is considered to be **Low**. The receptor has a Low value; as only the water column in relatively close proximity to the installation operations will be impacted, hence it is considered to be of local importance. The WoS area is characterised by persistent, long-period swells, complex current regimes and rapidly changing weather conditions. The water quality is subject to rapid refreshment rates and mixing of the water column, coupled with strong wave action on the sea surface. Therefore, the overall resistance and resilience is Very High to the increased turbidity due to the installation of Tornado infrastructure. The magnitude of impact is predicted to be **Minor,** with a short-term temporary change in baseline environmental conditions. Effects on water quality from the installation of subsea infrastructure are therefore assessed as **Minor** and not significant.

#### Seabed Sediments

Temporary Impact

There will be temporary disturbance arising from the potential trenching and backfill operations at depths less than 800 m, as well as from temporary initiation anchors and wires, and the use of temporary laydown areas for wet storage and equipment baskets, and from the deconstruction of GRP structures at the Tormore end. As a worst case, this disturbance will occur within an area of approximately 6.33 $km^2$ (refer to Section 7.2.5).

It is likely that a proportion of the sediments displaced for the purpose of pipeline laying and burial will become suspended in the bottom few metres of the water column. Within the vicinity of the proposed trench and burial operations (PR_ST18 to PR_ST24), the sediments are relatively coarse (sandy and gravelly) in nature which means that plumes or re-suspended sediment will tend to re-settle quickly and will not be prolonged or affect large areas. The trench and burial operations will also result in the temporary formation of mounds either side of the pipeline and umbilical during the trenching phase which will be replaced during the burial phase.

In addition, the use of the temporary initiation anchors, wires, temporary laydown areas (for wet storage) and the deconstruction of the GRP structures will physically disturb the sediment. There is little quantitative information available on the likely recovery time from the physical disturbance of temporary initiation anchor or wire placement, or temporary laydown areas. However, indications are available from studies carried out for seabed disturbance from towed fishing gear (Løkkeborg, 2005). These suggest that it is likely that some level of recovery will occur in the sediments following anchoring operations. The longevity of the physical abrasion scars on the seabed is dependent on the type and energy of the local benthic environment. Seabed scars in higher energy, sandy or shallow environments

may disappear within days or months of initial disturbance, whilst those in lower energy silty and deeper areas may still be faintly visible after 18 months.

As discussed in Section 4.2.3, seabed sediments within the Tornado field Development area have been identified as being sandy and gravelly showing small amounts of fines and a negligible silt and clay content (Fugro, 2025c; 2025d). The Tornado Development is also located within an area of moderate energy characterised by complex current regimes (BEIS, 2022). Consequently, seabed scars resulting from the use of temporary initiation anchors and wires, and temporary laydown areas in the Tornado Development have the potential to persist only in the short to medium term.

In summary, sensitivity of seabed sediments to the temporary seabed disturbance as a result of the Tornado seabed infrastructure installation is therefore considered to be **Low**. The receptor is of local importance for sediment type, classed as Low value, and the overall resistance and resilience is High as seabed currents and coarse nature of the sediment means that plumes or re-suspended sediment will tend to re-settle quickly and will not be prolonged or affect large areas. In addition, recovery following scarring is predicted in the medium term. The magnitude of impact is predicted to be **Minor**; although there is a relatively large worst case area for temporary seabed disturbance (6.33 $km^2$) it is assumed recovery will occur within the short to medium term. Effects on seabed sediments from the temporary seabed disturbance as a result of the Tornado seabed infrastructure installation are therefore assessed as **Minor** and not significant.

Long Term Impact

Installation of the subsea infrastructure will result in the loss of sandy and gravelly sediment habitat from the area, and the introduction of novel hard substrata. This will mostly comprise of subsea infrastructure items, pipelines, the control umbilical, pre-lay rock carpets and post-lay rock cover. In the worst case, the total area of long-term sandy and gravelly sediment habitat loss is estimated to amount to approximately 0.53 $km^2$ for the life of the Tornado Development (ca. 6 to 10 years) and beyond depending on how the infrastructure is decommissioned. The pipelines, umbilicals and any rock deposited on the seabed as part of the Tornado Development are likely to remain in situ. This area is small in comparison to the area of similar habitat available across the wider area.

In summary, the sensitivity of seabed sediments to the long term disturbance from the installation of subsea infrastructure, pipelines and protection / stabilisation material as a result of the Tornado Development is considered to be **Medium** in the vicinity of the proposed Tornado Development. The receptor is of local importance for sediment type, classed as Low value, but the overall resistance and resilience is Low, as there will be a long term / permanent change to the habitat type, which will last for as long as the subsea infrastructure, pre-lay rock carpets, post-lay rock cover and concrete mattresses stay remain in place. The magnitude of impact, however, is considered to be **Minor**; although the impact will be long term / permanent, the worst case area which will be impacted compared to the available sandy and gravelly sediment habitat type is relatively small (0.53 $km^2$). Effects on seabed sediments from the subsea infrastructure installation activities are therefore assessed as **Minor** and not significant, particularly as the impacted sediment is characteristic of the wider area.

### Benthic Communities

Temporary Impact

The installation of the pipelines and umbilical and subsea infrastructure will also result in sediment suspension and re-settlement outside of their direct footprint. Exposure to higher than normal loads of suspended sediments have the potential for negative impacts on habitats and species in the surrounding area. The re-settlement of sediments may result in the smothering of epifaunal species (Gubbay, 2003) with the degree of impact related to their ability to clear particles from their feeding and respiratory surfaces (Rogers, 1990). However, Defra (2010) states that impacts arising from sediment re-suspension are short-term (generally over a period of a few days to a few weeks). In addition, infaunal communities are naturally habituated to sediment transport processes and are therefore less susceptible to the direct impact of temporarily increased sedimentation rates. Depending on the sedimentation rates, infaunal species and communities can also work their way back to the seabed surface through blanket smothering (Neal and Avant, 2008).

Within the vicinity of the proposed seabed infrastructure, the sediments are relatively coarse (majority of which are sandy and gravelly) in nature which means that plumes or re-suspended sediment will tend to re-settle quickly and will not be prolonged or affect large areas. Where sediment re-suspension does occur, the majority of species present, particularly the infaunal communities, are expected to recover in the short term (Defra, 2010). Furthermore, large scale field experiments by 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 had the most rapid recovery rate following disturbance and mud the slowest. The sediment type that is prevalent within the proposed Tornado Development is muddy sand, which has a slower recovery rate following disturbance.

Both general field development activities and drilling operations commonly generate sediment resuspension, which can lead to alterations in the distribution and composition of benthic communities. For example, subsea cable installation has been shown to cause significant ecological impacts, including 100% mortality of glass sponges directly within the installation zone and up to 15% mortality within a 1.5-metre radius (Jones et al., 2012, as referenced in Vad et al., 2018). Comparable impacts are anticipated from pipeline installation, which can similarly disturb sensitive benthic habitats (OSPAR, 2010a, as referenced in Vad et al., 2018).

The habitat assessment results for Tornado highlighted the presence of the EUNIS biotope complex 'Arctic upper bathyal mixed sediment' (ME41) within the Tornado site survey area. This was also identified along the pipeline survey corridor along with EUNIS biotope complex 'Arctic upper bathyal mixed sand' (ME51) (Refer to Section 4.3.2). Both of these habitat types are encompassed within the PMF 'Offshore subtidal sands and gravels'. Arctic bathyal sediments are the component biotope of 'Offshore subtidal sands and gravels', which is a designated priority habitat within Scottish waters (Tyler-Walters et al., 2016). However both 'Arctic upper bathyal mixed sediment' (ME41) and 'Arctic upper bathyal sand' (ME51) are not included in the UK BAP priority habitat 'Subtidal sands and gravels' (BRIG, 2011).

Epibenthic fauna observed during the survey operations was relatively sparse in relation to the EUNIS habitat type 'Arctic Upper Bathyal Mixed Sediment (ME41)'. The most commonly observed fauna on the seabed photographs and video were brittlestars (Ophiuroidea). Fauna including sponges (Porifera: carnivorous forms: Cladorhizidae including *Asbestopluma sp.* and *Chondrocladia* (*Chondrocladia*) *grandis*; stalked forms including *Stylocordyla borealis*); glass sponges (Hexactinellida), starfish (Asteroidea including *Crossaster squamatus* and *Henricia sp.*) and carnation corals (Malacalcyonacea) anemones (Actiniaria including Halcampidae), tube anemones (*Cerianthus sp.*), feather stars (Crinoidea), sea spider (Pycnogonida including *Colossendeis proboscidea*), tube worms (Polychaeta) and faunal turf (Hydrozoa/Bryozoa) were also widely seen. The most commonly observed fauna in relation to EUNIS habitat 'Arctic Upper Bathyal Sand (ME51)' was brittlestars (Ophiuroidea). Other fauna including sponges (Porifera: stalked forms including *Stylocordyla sp.*; carnivorous forms including Cladorhizidae, *Asbestopluma sp.*, *Chondrocladia (Chondrocladia) grandis*; encrusting forms including *Hymedesmia sp.*), glass sponges (Hexactinellida), carnation corals (Malacalcyonacea), starfish (Asteroidea including Halcampidae and *Pontaster sp.*), anemones (Actiniaria) and feather stars (Crinoidea) were also widely seen.

The Tornado field is situated in an area identified as having the potential for Annex I 'stony reef' habitats. Stony reefs have a limited tolerance to direct physical impact, with recovery not expected for an extended period. A stony reef assessment (after Irving, 2009) for the Tornado site survey area found two occurrences of 'Low Reef' in terms of overall reefiness (structure vs epifaunal cover vs epifauna). These comprised single occurrences on each of the two transects approximately 1.7 km east and 0.6 km east of the proposed Tornado drill centre location. There were no occurrences of 'Medium Reef' or 'High Reef', with all other ground-truthing data indicating areas with no cobbles and boulders or were classified as 'Not a Reef' (Fugro, 2025a; Fugro, 2025b).

A stony reef assessment for the Tornado pipeline corridor survey area found that along sections of 13 transects, aggregated cobbles and boulders were observed meeting the composition and elevation criteria and were classified as 'low reef'. However, the areas of the 'low reef' observed along 12 of these transects did not exceed 25 $m^2$ and did not satisfy the area criteria for 'Reefs'. Only one patch along transect PR_TR15 was observed from the photographic data to exceed 25 $m^2$ and was thus

classed as 'low reef'. Patches of 'medium' stony reef meeting the composition and elevation criteria were observed along sections of four transects, but the size of these areas observed from the photographic data did not exceed 25 $m^2$. There were no occurrences of 'High Reef', with all other ground-truthing data indicating areas with no cobbles and boulders or were classified as 'Not a Reef' (Fugro, 2025a; Fugro, 2025b).

The epifaunal assemblage associated with the 'low reef' and 'medium reef' areas within the survey areas was sparse, comparable to the areas of cobbles and boulders classified as 'not a reef', and included anemones (Actiniaria), sponges (Porifera: carnivorous forms: Cladorhizidae including *Chondrocladia (Chondrocladia) grandis*; glass sponges Hexactinellida), carnation corals (Malalcyonacea), starfish (Asteroidea incl. *Crossaster squamatus*) and faunal turf (Hydrozoa/Bryozoa). Therefore, it is unlikely that the areas of 'low' stony reef were representative of Annex I 'Reef' habitat. In addition, the areas characteristic of 'medium' stony reef were of such small areas (<25 $m^2$) that these are also unlikely to be representative of Annex I reef, based on the Irving, 2009 criteria.

Deep sea sponge aggregations are recorded from the northern Scottish slope of the Faroe-Shetland Channel (OSPAR, 2010a) and are usually found in water depths greater than 250 m. Sponge density within the Faroe-Shetland Channel has been previously reported as 0.001 to 0.818 individuals/$m^2$, which is consistent with densities across much of the North Atlantic (Axelsson, 2003; Henry and Roberts, 2014, cited in Kazanidis et al., 2019). More recently, Kazanidis et al. (2019) investigated the composition and density of sponge communities within and outside of the Faroe-Shetland Sponge Belt NCMPA. They reported that, when averaging across all types of sponges, the density was 0.28 individuals/$m^2$. They found that densities were highest in a very narrow depth range (400 m to 600 m depth), and were also correlated with sediment type; the highest densities were recorded where cobbles/cobble with boulders were the dominant substrate (Kazanidis et al., 2019). It should be noted that the minimum depth of the Tornado Development is ca. 594 m and therefore does not significantly overlap this depth range.

As mentioned above, the presence of the Faroe-Shetland Sponge Belt NCMPA, in which approximately 18 km of the Tornado pipeline route is located (refer to Section 4.3.6), increases the likelihood for sponge aggregations to occur. In the Tornado site survey area, the sponge aggregations observed were sporadic and of low abundance and therefore did not reach the criteria for further assessment (Fugro, 2025a). However, due to observations of demosponges, the presence of 'Deep-sea sponge aggregations' was considered along the proposed pipeline route. The assessment found that along two sections of transect PR_TR24, the density of demosponges satisfied the density criteria for the Oslo and Paris Commission (OSPAR) threatened and/or declining habitat 'Deep-sea sponge aggregations'. Conversely, according to Henry and Roberts (2014a) "sponge assemblages should confer a clear functional role for deep-sea sponge communities, e.g. enhanced associated biodiversity, support a distinct associated megafaunal assemblage, ecological symbioses, and/or create habitat for mobile fauna". In the Tornado survey, the faunal assemblages associated with sponges were similar to the surrounding assemblages. Additionally, the areas where sponges satisfied the density criterion did not exceed 25 $m^2$ (14 $m^2$ and 9 $m^2$ respectively) and therefore no qualifying criteria were met (Fugro, 2025b). Therefore due to the limited aggregations of deep sea sponges recorded within the proposed development area, the installation of the Tornado Development subsea infrastructure is unlikely to directly significantly impact the objective to recover the extent, distribution, structure or function of deep sea sponge aggregations.

Ocean quahog (*Arctica islandica*) has also been reported to inhabit the wider region surrounding the proposed Tornado Development. More specifically the Faroe-Shetland Sponge Belt NCMPA, within which part of the Tornado Development is located (approximately 18 km of the proposed Tornado pipeline), is designated for the conservation of *A. islandica*. However, no individuals were recorded in the macrofauna data at the proposed Tornado drill centre or within the pipeline route corridor survey, no potential relict shells were observed along the video transects and no live individuals or their distinctive siphons were noted during analysis of video footage and still photographs from the survey areas (Fugro, 2025a; 2025b). In addition, no ocean quahog specimens were observed on camera or recorded in the macrofauna data within the vicinity of the Cambo and Rosebank development areas (MMT, 2019; Equinor, 2022). The ocean quahog is highly sensitive to physical pressures such as sediment deposition as discussed in Sections 7.3.1; however due to the lack of ocean quahog recorded

within the proposed development area, the installation of the Tornado Development subsea infrastructure is unlikely to cause direct mortality to ocean quahog.

Sporadic burrows were within the Tornado site survey area, but in conjunction with the sediment type and size of the area where burrows were observed, were not considered to be present in sufficient numbers to warrant a full 'Sea pens and burrowing megafauna' (OSPAR, 2010b) assessment. No sea pens were observed within the site survey area. Along the proposed pipeline route, sea pens and burrows were present, but did not warrant a full assessment due to the sporadic distribution and low abundance (Fugro, 2025b). Therefore, 'Sea pens and burrowing megafauna' were not thought to be present within the Tornado survey areas.

Carnation corals (Malacalcyonacea) were recorded throughout the Tornado survey areas (see examples in Section 4.3.2). Carnation corals potentially contribute to coral gardens within the UK (Henry & Roberts, 2014b); however, the occurrence of carnation corals was sporadic, with only single individuals recorded. The presence of carnation corals therefore did not warrant a full coral garden assessment due to the sporadic distribution and low abundance within the proposed Tornado Development area (Fugro, 2025a; Fugro, 2025b).

In summary, the sensitivity of seabed communities to the temporary seabed disturbance as a result of the Tornado subsea installation is generally considered to be **Low**. Some of the receptors are of national importance and are of High value, but for the majority of species the overall resistance and resilience is Very High as recoverability of benthic communities is expected in the short term. Ocean quahog and deep- sea sponge aggregations are the exception to this, being of **Very High** sensitivity, as they have a Low resistance and resilience to sub-surface abrasion. The magnitude of impact is predicted to be **Minor;** while changes will occur over a moderately sized area (ca. 6.33 $km^2$) in the worst case, these changes will only be temporary, predicted to occur in the short to medium term. Effects on seabed communities from the temporary seabed disturbance as a result of the Tornado pipeline and umbilical installation and subsea infrastructure are therefore assessed as **Minor** and not significant.

Long Term Impact

The seabed beneath the subsea infrastructure, pipelines, umbilical and protection / stabilisation material will be compacted. The sessile epifauna, and a proportion of the infauna (animals that burrow into the sediment or form tubes within it) such as polychaete worms in the direct footprint area of the Tornado Development field infrastructure will be lost from compression and abrasion. However, the consequences for most species in context to the wider region are expected to be short-lived as most of the smaller sedentary species (such as polychaete worms) have short lifecycles and high reproductive rates (Tillin and Tyler-Walters, 2014). Annelids dominated within the infaunal community, making up six of the top 10 ranked species within the Tornado site survey area and the pipeline route corridor survey area. The most abundant species within the Tornado site survey area was the annelida *Notoproctus* (Type B). The second and third most dominant taxa were the *Notoproctus* (Type A) and *Proclea graffii* (Fugro, 2025c). The most abundant species within the Tornado pipeline route corridor survey area was the annelida *Paramphinome jeffreysii*. The second and third most dominant taxa were the *Notoproctus* (Type A) and *Nephasoma (Nephasoma) lilljeborgi* (Fugro, 2025c).

The physical presence of the subsea infrastructure, pipelines, umbilical and protection / stabilisation material, will introduce a new stable hard substrata to the area and over time a new rocky substrate habitat will become established. Seabed animals within the direct footprint of the protective rock material will be damaged, displaced or smothered resulting in the mortality and loss of individuals of species but the material itself could, over time, function as reef habitat providing additional attachment sites for the indigenous sessile communities, such as sponges, as well as refugia for mobile epibenthos such as *Munida* sp. (squat lobster) or fish. Pidduck et al (2017) highlight that rock deposit material has the potential to act as an artificial reef supporting reef communities. The rate of colonisation of the rock protection / stabilisation material, if used, will be dependent on recruitment rates from local reproducing populations but is expected to be slow due to the slow growth, low recruitment rates and late maturity of deep, cold water assemblages (Cordes, 2016; Jones et al., 2012). However ultimately this new seabed feature is expected to be colonised by the same types of mobile and encrusting epifaunal animals already present on cobbles and boulders in the wider WoS area.

On the whole, epifaunal coverage was found to be generally high in richness across the Tornado site survey area. Overall, 165 taxa were recorded; the taxa consisted of 52 annelid species, which dominated the community, accounting for 61.7% of the total individuals. There were 74 species of arthropods recorded (26.6% of the total individuals), 32 species of molluscs (6.8% of the total individuals), and 2 species of echinoderms (4.3% of total individuals). The other phyla (Cnidaria, Hemichordata, Platyhelminthes and Nemertea) were represented by 5 species, accounting for 0.6% of the total individuals (Fugro, 2025c). Within the pipeline route corridor survey area, it was also found that epifaunal coverage was generally good to high in richness. Overall, 204 taxa were recorded; the taxa consisted of 76 annelid species, which dominated the community, accounting for 62.3% of the total individuals. There were 87 species of arthropods recorded (23.9% of the total individuals), 31 species of molluscs (10.5% of the total individuals), and 4 species of echinoderms (2.1% of total individuals). The other phyla (Cnidaria, Chordata, Platyhelminthes and Nemertea) were represented by 6 species, accounting for 1.2% of the total individuals (Fugro, 2025d). Therefore, it is possible that the introduction of a stable hard substrata within the Tornado Development area could encourage colonisation by similar species. Colonisation of steel structures on the seabed will be slowed by any protective wraps or antifouling applied, whereas colonisation of introduced rock deposits will be relatively uninhibited.

The habitat assessment results for Tornado highlighted the presence of the EUNIS biotope complex 'Arctic upper bathyal mixed sediment' (ME41) within the Tornado site survey area. This was also identified along the pipeline survey corridor along with EUNIS biotope complex 'Arctic upper bathyal mixed sand' (ME51) (Refer to Section 4.3.2). Both of these habitat types are encompassed within the PMF 'Offshore subtidal sands and gravels'. Arctic bathyal sediments are the component biotope of 'Offshore subtidal sands and gravels', which is a designated priority habitat within Scottish waters (Tyler-Walters et al., 2016). However both 'Arctic upper bathyal mixed sediment' (ME41) and 'Arctic upper bathyal sand' (ME51) are not included in the UK BAP priority habitat 'Subtidal sands and gravels' (BRIG, 2011).

These habitat types are characterized by mobile pebbles and cobbles; pressures that lead to penetration and disturbance could damage associated species through abrasion and by overturning surfaces could result in the smothering of fauna or reductions in respiration, feeding efficiency or fertilization of gametes in the water column. These habitat types are, however, likely to be exposed to at least seasonal movement of substrata and this movement and scour maintains these biotopes by preventing species that require more stable habitats from colonizing and developing stable populations.

As previously mentioned, the Tornado field is situated in an area identified as having the potential for Annex I 'stony reef' habitats. Stony reefs have a limited tolerance to direct physical impact, with recovery not expected for an extended period. A stony reef assessment (after Irving, 2009) for the Tornado site survey area found two occurrences of 'Low Reef' in terms of overall reefiness (structure vs epifaunal cover vs epifauna). These comprised single occurrences on each of the two transects approximately 1.7 km east and 0.6 km east of the proposed Tornado drill centre location. There were no occurrences of 'Medium Reef' or 'High Reef', with all other ground-truthing data indicating areas with no cobbles and boulders or were classified as 'Not a Reef' (Fugro, 2025a; Fugro, 2025b). A stony reef assessment for the Tornado pipeline corridor survey area found that along sections of 13 transects, aggregated cobbles and boulders were observed meeting the composition and elevation criteria and were classified as 'low reef'. However, the areas of the 'low reef' observed along 12 of these transects did not exceed 25 $m^2$ and did not satisfy the area criteria for 'Reefs'. Only one patch along transect PR_TR15 was observed from the photographic data to exceed 25 $m^2$ and was thus classed as 'low reef'. Patches of 'medium' stony reef meeting the composition and elevation criteria were observed along sections of four transects, but the size of these areas observed from the photographic data did not exceed 25 $m^2$. There were no occurrences of 'High Reef', with all other ground-truthing data indicating areas with no cobbles and boulders or were classified as 'Not a Reef' (Fugro, 2025a; Fugro, 2025b). Therefore, it is unlikely that the areas of 'low' stony reef were representative of Annex I 'Reef' habitat. In addition, the areas characteristic of 'medium' stony reef were of such small areas (<25 $m^2$) that these are also unlikely to be representative of Annex I reef, based on the Irving, 2009 criteria.

As mentioned above, deep sea sponge aggregations are recorded around the Faroe-Shetland Channel (OSPAR, 2010a). In the Tornado site survey area, the sponge aggregations observed were sporadic and

of low abundance and therefore did not reach the criteria for further assessment (Fugro, 2025a). However, due to observations of demosponges, the presence of 'Deep-sea sponge aggregations' was considered along the proposed pipeline route. The assessment found that along two sections of transect PR_TR24, the density of demosponges satisfied the density criteria for the OSPAR threatened and/or declining habitat 'Deep-sea sponge aggregations'. However, according to Henry and Roberts (2014a) "sponge assemblages should confer a clear functional role for deep-sea sponge communities, e.g. enhanced associated biodiversity, support a distinct associated megafaunal assemblage, ecological symbioses, and/or create habitat for mobile fauna". In the Tornado survey, the faunal assemblages associated with sponges were similar to the surrounding assemblages. Additionally, the areas where sponges satisfied the density criterion did not exceed 25 $m^2$ (14 $m^2$ and 9 $m^2$ respectively) and therefore no qualifying criteria were met (Fugro, 2025b). In terms of impacts associated with installation of the pipeline, based on information from FEAST (Marine Scotland, 2013) deep-sea assemblages are considered to have high sensitivity to physical changes to the seabed and direct damage, displacement and disturbance from direct physical impact on the sponges (mainly trawling but also other activity such as installation of a gas pipeline). However due to the limited aggregations of deep sea sponges recorded within the proposed development area, the installation of the Tornado Development subsea infrastructure is unlikely to cause direct mortality to deep sea sponges.

Ocean quahog (*Arctica islandica*) has also been reported to inhabit the wider region surrounding the proposed Tornado Development. More specifically the Faroe-Shetland Sponge Belt NCMPA, within which part of the Tornado Development is located (approximately 18 km of the proposed Tornado pipeline), is designated for the conservation of *A. islandica*. However, no individuals were recorded in the macrofauna data at the proposed Tornado drill centre or within the pipeline route corridor survey, no potential relict shells were observed along the video transects and no live individuals or their distinctive siphons were noted during analysis of video footage and still photographs from the survey areas (Fugro, 2025a; 2025b). The introduction of a new stable hard substrata to the area will cause a direct reduction in suitable seabed habitat that could support ocean quahog, with Tillin *et al*. (2010) reporting the species as having a high sensitivity to physical change to another seabed habitat type and FeAST indicating that high rates of siltation may adversely affect ocean quahog, with the species having no tolerance and low recovery to the pressure (Marine Scotland, 2013).

Overall, the introduction of novel hard substrata by the Tornado Development is relatively small and localised (confined to an area of ca. 0.53 $km^2$ in the worst case) and, whilst it will represent a change to the benthic environment locally it is not expected to cause any widespread changes to the marine life present in the area.

In summary, the sensitivity of seabed communities to long term impacts from the installation of seabed infrastructure and protection / stabilisation material as a result of the Tornado Development is considered to be **Very High.** The habitats and species present are typical of this area (note, the impact to the Faroe-Shetland Sponge Belt NCMPA is discussed separately below), classed as being of national importance and of High value, and the overall resistance and resilience is Low as there will be a permanent change to the habitat type. However, the magnitude of impact is predicted to be **Minor** as although the impact will last the duration of the Tornado Development, the changes will be limited to a relatively small area (0.53 $km^2$). Effects on seabed communities from installation of seabed infrastructure and protection / stabilisation material are therefore assessed as **Minor** and not significant, given that any change to the benthic environment will be local and is not expected to cause any widespread changes to the marine life present in the area.

### Fish and Shellfish

As discussed in Section 4.3.3, a number of fish species are known to use the waters in the vicinity of the Tornado Development location, and some use the area as a spawning and / or nursery ground. ICES Rectangles 50E5 and 50E6 have been identified as a potential spawning ground for blue whiting and Norway pout. ICES Rectangles 50E5 and 50E6 also acts as a nursery area for blue whiting (high intensity), ling, mackerel, and Norway pout.

Temporary Impact

A number of studies have been conducted on the effects of sedimentation on fish egg development of commercially valuable fish species, particularly in relation to dredging operations. Results are variable

with some studies demonstrating mortality of fish eggs when smothered by even a thin veneer of sediment (DOER, 2000), however many studies show no significant effects on fish egg and larval development and mortality (Auld and Schubel, 1978; Kiørboe et al., 1981; DOER, 2000).

In summary, the sensitivity of spawning fish to the temporary seabed disturbance as a result of the Tornado subsea infrastructure installation is considered to be **Low** as the species present are typical of the wider area. The species present are typical of the wider area in this region of the WoS, although blue whiting, ling, mackerel and Norway pout, are listed as PMFs in Scottish waters, whereby this designation should seek to protect these features (refer to Section 4.3.3) and, as such, are of High value, but the overall resistance and resilience is Very High as recoverability is expected in the short term. The magnitude of impact is predicted to be **Negligible** with immeasurable changes in the baseline environment. Effects on spawning fish from the temporary seabed disturbance as a result of the Tornado Development are therefore assessed as **Negligible** and not significant.

Long Term Impact

The physical presence of the Tornado Development subsea infrastructure, pipelines and protection / stabilisation material on the seabed will provide a new stable hard substrata, resulting in the long term loss of seabed habitat within an area of ca. 0.53 km$^2$. However, the spawning grounds within which the Tornado Development area is located are part of wider spawning grounds and, as such, is not considered to be a key habitat for these fish species. As discussed in Section 4.3.3, ICES Rectangles 50E5 and 50E6 have been identified as a potential spawning ground for blue whiting and Norway pout.

In summary, the sensitivity of spawning fish to the long term disturbance as a result of the installation of seabed infrastructure pipelines and protection / stabilisation material as a result of the Tornado Development is considered to be **Low** as the species present are typical of the wider area. The species present are typical of the wider area in this region of the WoS, although blue whiting, ling, mackerel and Norway pout, are listed as PMFs in Scottish waters, whereby this designation should seek to protect these features (refer to Section 4.3.3) and, as such, are of High value, but the overall resistance and resilience is Very High as recoverability is expected in the short term. The magnitude of impact is predicted to be **Negligible** with immeasurable changes in the baseline environment. Effects on spawning fish from the installation of seabed infrastructure, pipelines and protection / stabilisation material are therefore assessed as **Negligible** and not significant.

### 7.3.3 Decommissioning Operations

As discussed in Section 3.6, on the cessation of production the Tornado field will be decommissioned in accordance with the requirements of the prevailing UK and international law. Decommissioning operations can result in temporary disturbance to the seabed. This includes (but not limited to):

- Seabed sampling for pre-decommissioning and post- decommissioning survey work;
- Localised dredging or jetting to allow access for cutting;
- Recovery of subsea infrastructure;
- Potential temporary wet storage of items following disconnection and prior to recovery;
- Temporary positioning of baskets for recovery of tie-in spools, flying leads and jumpers.

To note estimating the area of impact associated with the above decommissioning activities for the proposed Tornado Development is not included in this ES but will be captured in the impact assessments required prior to decommissioning activities commencing.

### 7.3.4 Impacts to the Faroe-Shetland Sponge Belt NCMPA

The proposed Tornado Development, more specifically, approximately 18 km of the Tornado to Tormore pipeline route is located within the Faroe-Shetland NCMPA. The NCMPA covers an area of 5,278 km$^2$ is designated for the protection of the following nine features of conservation interest (JNCC, 2014a):

- Deep sea sponge aggregations;
- Ocean quahog (*Arctica islandica*) aggregations;
- Atlantic and Arctic influenced offshore subtidal sand and gravel habitats;

- An area of the Faroe-Shetland Channel continental slope; and
- Five geodiversity (geomorphological) features representative of the West Shetland Margin paleo-depositional system and the West Shetland Margin Contourite Deposits key geodiversity areas.

The conservation objectives for the Faroe-Shetland Sponge Belt NCMPA (JNCC, 2018a) are that the protected features:

- so far as already in favourable condition, remain in such condition; and
- so far as not already in favourable condition, be brought into such condition, and remain in such condition.

Table 7.9 lists the conservation objectives with respect to each designated protected feature of the Faroe-Shetland NCMPA. All protected features of the NCMPA are in an unfavourable condition and need to be recovered to favourable condition. The exception to this is the area of the Faroe-Shetland Channel continental slope protected as an example of a large-scale feature, which is already in a favourable condition (JNCC, 2020).

**Table 7.9: Conservation Objectives of the Designated Features of the Faroe-Shetland Sponge Belt NCMPA (JNCC, 2018a)**

| Designated Feature | Conservation Objective |
|---|---|
| Deep-sea sponge aggregations | • Extent is stable or increasing; and<br>• Structures and functions, quality, and the composition of characteristic biological communities (which includes a reference to the diversity and abundance of marine fauna forming part of or inhabiting each habitat) are such as to ensure they remain in a condition which are healthy and not deteriorating.<br>Any temporary deterioration in condition is to be disregarded if the habitats are sufficiently healthy and resilient to enable their recovery from such deterioration. Any alteration to the features brought about entirely by natural processes is to be disregarded. |
| Offshore subtidal sands and gravels | |
| Ocean Quahog (*Arctica islandica*) | |
| Faroe-Shetland Channel Continental Slope | • Its extent, distribution and structure is maintained;<br>• Its function is maintained so as to ensure that it continues to support its characteristic biological communities (which includes a reference to the diversity of any species associated with the large-scale feature) and their use of the site for, but not restricted to, feeding, courtship, spawning, or use as nursery grounds; and<br>• The processes supporting it are maintained.<br>Any alteration brought about entirely by natural processes is to be disregarded. |
| Continental slope channels, Iceberg plough marks, Prograding wedges, Slide deposits, Sand wave fields and Sediment wave fields representative of the West Shetland Margin Paleo-Depositional System and West | • Their extent, component elements and integrity are maintained;<br>• Their structure and functioning are unimpaired; and<br>• Their surfaces remain sufficiently unobscured for the purposes of determining whether the points noted above are satisfied. |

| Designated Feature | Conservation Objective |
|---|---|
| Shetland Margin Contourite Deposits Key Geodiversity Areas | Any obscuring of the features entirely by natural processes is to be disregarded. Any alteration to the features brought about entirely by natural processes is to be disregarded |

### Potential Temporary Impacts on the Designated Features of the Faroe-Shetland Sponge Belt NCMPA

The proposed installation of the subsea infrastructure, pipelines, umbilical, protection / stabilisation materials and use of temporary laydown areas have the potential to impact the designated features of the NCMPA. In the worst case, the total area of temporary seabed disturbance within the Faroe-Shetland Sponge Belt NCMPA is estimated to amount to approximately 1.81 km$^2$ (0.034% of the total area of the NCMPA). This area is small in comparison to the area of similar habitat available within the Faroe-Shetland Sponge Belt NCMPA.

Offshore Subtidal Sands and Gravels

The habitat assessment results for Tornado highlighted the presence of the EUNIS biotope complex 'Arctic upper bathyal mixed sediment' (ME41) along the pipeline survey corridor along with EUNIS biotope complex 'Arctic upper bathyal mixed sand' (ME51) (refer to Section 4.3.2). Both of these habitat types are encompassed within the PMF 'Offshore subtidal sands and gravels'. Arctic bathyal sediments are the component biotope of 'Offshore subtidal sands and gravels', which is a designated priority habitat within Scottish waters (Tyler-Walters et al., 2016). However, both 'Arctic upper bathyal mixed sediment' (ME41) and 'Arctic upper bathyal sand' (ME51) are not included in the UK BAP priority habitat 'Subtidal sands and gravels' (BRIG, 2011).

There will be temporary disturbance within the NCMPA arising from the potential trenching and backfill operations, and installation of subsea infrastructure at Tormore estimated to amount to approximately 1.81 km$^2$ (0.034% of the NCMPA) (refer to Section 7.2.2 and 7.2.5). It is likely that a proportion of the sediments displaced for the purpose of pipeline laying and burial and temporarily deconstructing GRP structures at Tormore will become suspended in the bottom few metres of the water column. Within the vicinity of the proposed seabed infrastructure, the sediments are relatively coarse (sandy and gravelly) in nature which means that plumes or re-suspended sediment will tend to re-settle quickly and will not be prolonged or affect large areas. The trench and burial operations may also result in the temporary formation of mounds either side of the pipeline during the trenching phase which will be replaced during the burial phase. The FeAST Sensitivity Tool indicates a Low to High sensitivity to heavy siltation (e.g. pipeline and umbilical burial and trenching) (Tillin et al., 2010). Due to the temporary nature of these effects, no permanent changes to protected sediment or habitat types (offshore subtidal sands and gravels) are expected to occur as a result of the temporary impacts. Therefore, the conservation objectives to recover this feature are unlikely to be significantly impacted (refer to Table 7.9; JNCC, 2018a; 2018b).

Deep-sea Sponge Aggregations

Where oil and gas extraction occur in parts of the Faroe-Shetland Sponge Belt NCMPA where Deep-sea sponge aggregations occur, sponges can become dislodged and displaced, crushed or brought up to the surface, all of which can kill the sponges (ICES, 2009). These activities can therefore have a direct impact upon the extent and distribution of Deep-sea sponge aggregations within the site. The FeAST Sensitivity Tool indicates a High sensitivity to heavy siltation (e.g. pipeline and umbilical burial and trenching) (Tillin et al., 2010). As mentioned in Section 7.3.2, densities of sponges are highest in a very narrow depth range within the Faroe-Shetland Channel (400 m to 600 m depth), and are also correlated with sediment type; the highest densities are recorded where cobbles/cobble with boulders were the dominant substrate (Kazanidis et al., 2019). It should be noted that the majority of the Tornado Development is not located within this depth range.

However, due to observations of demosponges, the presence of 'Deep-sea sponge aggregations' was considered along the proposed pipeline route. The assessment found that along two sections of

transect PR_TR24 (located within the Faroe-Shetland Sponge Belt NCMPA), the density of demosponges satisfied the density criteria for the OSPAR threatened and/or declining habitat 'Deep-sea sponge aggregations'. However, according to Henry and Roberts (2014a) "sponge assemblages should confer a clear functional role for deep-sea sponge communities, e.g. enhanced associated biodiversity, support a distinct associated megafaunal assemblage, ecological symbioses, and/or create habitat for mobile fauna". In the Tornado survey, the faunal assemblages associated with sponges were similar to the surrounding assemblages. Additionally, the areas where sponges satisfied the density criterion did not exceed 25 $m^2$ (14 $m^2$ and 9 $m^2$ respectively) and therefore no qualifying criteria were met (Fugro, 2025b). Due to the limited aggregations of deep sea sponges recorded within the proposed development area, the installation of the Tornado Development subsea infrastructure is unlikely to directly significantly impact the objective to recover the extent, distribution, structure or function of deep sea sponge aggregations (refer to Table 7.9; JNCC, 2018a; 2018b).

Ocean Quahog (*Arctica islandica*)

No individuals of *A. islandica* were recorded in the macrofauna data within the pipeline route corridor survey, and no potential relict shells were observed along the video transects and no live individuals or their distinctive siphons were noted during analysis of video footage and still photographs from the survey area (Fugro, 2025b). In addition, no ocean quahog specimens were observed on camera or recorded in the macrofauna data within the vicinity of the Cambo and Rosebank development areas (MMT, 2019; Equinor, 2022). Ocean quahog are highly sensitive to physical pressures such as sediment deposition, as discussed in Sections 7.3.1 and 7.3.2, and therefore if present would be adversely impacted by the proposed Tornado Development. However, the temporary disturbance within the NCMPA is limited scale, amounting to approximately 1.81 $km^2$ (0.034% of the NCMPA) and therefore will not significantly impact the conservation objectives set for this feature (refer to Table 7.9; JNCC, 2018a; 2018b).

### Potential Long Term Impacts on the Designated Features of the Faroe-Shetland Sponge Belt NCMPA

Installation of the subsea infrastructure, pipelines, umbilical and rock protection / stabilisation material will result in the loss of sandy and gravelly sediment habitat from the area, and the introduction of novel hard substrata. In the worst case, the total area of long-term sandy and gravelly sediment habitat loss within the Faroe-Shetland Sponge Belt NCMPA is estimated to amount to approximately 0.386 $km^2$ (0.007% of the total NCMPA area) for the life of the Tornado Development (ca. 6 to 10 years) and beyond depending on how the infrastructure is decommissioned. This area is small in comparison to the area of similar habitat available within the Faroe-Shetland Sponge Belt NCMPA.

Offshore Subtidal Sands and Gravels

The habitat assessment results for the Tornado Development highlighted the presence of the EUNIS biotope complex 'Arctic upper bathyal mixed sediment' (ME41) along the pipeline survey corridor along with EUNIS biotope complex 'Arctic upper bathyal mixed sand' (ME51) (refer to Section 4.3.2). Both of these habitat types are encompassed within the PMF 'Offshore subtidal sands and gravels'. Arctic bathyal sediments are the component biotope of 'Offshore subtidal sands and gravels', which is a designated priority habitat within Scottish waters (Tyler-Walters et al., 2016). However, both 'Arctic upper bathyal mixed sediment' (ME41) and 'Arctic upper bathyal sand' (ME51) are not included in the UK BAP priority habitat 'Subtidal sands and gravels' (BRIG, 2011).These habitat types are characterized by mobile pebbles and cobbles; pressures that lead to penetration and disturbance could damage associated species through abrasion and by overturning surfaces could result in the smothering of fauna or reductions in respiration, feeding efficiency or fertilization of gametes in the water column. The FeAST Sensitivity Tool indicates a High sensitivity to penetration or disturbance of the substratum surface (i.e. subsea infrastructure, pre-lay rock carpets and post-lay rock cover) (Tillin et al., 2010).

These habitat types are, however, likely to be exposed to at least seasonal movement of substrata and this movement and scour maintains these biotopes by preventing species that require more stable habitats from colonizing and developing stable populations. In addition, the total area within the Faroe-Shetland Sponge Belt NCMPA where there will be a long-term change from a sediment dominated habitat to a more stable hard substrata (infrastructure and rock protection) as a result of the proposed

Tornado Development is very small, estimated to amount to approximately 0.386 km$^2$ (0.007% of the total NCMPA area).

Deep-sea Sponge Aggregations

As previously mentioned, the areas within the NCMPA where sponges satisfied the density criterion did not exceed 25 m$^2$ and therefore no qualifying criteria were met (Fugro, 2025b). Therefore, due to the limited aggregations of deep sea sponges recorded within the proposed development area, the installation of the Tornado Development subsea infrastructure will not significantly impact the conservation objective to recover deep sea sponge aggregations within the NCMPA.

Ocean Quahog (*A. islandica*)

No individuals of *A. islandica* were recorded in the macrofauna data within the pipeline route corridor survey area, and no potential relict shells were observed along the video transects and no live individuals or their distinctive siphons were noted during analysis of video footage and still photographs from the survey areas (Fugro, 2025b). The introduction of a new stable hard substrata to the area will cause a direct reduction in suitable seabed habitat that could support ocean quahog, with Tillin et al. (2010) reporting the species as having a high sensitivity to physical change to another seabed habitat type. However, the introduction of novel hard substrata by the Tornado Development within the NCMPA is relatively small and localised (confined to an area of 0.386 km$^2$, which equates to 0.007% of the total NCMPA area). Therefore, the conservation objectives to recover this feature will not be significantly impacted (refer to Table 7.9; JNCC, 2018a; 2018b).

Geomorphological (Geodiversity) Features

The Tornado Development is not located in proximity to the five geodiversity (geomorphological) features representative of the West Shetland Margin paleo-depositional system and the West Shetland Margin Contourite Deposits key geodiversity areas protected by the NCMPA (the closest features lies approximately 1.3 km south west of the proposed development), so is unlikely to have an effect on these features or significantly impact the conservation objectives associated with these features (refer to Table 7.9; JNCC, 2018a; 2018b). The Rosebank Development has proposed operations that will occur within the NCMPA. However, Ithaca is not aware of any construction activities that could be ongoing within the NCMPA during the period when the proposed Tornado Development operations within the NCMPA will be taking place (2027 and 2028); the pipeline installation operations for the Rosebank Development have already taken place.

Any long term disturbance caused by the proposed Tornado Development will result in a very small, permanent reduction in potential protected habitat type (0.007% of the total area of the Faroe-Shetland Sponge Belt NCMPA). As mentioned above, this will not result in a significant impact to achieving the site's conservation objectives (JNCC, 2018a; 2018b). Any other impacts are deemed temporary and of a small scale (0.034% of the Faroe-Shetland Sponge Belt NCMPA).

### In-Combination Effects

The overall area of seabed estimated to be permanently impacted by other projects within the Faroe-Shetland Sponge Belt NCMPA, based on publicly available information (noting that data was not available for all projects), in-combination with the proposed Tornado Development activities, is summarised in Table 7.10.

**Table 7.10: Total Estimated In-combination Permanent Seabed Impacts within Faroe-Shetland Sponge Belt NCMPA**

| Project | Area of Seabed Permanently Impacted within the NCMPA (km$^2$) | Distance to Tornado Development |
|---|---|---|
| Tornado Development | 0.386 [14] | - |
| Foinaven FPSO Offstation Decommissioning [1] | 0.031 | 29 km southeast |
| Rosebank Field Development [2] | 0.114 | 13.5 km west |

| Project | Area of Seabed Permanently Impacted within the NCMPA ($km^2$) | Distance to Tornado Development |
|---|---|---|
| 204/20a Drilling Campaign (7 wells) [3] | 0.124 | 25 km southeast |
| Schiehallion 204/25a Drilling [4] | 0.216 | 33 km southeast |
| Schiehallion 204/20a Drilling PX204 Well [5] | 0.009 | 30 km southeast |
| Glen Lyon Pipeline PL6305 [6] | 0.0031668 | 32 km southeast |
| Glen Lyon Sub-sea Phase A and Pipeline PL6491[7] | 0.000868 | 32 km southeast |
| Schiehallion Central Drill Centre Electrical Flying Lead (EFL) installation [8] | 0.00022 | 30 km southeast |
| Schiehallion Drilling of WI well 204/20a- IX215 [9] | 0.025 | 30 km southeast |
| Schiehallion, Glen Lyon FPSO, Drilling of Producer Well 204/20a [10] | 0.040 | 30 km southeast |
| Rosebank Phase 1 SURF Installation [11] | 0.174 | 13.5 km west |
| BP Subsea works Northwest, Central and West drill centres [12] | 0.00267 | 30 km southeast |
| **Total:** | **1.13** | - |
| **% of Faroe-Shetland Sponge Belt NCMPA Impacted[13]:** | **0.02** | - |

[1] FOINAVEN FPSO OFFSTATION DECOMMISSIONING PROGRAMMES (April 2022)
[2] Rosebank Environmental Statement ES/2022/001
[3] https://assets.publishing.service.gov.uk/media/67d82acc752bf117d6c15e82/DRA-1018_-_DR-2413-7_-_Redacted.pdf
[4] https://assets.publishing.service.gov.uk/media/677277dc94d6140e8459dc85/DR-2414-4_Redacted.pdf
[5] https://assets.publishing.service.gov.uk/media/682c765d5ba51be7c0f4530f/DR-2311-11_-_Redacted.pdf
[6] https://assets.publishing.service.gov.uk/media/66d1d8655e39b54bdb1833de/PLA-1012_-_PL-2392-5.pdf
[7] https://assets.publishing.service.gov.uk/media/681e05d9ced319d02c906083/PL-2486.pdf
[8] https://assets.publishing.service.gov.uk/media/667ac5097d26b2be17a4b2ed/PL-2459-1.pdf
[9] https://assets.publishing.service.gov.uk/media/67d989b3594182179fe087ab/ExtractPage1__007_.pdf
[10] https://assets.publishing.service.gov.uk/media/6798c676cfd3deafa04fdf42/DR-2311-8_Redacted__1_.pdf
[11] https://assets.publishing.service.gov.uk/media/67f689bb555773bbf109e246/PL-2549__002_.pdf
[12] https://assets.publishing.service.gov.uk/media/67efdedc27eb76c92cf7e569/PL-2531-1.pdf
[13] Total area of Faroe-Shetland Sponge Belt NCMPA = 5,278 $km^2$
[14] Total of permanent seabed disturbance arising from installation of pipelines and umbilical in 'Section 2' of the route (< 800 m), construction of pipeline crossings and the installation of subsea infrastructure at the Tormore manifold (refer to Table 7.4 and Table 7.8).

The long-term habitat loss resulting from the above listed projects represents a relatively small percentage of the NCMPA at ca. 0.02% and any impacts relating to the rock substrate (either rock which is introduced to the site or rock decommissioned in situ) are predicted to be highly localised. Of note, for Tornado although a small amount of new hard substrate may be introduced into the Faroe-Shetland Sponge Belt NCMPA if protection / stabilisation material is required, alongside the placement of the subsea infrastructure. Based on the small area of seabed that will be impacted (0.386 $km^2$), in comparison to the overall NCMPA area (5,278 $km^2$), no likely significant effects are predicted as a result of the proposed activities either alone or in-combination with other plans or projects.

In contrast, any temporary disturbance to the seabed within the NCMPA from the above listed projects is expected to recover it is assumed recovery will occur within the short to medium term as the WoS area is characterised by persistent, long-period swells, complex current regimes and rapidly changing weather conditions in the WoS. In addition, given the limited scale and duration of the disturbance, it is not anticipated to undermine the site's conservation objectives or result in an adverse effect on site integrity.

Given the above, it is therefore considered that in-combination impacts will not have a likely significant effect on the qualifying features of the NCMPA.

## 7.4 Mitigation Measures

Seabed disturbance impacts as a result of the proposed Tornado Development will be minimised by the implementation of the following mitigation measures:

- 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 and subsea operations commencing and, as part of chemical selection and assessment process, where practicable less hazardous alternatives will be sought in preference for any chemicals identified to be high risk (e.g. those with substitution warnings).
- Planned use of CAN-ductors will reduce the volume of cuttings being generated from the top hole section.
- Drill cuttings to be passed through the cuttings cleaning system on the MODU prior to discharge.
- A ROV and chemical dye will be used to monitor cement returns when cementing either the CAN-ductor option or the conductor and 20" casing option to help ensure the volume of cement discharged to the seabed is kept at a minimum.
- Route selection and optimisation will be based on acquired Environmental, Geophysical, and Geotechnical survey data, and minimises length through the Faroe-Shetland Sponge Belt NCMPA.
- Fishing intensity study carried out to define depth to which pipeline protection is required.
- Working corridors will be minimised as far as possible.
- Any boulders removed from the pipeline and umbilical lay corridors will be placed appropriately on the seabed to avoid a snag hazard and their as-left position recorded.
- Use of DP installation vessels as opposed to anchored vessels or anchored MODU.
- Rock will be deployed from a DP rock deposit vessel using a fall pipe and the rate and locations of deployment will be controlled on board the vessel and monitored using high resolution survey / sonar equipment.
- Size of subsea infrastructure will be optimised for the Tornado Development.
- Subsea infrastructure layout and pipeline crossing designs optimised to minimise material deposited.
- Monitoring of integrity of subsea infrastructure, including the pipeline / umbilical and stabilisation material throughout production operations and taking remedial action, if required. However, based on experience in the WoS area, subsea integrity is not expected to be an issue.
- Minimise amount of deposited material whilst still achieving the required level of stabilisation / protection in line with advice from the JNCC (JNCC, 2018b).

## 7.5 Residual Effects

In summary, no significant residual effects on water quality, seabed sediments, seabed communities or fish are predicted as a result of disturbance to the seabed during the life of the Tornado Development. The worst case total area of seabed that will be directly impacted temporarily by the Tornado Development is estimated at around 8.24 $km^2$, and the worst case total area of seabed that will be directly impacted in the long term by the Tornado Development is estimated at around 0.53 $km^2$. It is unlikely that both of these full areas will be affected due to the conservative disturbance areas

presented for pipeline installation operations. This is a relatively small area in comparison to the seabed available in the WoS region, with similar water depths, sediment types and benthic communities. It is, however, recognised that some aspects associated with the Tornado Development (i.e. installation of the subsea structures; pipelines and control umbilical; and associated protection / stabilisation material) will have longer term impacts on sediment communities, due to permanent habitat change, although direct physical injury of benthic species will only occur when the infrastructure or material is first placed on the seabed.

## 7.6 Transboundary Impacts

The Tornado Development lies approximately 6.5 km to the south east of the UK / Faroe Islands median line at its closest point. The environment within which the proposed Tornado Development area is located is relatively stable compared to other more heterogeneous and transient areas such as the southern North Sea. In the worst case, impacts arising from the Tornado Development extend out to 1.5 km (drill cuttings from the well locations) and therefore will not cross over the transboundary line. As such, significant transboundary impacts caused by seabed disturbance are not predicted.

## 7.7 Cumulative Impacts

The proposed Tornado Development lies within an area of moderate oil and gas activity (refer to Section 4.4.3) and will tie back into the existing Tormore subsea manifold in the Greater Laggan Area (GLA) development located approximately 79 km northeast of the proposed Tornado drill centre. The closest producing platforms to proposed Tornado Development area, namely the Clair Ridge DP and QU platforms (operated by BP), are located approximately 38 km southeast of the proposed pipeline route. As these fields are currently producing, the only activities that could result in cumulative seabed disturbance impacts are in the event of any maintenance construction work (e.g. spot rock-deposits) or incremental drilling activity. As such it is unlikely that there will be any significant cumulative impacts with respect to seabed disturbance and ongoing production activities.

As discussed in Section 7.3.4, other activities may cause a permanent seabed impact within the Faroe-Shetland Sponge Belt NCMPA. However, due to the relatively small percentage of the NCMPA at ca. 0.02%, permanently impacted, it is not anticipated that the proposed development and surrounding activities will undermine the site's conservation objectives or result in an adverse effect on site integrity.

In addition, Tornado is located approximately 9 km from the proposed Cambo development and 13 km from the proposed Rosebank development. Current project scheduling would not result in the overlap of operations. Therefore, significant cumulative effects are not predicted given the mitigation measures that will be in place for Tornado, coupled with the lack of proposed simultaneous operations resulting in seabed disturbance.

# 8 Underwater Noise Emissions

## 8.1 Introduction

Marine fauna, including fish and marine mammals, 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 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.

This section assesses whether the underwater noise emissions generated by the development of the Tornado field has the potential to result in a significant disturbance, or cause injury to, sensitive marine fauna.

In addition, the Conservation of Offshore Marine Habitats and Species Regulations 2017 make it an offence to deliberately capture, kill, injure or disturb any European Protected Species (EPS; species listed in Annex IV of the Habitats Directive, including all species of cetaceans), in such a way that is likely to:

a. Impair their ability to survive, to breed or reproduce, or to rear or nurture their young; or in the case the case of animals of a hibernating or migratory species, to hibernate or migrate;

b. Affect significantly the local distribution or abundance of the species to which they belong.

This section therefore also assesses if the Tornado Development activities, either alone or in combination with other activities, are likely to cause an offence involving an EPS.

## 8.2 Assessment of Impacts

### 8.2.1 Tornado Noise Sources

Development activities identified in the ENVID workshop which result in underwater noise emissions with the potential to result in significant effects on marine fauna were limited to the potential use of seismic sources (3 x 250 cubic inch airguns) during the contingent VSP survey as they form the greatest sound source in both power (i.e. pressure levels) and in character (i.e. as an impulsive sound).

It is acknowledged that the vessels associated with drilling, subsea installation, inspection and maintenance and decommissioning for the Tornado Development will also generate underwater noise of a continuous (non-impulsive) nature. The noise emissions from construction activities e.g. trenching or rock placement, are usually dwarfed by the noise emissions from the vessels themselves (DECC, 2011). In addition, no piling is planned, all subsea structures will be gravity based or use suction piles and therefore installation of these structures will not generate significant underwater noise emissions.

The MODU used to drill the Tornado wells will be held in place solely through the use of DP. The DP thrusters continually produce cavitation bubbles that, when they implode, leads to the generation of underwater noise (Fischer, 2000; Wyatt, 2008). In addition to the noise produced from the thrusters, sound will also propagate from rotating machinery such as generators, pumps and the drilling unit and risers (McCauley, 1994). Noise levels from drill ships whilst drilling have been measured at 195 dB re 1µPa @ 1 m and are generally broadband in frequency (40 – 600 Hz) but with greatest noise generated at lower frequencies (Nedwell and Edwards, 2004; Genesis, 2011; Wyatt, 2008).

For other vessels, sound levels and frequency characteristics are roughly related to ship size and speed, but there is significant individual variation among vessels of similar classes. Large vessels (greater than 100 m length) typically have sound pressure levels within the range of 180-190 dB re 1 µPa @ 1m, whilst most support vessels, assuming a medium-size ship (50 – 100 m in length), have sound pressure levels within the range of 165-180 dB re 1 µPa @ 1m (OSPAR, 2009b). The highest sound levels are expected from short-term energy-demanding activities, for example when using DP thrusters to position vessels on location (Genesis, 2011). The majority of the acoustic energy from vessels is below

1 kHz, typically within the 50-300 Hz range, although cavitation from propellers produces sounds at frequencies of between 1 kHz and 125 kHz (Genesis 2011; Hermannsen et al. 2014).

There is evidence that vessel traffic may influence marine mammals in several ways, with reported responses including avoidance, changes in swimming and surfacing patterns, alteration of the intensity and frequency of calls and increases in stress-related hormones (Erbe et al., 2019, Veirs et al. 2016, Rolland et al. 2012 and Dyndo et al. 2015). Harbour porpoise and minke whale have been shown to respond to vessels by moving away from them, while some other species, such as common dolphin, have shown attraction (Palka & Hammond, 2001). In addition, fish have been shown to avoid vessel traffic through diving, horizontal movements and tilting behaviours (De Robertis and Handegard, 2013). However, although vessel noise may cause localised changes in distribution of marine mammals and fish in the immediate vicinity of the vessel, the limited temporal scale of vessel use means these small-scale changes will not result in population level effects and therefore no significant impacts are predicted.

Given the above, this assessment is focused on the potential impact to marine fauna from the proposed VSP survey as the impulsive nature of the sound produced from this activity will result in the largest impact to marine fauna. The estimated source levels for the seismic airguns, based off data used in previous modelling for a similar noise source, as detailed in Barham and Mason (2022), are presented in Table 8.1.

**Table 8.1: Airgun Source Levels (Subacoustech, 2025)**

| Equipment | Estimated Source Level (@ 1m) Note 1 | |
|---|---|---|
| | $L_{p,pk}$ (dB re 1 µPa) | $L_{E,p,ss}$ (dB re 1 µPa$^2$s) |
| 3 x 250 cubic inch airguns | 232 | 215 |

Note 1
$L_{p,pk}$ = Sound Pressure Level peak ($SPL_{peak}$), the highest (zero-peak) positive or negative sound pressure, in decibels.
$L_{E,p,ss}$ = Sound Exposure Level, single strike ($SEL_{ss}$), calculation of the sound exposure level representative of a single noise impulse.

### 8.2.2 Underwater Noise Transmission

As sound spreads underwater, it decreases in intensity (attenuates) with distance from the source. The rate of attenuation is affected by 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, and the temperature, pressure, water column stratification, salinity and even weather (Munk and Zachariasen, 1991; Richardson et al., 1995). It also reflects and scatters at the sea surface, which varies depending on sea state conditions. Consequently, actual sound transmission has considerable temporal and spatial variability that is difficult to quantify.

In order to estimate the received sound pressure levels from the proposed VSP operations in the waters surrounding Tornado, Subacoustech was commissioned to undertake underwater sound propagation modelling in accordance with the recommendations in the National Physical Laboratory Good Practice Guide 133 for Underwater Noise (Robinson *et al.*, 2014). A copy of the underwater noise modelling report is provided for reference in Appendix D.

Modelling of underwater noise is complex and can be approached in several different ways. For this assessment, a numerical approach has been used based on two different solvers using the dBSea modelling software:

- A parabolic equation (PE) method for lower frequencies (12.5 Hz to 250 Hz); and
- A ray tracing method for higher frequencies (315 Hz to 100 kHz).

The PE method is widely used but has computational limitations at high frequencies. Ray tracing is more computationally efficient but is not suited to low frequency noise (Etter, 1991).

A wide array of input parameters including bathymetry, sediment data, sound speed and source frequency content were input into the model to ensure the results are as accurate as possible (Subacoustech, 2025). A summary of the key input parameters is provided in Table 8.2.

**Table 8.2: Modelling Input Parameters**

| Input Parameter | Tornado VSP Data |
|---|---|
| Modelling Location | 6,715,029 m; 421,638 m (ED50, UTM Zone 30N) |
| Location Depth | 1,057 m |
| Source Type (Equipment) | 3 x 205 cubic inch ($in^3$) airguns |
| Source Depth Below Surface | 5 m |
| Source Level | $L_{p,pk}$: 232 dB re 1 µPa @ 1 m<br>$L_{E,p,ss}$: 215 dB re 1 $\mu Pa^2s$ @ 1 m |

The results of the modelling are summarised below, with reference to the criteria used to assess the noise impact on relevant marine species; Popper et al. (2014) for fish and Southall et al. (2019) for marine mammals. Note, the Southall et al. (2019) paper is effectively an update of the previous Southall et al. (2007) paper and provides identical thresholds to those from the National Marine Fisheries Service (NMFS) (2018) guidance for marine mammals.

It should be stressed that while the modelling results present specific ranges at which impact thresholds are met, these ranges should be considered worst case in determining whether receptors will experience environmental effects during the proposed VSP operations.

### 8.2.3 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 swim bladder, 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:

- Category I - Fish with no swim bladder or other gas volume (particle motion detectors), such as flatfish, mackerel and sharks, skates and rays (Myrberg, 2001) and sandeels (Mason, 2013). These species tend to have relatively low auditory sensitivity;
- Category II - Fish with a swim bladder or other gas volume, and therefore susceptible to barotrauma (injury caused by increased air or water pressure), but where the organ is not involved in hearing (particle motion detectors);
- Category III - Fish with a swim bladder or other gas volume, and therefore susceptible to barotrauma, where the organ is also involved in hearing (sound pressure and particle motion detectors), such as cod and herring and relatives (Hawkins, 1993; Popper et al., 2014; DOSITS, 2017).

The adult fish community in the vicinity of the Tornado Development is dominated by demersal species such as Arctic skate, rockling, Greenland halibut, monkfish and deepwater species of eelpout. Species such as ling, blue whiting, mackerel and Norway pout are also predicted to have nursery and spawning grounds within the vicinity of the Tornado Development area. In addition, elasmobranch species such as porbeagle shark, Portuguese dogfish, spurdog, basking shark and leafscale gulper shark may be present in the area and Atlantic salmon and the common eel may move through the waters WoS as part of their respective yearly migrations (see Section 4.3.3). The majority of these species have a swim bladder which is either in close proximity, or mechanically connected to the ears and would therefore be classified as Category III fish. Although, Category III fish are more sensitive to noise, in general, marine species tend to have relatively poor auditory sensitivity, and generally cannot hear sounds at frequencies above 1 kHz (DOSITS, 2017). 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). Species that may spawn within the wider region surrounding the Tornado Development area include blue whiting, Norway pout, Arctic skate, halibut, Greenland halibut, roughhead grenadier, blue ling, tusk, monkfish and redfish (see Section 4.3.3).

Potential effects on fish from intense noise sources, such as those from VSP operations, range from behavioural changes including fish moving away from an area or ceasing feeding, to physiological changes such temporary hearing loss, tissue damage or even death (DOSITS, 2017). For this application, the effects of noise on fish have been assessed using the criteria from Popper et al. (2014) for seismic airguns (see Table 8.3).

**Table 8.3: Popper *et al.* (2014) Criteria for Seismic Airguns – Quantitative and Qualitative [1, 2, 3]**

| Fish Category | Mortality and Potential Mortal Injury | Impairment | | | Behaviour |
|---|---|---|---|---|---|
| | | Recoverable Injury | Temporary Threshold Shift (TTS) | Masking | |
| Category I fish | >219 $L_{E,p}$<br>>213 $L_{p,pk}$ | >216 $L_{E,p}$<br>>213 $L_{p,pk}$ | >>186 $L_{E,p}$ | (N) Low<br>(I) Low<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low |
| Category II fish | 210 $L_{E,p}$<br>>207 $L_{p,pk}$ | 203 $L_{E,p}$<br>>207 $L_{p,pk}$ | >186 $L_{E,p}$ | (N) Low<br>(I) Low<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low |
| Category III fish | 207 $L_{E,p}$<br>>207 $L_{p,pk}$ | 203 $L_{E,p}$<br>>207 $L_{p,pk}$ | 186 $L_{E,p}$ | (N) Low<br>(I) Low<br>(F) Moderate | (N) High<br>(I) High<br>(F) Moderate |
| Eggs and larvae | >210 dB $SEL_{cum}$<br>>207 $L_{p,pk}$ | (N) Moderate<br>(I) Low<br>(F) Low | (N) Moderate<br>(I) Low<br>(F) Low | (N) Low<br>(I) Low<br>(F) Low | (N) Moderate<br>(I) Low<br>(F) Low |

[1] N = Near-field, I = Intermediate-field, F = Far-field

[2] Where insufficient data on impacts are available (which is the case for masking and behavioural effects from airguns), qualitative criteria have been given, summarising the effect of the noise as having either a high, moderate or low effect on a receptor in either the near-field (tens of metres), intermediate field (hundreds of metres), or far-field (thousands of metres). These qualitative effects are not investigated further.

[3] $L_{p,pk}$ = peak SPL, $L_{p,RMS}$ = Root Mean Square (RMS) SPL and $L_{E,p}$ = SEL

Where cumulative thresholds are required for fish, both a stationary and fleeing animal model has been used. Most species described by Popper et al. (2014) are likely to move away from a sound that is loud enough to cause harm (Dahl et al., 2015; Popper et al., 2014). For those species that flee, a speed of 1.5 m/s (based on Hirata, 1999) is considered a conservative speed at which to base a fleeing animal model. However, considering the diversity of species described by Popper et al. (2014), whether an animal flees or remains stationary in response to a loud noise will differ between species. It is recognised that there is limited evidence for fish fleeing from high level noise sources in the wild. Those species that are likely to remain stationary are thought more likely to be benthic species or species without a swim bladder, due to their reduced hearing capabilities making these species the least sensitive to noise (e.g., Goertner et al., 1994, 1978; Stephenson et al., 2010; Halvorsen et al., 2012). Despite this, including only a stationary animal model as a worst-case scenario is likely to greatly overestimate the potential risk to fish species. Therefore, this assessment considers impact ranges from both fleeing and stationary receptors.

Table 8.4 gives the predicted maximum impact ranges for species of fish as a result of the underwater noise generated from the proposed VSP operations, using the Popper et al. (2014) criteria.

**Table 8.4: Predicted Maximum Impact Ranges for Fish (from Seismic Airguns), based on Popper et al., 2014 Thresholds (Subacoustech, 2025)[1]**

| Criteria | Maximum Impact Range[2] | | |
|---|---|---|---|
| | Category I fish | Category II fish | Category III fish |
| **Mortality and Potential Mortal Injury** | | | |
| $L_{p,pk}$ | < 10 m | 20 m | 20 m |
| $L_{E,p,24h}$ (Fleeing 1.5 $ms^{-1}$) | < 10 m | 10 m | 10 m |
| $L_{E,p,24h}$ (Stationary) | 50 m | 120 m | 170 m |
| **Recoverable Injury** | | | |
| $L_{p,pk}$ | < 10 m | 20 m | 20 m |
| $L_{E,p,24h}$ (Fleeing 1.5 $ms^{-1}$) | < 10 m | 10 m | 10 m |
| $L_{E,p,24h}$ (Stationary) | 60 m | 270 m | 270 m |
| **Temporary Threshold Shift (TTS)** | | | |
| $L_{p,pk}$ | - | - | - |
| $L_{E,p,24h}$ (Fleeing 1.5 $ms^{-1}$) | 50 m | 50 m | 50 m |
| $L_{E,p,24h}$ (Stationary) | 5,100 m | 5,100 m | 5,100 m |

**Notes**

[1] For Popper et al., 2014 Thresholds see Table 8.3.

[2] Values and impact ranges below 10 m have not been presented as the modelling processes are unable to specify any greater level of accuracy at these ranges with confidence.

It can be seen from Table 8.4 that according to the peak sound pressure level ($SPL_{peak}$ or $L_{p,pk}$) metric, the largest predicted range for the threshold of mortality is predicted for fish with a swim bladder (involved and not involved in hearing) at 20 m from the airguns.

Using the sound exposure level (SEL or $L_{E,p}$) metric, the largest predicted range for the threshold for mortality is predicted for fish with a swim bladder (involved and not involved in hearing) at 10 m from the airguns if they are assumed to flee from the source. If they are assumed to remain stationary, the largest predicted range for mortality is for fish with a swim bladder involved in hearing at 170 m from the airguns.

Using the sound exposure level (SEL or $L_{E,p}$) metric, the largest predicted range for the threshold for recoverable injury is predicted for fish with a swim bladder (involved and not involved in hearing) at 270 m from the airguns, if they are assumed to remain stationary. Using the sound exposure level (SEL or $L_{E,p}$) metric, the largest predicted range for the threshold of Temporary Threshold Shift (TTS) is at 50 m (all fish categories), if they are assumed to flee from the source, and is at 5.1 km from the airguns (all fish categories), if they are assumed to remain stationary.

However, it is worth noting that that a stationary receptor is likely to be over-precautionary as it involves a receptor staying in the same location throughout the entire VSP operation (Subacoustech, 2025).

Most noise produced by fish is related to reproduction, therefore many fish are more receptive and more sensitive to introduced noise during reproductive periods and spawning events. Disturbance to fish during key lifecycle events may have greater impacts at a population level as it could deter individuals away from crucial habitats. The waters surrounding the Tornado field have been identified as spawning and nursery grounds for a number of fish species (refer to Section 4.3.3). However, the area likely to be impacted by the proposed VSP operations is considered to represent only a small proportion of the spawning and nursery grounds available to each fish species. In addition, as the proposed VSP operations will be temporary (occurring for approximately 24 hours) they will not be conducted over an entire spawning / nursery period for any one species and are therefore unlikely to result in significant disruption.

The sensitivity of fish to the underwater noise generated during the proposed VSP operations is therefore considered to be **High**; the receptor is of Very High value as many of the species that may be present in the Tornado area (e.g. blue whiting, Norway pout, Greenland halibut, ling, mackerel, anglerfish (monkfish), Atlantic salmon, common eel, spurdog, basking shark and porbeagle shark) are listed as Priority Marine Features (PMFs) in Scottish waters (see Section 4.3.3), but has some tolerance / ability to adapt to effects (High resistance and resilience). Based on the assessment as detailed above, the magnitude of impact is predicted to be **Minor** as any impacts will be in fairly close proximity to the source and the period during which fish may encounter sound from the proposed operations is short, with VSP operations anticipated to only be ongoing for approximately 24 hours. With the implementation of an airgun soft-start procedure (refer to Section 8.3), it is expected that the majority of fish in the area would be able to disperse to areas where injury or mortality would not occur. Furthermore, if fish are disturbed by sound, evidence suggests they will return to an area once the activity causing the disturbance has ceased (Slabbekoorn et al., 2010). Effects on fish are therefore considered to be **Minor** and not significant.

It is also noted that fish are an important food source for seabirds and marine mammals. As such, seabirds and marine mammals could be indirectly impacted by changes in the abundance of fish; however, given the relatively small impact range for fish, indirect impacts on seabirds and marine mammals are not predicted to be significant.

### 8.2.4 Potential Impacts on Marine Mammals

#### Introduction

Marine mammals, in particular, cetaceans, rely almost exclusively on sound for navigating, foraging, breeding and communicating (Clark, 1990; Edds-Walton 1997; Tyack and Clark, 2000). The extent to which intense underwater sound might adversely impact a species is dependent upon the incident sound level, sound frequency, and duration of exposure and/or repetition rate of the sound wave.

The Southall et al. (2019) guidance groups marine mammals into categories of similar species and applies filters to the unweighted noise to approximate the hearing sensitivities of the receptor. The hearing groups given in Southall et al. (2019) are summarised in Table 8.5, along with the corresponding marine mammal species that have been recorded WoS (some of these are resident, whilst others use the Faroe-Shetland Channel as a migratory pathway).

**Table 8.5: Marine Mammal Hearing Groups and their Generalised Hearing Range (Southall et al., 2019)**

| Functional Group | Estimated Auditory Bandwidth | Marine Mammal Species Found WoS [1] |
|---|---|---|
| Low-frequency (LF) cetaceans | 7 Hz – 35 kHz | Minke whale, humpback whale, fin whale, sei whale |
| High-frequency (HF) cetaceans | 150 Hz – 160 kHz | White-sided dolphin, white-beaked dolphin, common dolphin, Risso's dolphin, striped dolphin, long-finned pilot whale, sperm whale, killer whale, northern bottlenose whale, bottlenose dolphin, beaked whales |
| Very High-frequency (VHF) cetaceans | 275 Hz – 160 kHz | Harbour porpoise |
| Phocid carnivores in water (PCW) | 50 Hz to 86 kHz | Harbour seal, Grey seal |

[1] See Section 4.3.5

#### Physiological Impacts

When marine mammals are exposed to intense sound, an elevated hearing threshold may occur, known as a threshold shift (TS). If the hearing threshold returns to the pre-exposure level after a period

of time, the TS is known as a temporary threshold shift (TTS). If the threshold does not return to the pre-exposure level, it is known as a permanent threshold shift (PTS) and is considered to result in injury (Finneran et al., 2000; Southall et al., 2007).

Southall et al. (2019) gives individual criteria for marine mammal hearing groups based on whether the noise is considered impulsive or non-impulsive. The study categorises impulsive noises as having high peak sound pressure, short duration, fast rise-time and broad frequency content at source, and non-impulsive sources as steady-state noise. Seismic airguns are considered an impulsive noise, whereas drilling, as well as other more low-level, continuous noises, such as that generated by vessel activity, are considered non-impulsive. These differences are important to consider regarding the potential for auditory injury, as impulsive noise is generally more injurious than non-impulsive noise.

Southall et al. (2019) also presents single pulse, unweighted peak sound pressure level ($SPL_{peak}$ or $L_{p,pk}$) and cumulative weighted sound exposure level ($SEL_{cum}$ or $L_{E,24h,wtd}$) criteria for both onset of PTS and TTS . To account for the fact that different species groups use and hear sound differently, the thresholds in the cumulative weighted sound exposure level metric incorporate auditory weighting functions. As dual metrics, onset of PTS /TTS is considered to have occurred when either one of the two metrics is exceeded.

The predicted maximum PTS and TTS impacts ranges using the impulsive criteria for marine mammals for the airgun array associated with the proposed VSP operations are summarised in Table 8.6.

**Table 8.6: Predicted Marine Mammal PTS / TTS Maximum Impact Ranges, based on Southall et al. (2019) Impulsive criteria (Subacoustech, 2025) [1]**

| Hearing Group [2] | Threshold (Unweighted $L_{p,pk}$) | Max Impact Range | Threshold (Weighted $L_{E,24h,wtd}$) [3] | Max Impact Range |
|---|---|---|---|---|
| **PTS Onset (Impulsive)** | | | | |
| LF cetaceans | 219 dB | < 10 m | 183 dB | 10 m |
| HF cetaceans | 230 dB | < 10 m | 185 dB | < 10 m |
| VHF cetaceans | 202 dB | 40 m | 155 dB | < 10 m |
| PCW | 218 dB | < 10 m | 185 dB | < 10 m |
| **TTS Onset (Impulsive)** | | | | |
| LF cetaceans | 213 dB | < 10 m | 168 dB | 270 m |
| HF cetaceans | 224 dB | < 10 m | 170 dB | < 10 m |
| VHF cetaceans | 196 dB | 70 m | 140 dB | 10 m |
| PCW | 212 dB | 10 m | 170 dB | 10 m |

[1] Values and impact ranges below 10 m have not been presented as the modelling processes are unable to specify any greater level of accuracy at these ranges with confidence.
[2] LF = Low-frequency, HF = High-frequency, VHF = Very high-frequency and PCW = Phocid carnivores in water (see generalised hearing ranges in Table 8.5).
[3] For the $L_{E,24h,wtd}$ modelling a fleeing animal model has been assumed. The fleeing animal model assumes that marine mammals flee from the source at a constant rate of 1.5 $ms^{-1}$ (Otani et al., 2000), with the exception of LF cetaceans, which flee at a rate of 3.25 $ms^{-1}$ (Blix and Folkow, 1995).

Using the unweighted peak SPL ($L_{p,pk}$) criteria, the very high frequency (VHF) cetacean group are predicted to have the largest PTS impact ranges, with animals within 40 m of the airguns likely to exceed the PTS threshold for VHF cetaceans.

When the weighted cumulative SEL ($L_{E,24h,wtd}$) criteria for impulsive noise is applied to the predicted noise contours, the low frequency (LF) cetacean group are predicted to have the largest PTS impact ranges. Animals within 10 m of the airguns at the start of the survey are predicted to exceed the PTS threshold for LF cetaceans, under the impulsive criteria. This assumes that the VSP equipment is continuously operational for 24 hours, and that the animals flee away from the noise source at a constant speed.

To put the modelling results into context, Table 8.7 calculates the number of animals which may be exposed to PTS / TTS onset using the density and abundance estimates from the Marine Mammal Management Units (MMMU) of relevance to the Tornado field (refer to Section 4.3.5). Note estimated

density and abundance is only available for those species which are commonly observed in the Greater North Sea area. The number of harbour seals and grey seals has not been calculated due to the extremely low density (0.00% of the at-sea population per 25 $km^2$) found in the vicinity of Tornado. It can be seen from Table 8.7 that for all species it is predicted that less than one individual may be injured by the proposed VSP operations or experience a temporary, recoverable reduction in hearing sensitivity. This number is small enough that there would be no effect at the population level, based on the percentage of the corresponding reference population potentially impacted.

Given the above, the sensitivity of marine mammals to physiological impacts has been evaluated as **Very High**; the receptor is of international importance (Very High value) and has limited tolerance / ability to adapt to the effect (Low to Medium resistance and resilience). As there is the potential for individuals to be permanently physically injured as a result of the proposed VSP operations, albeit only a very small number, the magnitude of the impact has been assessed as **Moderate**, although it should be noted that the period during which individuals may encounter sound from the proposed operations is relatively short (VSP operations may be ongoing for approximately 24 hours) and individuals are likely to move out of the area of impact once the proposed VSP operations have commenced. Effects on marine mammals due to PTS / TTS onset as a result of the underwater noise emissions generated from the proposed VSP operations are therefore predicted to be **Moderate** and significant prior to the implementation of operational mitigation measures. However, the possibility of PTS / TTS impacts occurring will be significantly reduced with the use of a 500 m mitigation zone, since VSP operations will not commence until monitoring confirms that the area is clear of marine mammals. Soft-starts will also be incorporated into the survey design (see Section 8.3). Residual effects on marine mammals are therefore reduced to **Minor** and would not be significant.

**Table 8.7: Estimated Number of Animals Potentially Experiencing PTS / TTS from the proposed Tornado VSP Operations [1, 2, 3]**

| Species | Management Unit | Abundance | Estimated Density in Area (animals / km$^2$) | Southall et al. (2019) Unweighted $L_{p,pk}$ criteria | | | | Southall et al. (2019) Weighted $L_{E,24h,wtd}$ criteria (fleeing) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | PTS | | TTS | | PTS | | TTS | |
| | | | | Max number of animals impacted | Approx. % of reference population | Max number of animals impacted | Approx. % of reference population | Max number of animals impacted | Approx. % of reference population | Max number of animals impacted | Approx. % of reference population |
| Harbour porpoise | North Sea (678,206 km$^2$) | 346,601 | 0.511 | < 1 | 0.0003 % | < 1 | 0.0003 % | < 1 | 0.0003 % | < 1 | 0.0003 % |
| | West Scotland (343,035 km$^2$) | 28,936 | 0.084 | < 1 | 0.0035 % | < 1 | 0.0035 % | < 1 | 0.0035 % | < 1 | 0.0035 % |
| Bottlenose dolphin[4] | Greater North Sea (639,886 km$^2$) | 2,022 | 0.003 | < 1 | 0.049 % | < 1 | 0.049 % | < 1 | 0.049 % | < 1 | 0.049 % |
| | Oceanic Waters (559,408 km$^2$) | 70,429 | 0.126 | < 1 | 0.0014 % | < 1 | 0.0014 % | < 1 | 0.0014 % | < 1 | 0.0014 % |
| Risso's dolphin | Celtic and Greater North Seas (1,560,875 km$^2$) | 12,262 | 0.007 | < 1 | 0.0082 % | < 1 | 0.0082 % | < 1 | 0.0082 % | < 1 | 0.0082 % |
| Common dolphin | | 102,656 | 0.065 | < 1 | 0.0009 % | < 1 | 0.0009 % | < 1 | 0.0009 % | < 1 | 0.0009 % |
| Minke whale | | 20,118 | 0.012 | < 1 | 0.005 % | < 1 | 0.005 % | < 1 | 0.005 % | < 1 | 0.005 % |
| White-beaked dolphin | | 43,951 | 0.028 | < 1 | 0.0023 % | < 1 | 0.0023 % | < 1 | 0.0023 % | < 1 | 0.0023 % |
| White-sided dolphin | | 18,128 | 0.011 | < 1 | 0.0055 % | < 1 | 0.0055 % | < 1 | 0.0055 % | < 1 | 0.0055 % |

**Notes**

[1] See Section 4.3.5 for MMMU abundance and population data; taken from IAMMWG (2022).

[2] Calculation method based on Southall et al. (2007) as recommended by JNCC (2010): impact area x density

[3] Max number of animals impacted has been rounded up to a whole number.

[4] Bottlenose dolphins are more prominent in shelf waters and are therefore unlikely to be found in the deep waters of the Faroe Shetland Chanel where the proposed VSP operations will be undertaken (Thompson et al., 2011)

### Behavioural Impacts

Marine mammals may also experience behavioural impacts in response to underwater noise emissions. Examples of behavioural responses include orientation or attraction to or from the noise source, increased alertness, modification of their own sound production characteristics, change in movement or diving behaviour, temporary change in habitat use and, in severe cases, panic, fleeing, or stranding behaviour, which may indirectly result in injury or death.

Southall et al. (2019) do not provide quantitative thresholds for disturbance to marine mammals from impulsive or non-impulsive noise sources. For SACs in UK waters, a minimum Effective Deterrent Range (EDR) of 12 km has been proposed by JNCC for assessing the significance of noise disturbance to harbour porpoise (VHF cetacean) from seismic operations (JNCC, 2020). This value is based on two studies of harbour porpoise deterrence during seismic surveys, namely a reduction in acoustic activity within 10 km of a 2D survey using a 470 cubic inch capacity airgun array (Thompson et al., 2013) and a reduction in acoustic activity within ranges between 8 and 12 km away from a larger 3D seismic survey (3,570 $in^3$) (Sarnocińska et al., 2020). In the absence of agreed metrics for measuring marine mammal disturbance outside of SACs, an EDR of 12 km has been applied for all species in this assessment.

Using an EDR of 12 km, Table 8.8 calculates the number of animals which may experience some sort of behavioural impact using the density and abundance estimates from the MMMUs of relevance to the Tornado field.

**Table 8.8: Estimated Number of Animals Potentially Experiencing Behavioural Impacts from the Proposed Tornado VSP Operations [1,2]**

| Species | Management Units | MMMU Data (IAMMWG, 2022) | | Behavioural Changes | |
|---|---|---|---|---|---|
| | | Abundance | Estimated Density in Area (animals / $km^2$) | Max number of animals impacted | Approx. % of reference population |
| Harbour porpoise | North Sea (678,206 $km^2$) | 346,601 | 0.511 | < 232 | 0.067 |
| | West Scotland (343,035 $km^2$) | 28,936 | 0.084 | < 39 | 0.135 |
| Bottlenose dolphin | Greater North Sea (639,886 $km^2$) | 2,022 | 0.003 | < 2 | 0.100 |
| | Oceanic Waters (559,408 $km^2$) | 70,429 | 0.126 | < 57 | 0.081 |
| Risso's dolphin | Celtic and Greater North Seas (1,560,875 $km^2$) | 12,262 | 0.007 | < 4 | 0.033 |
| Common dolphin | | 102,656 | 0.065 | < 30 | 0.029 |
| Minke whale | | 20,118 | 0.012 | < 6 | 0.030 |
| White-beaked dolphin | | 43,951 | 0.028 | < 13 | 0.030 |
| White-sided dolphin | | 18,128 | 0.011 | < 5 | 0.028 |

[1] See Section 4.3.5 for MMMU abundance and population data.
[2] Calculation method based on Southall et al. (2007) as recommended by JNCC (2010): impact area x density

It can be seen from Table 8.8 that although the number of individual cetaceans which could temporarily exhibit some form of change in behaviour for the period in which they encounter sound from the proposed VSP operations ranges from less than 2 for bottlenose dolphin to less than 232 for harbour porpoise, the percentage of the corresponding reference population impacted is comparatively low (less than 1%) for all species.

It should be noted, however, that the proposed VSP operations will only be ongoing for approximately 24 hours. Temporarily affecting a small proportion of a population is highly unlikely to result in population level effects. In addition, behavioural changes such as moving away from an area for short periods of time, reduced surfacing time, masking of communication signals or echolocation clicks, vocalisation changes and separation of mothers from offspring for short periods, do not necessarily imply that detrimental effects will result for the animals involved (JNCC, 2010).

Given the above, the sensitivity of marine mammals to behavioural impacts has been evaluated as **High**; the receptor is of international importance (Very High value) but is generally tolerant of behavioural effects and will immediately recover once operations cease (High resistance and resilience). The magnitude of impact is predicted to be **Minor** as the period during which marine mammals may encounter sound from the proposed operations is short and individuals are likely to move out of the area of impact once the proposed operations have commenced. Any behavioural impacts will be short term and temporary and will cease once the VSP operations have been completed and there will be no long-term reduction in the size of their available habitat, with individuals returning to the area on completion of the operations. Effects on marine mammals due to behavioural impacts as a result of the underwater noise emissions generated from the VSP operations are therefore predicted to be **Minor** and are not considered to result in significant effects on the environment. However, operational measures will be implemented, as outlined in Section 8.3, to ensure behavioural impacts are minimised as much as possible.

### 8.2.5 European Protected Species (EPS) Risk Assessment

JNCC has produced good practice guidelines (JNCC, 2010) and protocols for marine industries on how to assess the likelihood of committing an offence under The Conservation of Offshore Marine Habitats and Species Regulations 2017, how to avoid it and whether a licence to carry out activity might be required or not. It is considered that adherence to these guidelines constitutes best practice and will minimise the risk of committing an injury offence.

To reduce the risk of deliberate injury to any EPS, Ithaca will ensure that the JNCC protocol for minimising the risk of injury to marine mammals from geophysical surveys (JNCC, 2017b) is followed.

With regards to a disturbance offence, this 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 EPS is unlikely to result from single, short term operations such as the proposed Tornado VSP operations. Although the activity may result in temporary sporadic disturbance to cetaceans, it is unlikely to impair the ability of an animal to survive or reproduce nor result in significant effects on the local abundance or distribution.

Given the above, the proposed Tornado VSP survey will therefore not constitute an offence under The Conservation of Offshore Marine Habitats and Species Regulations 2017. However, in order to minimise the risk of disturbance to an EPS, mitigation measures have been proposed in Section 8.3.

### 8.2.6 Potential Impacts on Seabirds

Direct effects on seabirds from the underwater noise generated during the proposed VSP operations could occur through physical damage, or through disturbance of normal behaviour. The proposed Tornado Development is located within an important area for storm petrel, northern gannet and northern fulmar in the breeding season. During the winter months, black-legged kittiwake and northern fulmar are predicted to be found in comparatively higher densities in the Faroe-Shetland Channel, with guillemot also present during the post-dispersal period (refer to Section 4.3.4).

There is little information on the ability of seabirds to hear underwater, although it is thought that they have relatively poor hearing, with peak hearing sensitivity below 2 kHz (Dooling and Therrien, 2012). Surface diving seabirds are considered to be more at risk of underwater noise emissions as they spend

longer periods of time below the water compared to seabirds which forage by surface feeding or plunge diving. Noise modelling undertaken on diving species including gannet, puffin, guillemot and razorbill indicates that if the species spend a period of up to 2 minutes underwater then the potential for physical impact is generally localised and extends up to 42 m from the airgun, while if a species spends less than 30 seconds underwater, the extent of physical impact is likely to less than 20 m from the airgun (BEIS, 2016). However, mortality of seabirds has not been observed during extensive seismic operations in the North Sea and elsewhere. While there is some evidence of noise induced changes in the distribution and behaviour of diving birds in response to impulsive underwater noise, these have been temporary and may be a direct disturbance or reflect a change in prey distribution during that period (BEIS, 2019a).

Given the above, the sensitivity of seabirds to underwater noise from the proposed VSP operations has been evaluated as **High**; seabirds are of international importance (Very High value) but any impacts are likely to be temporary caused by displacement, with the majority of birds likely to have vacated the area due to disturbance before the airguns start firing (High resistance and resilience). The magnitude of impact is predicted to be **Minor** due to the low duration (24 hours) and limited scale of the proposed VSP operations. In addition, there is alternative foraging habitat available to the seabirds in the wider area. Effects on seabirds as a result of the underwater noise emissions generated from the proposed survey operations are therefore **Minor** and are not considered to result in significant effects on the environment.

## 8.3 Mitigation Measures

As noted in Section 8.2.4, the use of soft start procedures and the 500 m mitigation zone is important to reduce the overall impact of the proposed VSP survey operations on marine mammals. Ithaca will therefore ensure that the survey contractor follows the JNCC protocol for minimising the risk of injury to marine mammals from geophysical surveys (JNCC, 2017b). Specifically, this will involve applying the following measures:

- Use the lowest practicable power levels needed to achieve the survey objectives;
- Pre-shooting surveys and soft-starts will be incorporated into the survey design. A soft-start will be conducted by slowly increasing the seismic source power. The soft-start will be planned to commence during daylight hours;
- A marine mammal observer (MMO) and Passive Acoustic Monitoring (PAM) operator will be onboard the MODU to monitor for the presence of marine mammals within a 500 m mitigation zone during the pre-shooting search and soft-start procedure;
- All observations (MMO or PAM) will be undertaken during a pre-shooting search for 60 minutes, i.e. prior to the commencement of any use of the seismic source as water depths are greater than 200 m. The longer search period is to allow for deep diving species (e.g. sperm whale and beaked whale) which are known to dive for longer than 30 minutes. If marine mammals are detected in the 500 m mitigation zone during the pre-shooting search then operations must be delayed until their passage, or the transit of the vessel, results in the marine mammals being outside of the mitigation zone. Either way there should be a minimum of a 20-minute delay from the time of the last sighting within the mitigation zone and the commencement of the soft-start procedure, to allow animals unavailable for detection to leave the area.
- In line with the JNCC guidelines, during VSP operations the breaks taken to reposition geophones are treated in the same manner as line changes. Where geophone repositioning is expected to take longer than 40 minutes:
    - Firing is to be terminated during geophone repositioning;
    - A pre-shooting search will be undertaken during geophone repositioning;
    - The soft start procedure is to be delayed if marine mammals are sighted within the 500 m mitigation zone during the pre-shooting search;
    - A full 20-minute soft-start will be undertaken before restarting VSP data collection.

- For unplanned breaks of longer than 10 minutes (e.g. if the acoustic output of the survey equipment ceases due to a technical problem), a full pre-shooting search and soft-start will be carried out before the survey re-commences. For unplanned breaks of less than 10 minutes, there is no requirement for a soft-start and firing can recommence at the same power level as at prior to the break (or lower), provided no marine mammal(s) have been detected in the mitigation zone during the breakdown period. If marine mammals are detected there must be a minimum of a 20 minute delay from the time of the last detection within the mitigation zone and a soft-start must then be undertaken. For planned breaks the same procedures will be applied; however, if the planned break is for less than 10 minutes, the MMO must begin monitoring 20 minutes prior to the planned break and continue for the duration of the break.

The use of soft-start procedures, as described above, is also likely to reduce the impact of acoustic emissions on other marine species as it allows mobile species, such as fish, to move out of the area of greatest impact.

## 8.4 Residual Effects

In summary, it is possible that short term behavioural effects may be observed among marine mammals, fish and seabirds as a result of the underwater noise emissions generated from development of the Tornado field, but any impacts will be mitigated by adherence to the mitigation measures detailed in Section 8.3 such that any residual effects are predicted to be **Minor** and not significant.

## 8.5 Transboundary Impacts

The Tornado field lies approximately 6.5 km to the south east of the UK / Faroe Islands median. There is therefore the potential for transboundary impacts on fish, marine mammals and seabird species from the underwater noise emissions generated by the proposed Tornado Development activities, particularly as these mobile species forage over wide areas.

The proposed VSP survey will result in the largest impact to marine fauna, due to the impulsive nature of the sound produced from this activity. For fish, noise modelling indicates that using the sound exposure level (SEL or $L_{E,p}$) metric, the largest predicted range for the threshold of TTS is at 50 m (all fish categories), if they are assumed to flee from the source, and is at 5.1 km from the airguns (all fish categories), if they are assumed to remain stationary. Significant transboundary impacts to fish species are therefore not predicted as any impacts will be in fairly close proximity to the source and the period during which fish may encounter sound from the proposed operations is short.

Seabirds are likely to be displaced by the proposed development operations to adjacent sea areas, but given distance to the transboundary line and the abundant alternative foraging habitat in the wider area significant transboundary impacts are not predicted.

It is noted that marine mammals could experience PTS impacts during the proposed VSP operations, but the risk of deliberately injuring a marine mammal would be mitigated by the implementation of the JNCC protocol for minimising the risk of injury to marine mammals from geophysical surveys (JNCC, 2017b) (see Section 8.3). It is also acknowledged that marine mammals are likely to exhibit some form of change in behaviour during the proposed Tornado Development activities. However, any behavioural impacts will be short term and temporary and will cease once the development activities have been completed. As such, significant transboundary impacts to marine mammals are not predicted.

## 8.6 Cumulative Impacts

There is the potential for underwater noise emissions to have a cumulative impact on marine fauna, particularly on marine mammals, if impulsive noise was generated from other anthropogenic sources (e.g. seismic or piling from other WoS oil and gas activity) within a similar timeframe. Note, there are no renewable energy projects in the vicinity of the Tornado field that could generate underwater noise during the proposed operations.

The closest producing fields to the proposed Tornado drill centre location are the Alligin, Loyal and Schiehallion oil fields (operated by BP), developed through the Glen Lyon FPSO, which is located approximately 30 km southeast of the Tornado drill centre. The Clair Ridge and Clair Phase One platforms (operated by BP), are located approximately 38 km southeast of the proposed Tornado pipeline route at the Tormore manifold end (refer to Section 4.4.3). In addition, the proposed Tornado drill centre is located approximately 32 km from the proposed Cambo development and 63 km from the proposed Rosebank development.

However, significant cumulative effects are not predicted given the mitigation measures that will be in place for Tornado, coupled with the temporary and short term nature of proposed VSP operations.

# 9 Greenhouse Gas Emissions

## 9.1 Introduction

This section focuses on the assessment of potentially significant effects on climate from the GHG emissions generated by the proposed Tornado Development, namely $CO_2$, $CH_4$ and $N_2O$. It has been written with reference to the new DESNZ supplementary guidance for assessing the effects of downstream Scope 3 emissions on climate from offshore oil and gas projects (DESNZ, 2025d), published following the Finch judgment, 2024[1] and the Jackdaw / Rosebank judgment, 2025[2]. As discussed in Section 4.2.6, anthropogenic sources of GHG emissions are implicated in amplifying the natural greenhouse effect resulting in climate change. The potential effects of emissions of GHG are therefore global in scale.

This section is structured as follows:

- **Section 9.2 (GHG Emissions Sources):** defines the direct and indirect GHG emissions sources arising from the Tornado Development.
- **Section 9.3 (Environmental Protection Objectives):** sets out the key international climate change agreements and UK climate legislation and policies designed to reduce GHG emissions and reach Net Zero by 2050.
- **Section 9.4 (UK Oil & Gas Industry - Net Zero Targets and Progress to Date):** describes the North Sea Transition Deal (NSTD), a strategic partnership between the UK government and the offshore oil and gas industry to support the sector's shift toward Net Zero and identifies the key milestones achieved to date.
- **Section 9.5 (Ithaca's Operational GHG Emissions Baseline and Performance):** presents Ithaca's operational GHG emissions baseline and performance.
- **Section 9.6 (Assessment of Impacts):** assesses the impact of the GHG emissions generated from the proposed Tornado Development on the climate and the significance of any likely effects, using the principles set out in IEMA (2022). The GHG emissions have been evaluated in the context of a global baseline scenario of GHGs, as described in Section 4.2.6, with consideration in this chapter given to the impact the emissions will have on global climate change agreements, UK climate legislation and policies and their associated emissions reduction pathways. Note, the alternative concept options considered for the Tornado Development are explored in Section 2, but do not significantly affect the estimate of GHG emissions to be generated.
- **Section 9.7 (Mitigation measures):** identifies the measures available to Ithaca to avoid, prevent, or reduce any likely significant adverse effects on the climate from GHG emissions generated by the Tornado Development.
- **Section 9.8 (Other Relevant Considerations):** provides information on how the proposed Tornado Development would contribute to the UK's energy security and economic growth, align with the UK Government's stated objectives for the future of the North Sea and enable a managed transition to Net Zero.
- **Section 9.9 (Residual Effects):** presents the residual effects which will remain after the implementation of the proposed mitigation measures.

[1] Finch Judgment, 2024: UK's Supreme Court ruling in 2024 that a decision to grant planning permission for an onshore oil development project at a site in Surrey was unlawful, because downstream GHG emissions from the combustion of the oil produced were not assessed in the EIA as part of the planning decision.

[2] Jackdaw / Rosebank Judgment, 2025: Scotland's Court of Session ruling in 2025 in relation to assessment of downstream Scope 3 emissions under The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020.

## 9.2 GHG Emissions Sources

To help delineate direct and indirect emission sources, the GHG Protocol, a widely used international accounting tool for government and business leaders to understand, quantify, and manage GHG emissions, categorises GHG emissions into the following three 'Scopes':

- Scope 1 covers direct GHG emissions from sources that are owned or controlled by the company;
- Scope 2 covers indirect GHG emissions generated from purchased or acquired electricity, steam, heat and cooling;
- Scope 3 emissions include all other indirect GHG emissions that occur in a company's value chain, which are not directly controlled or owned by the company.

Table 9.1 categorises the GHG emissions which will be generated from the proposed Tornado Development into the relevant GHG Protocol Scope, noting that Ithaca has control over its direct emissions and has limited or no influence over its indirect emissions, particularly those associated with the end use of sold hydrocarbons.

**Table 9.1: GHG Emission Types, Scopes and Tornado Development Sources**

| Emissions Type | GHG Protocol Scope | Definition [1] | Tornado Development GHG Emissions Sources |
|---|---|---|---|
| Direct emissions | Scope 1 | Emissions from operations that are owned or controlled by the reporting company | • Operation of the SGP, namely incremental emissions as a result of Tornado coming online, including fuel combustion for power generation and flaring [2]. |
| Indirect emissions [3] | Scope 2 | Emissions from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the reporting company | • Not applicable as electricity will not be purchased or acquired by Ithaca for the Tornado Development. |
| | Scope 3 | All indirect emissions (not included in Scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions | • Fuel burnt for power generation on the MODU, vessels and helicopters during drilling, installation, inspection, maintenance and decommissioning activities;<br>• Flaring of hydrocarbons offshore during well test and clean-up operations;<br>• Further refinement, transportation and distribution of Tornado hydrocarbons once they leave SGP, but prior to end use of sold products;<br>• Burning of the extracted Tornado hydrocarbons (i.e. end use of sold products, based on the worst case presumption that all end use Tornado hydrocarbons are eventually combusted). |

[1] Definitions taken from Greenhouse Gas Protocol Corporate Value Chain (Scope 3) Standard

[2] Tornado will be a subsea development with production processed onshore at SGP (operated by TotalEnergies E&P UK Limited at the time of this document being submitted). For the purposes of this ES, incremental GHG emissions produced at SGP as a result of Tornado coming online are considered to be 'direct emissions' as Tornado production is controlled by Ithaca. During production, all GHG emissions associated

with processing at SGP will be reported and administered by the SGP operator as their Scope 1 emissions, not Ithaca.

[3] Indirect emissions are a consequence of the activities of the reporting company, but occur at sources owned or controlled by another company.

The GHG Protocol further divides Scope 3 emissions into distinct categories split between two main groups: upstream and downstream emissions.

Tornado Scope 3 upstream emissions are the indirect emissions which will be generated by Ithaca's contractors offshore when extracting, producing and exporting Tornado hydrocarbons to the SGP, as well as during offshore decommissioning operations upon cessation of production.

Tornado Scope 3 downstream emissions are the indirect emissions which will be generated once the Tornado hydrocarbons have been processed at the SGP and sold, including from further processing at the Sullom Voe and St Fergus terminals, transportation and distribution and from the end use of the sold product (namely, the worst case presumption that all end use Tornado hydrocarbons are eventually combusted).

Figure 9.1 provides an overview of the GHG emissions sources and GHG Protocol Scopes relevant to the proposed Tornado Development value chain.

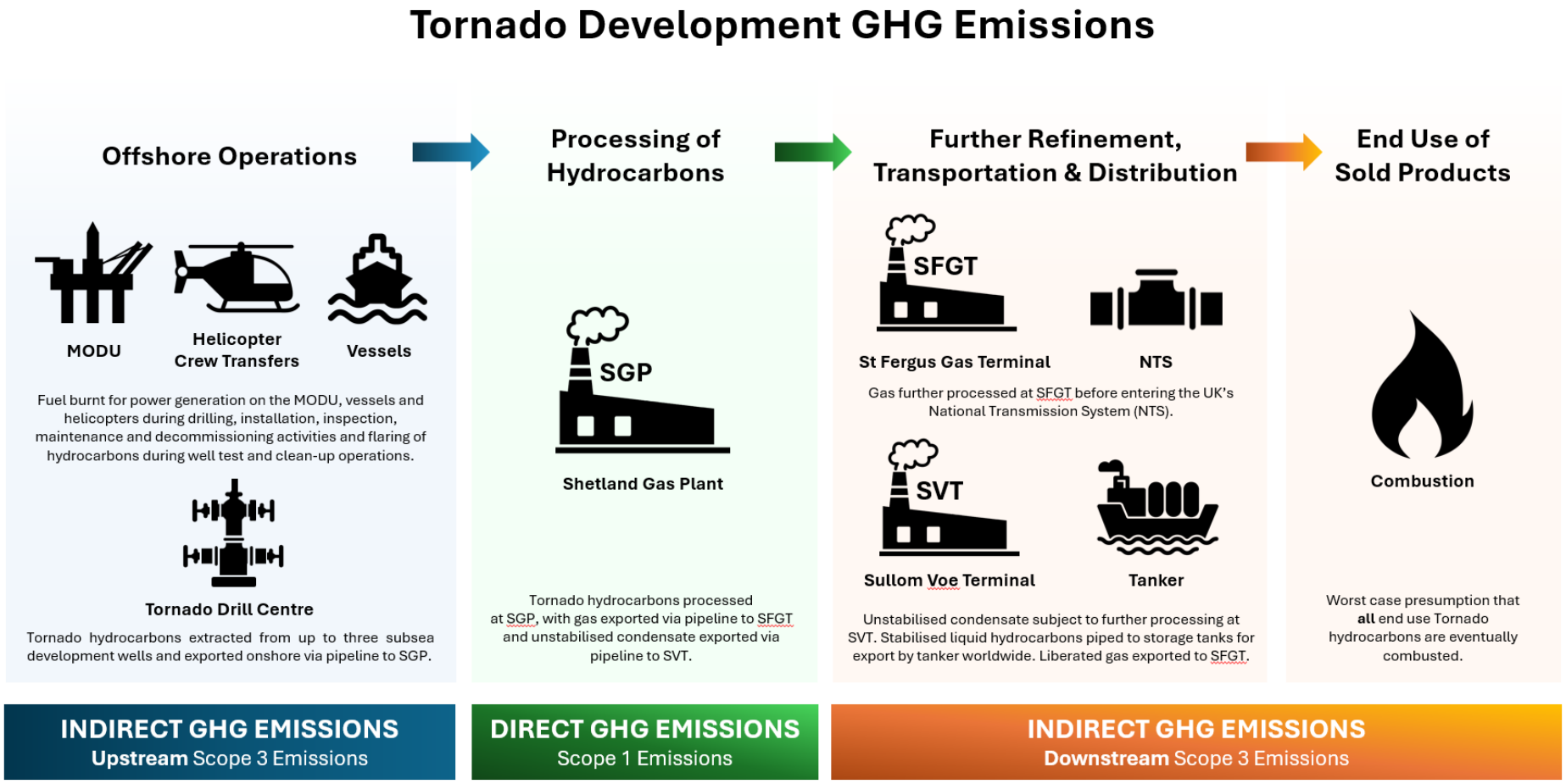



**Figure 9.1: Overview of Tornado Development GHG Emission Sources and GHG Protocol Scopes over the Project Value Chain**

## 9.3 Environmental Protection Objectives

Environmental Protection Objectives (EPOs) related to climate change are the international agreements and national legislation and policies, including sector specific strategies, which aim to mitigate climate change, with a target of reaching Net Zero[3] global GHG emissions. A summary of key climate change EPOs relevant to oil and gas projects has been provided below. These have been considered when assessing the impact of the proposed Tornado Development's GHG emissions on the global climate and the significance of any likely effects.

### 9.3.1 International Agreements

The UNFCCC signed in 1992, is the principal global treaty for coordinating international responses to climate change. It entered into force in March 1994 and has been ratified by 197 countries who have committed to act on climate change and regularly report on their progress. The COP, which meets annually, is the supreme decision-making body of the UNFCCC and relies on the scientific assessments of the IPCC to inform its decisions and guide negotiations. The IPCC produces co-ordinated assessments of climate science, the social and economic impacts of climate change, and potential response strategies, achieving this through a series of assessment cycles. The 6$^{th}$ IPCC assessment report cycle concluded in March 2023, the conclusions from which have been used to inform this assessment. The 7$^{th}$ IPCC assessment report cycle is currently ongoing, having formally begun in July 2023, and will run until at least 2029.

The Kyoto Protocol was the first global initiative to minimise GHG emissions, adopted at COP3 in 1997 and ratified by the UK in May 2022. It set legally binding quantified targets for developed, industrialised countries to reduce their GHG emissions on average by 5% by 2012 (in relation to 1990), followed by a second commitment period to reduce emissions on average by 18% by 2020 (in relation to 1990).

Building upon this, the Paris Agreement was adopted at COP21 in 2015 and requires all major GHG emitting countries to reduce their emissions. The aim of the Paris Agreement is to restrict global temperature change to well under 2°C above pre-industrial levels and pursue efforts to keep it below 1.5°C. The Agreement also established Nationally Determined Contributions (NDCs), which describe individual countries' climate action plans. The UK ratified the Paris Agreement on 18 November 2016.

The United Nations Sustainable Development Goals (SDGs) are 17 global objectives established to promote peace, prosperity, and environmental protection by 2030. These goals were adopted by all UN Member States in 2015 as part of the 2030 Agenda for Sustainable Development. SDG 13 (Climate Action) is focused on limiting and adapting to climate change and aims to take urgent action to combat climate change and its impacts. The Paris Agreement is explicitly referenced in SDG 13's targets and indicators, making it a cornerstone of global climate governance (United Nations, 2025).

The Glasgow Climate Pact, agreed at COP26 in 2021, applies to all countries that are parties to the Paris Agreement. It aims to turn the 2020s into a decade of climate action and support. Key components of the Pact include agreements to strengthen efforts to build resilience to climate change, to curb GHG emissions and to provide the necessary finance for both.

### 9.3.2 UK Climate Change Legislation, Policies and Sector Specific Plans

In the UK, the Climate Change Act 2008 (as amended) sets a legal requirement to achieve a 100% reduction in GHG emissions by 2050 relative to 1990 levels ('Net Zero') and delivers on the commitment that the UK made by signing the Paris Agreement. The Act also established the Climate Change Committee (CCC), an independent statutory body set up to advise the UK government on setting and meeting carbon goals.

The Climate Change Act requires the UK government to set five-yearly legally-binding carbon budgets, 12 years in advance, from 2008 to 2050, which restrict the amount of GHGs the UK can emit (Table 9.2). The UK is currently in the Fourth Carbon Budget period (2023 - 2027).

[3] A state where the amount of GHGs emitted is balanced by the amount removed from the atmosphere.

Under the Paris Agreement, the UK has also set two NDC emissions reduction targets, as detailed in Table 9.2.

**Table 9.2: UK Carbon Budgets & NDCs**

| Carbon Budget / NDC | Carbon Budget Level | Reduction Below 1990 Levels | Met? |
|---|---|---|---|
| 1st Carbon Budget (2008 to 2012) | 3,018 $MtCO_2e$ | 25% | Yes |
| 2nd Carbon Budget (2013 to 2017) | 2,782 $MtCO_2e$ | 31% | Yes |
| 3rd Carbon Budget (2018 to 2022) | 2,544 $MtCO_2e$ | 37% by 2020 | Yes |
| 4th Carbon Budget (2023 to 2027) | 1,950 $MtCO_2e$ | 51% by 2025 | - |
| NDC (2030) | - | 68% by 2030 | - |
| 5th Carbon Budget (2028 to 2032) | 1,725 $MtCO_2e$ | 57% by 2030 | - |
| 6th Carbon Budget (2033 to 2037) | 965 $MtCO_2e$ | 78% by 2035 | - |
| NDC (2035) | - | 81% by 2035 | - |
| *7th Carbon Budget (2038 to 2042)* [1] | *535 $MtCO_2e$* | *87% by 2040* | - |

[1] Published by the CCC in February 2025. The UK Government will respond to the CCC's advice and set the seventh carbon budget in law by 30 June 2026.

In 2021, the UK submitted its Net Zero Strategy: Build Back Greener (HM Government, 2021) to the UNFCCC, which set out how it proposes to deliver the Fourth, Fifth and Sixth Carbon Budgets and the 2030 NDC, as well as Net Zero GHG emissions by 2050. However, following the energy security crisis and rising gas and fossil fuel prices in 2022, an Independent Review of Net Zero (DESNZ, 2023) was commissioned to make recommendations on how the UK could achieve its legally binding Net Zero target in a way that drives economic growth, energy security, and affordability. The Review recognises that in the short term we will still need oil and gas to secure our energy independence and as transition fuels towards 2050, although it does highlight the importance of decarbonising the upstream oil and gas process as quickly as possible.

Powering Up Britain, The Net Zero Growth Plan (DESNZ, 2023) builds on the Net Zero Strategy, and responds to the expert recommendations made in the Independent Review of Net Zero. It also acknowledges that fossil fuels will retain a crucial role in the energy system until there are credible clean energy alternatives that can replicate their role, with natural gas playing a role for years to come, particularly in the hardest to decarbonise sectors.

In 2024, the Clean Power 2030 Action Plan (DESNZ, 2024a) was published which outlines the UK government's strategy to achieve a fully decarbonised electricity system by 2030. It supports the Carbon Budgets by targeting the phase-out of unabated fossil fuels, including oil and gas, from power generation. However, it makes clear the important role that unabated gas will continue to play in a new back-up role to provide security of supply throughout the transition to clean power into the 2030s and beyond.

The Carbon Budget and Growth Delivery Plan (CBGDP) (HM Government, 2025) sets out how the UK will continue to reduce emissions in a way that lowers bills and secures good jobs, in line with the Climate Change Act. It includes commitments to electrify upstream oil and gas production and abate emission from routine flaring and venting during oil and gas production, targeting an average annualised saving of 1.34 Mt $CO_2e$ and 0.13 Mt $CO_2e$, respectively over the Sixth Carbon Budget period.

The 'Balanced Pathway' Scenario (CCC, 2025a) is a framework proposed by the CCC for the UK's approach to achieving Net Zero emissions by 2050, guiding the UK's Seventh Carbon Budget. The Balanced Pathway involves a steep decline in the consumption of oil and gas, reducing by 84% and 77% from 2025 levels respectively by 2050. However, a demand for oil and gas continues to remain in the Net Zero aligned Balanced Pathway scenario to 2050 and beyond.

The UK's Net Zero target and strategies are supported by sector-specific policies and plans. For the oil and gas industry this includes the NSTD (refer to Section 9.4) and the British Energy Security Strategy (HM Government, 2022), which support oil and gas production while mandating emissions reductions and decarbonisation through measures such as offshore electrification. In addition, the revised OGA Strategy (OGA, 2020), which amends the earlier MER UK Strategy, retains the focus on maximising the economic recovery of petroleum while integrating obligations to reduce GHG emissions. Licensees must take reasonable steps to limit emissions from flaring, venting, and power generation, and support CCS initiatives.

The NSTA has also produced a series of documents, referred to as Stewardship Expectations. These expectations promote responsible emissions monitoring, reporting, and reduction initiatives and reinforce the industry's role in achieving Net Zero by 2050. A total of 12 Stewardship Expectations have been produced to date, with Stewardship Expectation 11 'Net Zero' setting out typical examples of actions that could be undertaken to reduce GHG emissions during all stages of the project lifecycle. Oil and gas developments which are considered to align with the aims of Stewardship Expectation 11 will contribute to meeting the Net Zero target. Building on Stewardship Expectation 11, in March 2024, the NSTA published the OGA Plan to reduce UKCS GHG emissions (NSTA, 2024c), which sets out requirements for industry to meet the Net Zero obligation in the OGA Strategy.

The Zero Routine Flaring (ZRF) Initiative, introduced by the World Bank in 2015, also commits the UK government and industry to end routine flaring at production sites no later than 2030 and to ensure that new developments are designed without the need for routine flaring of any associated gas which may be produced from the field. The UK is also a member of the Global Methane Pledge, to collectively reduce global methane emissions by at least 30% by 2030 compared to 2020 levels.

Of note, the majority of GHG emissions generated offshore during the development of the Tornado field will be as a result of vessel usage. In 2023, the International Maritime Organization (IMO) adopted the 2023 strategy on the reduction of GHG emissions from ships (IMO, 2023). The strategy envisages, in particular, a reduction in carbon intensity of international shipping (to reduce $CO_2$ emissions per transport work), as an average across international shipping, by at least 40% by 2030 (compared to 2008). It also sets out an ambition that zero or near-zero GHG emission technologies, fuels and/or energy sources are to represent at least 5%, striving for 10%, of the energy used by international shipping by 2030.

## 9.4 UK Oil & Gas Industry - Net Zero Targets and Progress to Date

The North Sea Transition Deal (DESNZ, 2021b), signed in March 2021, sets out an ambitious plan for how the UK's offshore oil and gas sector and the government will work together to deliver the skills, innovation and new infrastructure required to meet stretching GHG reduction targets. It is built on five closely interlinked outcomes relating to supply decarbonisation, carbon capture usage and storage, hydrogen, supply chain transformation, and people and skills.

The deal includes early reductions in offshore production GHG emissions of 10% by 2025; 25% by 2027; and 50% by 2030, against a 2018 baseline, to meet the sector's aim of creating a Net Zero basin by 2050. To date the UK's oil and gas industry has successfully reduced upstream emissions by 34%, surpassing the 25% by 2027 target (Figure 9.2). Based on the current trajectory, the target of halving emissions between 2018 and 2030 is also well within reach (OEUK, 2025a; NSTA, 2025b).

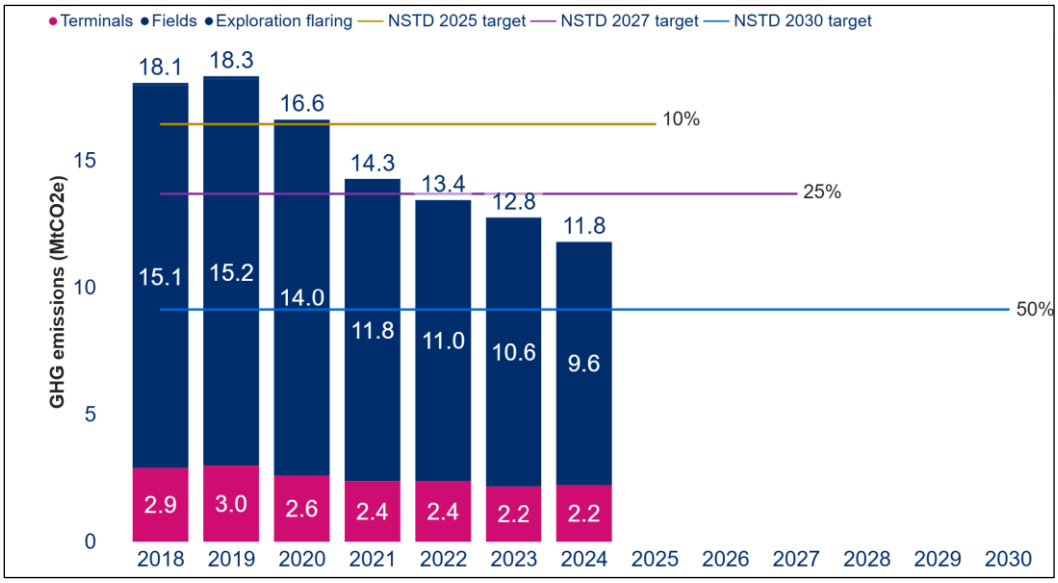



**Figure 9.2: Progress of UK upstream oil & gas GHG emissions against NSTD targets (NSTA, 2025b)**

In 2024, GHG emissions from the production of UK oil and gas, which includes emissions from offshore oil and gas fields, onshore processing terminals and oil and gas exploration activity, totalled an estimated 11.8 Mt $CO_2e$. To put this in content, GHG emissions from upstream oil and gas activity accounted for 3.3% of net UK territorial GHG emissions in 2023, according to data from NAEI (NSTA, 2025b).

The majority of GHG emissions are generated from the offshore installations themselves, with the largest contributors being gas and diesel combustion for power generation, followed by flaring and venting (NSTA, 2025b). Emissions from offshore installations fell in 2024, down 5% compared to 2023, and 34% against the 2018 baseline year, mainly driven by improvements in power efficiency and management, as well as reductions in venting and flaring (OEUK, 2025a).

Methane emissions from offshore installations have reduced substantially since the NSTD was agreed, down by 57% against a 2018 baseline, delivering a reduction of 0.85 million tonnes of $CO_2e$ and exceeding the original target of 50% by 2030 (OEUK, 2025a).

Using emissions data from Rystad and gas import data from DESNZ, the NSTA estimates the average emissions intensity for methane and $CO_2$ of supplying gas from the UKCS (including upstream and processing emissions) to be 28 $kgCO_2$/boe on average in 2024. In contrast, importing LNG (including production, processing, transport, shipping and regasification) had an average equivalent emissions intensity of 85 $kgCO_2$/boe in 2024 (NSTA, 2025b).

Beyond 2030, absolute emissions associated with oil and gas production are predicted to fall steeply along with output, but also due to the reduction in flaring and venting, and lower-emission installations taking over from older and more energy-intensive installations (OEUK, 2024a).

## 9.5 Ithaca's Operational GHG Emissions Baseline and Performance

### 9.5.1 GHG Emissions Baseline and Performance

Ithaca's emissions baseline is established through GHG emissions data recorded in line with the GHG Protocol and used for regulatory submissions including those for the Emissions Trading Scheme (ETS) and the Environmental and Emissions Monitoring System (EEMS), covering direct emissions from production operations. Aligned with the NSTA targets, Ithaca's baseline year for performance tracking is 2018.

From 2018 to 2024, Ithaca achieved emissions reductions of 21% compared to the baseline year. This was driven by:

- Operational efficiencies;

- Reduction in flaring and venting;
- Asset divestment and decommissioning;
- Routine equipment upgrades and maintenance improvements; and
- Execution of projects planned in out in the Company's Emissions Reduction Action Plan (ERAP).

In addition, gross operated emissions intensity reduced from 25 kg $CO_2$e/boe in 2023 to 23.9 kg$CO_2$e/boe in 2024 on a Scope 1 and 2 basis, and methane intensity reduced from 0.2% to 0.1% in the same period. Ithaca is committed to the continual year-on-year emissions intensity reduction and maintaining lower than basin average intensities.

### 9.5.2 Ithaca's Emissions Reduction Action Plan (ERAP)

Ithaca's ERAP demonstrates its commitment to the NSTD in reducing emissions from the sector in line with the Net Zero targets of the UK. The ERAP is aligned with Stewardship Expectation 11 of the NSTA (refer to Section 9.3) and covers all Ithaca's operated UKCS assets, with topsides equipment. Tornado, as a subsea development, will therefore not be incorporated into the ERAP once operational. Instead, responsibility for identification and implementation of emissions reduction initiatives will reside with the operator of SGP, where the Tornado production fluids will be processed.

Ithaca's ERAP is reviewed and updated to take account of work completed each year and to review and agree opportunities to reduce emissions. ERAP projects under consideration which are at varying stages of construction / implementation include:

- Projects which allow zero routine flaring, including flare gas recovery
- Cargo tank vent vapour minimisation and recovery;
- Replacement of all hydrocarbon blanket gas with nitrogen;
- Right size equipment to fit its duty and avoid waste;
- Control logic improvements to reduce likelihood of trips and flaring events; and
- Alternative fuels to replace diesel used offshore.

A database (also referred to as the 'opportunity hopper') of all potential emissions reduction opportunities is managed on behalf of the assets by the Environment Team. The database comprises of opportunities in all stages of development, from ideas and areas to explore, to projects undertaking feasibility studies, right through to already completed scopes. The database is updated frequently as new ideas and added information is made available. It is periodically reviewed by all levels of the organisation up to the executive leadership team.

Emissions benefits are determined based upon their relative performance to Ithaca's baseline year of 2018.

## 9.6 Assessment of Impacts

### 9.6.1 Quantification of GHG Emissions

Table 9.3 quantifies the GHG emissions (expressed in terms of kilotonnes (kt) of $CO_2e$) arising from the proposed Tornado Development, over the life of the field. Appendix H provides a breakdown of the emissions generated from the sources identified in Section 9.2 and outlines the method, assumptions and GHG conversion factors used to quantify the emissions.

**Table 9.3: Tornado Development Total GHG Emissions (Worst Case)**

| Emissions Category | Total GHG Emissions (kt $CO_2e$) [1] | | | |
|---|---|---|---|---|
| | Max Case [5] | High Case [5] | Mid Case [5] | Low Case [5] |
| Total Direct GHG Emissions (Scope 1) [2] | 1,466.01 | 1,437.44 | 1,061.53 | 790.98 |
| Total Indirect Upstream GHG Emissions (Scope 3) [3] | 140.58 | 140.58 | 140.58 | 140.58 |
| Total Indirect Downstream GHG Emissions (Scope 3) [4] | 34,086.21 | 30,143.38 | 22,747.44 | 15,860.55 |
| **Grand Total** | **35,692.81** | **31,721.41** | **23,949.55** | **16,792.11** |

[1] Refer to Appendix H for the methodology used to estimate GHG emissions.
[2] Accounts for Tornado incremental GHG emissions at SGP, assuming all emissions are unabated (i.e. SGP continues to be powered by gas turbine generator(s) without partial electrification).
[3] Accounts for GHG emissions arising from offshore operations, namely from fuel burnt for power generation on the MODU, vessels and helicopters during drilling, installation, inspection, maintenance and decommissioning activities and flaring of hydrocarbons during well test and clean-up operations.
[4] Accounts for GHG emissions related to downstream processing of Tornado hydrocarbons, before they reach the end user, as well as end use GHG emissions arising from the combustion of Tornado gas in homes, businesses and power stations and from the combustion of Tornado condensate, assuming this is refined into petrol, which is then combusted in vehicles.
[5] Refer to Appendix G for production profile case definitions.

In summary, the worst-case total gross GHG emissions generated over the life of the Tornado Development are estimated to be ca. 35,692.81 kilotonnes of $CO_2e$, based on the max production case (a contingency accelerated production scenario where additional capacity ullage is made available (subject to commercial negotiations) in the GLA flowline system, and the Tornado project can maximise production rates to fill the available ullage by drilling and producing from a third well at Tornado). The availability of ullage to support the Max case is uncertain at this time but has been included as a basis for the EIA as it represents the worst-case scenario in terms of total production volume, and resulting in emissions, albeit at a lower GHG intensity than all other cases.

For context, the High production case scenario, which assumes a two well development, generates total GHG emissions about 11% lower than the Max production case estimate. The Mid production case scenario, which represents the most likely production outcome, is about 33% lower than the Max production case estimate and the Low production case scenario, representing a conservative, lower production outcome, is about 53% lower than the Max production case estimate.

In the event the SGP is partially electrified, it is estimated there would be a ca. 20% decrease in the Tornado incremental $CO_2e$ emissions produced (i.e. Scope 1 emissions).

Burning of the extracted Tornado hydrocarbons (i.e. the worst case presumption that all end use Tornado hydrocarbons are eventually combusted) results in the largest amount of GHG emissions generated over the life of the field (ca. 81% of the total $CO_2e$ emissions). However, it should be

recognised that the actual end-use and fate of the Tornado hydrocarbons may vary. Tornado gas will enter the UK's NTS via the St Fergus terminal to be transported through a network of pipelines across the UK. The gas is delivered to places where it is used, such as gas-fired power stations, large industrial users, or regional gas distribution networks that connect to individual homes and businesses. In contrast, the stabilised liquid hydrocarbons exported by tanker from the Sullom Voe Terminal are primarily sent to refineries worldwide where they are converted into usable fuels such as gasoline, diesel, and jet fuel. The byproducts from this process often serve as raw materials for chemical productions, leading to the generation of plastics, fertilizers, and pharmaceuticals. As such, it is possible that not all end use Tornado hydrocarbons will be combusted. However, to ensure a worst case scenario has been presented, for the purposes of this assessment it is assumed that all Tornado condensate is refined into petrol and is then combusted in vehicles.

### 9.6.2 Evaluating Significance

The principles set out in IEMA (2022) have been used to help determine the significance of the likely effects of the GHG emissions generated from the proposed Tornado Development on the global climate, whereby the sensitivity of the receptor (i.e. the global climate) and magnitude of impact have been combined to derive the overall significance level.

As the assessment of impact significance is an inherently difficult process involving the projection of potential climate futures, consistent criteria (as defined in Section 5.3.1) have been applied to the process, noting that a key consideration when evaluating significance is not simply whether the Project results in GHG emissions, nor the absolute volume of those emissions, but whether the Project aligns with the global and UK emission reduction pathways required to meet the goals of the Paris Agreement.

In order to contextualise and evaluate the significance of the Tornado Development's GHG emissions, the following key data sources have been used:

- IPCC Sixth Assessment Report (AR6) (IPCC, 2022) which explores the projected climate response to five emissions scenarios based on Shared Socio-economic Pathways (SSPs). The SSPs are baseline narrative scenarios that identify socio-economic and geopolitical assumptions and economic and technological trends. These are then combined with different emissions trajectories, based on the Representative Concentration Pathways (RCP) scenarios from the IPCC's Fifth Assessment Report (AR5), to impose global warming targets.
- International Energy Agency (IEA) World Energy Outlook Scenarios (IEA, 2024; IEA, 2025), which model future global energy demand and supply under different policy scenarios, including:
    - The Announced Pledges Scenario (APS) which assumes governments will meet, in full and on time, all the climate-related commitments that they have announced, such as NDCs, to achieve Net Zero emissions by 2050. Note, IEA (2025) does not consider APS as at the time of publication an insufficient number of countries had submitted their 2035 NDCs.
    - The Net Zero Emissions by 2050 Scenario (NZE) which shows a global pathway to reach Net Zero emissions from the energy sector by 2050.
- UK carbon budgets, NDCs and the CCC's 'Balanced Pathway' Scenario (CCC, 2025a), which is a framework for the UK's approach to achieving Net Zero emissions by 2050. The 'Balanced Pathway' Scenario includes future projections for UK oil and gas demand and UK oil and gas production based on NSTA production projections of existing and future developments (including sanctioned but not yet producing fields).

As global reduction pathways have been used to contextualise the magnitude of impact the Tornado Development's GHG emissions will have on the climate, this approach is considered to be inherently cumulative as these pathways take into account a wide range of existing and planned projects and other activities. These forward-looking pathways provide a proxy for the evolving baseline, as they incorporate anticipated GHG emissions from existing and planned oil and gas developments, such as Tornado, as well as broader sectoral and policy trends - including those relating to future oil and gas development and consumption.

The non-development of the Tornado field (the 'do-nothing' scenario) would avoid project-related GHG emissions but would also result in the non-recovery of a viable domestic hydrocarbon resource, with no associated contribution to UK energy supply or economic activity.

The IPCC indicates that global demand for oil and gas is expected to continue as the world transitions to net-zero, therefore combustion of hydrocarbons and their associated GHG emissions will be prevalent at least for the short-term across all future climate pathway scenarios. Similarly, in the UK, a demand for oil and gas continues to remain in the Net Zero aligned Balanced Pathway scenario to 2050 and beyond, noting that the UK Carbon Budgets and UK NDCs are economy-wide emissions limits, and do not prohibit oil and gas production.

All gas produced from the Tornado field will flow into the NTS via the SGP and will be used domestically and not exported. Tornado will provide the UK with low carbon, indigenous gas, helping contribute to energy security during the transition to Net Zero. Responsible stewardship of remaining offshore reserves ensures that the UK meets its energy demand while retaining control over GHG emissions.

### 9.6.3 Sensitivity of the Global Climate

The sensitivity of the global climate to GHG emissions is **Very High** (refer to Table 5.3). The receptor is of global importance, classed as Very High value. As described in Section 4.2.6, the Earth's climate is changing. Global temperatures continue to increase, with 2024 the warmest year on record, at 1.6°C above pre-industrial average levels. Global warming has unequivocally been caused by GHG emissions, with 100% of the observed long-term temperature change attributable to human causes (CCC, 2025d). The world is currently not on track to meet the Paris Agreement climate goals. Estimates of current human-induced long-term global warming are around 1.31°C above pre-industrial levels and are rising at 0.26°C per decade (Foster, 2024). It is still considered technically possible that we can limit long-term global temperature rise to 1.5°C (WMO, 2025), however at the recent COP30 in Brazil it was acknowledged that the world is likely to breach this threshold in the next decade at least temporarily. As such, Resistance and resilience is Medium.

### 9.6.4 Tornado in the Context of the Paris Agreement and Global Emissions Reduction Pathways

As previously noted in Section 4.2.6, the IPCC's SSP scenarios, combined with RCP scenarios - SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5 - provide a framework for assessing future global GHG emissions trajectories under differing socio-economic and policy assumptions. These pathways illustrate how emissions may evolve under varying levels of climate ambition; from very low (SSP1-1.9) pathways consistent with limiting warming to 1.5°C, to very high (SSP5-8.5) pathways associated with continued fossil fuel use and limited mitigation.

To place the Tornado Development in this global context, Table 9.4 compares the total GHG emissions predicted to be generated by the Development in the reference year (2030) with the median global GHG emissions projected under each SSP scenario to illustrate the proportional contribution of the Project under a range of future climate pathways. Of note, cessation of production for Tornado is predicted to occur in or before 2038 and therefore the Project will not contribute to the global GHG emissions in 2040 and 2050.

In 2030, Tornado's projected GHG emissions are estimated to represent between 0.01211% and 0.02605% of median global GHG emissions, depending on the SSP pathway considered (refer to Table 9.4). The proportion is highest under the SSP1-1.9 (very low) scenario, where global GHG emissions are projected to decline rapidly to around 33 $GtCO_2e$ (median) per year in 2030, and lowest under the SSP5-8.5 (very high) scenario, where emissions reach approximately 71 $GtCO_2e$ (median) per year in 2030. This variation reflects the differing assumptions about future global energy use and mitigation policy embedded within each pathway. Regardless, Tornado's contribution represents a very small fraction of projected global totals under all SPP scenarios. This comparison provides context for the Project's scale relative to global GHG emissions trajectories, resulting in a **Minor** magnitude of impact (refer to Table 5.4), particularly as Tornado cessation of production is well before 2050.

This point is further illustrated by the fact that the worst case total GHG emissions generated from the Tornado Development over the life of the field (ca. 2028 – 2038) represent less than 0.01519% of the remaining global carbon budget under a 1.5°C scenario (235 $GtCO_2e$; GCP, 2024), 0.00610% under a

1.7°C scenario (585 $GtCO_2e$; GCP, 2024), and less than 0.00322% under a 2.0°C scenario (1,110 $GtCO_2e$; GCP, 2024). Given this negligible proportional impact, the Tornado Development is not expected to affect the trajectory of global temperature rise or the achievement of international climate targets in a significant way.

**Table 9.4: Tornado Development in the context of Future Global Shared Socioeconomic Pathways (IPCC, 2022)**

| Parameter | Reference Year | | | Key Assumptions of SSP |
|---|---|---|---|---|
| | 2030 | 2040 | 2050 | |
| **GHG Emissions Scenario: SSP 1 – 1.9 (Very Low), limit warming to 1.5°C** | | | | |
| Median Global GHG Emissions ($GtCO_2e/yr$) [1] | 33 (22 – 37) | 18 (6 – 24) | 8 (0 – 15) | Rapid decarbonisation, societies switch to more sustainable practices, inequality falls. Net zero $CO_2$ achieved in ca. 2050. |
| Tornado projected proportion [2] | 0.02605% | N/A | N/A | |
| **GHG Emissions Scenario: SSP 1 – 2.6 (Low), limit warming to 2°C** | | | | |
| Median Global GHG Emissions ($GtCO_2e/yr$) [1] | 40 (30 – 49) | 29 (21 – 36) | 20 (14 – 27) | Socioeconomic shifts towards sustainability, but reduction in $CO_2$ emissions is slower than SSP1-1.9. Net zero $CO_2$ achieved in ca. 2070. |
| Tornado projected proportion [2] | 0.02149% | N/A | N/A | |
| **GHG Emissions Scenario: SSP 2 – 4.5 (Intermediate), limit warming to 3°C** | | | | |
| Median Global GHG Emissions ($GtCO_2e/yr$) [1] | 54 (50 – 62) | 53 (48 – 61) | 52 (45 – 57) | Current policies continue. Slow progress toward sustainability and development and income grow unevenly. $CO_2$ emissions hover around current levels before starting to fall mid-century. Net zero $CO_2$ is not achieved by 2100. |
| Tornado projected proportion [2] | 0.01592% | N/A | N/A | |
| **GHG Emissions Scenario: SSP 3 – 7.0 (High), limit warming to 4°C** | | | | |
| Median Global GHG Emissions ($GtCO_2e/yr$) [1] | 62 (53 – 69) | 67 (56 – 76) | 70 (58 – 83) | Fragmented, high fossil use, inequality. $CO_2$ emissions roughly double from current levels by 2100 |
| Tornado projected proportion [2] | 0.01387% | N/A | N/A | |
| **GHG Emissions Scenario: SSP 5 – 8.5 (Very High), exceed warming of 4°C** | | | | |
| Median Global GHG Emissions ($GtCO_2e/yr$) [1] | 71 (69 – 81) | 80 (78 – 96) | 88 (82 – 112) | Rapid economic growth without mitigation, fuelled by exploiting fossil fuels and energy-intensive lifestyles. Current $CO_2$ emissions roughly double by 2050. |
| Tornado projected proportion [2] | 0.01211% | N/A | N/A | |

[1] Data source (IPCC, 2022; Chapter 3, Table 3.2), median data shown with (Lower Range – Upper Range) of harmonised GHG emissions across the pathways.

[2] Based on the worst-case total gross GHG emissions generated from the Tornado Development in 2030 (End Use + WTT) of 8597.79 kt $CO_2e$, assuming the Max production case without partial electrification.

### 9.6.5 Tornado in the Context of Future Global Oil and Gas Production Demand

In global energy analysis, “demand” and “use” describe related but distinct concepts. Global demand refers to the amount of energy or fuel that consumers require to meet their needs for power, heating, and transport, and is influenced by factors such as population, economic growth, and efficiency improvements (IEA, 2023a). In contrast, global use refers to the actual quantity of fuels that are produced and consumed worldwide (PGR, 2025).

The IPCC indicates that global demand for oil and gas continues across all future climate scenarios, including those consistent with limiting warming to 1.5°C (SSP1-1.9) (IPCC, 2022). While projections for energy-system use indicate declines of around 60% for oil and 45% for gas (ca. 70% for gas without Carbon Capture and Storage) by 2050 compared to 2019 levels (median estimates) (ibid., 2022), these figures refer specifically to use in the energy sector and do not account for resilient or growing demand for other hydrocarbon applications, such as petrochemicals, feedstocks, and non-energy uses (IEA, 2018). Consequently, while the energy-system share of oil and gas may decline under stringent climate scenarios, the broader global demand for hydrocarbons remains.

The “production gap” represents the shortfall between governments’ planned fossil fuel output and the production levels consistent with pathways limiting global temperature change to 1.5°C or well below 2°C above pre-industrial levels. The UNEP Production Gap Report (PGR) (SEI, 2023; PGR; 2025) evaluates the fossil fuel production outlooks of twenty major producing countries, including the UK, and benchmarks these against climate model projections aligned with the Paris Agreement’s temperature objectives.

Table 9.5 and Table 9.6 compare the proposed Tornado production rates in five reference years during the period from 2030 to 2050 with predicted future global gas and oil production rates under different international energy demand pathway scenarios, noting that Tornado will cease production in or before 2038. In contrast, Table 9.7 compares the proposed Tornado production rates during this period with predicted future global energy demand for total energy, oil, and gas.

It can be seen from Tables 9.5 to 9.7 that the proposed Tornado Development contributes a very small percentage towards predicted global oil and gas production rates and forecasted demand. While these figures indicate the Project’s relative scale, the assessment considers its emissions within the broader context of cumulative global GHG emissions, existing and planned developments, anticipated policy and technology advancement, and future pathways consistent with limiting warming to well under 2 °C. As such, production from the Tornado field will have an insignificant impact on deviating the world from the pathways consistent with restricting global temperature change to well under 2°C above pre-industrial levels, resulting in a **Minor** magnitude of impact.

It should be noted that estimating future fossil fuel availability and use across mitigation pathways is subject to considerable uncertainty (IPCC, 2023c; IEA, 2021; IEA, 2025). Integrated assessment models used by the IPCC and IEA show that outcomes vary significantly depending on assumptions about policy strength, energy demand, and technological change. As such, projections of fossil fuel production and consumption should be interpreted as indicative ranges rather than precise forecasts (IPCC, 2023c; IEA, 2021; IEA, 2025).

The pace of future reductions in GHG emissions will be determined by how quickly national and global efforts succeed in decarbonising fossil-fuel-intensive sectors such as power generation, transport, and building and industrial heating, primarily through electrification and a shift toward low-carbon energy sources (IEA, 2021; IPCC, 2022, 2023c; UNEP, 2024). Success in decarbonisation will reduce the demand for fossil fuels, however not all end-uses are expected to be commercially electrifiable in the short to medium term (i.e. within the life of Tornado Development) and many will require low GHG liquid and gaseous fuels (IPCC, 2023c).

**Table 9.5: Tornado Development in the context of Future Global Gas Demand across International Pathways (PGR, 2025)**

| Parameter | Reference Year | | | | |
|---|---|---|---|---|---|
| | 2030 | 2035 | 2040 | 2045 | 2050 |
| **IEA Announced Pledges Scenario (APS) [3]** | | | | | |
| Global Gas Production Value ($Tm^3/yr$) [1] | 4.03 | 3.51 | 3.08 | 2.76 | 2.48 |
| Tornado projected proportion [2] | 0.079% | 0.029% | N/A | N/A | N/A |
| **Pathways Consistent with 2℃ (Median)** | | | | | |
| Global Gas Production Value ($Tm^3/yr$) [1] | 3.91 | 3.67 | 3.46 | 3.32 | 3.34 |
| Tornado projected proportion [2] | 0.082% | 0.027% | N/A | N/A | N/A |
| **Pathways Consistent with 1.5℃ (Median)** | | | | | |
| Global Gas Production Value ($Tm^3/yr$) [1] | 2.72 | 2.37 | 2.20 | 1.99 | 1.78 |
| Tornado projected proportion [2] | 0.118% | 0.042% | N/A | N/A | N/A |

[1] Data source (PGR, 2025), values converted from exajoules (EJ) per year (EJ/yr) to Gas using a factor of 0.029 Trillion (Tera, $10^{12}$) cubic metres per year ($Tm^3/yr$).
[2] Based on Tornado Max production case production profile for Gas in the reference year (2030 = 2,544.46 kt; 2035 = 807.44 kt) – Refer to Appendix G.
[3] An IEA scenario that models future energy demand and supply based on governments' announced climate pledges, even if not yet backed by detailed policies.

**Table 9.6: Tornado Development in the context of Future Global Oil Demand across International Pathways (PGR, 2025)**

| Parameter | Reference Year | | | | |
|---|---|---|---|---|---|
| | 2030 | 2035 | 2040 | 2045 | 2050 |
| **IEA Announced Pledges Scenario (APS) [3]** | | | | | |
| Global Oil Production Value (Mbbl/d) [1] | 90.50 | 79.98 | 68.47 | 59.06 | 52.16 |
| Tornado projected proportion [2] | 0.00544% | 0.00044% | N/A | N/A | N/A |
| **Pathways Consistent with 2℃ (Median)** | | | | | |
| Global Oil Production Value (Mbbl/d) [1] | 99.65 | 94.00 | 83.03 | 69.78 | 57.83 |
| Tornado projected proportion [2] | 0.00495% | 0.00038% | N/A | N/A | N/A |
| **Pathways Consistent with 1.5℃ (Median)** | | | | | |
| Global Oil Production Value (Mbbl/d) [1] | 88.55 | 78.92 | 63.32 | 45.85 | 32.20 |
| Tornado projected proportion [2] | 0.00556% | 0.00045% | N/A | N/A | N/A |

[1] Data source (PGR, 2025), values converted from exajoules (EJ) per year (EJ/yr) to Oil using a factor of million barrels per day (Mbbl/d)
[2] Based on Tornado Max production case profile for Oil in the reference year (2030 = 225.96 kt; 2035 = 16.25 kt) – Refer to Appendix G.
[3] An IEA scenario that models future energy demand and supply based on governments' announced climate pledges, even if not yet backed by detailed policies.

**Table 9.7: Tornado Development in the context of Future Global Energy Supply (IEA, 2025)**

| Parameter | Reference Year | | |
|---|---|---|---|
| | 2035 | 2040 | 2050 |
| **IEA Net Zero Emissions by 2050 Scenario [5]** | | | |
| Natural Gas World Energy Supply ($GtCO_2e$) [1] | 5.12 | 3.49 | 1.69 |
| Tornado projected Gas proportion [2] | 0.05010% | N/A | N/A |
| Oil World Energy Supply ($GtCO_2e$) [1] | 9.50 | 6.74 | 3.33 |
| Tornado projected Oil proportion [3] | 0.00075% | N/A | N/A |
| Total World Energy Supply ($GtCO_2e$) [1] | 42.74 | 41.26 | 42.72 |
| Tornado projected Total proportion [4] | 0.00617% | N/A | N/A |

[1] Source IEA World Energy Outlook 2025 Report (IEA, 2025), reference year values were calculated from EJ to Gt $CO_2e$ using IPCC (2006) conversion factor (kg $CO_2$/GJ, kg $CH_4$/GJ and kg $N_2O$/GJ) alongside relevant AR5 GWP Values ($CO_2$ = 1, $CH_4$ = 28, $N_2O$ = 265).

[2] Gas comparison based on the worst-case total GHG emissions generated from the Tornado Development in 2035 of 2,565.26 kt $CO_2e$, assuming the Tornado Max production case for Gas, without partial electrification of SGP. The total is based on the total direct GHG emissions (Scope 1) and total indirect downstream GHG emissions (Scope 3) generated in 2035, with the Scope 1 emissions adjusted based on Gas:Oil production ratio of 94.7:5.3

[3] Oil comparison based on the worst-case total GHG emissions generated from the Tornado Development in 2035 of 71.19 kt $CO_2e$, assuming the Tornado Max production case for Oil, without partial electrification of SGP. The total is based on the total direct GHG emissions (Scope 1) and total indirect downstream GHG emissions (Scope 3) generated in 2035, with the Scope 1 emissions adjusted based on Gas:Oil production ratio of 94.7:5.3.

[4] Total World Energy Comparison based on the worst-case total gross GHG emissions generated from the Tornado Development in 2035 of 2636.45 kt $CO_2e$, assuming the Tornado Max production case, without partial electrification of SGP. The total is based on the total direct GHG emissions (Scope 1) and total indirect downstream GHG emissions (Scope 3) generated in 2035 for Gas[2] + Oil[3].

[5] An IEA Scenario where Net Zero emissions by 2050 are consistent with a pathway well below 2°C.

### 9.6.6 Tornado in the Context of UK Carbon Budgets, NDCs and Emissions Reduction Pathways

#### Climate Change Committee's (CCC's) Balanced Pathway

The CCC's Balanced Pathway, an emissions reduction pathway from 2025 to Net Zero by 2050, is in line with all of the UK's legislated carbon budgets and stated NDCs. The Balanced Pathway involves a steep decline in the consumption of oil and gas, reducing by 84% and 77% from 2025 levels respectively by 2050. However, a demand for oil and gas continues to remain in the Net Zero aligned Balanced Pathway scenario to 2050 and beyond.

Oil and gas fields in the North Sea are mature and declining in output. Even without any global action to reduce GHG emissions, production is expected to fall significantly by 2050. Declining production from the UK's mature North Sea basin indicates that GHG emissions will fall in the baseline pathway[4] by around 40% by 2040 compared to 2025 levels, including the production emissions from potential new oil and gas fields. After taking account of the reduction in production and refining emissions due to declining baseline activity and cross-economy fuel switching, only around 13 $MtCO_2e$ of emissions remain by 2040. In the Balanced Pathway, around 60% of these remaining emissions are abated. For oil and gas platforms, the majority of abatement results from electrification of offshore oil and gas platforms, and from reducing methane flaring and venting (CCC, 2025a).

The majority of fuels currently used in the UK are traded internationally, and the UK is a net importer of both oil and gas (PGR, 2025; CCC, 2025a). In the short term the UK will continue to be dependent on gas, including for heating buildings and marginal production within the power sector (CCC, 2020) and while demand for petroleum products is likely to fall in some parts of the economy such as road transport (i.e. a shift towards electric vehicles), all major forecasters expect resilient or even growing demand for other uses of hydrocarbons such as petrochemicals (IEA, 2018).

[4] A hypothetical baseline pathway that does not include further climate action.

Table 9.8 and Figure 9.3 compares Tornado Max case gas production rates with projected UK gas demand and domestic gas production over Tornado's likely period of production (2029 – 2036). It can be seen from this that during the period 2029 to 2036, the proposed Tornado Development would account for ca. 6.75% or less of UK gas demand under the CB7 Balanced Pathway and ca. 6.59% or less under the DESNZ Net Zero Pathway. Projected UK gas production follows a declining trend, consistent with historical patterns and field maturity in the UKCS, but is less than UK gas demand under both the CB7 Balanced Pathway and DESNZ Net Zero Pathway in all years during the period 2029 - 2036. At its peak, Tornado makes up ca. 20.90 % of projected UK gas production.

**Table 9.8: Tornado Development in the context of Projected UK Gas Demand and Domestic Production (2029 - 2036) (NSTA, 2025c)**

| Year | UK Gas Demand | | | | UK Gas Production | |
|---|---|---|---|---|---|---|
| | CCC 7th Carbon Budget Balanced Pathway (Mtoe)[1] | Tornado projected proportion[2] | DESNZ Net Zero Pathway (Mtoe)[1] | Tornado projected proportion[2] | NSTA UK (Aug 2025 Projection) (Mtoe)[1] | Tornado projected proportion[2] |
| 2029 | 49.62 | 1.57% | 47.00 | 1.66% | 16.02 | 4.86% |
| 2030 | 43.69 | 6.75% | 44.72 | 6.59% | 14.10 | 20.90% |
| 2031 | 40.53 | 5.86% | 42.97 | 5.53% | 12.41 | 19.16% |
| 2032 | 37.77 | 5.03% | 40.02 | 4.74% | 10.95 | 17.34% |
| 2033 | 35.34 | 4.29% | 38.16 | 3.98% | 9.61 | 15.79% |
| 2034 | 33.07 | 3.64% | 36.56 | 3.30% | 8.46 | 14.25% |
| 2035 | 30.66 | 3.05% | 34.65 | 2.70% | 7.44 | 12.57% |
| 2036 | 28.64 | 1.78% | 32.61 | 1.56% | 6.57 | 7.75% |

[1] August 2025 Projections (NSTA, 2025c)

[2] Tornado projected proportion from the Max production case (refer to Appendix G) gas converted from tonnes to Mtoe; Assumes 1 toe = ~41.868 GJ (IEA, 2023b); Assumes 1 tonne of Natural Gas = ~48.5 GJ (based on average 42-55 MJ/kg for Natural Gas (WNA, 2025)), therefore Mtoe = Natural Gas (tonnes) × (48.5/ (41.868 × $10^6$)), or 1 t Natural Gas = 0.0000011584 Mtoe

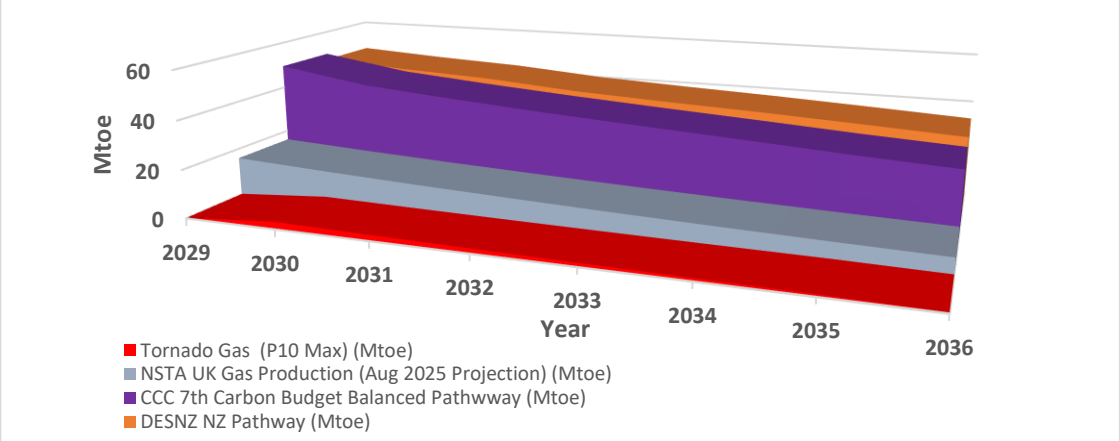



**Figure 9.3: Tornado Production (Max case) in the Context of Future UK Gas Demand and Domestic Production (NSTA, 2025c)**

### UK Carbon Budgets

As noted in Section 9.3.2, the Climate Change Act requires the UK government to set five-yearly legally-binding carbon budgets, 12 years in advance, from 2008 to 2050, which restrict the amount of GHGs the UK can emit. UK Carbon Budgets are economy-wide emissions limits, and do not prohibit oil and gas production.

To place the Tornado Development in the context of the UK carbon budgets, Table 9.9 compares the total gross GHG emissions predicted to be generated by the Tornado Development with the fifth and sixth carbon budget allowances (i.e. the budgets which cover the period when the Tornado field is likely to be in production). As it is possible that not all end use Tornado hydrocarbons will be combusted in the UK (refer to Section 9.6.1), the carbon budget allowances have also been compared with the total direct (Scope 1) GHG emissions predicted to be generated from the Tornado Development, which will occur in the UK.

**Table 9.9: Tornado Development Emissions in the context of UK Carbon Budgets (CCC, 2025a)**

| Carbon Budget (CB) | Period | Allowance (Mt $CO_2e$) | Tornado Total gross GHG projected proportion [1] | Tornado Scope 1 projected proportion [2] | Tornado Scope 1 projected proportion (Partial Electrification) [3] |
|---|---|---|---|---|---|
| CB5 | 2028 to 2032 | 1,725 | 1.37644% | 0.05229% | 0.04201% |
| CB6 | 2033 to 2037 | 965 | 1.22368% | 0.05844% | 0.04668% |

[1] Based on the worst-case total gross GHG emissions (Scope 1 + Scope 3 Downstream) generated from the Tornado Development for the relevant CB period (23,743.67 kt $CO_2e$ for CB5 and 11,808.56 kt $CO_2e$ for CB6), assuming the Tornado Max production case, without partial electrification of SGP. Noting that emissions from Tornado will start in 2029, and end in 2036 for the Max production case.

[2] Based on the total direct (Scope 1) GHG emissions generated from the Tornado Development for the relevant CB period (902.05 kt $CO_2e$ for CB5 and 563.96 kt $CO_2e$ for CB6), assuming the Tornado Max production case, without partial electrification of SGP. Noting that emissions from Tornado will start in 2029, and end in 2036 for the Max production case.

[3] Based on the total direct (Scope 1) GHG emissions generated from the Tornado Development for the relevant CB period (724.60 kt $CO_2e$ for CB5 and 450.44 kt $CO_2e$ for CB6), assuming the Tornado Max production case, with partial electrification of SGP. Noting that emissions from Tornado will start in 2029, and end in 2036 for the Max production case.

It can be seen from Table 9.9, that Tornado's contribution is less than ca. 1.37644% of CB5 and 1.22368% of CB6 when comparing the total gross GHG emissions (Scope 1 + Scope 3 Downstream) that will be generated during the relevant carbon budget period and less than ca. 0.05229% of CB5 and 0.05844% of CB6 when comparing the total direct (Scope 1) GHG emissions that will be generated during the relevant carbon budget period.

Given that this represents an insignificant proportion of the budgets, the GHG emissions generated by the Tornado Development would have no material influence on the UK's ability to meet its statutory carbon budget targets, resulting in a **Minor** magnitude of impact (refer to Table 5.4). In addition, UK Carbon Budgets are economy-wide emissions limits, and do not prohibit oil and gas production, including the Tornado development.

### UK Nationally Determined Contribution (NDC)

Under the Paris Agreement, the UK has set two NDC emissions reduction targets. UK NDC's are economy-wide emissions limits, and do not prohibit oil and gas production.

The UK's 2030 NDC commitment is to reduce all GHG emissions by at least 68% by 2030, based on 1990 levels (excluding international aviation and shipping emissions). The rate of GHG emissions reduction

seen in 2023 is roughly in line with the annual pace of change needed to meet the 2030 NDC target (CCC, 2025a).

The UK's 2035 NDC target to reduce all GHG emissions by at least 81% by 2035, compared to 1990 levels (excluding international aviation and shipping emissions) was announced at COP29 and was subsequently presented to Parliament in January 2025 (UK Government, 2025).

To place the Tornado Development in the context of the UK's NDCs, Table 9.10 compares total gross GHG emissions predicted to be generated by the Tornado Development in 2030 and 2035 respectively with the 2030 and 2035 NDC allowances. As noted above, it is possible that not all end use Tornado hydrocarbons will be combusted in the UK, therefore the NDC allowances have also been compared with the total direct (Scope 1) GHG emissions predicted to be generated from the Tornado Development in 2030 and 2035, which will occur in the UK.

**Table 9.10: Tornado Development Emissions in the context of UK NDC targets (UK Government, 2025)**

| NDC Target | Allowance (Mt $CO_2e$) | Tornado Total gross GHG projected proportion [1] | Tornado Scope 1 projected proportion [2] | Tornado Scope 1 projected proportion (Partial Electrification) [3] |
|---|---|---|---|---|
| NDC 2030 | 254.08 | 3.50164% | 0.11775% | 0.09629% |
| NDC 2035 | 155.3 | 1.69765% | 0.08259% | 0.06503% |

[1] Based on the worst-case total gross GHG emissions (Scope 1 + Scope 3 Downstream) generated from the Tornado Development for the relevant NDC period (8,896.96 kt $CO_2e$ for NDC2030 and 2,636.45 kt $CO_2e$ for NDC2035), assuming the Tornado Max production case, without partial electrification of SGP. Noting that emissions from Tornado will start in 2029, and end in 2036 for the Max production case.
[2] Based on the total direct (Scope 1) GHG emissions generated from the Tornado Development for the relevant NDC period (299.17 kt $CO_2e$ for NDC2030 and 128.26 kt $CO_2e$ for NDC2035), assuming the Tornado Max production case, without partial electrification of SGP. Noting that emissions from Tornado will start in 2029, and end in 2036 for the Max production case.
[3] Based on the total direct (Scope 1) GHG emissions generated from the Tornado Development for the relevant NDC period (244.65 kt $CO_2e$ for NDC2030 and 101.00 kt $CO_2e$ for NDC2035), assuming the Tornado Max production case, with partial electrification of SGP. Noting that emissions from Tornado will start in 2029, and end in 2036 for the Max production case.

It can be seen from Table 9.10 that Tornado's total gross GHG emissions account for ca. 3.50164% of the 2030 NDC allowance and ca. 1.69765% of the 2035 NDC allowance, whilst Tornado's total direct (Scope 1) GHG emissions account for ca. 0.11775% of the 2030 NDC allowance and 0.08259% of the 2035 NDC allowance.

Given these non-significant proportions, the GHG emissions generated by the Tornado Development would have no material influence on the UK's ability to meet its NDC emissions reduction targets, resulting in a **Minor** magnitude of impact (refer to Table 5.4).

## 9.7 Mitigation Measures

Since the use (including whether or not this is by combustion) of the production is not within the control of Ithaca, no mitigation measures that could be taken by the Tornado Development to reduce Scope 3 downstream emissions have been identified.

Ithaca's general emission reduction initiatives which will be applied to the Tornado Development project are focused on reducing indirect (Scope 3) upstream GHG emissions and include:

- Vessel's environmental emissions will be factored into the tender evaluation process;
- Compliance with International Maritime Organisation requirements on fuels;
- Optimise drilling, installation, maintenance and repair and decommissioning activities, including vessel movements, by careful planning to optimise fuel use holistically.
- Well test and clean-up durations will be optimised and permitted appropriately.

With regards to direct (Scope 1) GHG emissions, responsibility for identification and implementation of emissions reduction initiatives at SGP resides with the SGP operator (TEPUK) under the regulation of SEPA and NSTA in their respective capacities as regulators of onshore Oil and Gas facilities. Ithaca, as the operator of Tornado, will support the SGP operator as they continue to assess and implement reasonable decarbonisation strategies for SGP.

The SGP ERAP lists the following as future potential emissions reduction initiatives:

- **Flare Reduction Projects:**
  - Flare gas composition studies; understand ratio of hydrocarbon and $N_2$; develop real-time burn efficiency monitoring.
  - Localised recovery and compression; target individual sources and recompress rather than build standalone Flare Gas Recovery System.
- **Fuel Gas Reduction Projects:**
  - Single heating medium pump; reduce redundancy for reliable high-power demand equipment.
  - Condensate export batching; export liquids in batches rather than continuously to reduce average power demand.
- **Import Power Projects:**
  - Partial Electrification, upgrade of grid connection from 2MW to 6MW - reduce use of fuel gas by importing all plant electricity from the grid, purchasing green energy.

## 9.8 Other Relevant Considerations

The proposed Tornado Development concept has been selected and defined with consideration to the central obligation of the OGA Strategy (OGA, 2020) and with cognisance of the requirements of NSTA's Net Zero Stewardship Expectation 11 (NSTA, 2021).

As noted in Section 9.3.2, the UK Net Zero Growth Plan (DESNZ, 2023b) acknowledges that fossil fuels will retain a crucial role in the energy system until there are credible clean energy alternatives that can replicate their role. The Independent Review of Net Zero (Mission Zero, 2023) also recognises that in the short term the UK will still need oil and gas to secure our energy independence and as transition fuels towards 2050. In addition, unabated gas will continue to play in a new back-up role to provide security of supply throughout the transition to clean power into the 2030s and beyond as outlined in the Clean Power 2030 Action Plan (DESNZ, 2024a).

By lowering dependence on fossil fuel imports, the UK can cut emissions intensity. For the chosen development concept, Tornado when produced via the SGP has a forecasted carbon intensity between 16.0 kg $CO_2$e/boe and 18.6 kg $CO_2$e/boe (depending on the production case). These figures exclude GHG emissions resulting from further refinement transportation and distribution activities which have been classified and accounted for as Tornado Downstream Scope 3 Emissions. The above stated values, even with margin to account for further refinement, transportation and distribution activities are well below the UKCS average of 28 kgCO2e/boe, and significantly lower than the average GHG intensity of imported LNG (85 kgCO2/boe), as illustrated in Figure 9.4 (NSTA, 2025b).

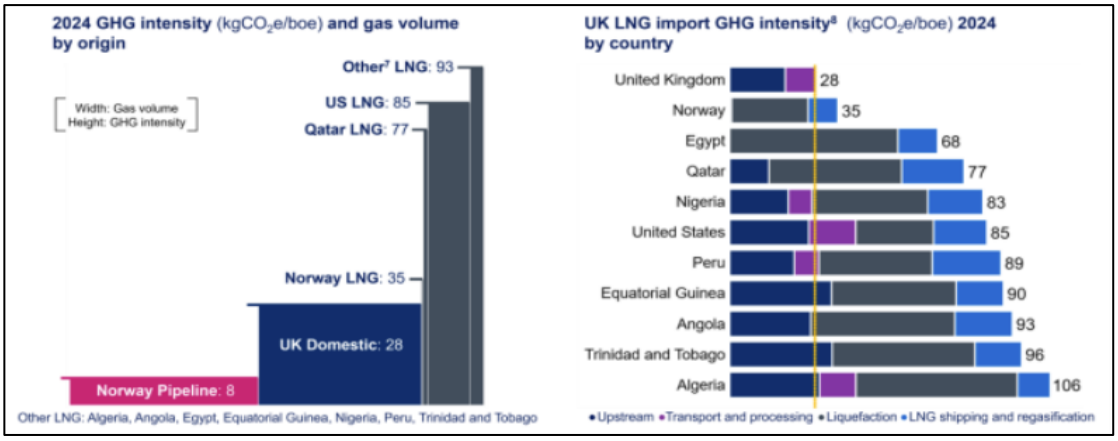



**Figure 9.4: 2024 UK Gas Supply Carbon Intensities (NSTA, 2025b)**

All gas produced from the Tornado field will flow into the NTS via the SGP and will be used domestically and not exported. In a time of historically low domestic energy production with more than 40 % of the UK's energy now imported (DESNZ, 2025d), responsible development of low carbon intensity fields ensures that the UK meets its energy demand while retaining control over GHG emissions, energy pricing, and job creation. Moreover, according to the Climate Change Committee (CCC), the UK will require 13–15 billion barrels of oil equivalent in the period 2025 to 2050 but is currently only forecast to produce 4 billion (CCC, 2025a; NSTA, 2025c). Development of Tornado therefore provides the UK with low carbon, indigenous gas, helping contribute to energy security during the transition to Net Zero.

In addition to the above, the Project aligns with the UK Government's strategy to maintain domestic production to preserve critical infrastructure, skills, and supply chain capacity for the energy transition.

## 9.9 Residual Effects

In summary, the sensitivity of the global climate to GHG emissions is **Very High** (refer to Table 5.3).

In a global context, the magnitude of the proposed Tornado Development's GHG impacts is **Minor** (refer to Table 5.4) as:

- The GHG emissions generated as a result of the proposed Tornado Development are considered to be compatible with emission reduction pathways that hold the global average temperature to well below 2°C above pre-industrial levels. Tornado will also cease production in or before 2038, well before the global target for Net Zero emissions by 2050. Future global GHG emissions will depend on the success of international collaborative efforts to decarbonise the global energy system; however, Tornado's contribution represents a very small fraction of projected global GHG emissions under the IPCC's low (SSP1-2.6) emissions pathway consistent with limiting warming to 2°C (ca. 0.02149% of median global GHG emissions in 2030);
- Tornado contributes a very small percentage towards predicted global oil and gas production rates in international pathways consistent with limiting warming 2°C (ca. 0.082% in 2030 and ca. 0.027% in 2035 of global gas production and ca. 0.00495% in 2030 and ca. 0.00038% in 2035 of global oil production). Of note, natural gas will continue to play a crucial role in global energy systems for the foreseeable future, displacing higher-carbon fuels such as coal and heavy fuel oil and supporting the expansion of renewables in the power sector.

In a national context, the Tornado Development is aligned with UK government climate policies and strategies. The GHG emissions generated by the Tornado Development would have no material influence on the UK's ability to meet its statutory carbon budget targets or NDC emissions reduction targets. Tornado when produced via SGP has a forecasted carbon intensity below the UKCS average and significantly lower than the average GHG intensity of imported LNG. Development of Tornado will therefore provide the UK with low carbon, indigenous gas, helping contribute to energy security during the transition to Net Zero.

Given the above, in a Paris Aligned oil and gas production pathway, the effect of the Tornado Development's worst-case total gross GHG emissions (based on the Max production case) on the global climate is therefore considered to be **Minor** and not significant.

# 10 Marine Discharges

## 10.1 Introduction

Ithaca is committed to minimising discharges into the marine environment from its operations, as far as possible. This section assesses the potentially significant impacts on water quality and local flora and fauna that may arise from the following planned operational discharges associated with the proposed Tornado Development:

- Discharge of drill cuttings at the sea surface;
- Discharge of residual hydrocarbons when drilling through the payzone with WBM, when conducting well clean-up and testing operations and during pipeline dewatering;
- Discharge of drilling, cementing, completion and rig chemicals during drilling operations;
- Discharge of chemicals during hook-up and commissioning of subsea infrastructure, including commissioning and preservation fluids;
- Discharge of water-based hydraulic fluid for subsea valve activation during production operations (open loop control system) and maintenance activities;
- Discharge of chemicals and hydrocarbons during subsea intervention activities and during decommissioning operations.

Unplanned discharges leading to accidental releases to the sea are discussed in Section 11.

## 10.2 Assessment of Impacts

### 10.2.1 Discharge of Drill Cuttings and WBM

As described in Section 3.3.5, on the worst case assumption that the Tornado wells are drilled conventionally (i.e. without CAN-ductor), the two top hole sections (42" × 36" and 26") will be drilled riserless with seawater and frequent bentonite "sweeps" passed down the wells to clean out the hole. Cuttings from these top-hole sections will be discharged directly from the wellbore at the seabed. For the deeper 17½, 12¼" and 8½" (underreamed up to 12¼") sections, a marine riser will be situated between the well and the drilling deck so that cuttings and drilling fluid are circulated back up to the MODU. These sections will be drilled with either WBM or LTOBM. For the purposes of this ES, conventional drilling with WBM has been assumed (refer to justification in Section 2.5.3). The WBM and cuttings returned to the MODU from the deeper well sections will therefore pass through shale shakers, with the separated cuttings passed through a cleaning system and discharged to sea from the MODU just below the sea surface.

#### Drill Cuttings and Muds Dispersion Modelling

The discharge of WBM drill cuttings and fluids from the MODU will result in a temporary effluent plume descending through the water column. To quantify the total suspended solids (TSS) concentrations in the water column and inform the assessment of potential environmental effects, simulations of the discharged WBM drill cuttings and fluids from the proposed Tornado wells have been completed using the three-dimensional (3D) dispersion model (MUDMAP) by RPS on behalf of Ithaca. A copy of the drill cuttings and muds dispersion modelling report is provided for reference in Appendix C[1]. Note, impacts to the marine environment from the settlement of drill cuttings, muds and cement on the seabed are considered separately in Section 7.

To represent the combined influence of ocean drift currents and tidal currents at Tornado, ten years (2010 to 2019) of 3D HYCOM ocean data and HYDROMAP tidal data was generated for the study site.

[1] Cuttings volumes used in the dispersion modelling reflect conservative, worst-case assumptions based on well profiles available at the time of modelling. Subsequent refinements to well section lengths during detailed well planning have resulted in minor differences compared to the volumes presented in the Project Description; these differences do not affect the conservatism or conclusions of the modelling.

Discharges were modelled for all three well locations (W1, W3 and contingent N1), with a total of 150 trajectory simulations (50 per well) conducted to represent seasonal variability and support a robust cumulative impact assessment (RPS, 2025a).

The environmental thresholds applied to the dispersion modelling to evaluate potential effects on the water column are defined in Table 10.1. These thresholds were used to define zones of undetectable, low, and high potential ecological exposure for water column turbidity. Nelson et al. (2016) reports concentrations less than 10 mg/l as a minimal or no effect concentration, whilst concentrations above 10 mg/l have a sublethal effect to pelagic biota. Furthermore, IOGP (2016) cite that very high concentrations (>1,830 mg/l) of TSS have been shown to result in mortality of pelagic biota. Hence, a threshold range of 10-1,830 mg/l and above 1,830 mg/l were used to define low and high TSS exposures, respectively.

**Table 10.1: Reporting Thresholds for TTS Concentrations**

| Reporting Criteria | Total Suspended Solids Concentration (mg/l) |
|---|---|
| Minimum reporting threshold | 5 |
| Low exposure | 10 – 1,830 |
| High exposure | > 1,830 |

Figure 10.1 illustrates the combined predicted 95$^{th}$ percentile TSS concentrations, from the discharge of drill cuttings and muds at all three release locations. Elevated TSS concentrations at the high exposure threshold were predicted to occur in the immediate vicinity of the release locations (<50 m). Predicted maximum instantaneous TSS concentrations arising from the discharge of cuttings and muds from the release locations were 311.5 mg/l (N1), 311.0 mg/l (W1), and 313.7 mg/l (W3) (RPS, 2025a).

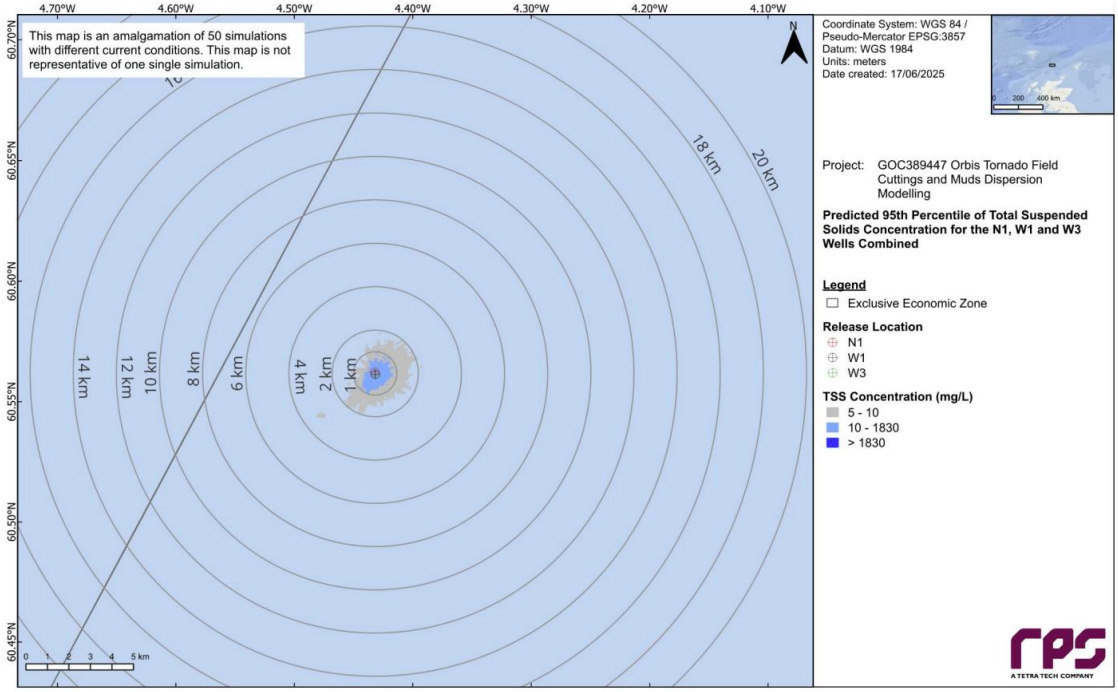



**Figure 10.1: Combined predicted maximum instantaneous TSS concentrations, based on 95$^{th}$ percentile concentrations from the discharge of drill cuttings and muds at all three release locations, N1, W1 and W3. Results are based on 150 simulations (RPS, 2025a)**

Based on the assessment of 50 simulations per well and 95$^{th}$ percentile analysis, maximum distances from the release location to the edge of the minimum reporting threshold (5 mg/l) ranged between 1.5 km (W3) and 3.3 km (W1). The maximum distances to the low exposure thresholds (10 mg/l) were 1.1 km for N1 and W1, and 0.7 km for W3. The total area of coverage for the minimum reporting threshold (5 mg/l) ranged between 2.3 km$^2$ (W3) and 4.6 km$^2$ (W1). Additionally, the total area of

coverage for the low exposure thresholds (10 mg/l) ranged from 0.6 km$^2$ (W3) to 1.2 km$^2$ (N1 and W1) (RPS, 2025a).

Table 10.2 presents the combined predicted areas of coverage and maximum distances resulting from all three release locations, N1, W1 and W3. Based on the combined assessment of all 150 simulations and 95$^{th}$ percentile analysis, the maximum distances (measured from the mid-point between the proposed N1, W1 and W3 wells) to the edge of the minimum reporting threshold (5 mg/l) and the low exposure thresholds (10 mg/l) were 3.3 km and 1.1 km, respectively (RPS, 2025a).

**Table 10.2: Combined predicted 95$^{th}$ percentile total areas of coverage and maximum distances from the release location, N1, W1 and W3, to each reporting threshold based on the results of all 150 simulations (RPS, 2025a)**

| Reporting Criteria | 95$^{th}$ Percentile Total Area of Coverage (km$^2$) | 95$^{th}$ Percentile Maximum Distance (km) from the Release Location |
|---|---|---|
| 5 mg/l TSS concentration (Minimum reporting threshold) | 5.6 | 3.3 |
| ≥10 mg/l TSS concentration (Low exposure threshold) | 1.4 | 1.1 |
| ≥1,830 mg/l TSS concentration (High exposure threshold) | - | - |

As noted in Section 2.5.3, preliminary drill cuttings and muds dispersion modelling was also run for the LTOBM scenario. As the LTOBM scenario resulted in elevated TSS concentrations over a wide area than the WBM scenario, a summary of the combined predicted areas of coverage and maximum distances resulting from all three release locations, N1, W1 and W3, has been provided in Table 10.3, for comparison. However, regardless of whether WBM or LTOBM is used to drill the Tornado wells, the discharge of cuttings and muds will lead to relatively short-lived increased TSS concentrations, which are expected to dilute and reduce with distance from the release locations.

**Table 10.3: LTOBM Scenario - combined predicted 95$^{th}$ percentile total areas of coverage and maximum distances from the release location, N1, W1 and W3, to each reporting threshold based on the results of all 150 simulations (RPS, 2025c)**

| Reporting Criteria | 95$^{th}$ Percentile Total Area of Coverage (km$^2$) | 95$^{th}$ Percentile Maximum Distance (km) from the Release Location |
|---|---|---|
| 5 mg/l TSS concentration (Minimum reporting threshold) | 9.4 | 5.9 |
| ≥10 mg/l TSS concentration (Low exposure threshold) | 2.5 | 1.4 |
| ≥1,830 mg/l TSS concentration (High exposure threshold) | - | - |

### Water Quality

The sensitivity of the water column to contamination from the discharge of drill cuttings and WBM is considered to be **Low**. The receptor has a Low value; as only the water column in relatively close proximity to the discharge point will be impacted, hence it is considered to be of local importance. The WoS area is characterised by persistent, long-period swells, complex current regimes and rapidly changing weather conditions. The water quality is subject to rapid refreshment rates and mixing of the water column, coupled with strong wave action on the sea surface. Therefore, the receptor resistance and resilience is Very High to drill cutting and WBM discharges. The magnitude of impact is considered to be **Minor**, with a short-term temporary change in baseline environmental conditions. Effects on water quality due to the discharge of drill cuttings and WBM are therefore assessed as **Minor**.

#### Plankton

The sensitivity of plankton to the planned discharge of drill cuttings and WBM is considered to be **Low**. The receptor is of Medium value; the plankton community has a regional importance to the Faroe-Shetland Channel, providing a food source to higher trophic levels in this region. However, the temporary effluent plume resulting from the discharge of drill cuttings and WBM is expected to disperse rapidly and the plankton has high recoverability in the short-term with high reproduction rates. Therefore, the receptor resistance and resilience is Very High to drill cutting and WBM discharges. The magnitude of impact is considered to be **Negligible**, as the rapid dilution of the WBM and cuttings plume in the water column is anticipated. Any changes to the plankton community are anticipated to be immeasurable / undetectable. Effects on plankton due to the discharge of drill cuttings and WBM are therefore assessed as **Negligible**.

#### Benthic Communities

The impact to benthic communities from the accumulation of WBM drill cuttings, mud and cement on the seabed at the proposed Tornado drill centre location is assessed in Section 7 (Seabed Disturbance).

#### Fish

The sensitivity of fish to the planned discharge of drill cuttings and WBM is considered to be **Low**. The receptor has a Very High value; many of the species that may be present in the Tornado area (e.g. blue whiting, Norway pout, Greenland halibut, ling, mackerel, anglerfish (monkfish), Atlantic salmon, common eel, spurdog, basking shark and porbeagle shark) are listed as Priority Marine Features (PMFs) in Scottish waters (see Section 4.3.3). However, the temporary effluent plume made from drill cuttings and WBM is expected to disperse rapidly, and fish have the ability to avoid the impacted area. Therefore, the receptor resistance and resilience is Very High to drill cutting and WBM discharges. The magnitude of impact is considered to be **Negligible**, as the rapid dilution of the WBM and cuttings plume in the water column is anticipated. Any changes to the fish community are anticipated to be immeasurable / undetectable. Effects on fish due to the discharge of drill cuttings and WBM are therefore assessed as **Negligible**.

### 10.2.2 Discharge of the Residual Reservoir Hydrocarbons

Residual hydrocarbons may be discharged when drilling through the payzone, when conducting well clean-up and testing operations and during pipeline dewatering, as detailed below. In addition, there is the potential for small volumes of hydrocarbons to be discharged during subsea intervention activities and during decommissioning operations.

#### Drilling through the Pay Zone

When drilling through the pay zone, conservatively assumed to extend for up to 100 m and drilled as an underreamed hole section up to 12¼", an estimated 23,730 kg (23.73 tonnes) of cuttings will be generated per well (refer to Section 3.3.5). These cuttings could be contaminated with up to 130 kg (0.13 tonnes) of residual reservoir hydrocarbons, which would be discharged to sea from the MODU with the cuttings after they have passed through the cuttings cleaning system.

Should all three wells be drilled, including a repeat contingency side-track, the total quantity of cuttings generated for discharge would increase to approximately 94,920 kg (94.92 tonnes), with an associated maximum of 520 kg (0.52 tonnes) of residual reservoir hydrocarbons. It is noted that the Tornado reservoir is gas-dominated, which substantially reduces the likelihood and magnitude of oil being present in the discharged cuttings.

. In addition to the primary cuttings dispersion modelling, a provisional sensitivity assessment was undertaken by RPS using the MUDMAP model to explore the potential for visible oil at the sea surface from residual hydrocarbons discharged with cuttings. Under representative offshore conditions, no persistence of visible oil was predicted by the model. Accounting for model resolution limits, this indicates that any visible oil would be highly localised (<5 m from the discharge point) and short-lived (<1 minute). Consequently, further detailed surface oil modelling and a full standalone modelling write-up were not considered necessary to inform the environmental assessment. The combination of deep water, strong currents, and rapid dilution through vertical and horizontal mixing is expected to further

limit the potential for widespread contamination. As such, any hydrocarbons discharged to sea whilst drilling through the pay zone are anticipated to be rapidly diluted with the turbidity of the water column and broken down through biodegradation processes.

During the proposed drilling operations, a minimum of five samples will be taken from the shakers (at the point of discharge) and will be sent to a laboratory for analysis to estimate the amounts of reservoir hydrocarbons discharged. Ithaca will seek permission to discharge the potentially contaminated drill cuttings and muds via the submission of an Oil Discharge Permit SAT on the UK Energy Portal, as required under The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended).

In the event LTOBM is used when drilling through the pay zone, a thermal cuttings treatment unit will be installed on the MODU to safely treat the contaminated cuttings to an acceptable overboard disposal limit (<1% OOC).

### Well Clean-up and Testing Operations

As described in Section 3.3.7, prior to production commencing, the wells will be cleaned up to remove any drilling fluids waste and debris remaining in the wells to minimise the risk of plugging of the lower completion and prevent damage to the pipeline. Initially each wellbore will be cleaned-up with the in-situ drilling mud and then replaced with a completion brine. Afterward, the lower completion will be installed, and a gravel pack operation carried out. Once the gravel pack is completed, the area above the lower completion will be displaced using a suitable brine. Finally, the upper completion will be installed. Throughout this process, it is estimated that approximately 3,000 barrels (477 $m^3$) of completion brine will be discharged per well.

Well clean-up operations will be followed by a flowing period to allow data acquisition for the assessment of productivity (well test). At this time, it is not known what quantity of hydrocarbon will be flared during the well test, however it will not exceed 2,000 tonnes of hydrocarbon over a 96-hour period (per well). The maximum amount of formation water expected to be produced during the well flow tests, is 500 bbls (80 $m^3$). The formation water will be separated from the gas and condensate streams via the well test package.

All returned aqueous well clean-up and well testing fluids will be pumped to a filter unit on the MODU prior to being discharged overboard. These well fluids have the potential to be contaminated with residual reservoir hydrocarbons and will only be discharged after passing through a water treatment filtration package to meet the oil discharge permit. It is estimated that up to 2.4 kg of hydrocarbons might be discharged (based on a concentration of 30 mg/l).

As noted, above, any hydrocarbons discharged to sea from the Tornado well clean-up and testing operations are anticipated to dilute rapidly with the turbidity of the water and broken down through biodegradation processes.

During the proposed well clean-up and testing operations, representative oil in water samples will be taken (at the point of discharge) and will be sent to a laboratory for analysis to estimate the amounts of reservoir hydrocarbons discharged. Ithaca will seek permission to discharge the potentially contaminated well clean-up and test fluids via the submission of an Oil Discharge Permit SAT on the UK energy portal, as required under The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended).

### Pipeline Dewatering

Following receipt of the dewatering pig at the Tornado end of the pipeline there is potential for a quantity of SIRGE hydrocarbon gas (and associated small volume of liquid condensate) to be discharged to the environment prior to valve closure. The final methodology for dewatering of the production pipeline will be developed by the execution contractor, which is yet to be selected. The quantity of this release will be determined during detailed design and will be minimised as far as practicable by visual monitoring to ensure quickest possible closure of required valves post dewatering.

### Assessment of Impacts

Hydrocarbons cause toxicity in aquatic organisms by a mechanism referred to as non-polar narcosis (or non-specific) toxicity. This toxicity is reversible and is observed in most organisms when exposed to sufficient levels of hydrocarbons (e.g. the effects of alcohol or solvents on humans). The partitioning of an organic substance between water and a hydrocarbon phase is described by its octanol water partition coefficient. This value is determined in the laboratory by a standardised method and reported as a logarithmic value (log $P_{ow}$). The higher the Log $P_{ow}$ value the greater the amount of substance that dissolves in the organic (octanol) phase. Correlations of Log $P_{ow}$ values with toxicity for single hydrocarbons indicate that solubility increases more rapidly with increasing Log $P_{ow}$ than does the dissolved fraction of the hydrocarbon (i.e. the concentration that causes effects). Although this relationship varies with species it may be concluded that above a certain Log $P_{ow}$ value a hydrocarbon will not exhibit acute toxicity. This relationship has been verified experimentally for fish and invertebrates; parafinic hydrocarbons with carbon number 10 or greater (Log $P_{ow}$ >5) show no acute toxicity and parafinic hydrocarbons with carbon number greater than 14 (Log $P_{ow}$>7.3) show no chronic toxicity (CONCAWE, 2001). As such when an oil is released the lighter ends are likely to rapidly evaporate from the aquatic environment, whilst the heavier ends are not inherently toxic in aquatic systems.

Nonetheless, hydrocarbon constituents such as PAHs are of concern due to their potential mutagenic and carcinogenic properties. Despite this, many marine organisms, including fish and invertebrates possess enzymatic pathways to metabolise and detoxify PAHs at concentrations typically found in the marine environment (Stein *et al*., 2010; Tuvikene, 1995; Rust *et al*., 2004). Furthermore, the environmental fate of hydrocarbons involves a range of natural attenuation processes. Low molecular weight compounds may volatilise at the air–water interface or undergo biodegradation by native microorganisms. Others may precipitate after oxidation or become adsorbed onto suspended solids and sediments. These combined processes contribute to reducing both the concentration and bioavailability of hydrocarbon compounds in the receiving environment, thereby diminishing their overall toxicity to marine organisms (OGP, 2005).

Modelling and literature data suggest that the impacts of hydrocarbon discharges in open offshore environments are highly localised and transient. For example, a study conducted for the Norwegian petroleum sector found that while hydrocarbon effects may be observed at the level of individual organisms, no impacts were evident at the population or community level (OGUK, 2014).

In WBM systems, such as those that may be used during the proposed Tornado drilling operations, most of the reservoir hydrocarbons will remain associated with the weighting agent and surfactant particulate and polymer components and will be widely dispersed in the marine environment. In the unlikely event that the oil is dispersed over the seabed after falling through the water column whilst being dispersed by the currents, levels of THC in the sediments are not expected to be significantly raised above background values because of these discharges. Due to the high-water content in the fluids, any marine impact would be anticipated to be transient and disperse throughout the water column under the effects of vertical and horizontal turbulence and current flows, particularly given the water depth at Tornado (ca. 1,060 m).

### Water Quality

The sensitivity of the water column to contamination from the discharge of residual reservoir hydrocarbons is considered to be **Low**. The receptor has a Low value; as only the water column in close proximity to the discharge point will be impacted, hence it is considered to be of local importance. The WoS area is characterised by persistent, long-period swells, complex current regimes and rapidly changing weather conditions. The water quality is subject to rapid refreshment rates and mixing of the water column, coupled with strong wave action on the sea surface. Therefore, receptor resistance and resilience is Very High to the discharge of residual reservoir hydrocarbons. The magnitude of impact is considered to be **Minor**, with no long-term changes in the baseline environment. Effects on water quality due to the discharge of residual reservoir hydrocarbons are therefore assessed as **Minor**.

#### Plankton

The sensitivity of plankton to the discharge of residual reservoir hydrocarbons is considered to be **Low**. The receptor is of Medium value; the plankton community has a regional importance to the Faroe-Shetland Channel, providing a food source to higher trophic levels in this region. However, the residual reservoir hydrocarbons are not expected to persist within the marine environment and the plankton has high recoverability in the short-term with high reproduction rates. Therefore, the receptor resistance and resilience is Very High. The magnitude of impact is considered to be **Negligible**, as the rapid dilution of the residual reservoir hydrocarbons in the water column are anticipated. Any changes to the plankton community are anticipated to be immeasurable / undetectable. Effects on plankton due to the discharge of residual reservoir hydrocarbons are therefore assessed as **Negligible**.

#### Fish

The sensitivity of fish to the planned discharge of residual reservoir hydrocarbon is considered to be **Low**. The receptor has a Very High value; many of the species that may be present in the Tornado area (e.g. blue whiting, Norway pout, Greenland halibut, ling, mackerel, anglerfish (monkfish), Atlantic salmon, common eel, spurdog, basking shark and porbeagle shark) are listed as PMFs in Scottish waters (see Section 4.3.3). However, the residual reservoir hydrocarbons are not expected to persist within the marine environment and fish do have some tolerance / ability to avoid, adapt and recover from hydrocarbon pollution. The magnitude of impact is considered to be **Negligible**, as the rapid dilution of the residual reservoir hydrocarbons in the water column are anticipated. Any changes to the fish community are anticipated to be immeasurable / undetectable. Effects on fish due to the discharge of residual reservoir hydrocarbons are therefore assessed as **Negligible**.

### 10.2.3 Discharge of Chemicals and Hydraulic Fluid

The proposed Tornado Development will result in routine discharges of chemicals during drilling, commissioning and subsea intervention activities. On cessation of production, chemicals will be discharged during decommissioning operations. Note, the discharge of pipeline commissioning chemicals has been assessed separately in Section 10.2.4.

These chemicals have the potential to result in a significant impact on the marine environment. Chemical discharges to the marine environment can result in wide ranging environmental impacts, including a decline in water quality, changes in water chemistry (such as pH and temperature), toxicity effects from chemical components and the contamination of seabed sediments as well as acute or long term effects on marine organisms. Whether these effects are realised depends on a number of factors such as the inherent toxicity of the material, the quantities discharged and resulting concentrations in the water column, the length of time biota are exposed to that concentration and the sensitivity of the organisms to the particular chemical (OGUK, 2019).

In accordance with the Offshore Chemical Regulations 2002 (as amended), Ithaca considers the minimisation of chemical usage a priority and recognises that substitution is an important aspect of the OSPAR Harmonised Mandatory Control Scheme (HMCS). Where practicable, chemicals with a high risk profile will be substituted out in favour of those with an improved environmental profile and, wherever possible, chemicals will be chosen which are PLONOR.

Prior to operations commencing offshore, all CHARMable (Chemical Hazard Assessment and Risk Management) chemicals to be discharged will be assessed by calculating a Risk Quotient (RQ). Where chemical use and discharge results in a RQ value >1, thus indicating a possible risk of the discharge causing harm to the marine environment, further investigation of the product will be carried out to determine if the RQ can be lowered or if an alternative product can be used which produces a lower RQ. The site-specific risk assessment of the chemicals to be used and discharged will be detailed within the appropriate Chemical Permit SAT.

It is anticipated that once discharged, the majority chemicals used will rapidly disperse given the hydrographic regime in the area and will be readily broken down through natural biodegradation processes. Note, in the event that LTOBM is used to drill the Tornado wells, the chemical additives returned to the MODU will pass through the thermal treatment unit on the MODU and are expected to be broken down by the thermal treatment (Vik et al., 2014).

In addition to the above, hydraulic fluid will be released during subsea valve operation and maintenance. However, given the use of a water based hydraulic fluid, which will disperse rapidly due to the currents in the area, any environmental impacts will be limited.

#### Water Quality

The sensitivity of water column to contamination from the planned, routine discharge of chemicals and hydraulic fluid is considered to be **Low**. The receptor has a Low value; as only the water column in close proximity to the discharge point will be impacted, hence it is considered to be of local importance. The West of Shetland area is characterised by persistent, long-period swells, complex current regimes and rapidly changing weather conditions. The water quality is subject to rapid refreshment rates and mixing of the water column, coupled with strong wave action on the sea surface. Therefore, the receptor resistance and resilience is Very High to planned, routine chemical and hydraulic fluid discharges. The magnitude of impact is considered to be **Minor**, with a short-term temporary change in baseline environmental conditions. Effects on water quality due to planned, routine chemical and hydraulic fluid discharges are therefore assessed as **Minor**.

#### Plankton

The sensitivity of plankton to the planned, routine discharge of chemicals and hydraulic fluid is considered to be **Low**. The receptor is of Medium value; the plankton community has a regional importance to the Faroe-Shetland Channel, providing a food source to higher trophic levels in this region. However, once discharged, the chemicals and hydraulic fluid are not expected to persist within the marine environment and the plankton has high recoverability in the short-term with high reproduction rates. Therefore, the receptor resistance and resilience is Very High. The magnitude of impact is considered to be **Negligible**, as the rapid dilution of the chemicals in the water column are anticipated. Any changes to the plankton community are anticipated to be immeasurable / undetectable. Effects on plankton due to the routine discharge of chemicals and hydraulic fluid are therefore assessed as **Negligible**.

#### Fish

The sensitivity of fish to the planned, routine discharge of chemicals and hydraulic fluid is considered to be **Low**. The receptor has a Very High value; many of the species that may be present in the Tornado area are listed as PMFs in Scottish waters (see Section 4.3.3). However, the planned, routine discharge of chemicals and hydraulic fluid is not expected to persist within the marine environment. The magnitude of impact is considered to be **Negligible**, as the rapid dilution of the planned, routine discharge of chemicals and hydraulic fluid in the water column is anticipated. Any changes to the fish community are anticipated to be immeasurable / undetectable. Effects on fish due to the planned, routine discharge of chemicals and hydraulic fluid are therefore assessed as **Negligible**.

### 10.2.4 Discharge of Pipeline Commissioning and Preservation Fluids Subsea

As discussed in Section 3.4.5, the production and MEG pipelines will be installed air filled which will be displaced by flooding with chemically treated filtered water. Once installed the pipeline will be hydrotested to verify system integrity, which will include the discharge of a pipeline hydrotest treatment at the Tornado end of the pipeline. It is anticipated that a hydrotest cocktail such as Roemex RX-5255 and seawater will be used during these operations. Roemex RX-5255 is a 4 in 1 liquid hydrotest cocktail chemical comprising corrosion inhibitor, biocide, oxygen scavenger and leak detection dye. The RX-5255 product carries a UK Level 4 substitution warning for high toxicity and poor biodegradation, which is representative of a worst-case chemical that is likely to be used.

#### Hydrotest Dispersion Modelling Approach

To assess the potential environmental effects on the marine environment from this discharge, a hydrotest dispersion modelling study was conducted by RPS using their CORMIX and MUDMAP models (refer to Appendix E). The physical mixing and dilution of the discharged hydrotest plume within the receiving environment is divided into two distinct zones: the near-field and the far-field. The modelling study addressed both near-field (initial mixing) and far-field (subsequent transport and dilution) dispersion processes, as follows:

- Initially, a near-field model (CORMIX) was used to simulate the hydrotest plume as it discharged from the pipeline. This allowed for the assessment of plume dynamics and achieved dilutions across three different current speed scenarios based on the 5$^{th}$, 50$^{th}$ and 95$^{th}$ percentiles: Weak (0.04 m/s), Medium (0.14 m/s), and Strong (0.34 m/s) current speeds.
- In the second phase, current data, discharge information and plume characteristics from the near-field results were input into the 3D discharge and plume behaviour model (MUDMAP). This model simulated 100 individual 2-day long simulations. The 100 simulations were modelled under a wide range of local current conditions by stochastic modelling (i.e. repeated simulations with each simulation using a unique time-sequence of current flow, chosen at random from the 10-year time series of current data). The results for each scenario were combined to create an annual assessment based on the 95$^{th}$ percentile dilutions.

The scenario modelled assumed a hydrotest discharge volume of 8,897.2 m³, over a period of 0.65 days (570.3 m³/h), discharged from a depth of 1,060 m, 1.5 m above the seabed from the proposed Tornado drill centre location. An initial chemical (RX-5255) concentration of 550 mg/l was also assumed. The model used a 10-year (2010 – 2019) hindcast of combined tidal and ocean current data to ensure statistical robustness. Vertical water column profiles for temperature and salinity informed density-driven mixing processes.

The assessment of chemical concentrations in the plume from the MUDMAP modelling outputs were based on the CHARM method of calculating the Predicted No Effect Concentration (PNEC); an accepted methodology in the UK. The PEC/PNEC approach (where the predicted environmental concentration (PEC) of a contaminant is divided by the PNEC (the highest concentration at which no environmental effect is predicted). A ratio of >1 indicates there may be an environmental effect.

Table 10.4 presents the key toxicity data for the RX-5255 pipeline hydrotest chemical which is used to determine the PNEC. The PNEC value is based on the RX-5255 worst case toxicity test data (0.13 mg/l after 3 tests) which is attributed to the biocide component which makes up 2.32% of the overall product. Additional product information on RX-5255 provided from the manufacturer is detailed in Table 10.5.

**Table 10.4: RX-5255 CEFAS Template Data**

| Chemical Information | RX-5255 |
|---|---|
| Manufacturer | Roemex Ltd |
| Function | Pipeline Hydrotest Chemical |
| DTI ID / CEFAS Registration No. | 27896 |
| CEFAS Template Dose Rate (ppm) | 550 |
| Worst Case Toxicity (mg/l) | 0.13 |
| Number of Aquatic Toxicity Tests | 3 |
| HQ Colour Band | Gold |
| PNEC [1] | 0.013 |
| Percentage in Product (%) | 2.32 |
| Log $P_{ow}$ | Not Available |
| Sediment Re-worker (mg/kg) | Not Available |
| Biodegradation Value (%) | Not Available |

[1] PNEC values were calculated from the data utilising the methodology used in the preparation of UK offshore chemical permits (i.e. CHARM assessment factor of 10) (CHARM Implementation Network (CIN), 2017).

**Table 10.5: RX-5255 Product Information from Manufacturer**

| | |
|---|---|
| **Description** | RX-5255 is a liquid combined corrosion inhibitor, biocide, oxygen scavenger and leak detection dye |
| **Comments** | The RX-5255 product consists of >90% PLONOR components and Water. Approximately 1% of the product is the active dye substance which has biodegradability <20%.<br>A UK Level 4 substitution warning is assigned to RX-5255 for high toxicity (0.13 mg/l) of the biocide component and poor biodegradation (<20%) of the dye component. |

### MUDMAP (Far-Field) Modelling Results

The 100 individual simulation model results from the 10-year hindcast period (2010-2019) were combined for stochastic analysis on an annual basis. Table 10.6 present the predicted 95$^{th}$ percentile dilutions of the hydrotest discharge from the proposed Tornado drill centre location. The modelling results present a large conservative range of dilutions with a maximum dilution of 1:42,300 (out to 11,200 m) being presented (RPS, 2025b).

Figure 10.2 shows example trajectory model results for a single simulation during October conditions; presenting the movement of the plume at 4 and 24 hours after the commencement of the discharge. The trajectory cross section of the water column shows a vertical plume height of 20 m from the seabed. The trajectory modelling results also demonstrate that plume dilutions of <1:12,500 do not persist to the 24-hour time stamp.

The environmental risk associated with the RX-5255 dilutions has been based on the ratio of a PEC to a PNEC. When assessing an offshore subsea release, the dilution factor at 500 m is the value that is commonly analysed when considering whether a release will cause harm to the environment (as per the Osborne-Adams Assessment Methodology). The MUDMAP modelling study indicated that the 95$^{th}$ percentile dilutions required to achieve a PEC/PNEC of <1 for the RX-5255 hydrotest discharge is predicted to occur 98 m from the release location (refer to Table 10.6).

In addition to the worst-case PEC/PNEC toxicity test, the hydrotest plume has the potential to cause localised smothering effects on benthic and pelagic communities with the spread of deoxygenated seawater close to the seabed (plume height of 20 m from the seabed). The oxygen scavenger and PLONOR components (that are readily biodegradable) of RX-5255 have the potential to deoxygenate the water column. Sedentary organisms on the seabed may be exposed to the plume for several hours (refer to Figure 10.2 which shows the plume movement between 4 and 24 hours), during which time mobile benthic and pelagic organisms would be able to move away from the plume. The limited spatial and temporal extent predicted for the plume in the far field will limit the exposure of smothering effects on marine organisms.

The above assessment conservatively assumes that the concentration of RX-5255 discharged equalled the application dosage (550 mg/l) when added for the hydrotest. As the RX-5255 (4 in 1 hydrotest cocktail) reacts within the pipeline it will start to break down into inert components in a process which protects the pipeline; the discharge concentration of these chemical components is much lower than the concentrations initially added. Consequently, the degree of dilution required to achieve concentrations of any excess chemical in the discharge which pose no risk to the environment is likely to be significantly lower.

**Table 10.6: Summary of the maximum distance from the hydrotest discharge release location to achieve given dilutions [1] (RPS, 2025b)**

| Dilution | Concentration of RX-5255 Whole Product (mg/l) | RX-5255 Biocide Component (PNEC = 0.013 mg/l) | | Maximum Distance (m) from Discharge Location to Achieve Given Dilution |
|---|---|---|---|---|
| | | PEC (mg/l) | PEC/PNEC Ratio | 95th Percentile Dilutions |
| 0 | 550 | 12.760 | - | - |
| 1:100 | 5.500 | 0.1276 | 9.815 | - |
| 1:200 | 2.750 | 0.0638 | 4.908 | - |
| 1:300 | 1.833 | 0.0425 | 3.271 | - |
| 1:400 | 1.375 | 0.0319 | 2.454 | - |
| 1:500 | 1.100 | 0.0255 | 1.963 | - |
| 1:750 | 0.733 | 0.0170 | 1.308 | 61 |
| **1:981** | **0.561** | **0.0130** | **1.001** | **87** |
| 1:1,000 | 0.550 | 0.0128 | 0.982 | 98 |
| 1:2,000 | 0.277 | 0.0064 | 0.494 | 211 |
| 1:5,000 | 0.110 | 0.0026 | 0.196 | 730 |
| 1:7,500 | 0.073 | 0.0017 | 0.130 | 1,890 |
| 1:10,000 | 0.055 | 0.0013 | 0.098 | 4,170 |
| 1:12,500 | 0.044 | 0.0010 | 0.079 | 7,457 |
| 1:15,000 | 0.036 | 0.0008 | 0.064 | 7,557 |
| 1:17,500 | 0.031 | 0.0007 | 0.055 | 7,688 |
| 1:20,000 | 0.027 | 0.0006 | 0.048 | 9,970 |
| 1:30,000 | 0.018 | 0.0004 | 0.032 | 10,200 |
| 1:42,300 | 0.013 | 0.0003 | 0.023 | 11,900 |

[1] Red outline indicates dilutions and maximum distences where PEC/PNEC ratio is >1.

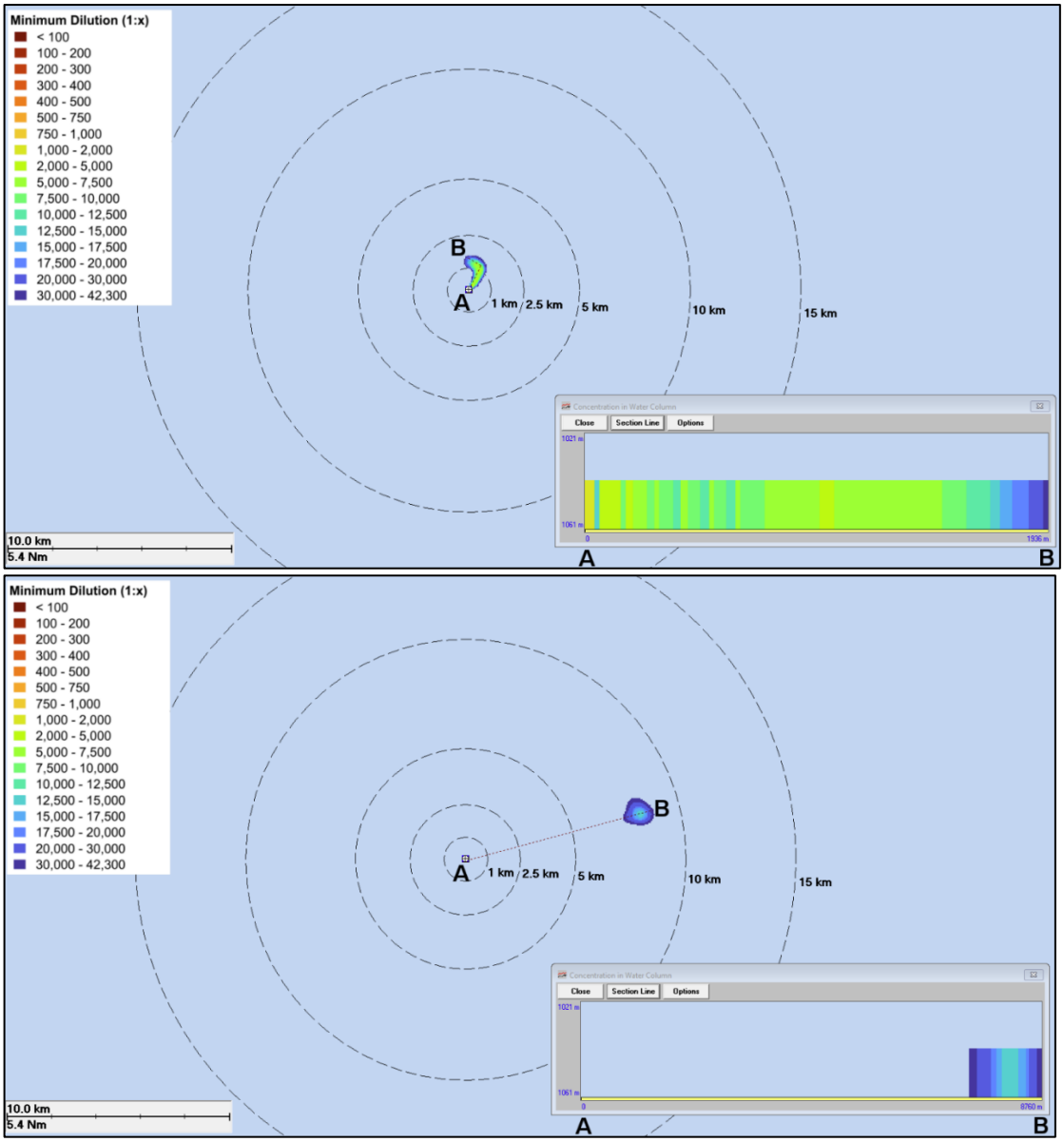



**Figure 10.2: Example plan-view and water column (cross section) of the predicted minimum dilutions of the hydrotest discharge (570.3 $m^3$/h) 4 hours (top image) and 24 hours (bottom image) into the discharge at proposed Tornado drill centre location during October conditions. Results are based on 1 simulation of the 100 modelled as part of the study.**

### Water Quality

The sensitivity of water column to contamination from the discharge of pipeline hydrotest treatment chemicals is considered to be **Low**. The receptor has a Low value; as only the water column in close proximity to the discharge point will be impacted, hence it is considered to be of local importance. Furthermore, the hydrotest modelling results have demonstrated that harmful plume concentrations of RX-5255 (resulting in a PEC/PNEC of >1) are limited to 87 m from the release location and do not persist. The water quality is subject to rapid refreshment rates and mixing of the water column. Therefore, the receptor resistance and resilience is Very High to planned, hydrotest chemical discharges. The magnitude of impact is considered to be **Minor**, with a short-term temporary change in baseline environmental conditions. Effects on water quality due to pipeline hydrotest chemical discharges are therefore assessed as **Minor**.

### Plankton

The sensitivity of plankton to the discharge of pipeline hydrotest treatment chemicals is considered to be **Low**. The receptor is of Medium value; the plankton community has a regional importance to the Faroe-Shetland Channel, providing a food source to higher trophic levels in this region. However, the hydrotest modelling results have demonstrated that harmful plume concentrations of RX-5255 (resulting in a PEC/PNEC of >1) are limited to 87 m from the release location and do not persist, and the plankton has high recoverability in the short-term with high reproduction rates. Therefore, the receptor resistance and resilience is Very High to planned, discharge of hydrotest chemicals. The magnitude of impact is considered to be **Negligible**, as the rapid dilution of the chemicals in the water column are anticipated. Any changes to the plankton community are anticipated to be immeasurable / undetectable. Effects on plankton due to pipeline hydrotest chemical discharges are therefore assessed as **Negligible**.

### Fish

The sensitivity of fish to the discharge of pipeline hydrotest treatment chemicals is considered to be **Low**. The receptor has a Very High value; many of the species that may be present in the Tornado area are listed as PMFs in Scottish waters (see Section 4.3.3). However, the hydrotest modelling results have demonstrated that harmful plume concentrations of RX-5255 (resulting in a PEC/PNEC of >1) are limited to 87 m from the release location and do not persist. Therefore, the receptor resistance and resilience is Very High to planned, discharge of hydrotest chemicals. The magnitude of impact is considered to be **Negligible**, as the rapid dilution of the planned, discharge of hydrotest chemicals in the water column is anticipated. Any changes to the fish community are anticipated to be immeasurable / undetectable. Effects on fish due to pipeline hydrotest chemical discharges are therefore assessed as **Negligible**.

### Seabed Communities

The sensitivity of seabed communities to the discharge of pipeline hydrotest treatment chemicals is considered to be **Medium**. The receptors are of national importance and are of High value, although epibenthic fauna observed during the Tornado survey operations was relatively sparse (refer to Section 4.3.2). As noted above, the hydrotest plume has the potential to impact seabed communities with the spread of deoxygenated seawater close to the seabed. Although mobile benthic organisms would be able to move away from the plume, sessile organisms on the seabed may be exposed to the plume for several hours. However, the species typically found in this region of WoS at depths of ca. 1,000 m are largely tolerant of hypoxic conditions. Therefore, the receptor resistance and resilience is High. The magnitude of impact is considered to be **Minor** as the plume will be heavily diluted upon release, with limited spatial and temporal extent predicted for the plume in the far field. Effects on seabed communities due to pipeline hydrotest chemical discharges are therefore assessed as **Minor**.

## 10.3 Mitigation Measures

Impacts from marine discharges during the development of the Tornado field will be minimised by the implementation of the following mitigation measures:

- A chemical risk assessment will be undertaken to identify the risk profile of chemicals to be used and / or discharged in accordance with the requirements of the Offshore Chemicals Regulations 2002 (as amended). Where practicable, chemicals with a higher risk profile will be substituted out in favour of those with an improved environmental profile;
- Chemical use and discharge will be minimised where practicable;
- In the event WBM is used to drill the Tornado wells, cuttings / mud cleaning equipment will ensure optimal cuttings cleaning prior to discharge and recovered WBM will be reused/ re-circulated where practical. In addition, WBM will be mixed offshore to ensure that only what is required is used;
- In the event that LTOBM is used to drill the Tornado wells, a thermal cuttings treatment unit will be installed on the MODU to safely treat the LTOBM contaminated cuttings to an acceptable overboard disposal limit (<1% OOC);

- During the drilling and pipeline dewatering operations, any discharges of residual reservoir hydrocarbons will be treated in accordance with the conditions of the approved Oil Discharge Permit, such that oil-in-water concentrations are within the permit limits. The discharge streams will also be monitored and sampled in accordance with an approved Oil Discharge Permit.

## 10.4 Residual Effects

In summary, no significant residual effects on water quality and local flora and fauna are predicted as a result of routine marine discharges during the Tornado Development operations. All chemicals will be risked assessed prior to use to ensure that there are no significant risks to the marine environmental upon discharge and any discharges of residual reservoir hydrocarbons will be treated to meet oil-in-water limits of the Oil Discharge Permit.

## 10.5 Transboundary Effects

The UK/Faroe Islands median line is located approximately 6.5 km to the northwest of the proposed Tornado field. It is very unlikely that marine discharges generated during the proposed Tornado Development operations would lead to transboundary impacts, as it is anticipated that discharges will be diluted rapidly, within close proximity to their release location.

## 10.6 Cumulative Effects

The Tornado Development lies within an area of relatively low oil and gas activity (refer to Section 4.4.3). The closest producing fields to the proposed Tornado drill centre location are the Alligin, Loyal and Schiehallion oil fields (operated by BP), developed through the Glen Lyon FPSO, which is located approximately 30 km southeast of the Tornado drill centre (refer to Section 4.4.3). In addition, the proposed Tornado drill centre is located approximately 32 km from the proposed Cambo development and 63 km from the proposed Rosebank development. Therefore, given the distances to nearby oil and gas activity, no cumulative impacts are expected as the marine discharges from the Tornado Development will be diluted rapidly within close proximity to their release location and are temporary in nature.

# 11 Accidental Releases

## 11.1 Introduction

This section assesses the risk of a worst case hydrocarbon release occurring from the Tornado Development and the potentially significant environmental and socio-economic effects that could occur as a result. It also details the control and mitigation measures that will be implemented to both reduce the risk of an incident occurring and limit the potential impacts in the event that a spill did occur. It should be noted that in planning its activities, a primary focus of Ithaca 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 of hydrocarbons occurring from the Tornado Development will be minimised through the implementation of physical barriers such as safety valves, maintenance to minimise leaks, and the implementation of handling and operational procedures and training to influence human behaviours. Measures to respond to a spill from the Tornado field if an incident did occur will be covered in an Oil Pollution and Emergency Plan (OPEP), approved by the Offshore Major Accident Regulator (OMAR) under The Merchant Shipping (Oil Pollution Preparedness, Response and Cooperation) Regulations 1998 (as amended) in advance of the proposed development operations commencing.

## 11.2 Sources and Likelihood of Accidental Releases

### 11.2.1 Historic UKCS Data for Hydrocarbon Releases

On the UKCS, all accidental oil releases to the marine environment, regardless of their size, are reportable to OPRED through the submission of a Petroleum Operations Notice 1 (PON 1). 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. However, the amount of oil accidentally released to the marine environment varies over recent years (2013 – 2023), highlighting the sensitivity of these data to single, low-frequency, high-mass events.

In 2023, the mass of unintentional oil releases to the marine environment on the UKCS was 4.75 tonnes. To put this into context, in the same year, about 1,600 tonnes of oil were discharged to sea in produced water, under permit; accidental oil releases therefore represent 0.3% of this total. Given that approximately 34 million tonnes of oil were produced in the UKCS during 2023, accidental oil releases represented less than 0.00001 % of total oil production (OEUK, 2024b).

Infrequent, but large releases form a big part of annual totals, which was the case in 2020. In general, oil releases of more than 50 tonnes have made up less than 0.22% of the total number of releases, but over 75% of the total mass released. In 2023, hydraulic oil accounted for the largest percentage of oil unintentionally released at 41%, followed by diesel (22%) and crude (16%) (OEUK, 2024b).

### 11.2.2 Tornado Hydrocarbon Release Scenarios

The following is a list of potential hydrocarbon release scenarios associated with the Tornado Development:

- Uncontrolled well blowout;
- Diesel spillage from MODU or vessel;
- Pipeline rupture and subsequent release of liquid hydrocarbon inventory to sea.

The likelihood of these unplanned events occurring is discussed below, using the Likelihood of Occurrence criteria defined in Section 5.3.2.

#### Likelihood of a Well Blowout

A blowout is an extremely rare event where total failure of all pressure control systems and related processes can result in an uncontrolled flow of oil or natural gas (or a mixture of the two) at the rig floor as a result of BOP failure.

Following the 2009 Montara and the 2010 Deepwater Horizon/Macondo well control incidents, EU Directive 2013/30/EU on the safety of offshore oil and gas operations came into force, which is implemented in the UK through the Offshore Installations (Offshore Safety Directive) (Safety Case etc) Regulations 2015 (SCR 2015). The main aim of SCR 2015 is to reduce the risks from major accident hazards, such as a blowout, to the health and safety of the workforce employed on offshore installations or in connected activities. In addition, SCR 2015 also aims to increase the protection of the marine environment and coastal economies against pollution and ensure improved response mechanisms in the event of such an incident.

Table 11.1 presents blowout frequencies for the North Sea. This indicates that for development drilling (on average), the blowout frequency is extremely low at $3.9 \times 10^{-5}$ per drilled well.

In summary, given the above, the likelihood of a blowout occurring at the Tornado field is considered to be **Extremely Rare**.

An uncontrolled and unmitigated well blowout scenario is considered to result in the largest, i.e. worst case, volume of hydrocarbons to sea from the proposed Tornado Development (a cumulative release of 201,266 $m^3$ of condensate over a period of 180 days) and has therefore been subject to oil spill modelling and assessed below.

**Table 11.1: Blowout Frequencies (data from IOGP, 2019)**

| Operation | Well Category | Frequency, Average Well | Frequency, Gas Well | Frequency, Oil Well | Unit |
|---|---|---|---|---|---|
| Development Drilling | Normal | $3.9 \times 10^{-5}$ | $4.2 \times 10^{-5}$ | $3.4 \times 10^{-5}$ | per drilled well |
| | HPHT Note 1 | $2.4 \times 10^{-4}$ | $2.6 \times 10^{-4}$ | $2.1 \times 10^{-4}$ | per drilled well |
| Exploration Drilling | Normal | $1.4 \times 10^{-4}$ | $1.5 \times 10^{-4}$ | $1.2 \times 10^{-4}$ | per drilled well |
| Completion | - | $2.1 \times 10^{-4}$ | $2.8 \times 10^{-4}$ | $1.4 \times 10^{-4}$ | per operation |
| Wirelining | - | $6.7x\ 10^{-6}$ | $9.0 \times 10^{-6}$ | $4.4 \times 10^{-6}$ | per operation |
| Coil Tubing | - | $8.5 \times 10^{-5}$ | $1.1 \times 10^{-4}$ | $5.6 \times 10^{-5}$ | per operation |
| Workover | - | $3.0 \times 10^{-4}$ | $4.0 \times 10^{-4}$ | $2.0 \times 10^{-4}$ | per operation |
| Producing Wells Note 2 | - | $3.7 \times 10^{-5}$ | $7.2 \times 10^{-5}$ | $2.1 \times 10^{-5}$ | per well year |

Note 1: HPHT – High Pressure, High Temperature
Note 2: Excludes external causes such as ship collisions

### Likelihood of a MODU or Vessel Collision

During development of the Tornado field there is the potential for a MODU and/or vessel collision, resulting in the entire loss of fuel inventory (which is typically around 3,500 $m^3$ for a DP deepwater MODU). The risk of collision will be highest when the MODU is on location at Tornado, although shipping densities are very low in the area, and when the pipelines and umbilical are installed, particularly in water depths < 800m where commercial fishing vessels are active. A vessel traffic survey (VTS) will be undertaken by Ithaca to inform the CTL permit application, which is required to site the MODU and subsea infrastructure at the Tornado location. A collision risk assessment (CRA) may also be undertaken if considered necessary.

In addition, information on the location of the MODU, 500 m safety zone, subsea infrastructure and vessel operations will be communicated to other sea users (via the UKHO) through the standard communication channels including Kingfisher, Notice to Mariners and Radio Navigation Warnings.

The pipeline laying vessels could pose a short term obstruction to shipping and navigation. However, the vessels will be moving continually along the proposed pipeline route during the installation period (28 days for the production pipeline and 15 days for the MEG pipeline) so any obstruction will be of very short duration and long term exclusion from any one area will not occur. Vessels involved in installation operations will also update their marks, lights and navigational status broadcast on AIS to indicate to other vessels when they are restricted in manoeuvrability. This will assist any passing vessels that encounter the installation vessels. In addition, in the event that pipelay operations are ongoing

when the MODU is on location at the Tornado, a SIMOPS plan will be developed to reduce the potential for a collision incident to occur.

Given the above, the likelihood of a MODU or vessel collision is considered to be **Unlikely**. As the loss of diesel inventory is small compared to the worst case well blow out scenario, it is not considered further in this assessment.

### Likelihood of a Pipeline Rupture

Accidental releases of hydrocarbons from subsea pipelines are most likely to occur as a result of structural failures of equipment (i.e. internal corrosion for rigid pipelines and stress corrosion cracking for flexible pipelines). Releases due to impact damage are considered rare.

Table 11.2 details the number of Loss of Containment (LOC) events for hydrocarbon pipelines and risers on the UKCS during a 20-year period from 2001 to 2020, with an estimate of LOC frequencies for operating pipelines outside of the 500 m safety zone provided in Table 11.3.

**Table 11.2: Number of LOC Events (2001-2020) (PARLOC, 2024)**

| Pipeline Type | Number of LOC Events 2001-2020 | | |
|---|---|---|---|
| | Pipeline (excluding jumpers) | Risers | Jumpers |
| Rigid | 16 | 6 | 7 |
| Flexible | 9 | 4 | 11 |

**Table 11.3: Estimated Pipeline Loss of Containment Frequencies (PARLOC, 2024)**

| Pipeline LOC frequencies outside the 500 m safety zone of a production installation for different pipeline lengths | | | | | |
|---|---|---|---|---|---|
| Pipeline length (per km.year) | 0 km to 3 km | 3 km to 10 km | 10 km to 30 km | 30 km to 100 km | >100 km |
| Rigid Pipeline | 4.3E-04 | 4.3E-04 | 7.7E-05 | 1.8E-05 | 1.1E-05 |
| Flexible Pipeline | 1.1E-03 | | | | No data |

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. Both of these events were recorded in the North Sea (Europe), during transfer operations and involved 'loss of buoyancy or sinking' (OGP, 2010).

In summary, the likelihood of a pipeline rupture is considered to be **Rare**. Significant leakage is estimated to be a short-term event, occurring over a period of a day(s). The total volume of condensate released is considerably less than the worst case well blowout scenario which has been modelled and is therefore not considered further in the impact assessment.

It is acknowledged that gas could also be lost in the event the Tornado production pipeline is ruptured. An event such as this would result in the increased concentration of GHG emissions in the atmosphere, further contributing to the effects of climate change, and could cause short term air quality impacts. The potential environmental effects from GHG emissions generated from the Tornado Development are discussed in Section 9 of the ES and have not been considered further in this Section given the unlikely and one-off nature of a pipeline rupture event.

## 11.3 Fate of Spills in the Marine Environment

### 11.3.1 Oil Properties and Weathering Processes

When oil is spilled at sea it normally spreads out and moves on the sea surface with the wind and currents. At the same time, a number of natural processes take place; collectively termed weathering, these process change the physical and chemical properties of the oil and determine its fate in the marine environment. The weathering of oil depends on the chemical and physical properties of the oil (e.g. density, viscosity, wax content and pour point), the weather conditions (e.g. wind, waves, temperature and sunlight) and the properties of the seawater (e.g. salinity, temperature and bacterial flora).

The International Tanker Owner Pollution Federation (ITOPF) has ranked oils according to their physical characteristics (API/SG) and likely spill behaviour (Table 11.4). The hydrocarbon present in the Tornado reservoir is predominantly going to resemble an ITOPF Group 1 condensate (based on a density of 0.7902 g/cm$^3$ @ 15°C and API of 47.6°) that does not form a stable emulsion. Light oils such of these are more susceptible to evaporation and oxidation and consequently reduce faster over time compared to heavier oils.

**Table 11.4: ITOPF Categories and Characteristics**

| Group | Specific Gravity | API | Viscosity (cSt) | Typical Examples | Scale |
|---|---|---|---|---|---|
| 1 | < 0.8 | > 45˚ | < 3 | Gasoline products | Light |
| 2 | 0.8 - 0.85 | 35˚ - 45˚ | 4 (semi solid) | Diesel-like products, light crude | |
| 3 | 0.85 - 0.95 | 17.5˚ - 35˚ | 8 (semi solid) | Medium crude, North Sea crude (e.g. Forties) | |
| 4 | > 0.95 | < 17.5˚ | 1,500 (semi solid) | Heavy crude and residual oils | Heavy |

There are eight main oil weathering processes: spreading, evaporation, dispersion, emulsification, dissolution, sedimentation, oxidation, and biodegradation. The effects of spreading, evaporation, dispersion, emulsification and dissolution are most significant early on in a spill whilst oxidation, sedimentation and biodegradation are more significant later (Figure 11.1) (ITOPF, 2014b).

Over time, as a consequence of weathering, an oil spill will normally break up and begin to dissipate into the marine environment. Light products such as the Tornado condensate (and diesel) under most conditions, evaporate and dissipate quickly and naturally.

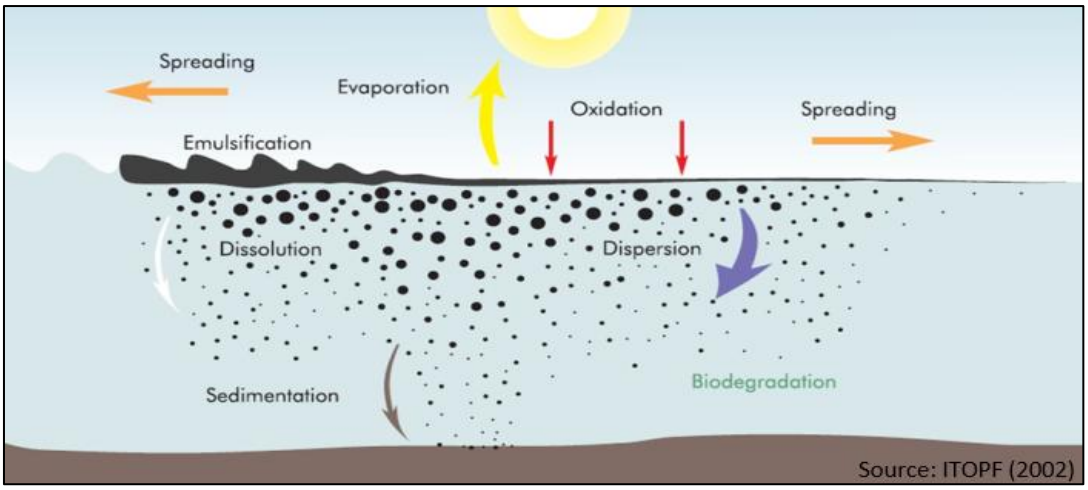



**Figure 11.1: Oil Weathering Process**

### 11.3.2 Oil Spill Modelling

Although extremely rare, a well blowout event is considered to be the worst case accidental release scenario that could occur as a result of the Tornado Development. Therefore, in order to gain an understanding of the fate of the Tornado condensate in the marine environment, the following scenario has been modelled:

- Subsurface blowout release from the Tornado W03 development well with a cumulative release of 1,265,922.7 barrels (bbl) (201,266 $m^3$) of 47.6°API condensate, released over a period of 180 days.

This represents the worst case scenario for the Tornado field in terms of both the volume of hydrocarbons 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). It should be noted that this is an extreme worst case scenario that assumes the complete failure of all control and preventative measures. In a real situation, steps would immediately be taken to stem the flow of hydrocarbons and in the event of a well control incident bring the well back under control. A counter-pollution response strategy would also be developed and initiated to minimise the impact to the marine environment.

The oil spill modelling has been undertaken with the use of OILMAP, an advanced oil modelling tool developed and licensed by RPS ASA, which provides predictions of the fate and transport of spilled hydrocarbons and calculates the probability of key areas being impacted.

To simulate a range of possible metocean conditions, stochastic results were calculated from over 100 trajectory runs per season. This provides insight into the range of probable behaviours of a potential oil spill in response to varying meteorological and oceanographic conditions in the study area. Stochastic modelling computes surface trajectories for an ensemble of many individual cases for each spill scenario. Each individual simulation start time is selected randomly, thus sampling the variability in the wind and current forcing. The stochastic model results that have been reported in the assessment include the following:

- The probability and minimum time for surface oiling (with a minimum thickness threshold of 0.3 µm). A surface thickness 0.3 µm is the minimum threshold identified by the Bonn Agreement Oil Appearance Code (BAOAC) capable of producing a visible rainbow sheen. The 0.3 µm threshold value is required by the OPEP guidance notes (OPRED, 2022) and is the chosen value for when potential significant environmental impacts may begin to occur.
- The probability and minimum time for water column oiling (with a minimum concentration threshold of 1 ppb). A concentration of oil in water above 1 ppb is the minimum threshold identified for screening potential effects on sensitive organisms and socio-economic activity (e.g. seafood production).
- The probability and minimum time for shoreline oiling (with a minimum thickness threshold of 1.0 µm). A shoreline thickness 1.0 µm is the minimum threshold identified for potential effects on socio-economic resource uses, as this amount of oil may conservatively trigger the need for shoreline clean-up on amenity beaches (French-McCay, *et al*. 2011 and French-McCay, *et al*. 2012).

It is important to note that the stochastic modelling results do not represent a single spill event, and instead show the aggregation of results computed by running the spill scenario multiple times (i.e. 100 times) over different weather conditions.

To analyse single spill scenarios, trajectory modelling was undertaken for each season by extracting the worst case simulation run from the stochastic results. The worst case trajectory simulation was identified by the greatest mass of shoreline oiling at any one location after 190 days. The trajectory modelling enables fates analysis on the released condensate over time.

The input parameters and modelling results are presented in full in Appendix F. A summary of the key conclusions has been provided below.

### Stochastic Modelling Results

**Summary of Results**

Table 11.5 summarises the stochastic results for a worst case subsea well blowout in the Tornado field across all seasons, reporting the minimum arrival time and probability of oil to reach land and the territorial waters of nearby countries.

**Table 11.5: Summary of Stochastic Modelling Results**

| **Subsea Well Blowout in the Tornado Field** | | | | | |
|---|---|---|---|---|---|
| **Spill Scenario / Descriptor:** 1,265,922.7 bbl (201,266 $m^3$) of Condensate (47.6 °API) released over 180 days | | | | | |
| **Season** | | Winter (December – February) | Spring (March – May) | Summer (June – August) | Autumn (September – November) |
| **Median Crossing** [Note 1] | | | | | |
| **Median Line** | **Surface Oil: Probability and Shortest Time to Reach (Minimum Thickness of 0.3 µm)** | | | | |
| Norway | *Maximum Probability* | 3 % | 1 % | 1 % | 2 % |
| | *Shortest Arrival Time* | 271 hrs | 296 hrs | 492 hrs | 288 hrs |
| Faroe Islands | *Maximum Probability* | 100 % | 100 % | 100 % | 100 % |
| | *Shortest Arrival Time* | 16 hrs | 19 hrs | 18 hrs | 24 hrs |
| **Median Line** | **Subsurface Oil: Probability and Shortest Time to Reach (Minimum Water Column Concentration 1.0 ppb)** | | | | |
| Sweden | *Maximum Probability* | 10 % | N/A | 6 % | 25 % |
| | *Shortest Arrival Time* | 1,102 hrs | N/A | 4,050 hrs | 1,754 hrs |
| Denmark | *Maximum Probability* | 32 % | 12 % | 9 % | 25% |
| | *Shortest Arrival Time* | 957 hrs | 1,929 hrs | 3,347 hrs | 1,615 hrs |
| Norway | *Maximum Probability* | 100 % | 100 % | 100 % | 100 % |
| | *Shortest Arrival Time* | 162 hrs | 219 hrs | 305 hrs | 177 hrs |
| Iceland | *Maximum Probability* | 3 % | 5 % | 22 % | 9 % |
| | *Shortest Arrival Time* | 2,748 hrs | 1,282 hrs | 2,309 hrs | 1,237 hrs |
| Faroe Islands | *Maximum Probability* | 100 % | 100 % | 100 % | 100 % |
| | *Shortest Arrival Time* | 17 hrs | 16 hrs | 21 hrs | 18 hrs |
| Jan Mayen (Norway) | *Maximum Probability* | 29 % | 42 % | 54 % | 30 % |
| | *Shortest Arrival Time* | 1,256 hrs | 1,559 hrs | 1,377 hrs | 1,043 hrs |
| **Landfall** [Note 1] | | | | | |
| **Predicted Locations** | **Shoreline Oil: Probability and Shortest Time to Reach (Minimum Thickness of 1.0 µm)** | | | | |
| United Kingdom | *Maximum Probability* | 3 % | 1 % | 1 % | 2 % |
| | *Shortest Arrival Time* | 189 hrs | 388 hrs | 4,069 | 1,783 hrs |

Note 1: 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.

**Surface Oiling**

Table 11.6 reports the maximum distance that the surface oil slick may occur from the Tornado release location for each of the BAOAC thresholds. This data is displayed graphically in Figure 11.2.

**Table 11.6: Surface Oiling by BAOAC Thresholds**

| Code | Description – Appearance | Layer Thickness Interval (µm) | Litres per $km^2$ | Max Distance from the Release Location Note 1 |
|---|---|---|---|---|
| 1 | Sheen (silvery/grey) | 0.04 to 0.30 | 40 – 300 | N/A |
| 2 | Rainbow | 0.30 to 5.0 | 300 – 5000 | N/A |
| 3 | Metallic | 5.0 to 50 | 5000 – 50,000 | 153 km |
| 4 | Discontinuous True Oil Colour | 50 to 200 | 50,000 – 200,000 | 456 km |
| 5 | Continuous True Oil Colour | More than 200 | More than 200,000 | 332 km |

Note 1: The spatial distribution of maximum surface oil thickness categories is influenced by stochastic variability, weathering processes and the finite duration of the model simulation. As a result, lower-thickness categories (i.e. BAOAC 3 - Metallic) occur as patchy features coincident with, rather than extending beyond, higher-thickness oiling.

There is a 100% probability of surface oil, at a thickness of > 0.3 µm, crossing the Faroe Islands median line and a low probability (1 – 3 %) of surface oil crossing the Norwegian median line (see Figure 11.3). Faroe Islands waters may experience BAOAC 5 (Continuous True Oil Colour) oiling and Norwegian waters may experience BAOAC 4 (Discontinuous True Oil Colour) oiling.

The minimum time for surface oil, at a thickness of > 0.3 µm, to reach the Faroe Islands and Norwegian median lines is 16 hours and 271 hours, respectively.

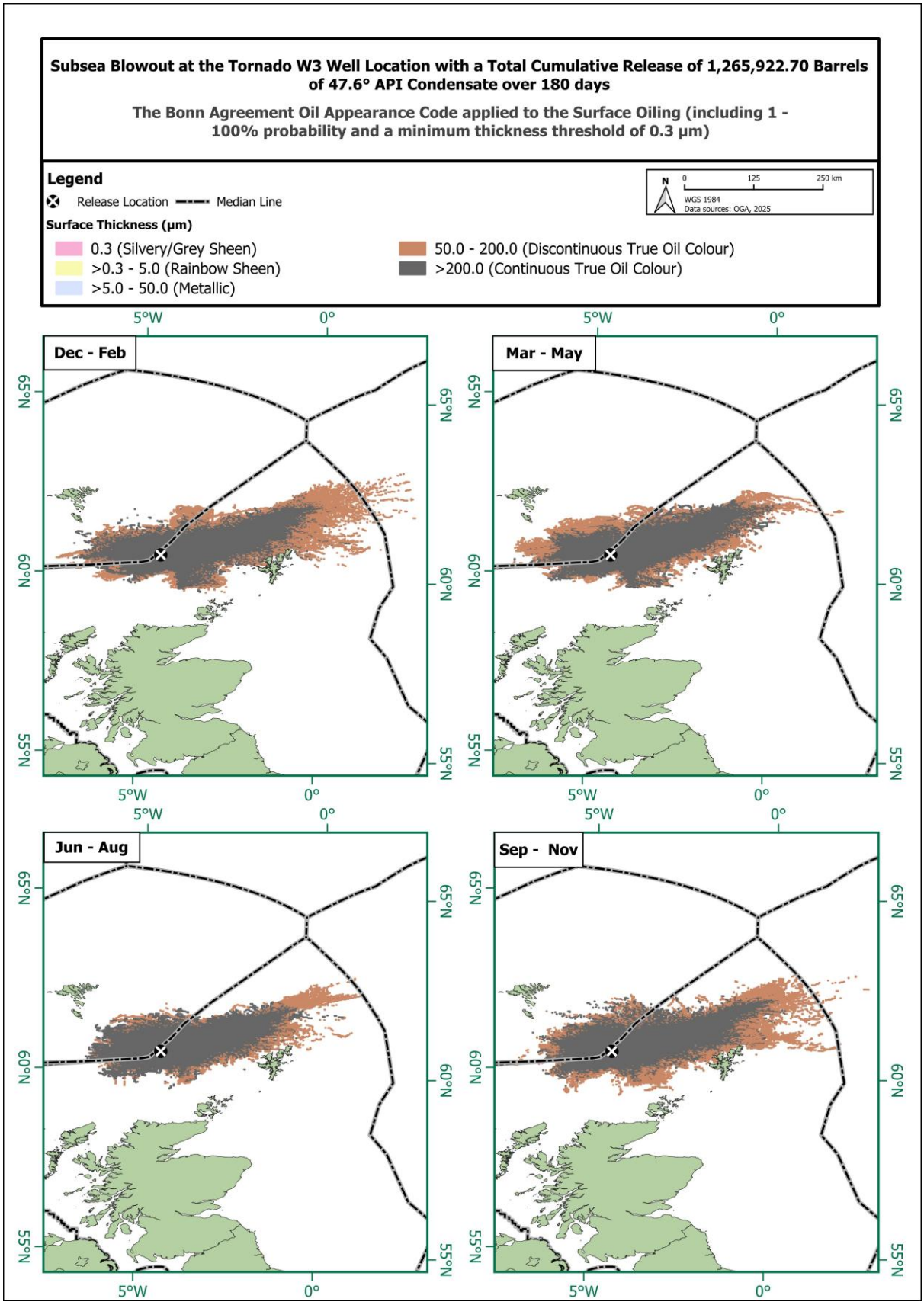



**Figure 11.2: Maximum Surface Oil Thickness (Bonn Code)**

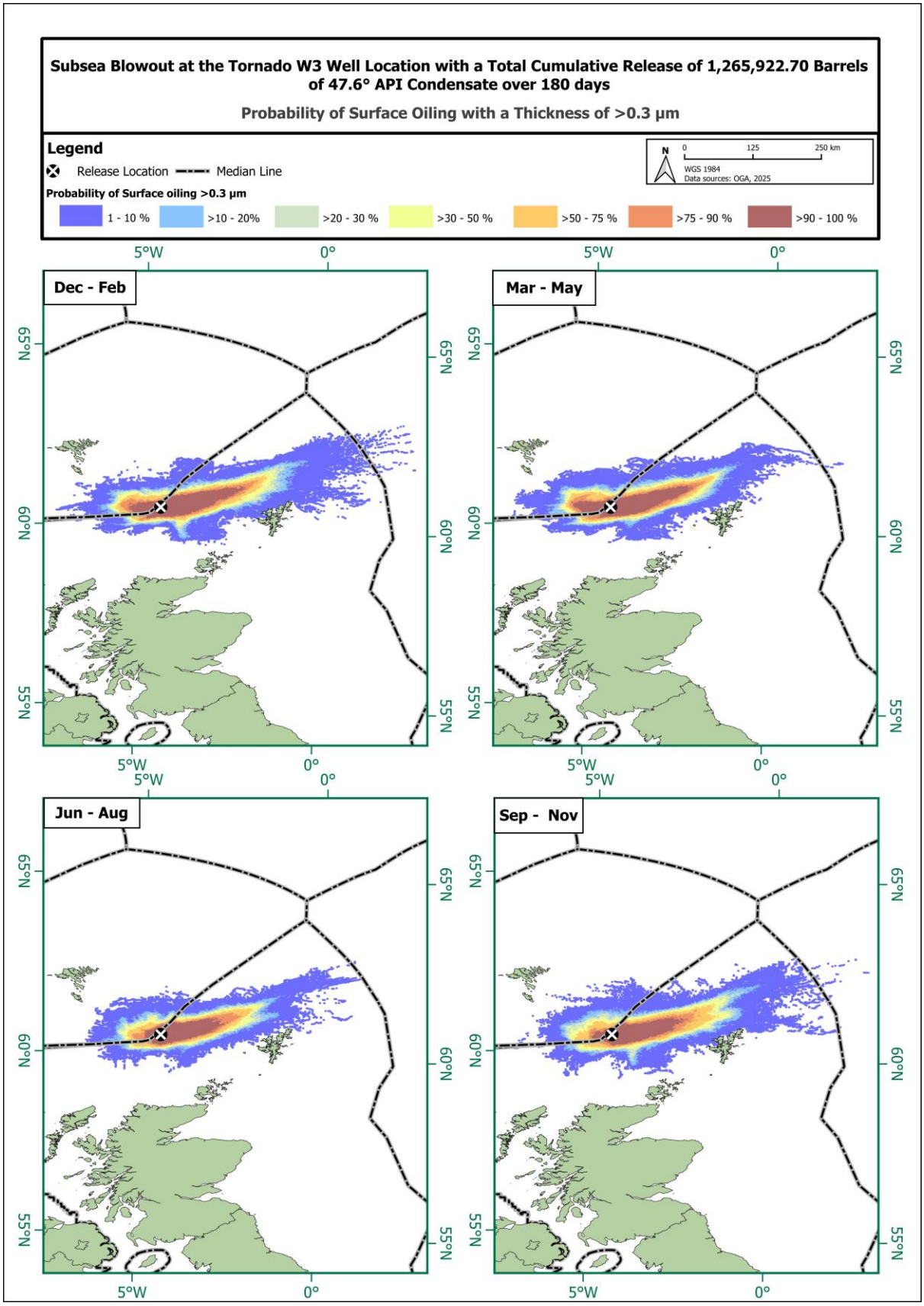



**Figure 11.3: Probability of Surface Oiling (>0.3 µm)**

**Subsurface Oiling**

Table 11.7 presents the water column oil concentration thresholds that have been used in the modelling study to help determine subsurface oiling severity in the spatial context.

**Table 11.7: Water Column Oil Concentration Thresholds**

| Threshold for Water Column Oil Concentration (ppb) | Threshold Justification (refer to Appendix F for detailed justification) |
|---|---|
| 1 | Screening threshold (Minimum Water Column Concentration modelled) (Trudel, 1989; French-McCay, 2002; French-McCay, 2004; French-McCay, *et al.,* 2012). |
| 58 | Conservative lethal exposure threshold for marine fauna (Nilsen *et al*., 2006). At this concentration mortality is highly unlikely. However, toxicological effects may be both short and long term. |
| 70.5 | OSPAR recommended predicted no-effect concentration threshold for marine fauna (Smit *et al*., 2009; OSPAR, 2014) |
| 100 | Lethal effect level on cod (*Gadus morhua*) larvae (Vikebø *et al*., 2013). |

A minimum water column concentration of 1 ppb has been used in the modelling study to determine the probability and minimum time for oiling subsea. This concentration is exceeded out to a maximum distance of 1,944 km from the release location. The modelling predicts that the majority of the subsurface oil will move in a north easterly direction through the Faroe Shetland Channel, as depicted in Figures F.6a and F.6b in Appendix F.

Subsurface oiling concentrations are highest (> 58 ppb to < 200 ppb) in the immediate vicinity of the release location and surrounding the north west coast of the Shetland Islands, approx. 200 km from the release location, where water depths are shallow. This is displayed graphically in Figure 11.4. The maximum area at risk of oiling at these higher concentrations is 323 $km^2$ at the release location and approximately 191 $km^2$ off the coast of the Shetland Islands.

There is a 100% probability of subsurface oil, at a concentration of $\geq$ 1 ppb, crossing the Faroe Islands and Norway median lines, a moderate probability of subsurface oil crossing the Jan Mayen (29- 54 %) median line and a low to moderate probability of subsurface oil crossing the Sweden (6 – 25%), Denmark (9% - 32%) and Iceland (3 – 22%) median lines.

The minimum time for subsurface oil to reach the Faroe Islands and Norwegian median lines is 16 hours and 162 hours, respectively. It is predicted that the water column oil concentration within the waters of the Faroe Islands will be between the 58 ppb and 70.5 ppb concentration threshold and in Norwegian waters will be below the 58 ppb concentration threshold.

**Shoreline Oiling**

The modelling predicts that shoreline oiling will occur on the Shetland Islands across all seasons, but the probability of this occurring is very low. The maximum probability of shoreline oiling on the Shetland Islands occurs during winter with a 3% chance. The minimum time to shore also occurs in winter, with oil reaching the coastline within 189 hours (see Table 11.5). All modelled shoreline oiling is of low severity and classified as 'light oiling' under the ITOPF (2014a) classification (refer to Figure 11.5).

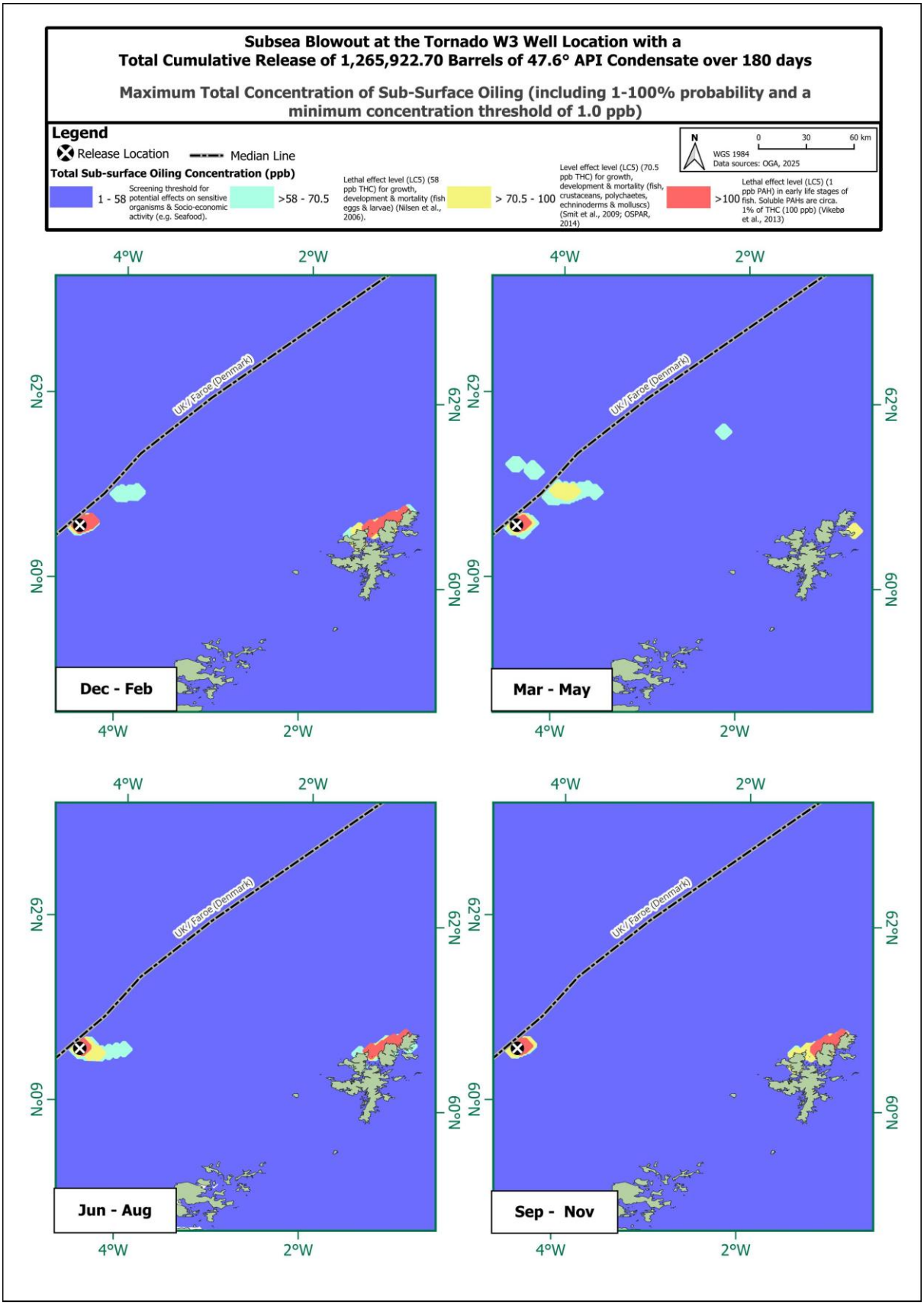



**Figure 11.4: Maximum Total Water Column Oil Concentrations**

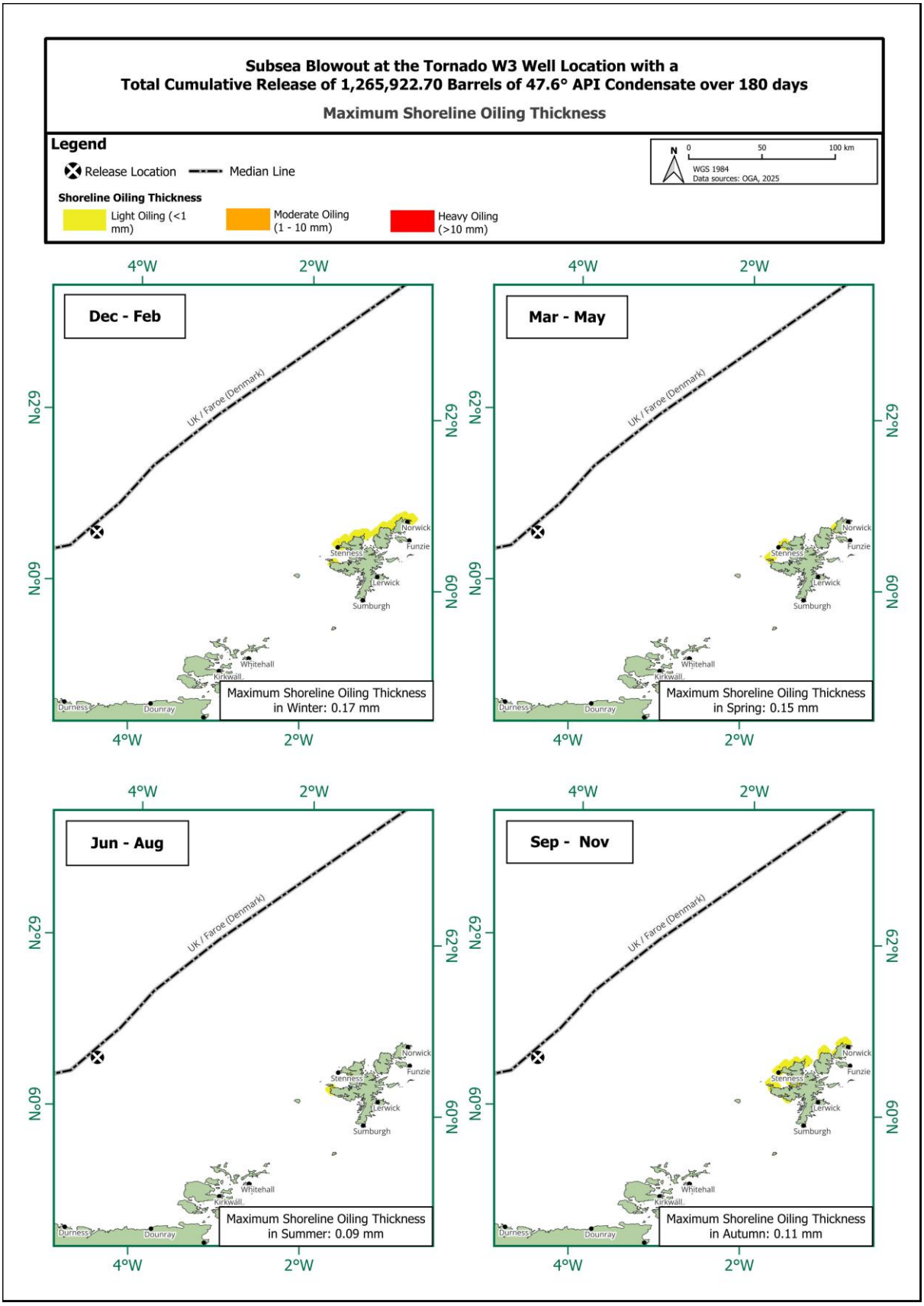



**Figure 11.5: Maximum Shoreline Oiling Thickness**

### Worst Case Trajectory Results Summary

Worst case trajectory simulations were identified per season by the greatest volume of oil beached in any one location, as detailed in Table 11.8. The worst case trajectory simulations have been displayed graphically in Appendix F showing the total swept area of surface and shoreline oiling.

**Table 11.8: Worst Case Trajectory Simulations Identified from Stochastic Results**

| Season | Run No | Greatest Volume of Oil Beached (in any one location) | | | Sim Start Date | Sim Start Time | Time (hrs) to Impact |
|---|---|---|---|---|---|---|---|
| | | $m^3$ | bbl | tonnes | | | |
| Winter | 26 | 29.55 | 185.85 | 23.35 | 15/12/2021 | 00:00 | 11 hrs |
| Spring | 74 | 7.42 | 46.67 | 5.86 | 22/03/2021 | 08:00 | 11 hrs |
| Summer | 30 | 4.07 | 25.60 | 3.22 | 24/08/2021 | 12:00 | 10 hrs |
| Autumn | 5 | 21.93 | 137.92 | 17.33 | 24/11/2021 | 12:00 | 11 hrs |

Table 11.9 provides summary statistics for each of the worst case trajectory simulations. It can be seen from this that the maximum surface slick area ranges between 1,305.42 – 2,017.61 $km^2$ across all seasons, although this is short lived due to relatively high evaporation rates.

The fate of released condensate after 190 days is consistent between seasons. The released condensate does not persist in the marine environment with the majority evaporated (21.91 – 22.57%) and degraded (49.41 – 49.98%) after 190 days. A proportion (28.02 – 28.14 %) of released condensate remains in the water column after 190 days. The trajectory simulations predict zero condensate in the sediment, ashore and on the sea surface after 190 days.

Figure 11.6 shows the fate of released condensate (mass balance) over time for the winter trajectory simulation (the worst case season for shoreline oiling). At any one time during the winter simulation, the amount of oil on the surface is less than 1,871.0 tonnes. After 180 days (4,320 hours) the condensate blowout release stops and the proceeding 10 days show a decline in surface oil (from 97.94 tonnes to 0 tonnes) and subsurface oil (from 50,064.40 tonnes to 45,305.76 tonnes), therefore highlighting the short persistence of the released condensate in the marine environment.

The seabed sediment is subject to a negligible amount of condensate oiling (< 1 tonne) at any one time during the spill duration.

**Table 11.9: Fate Analysis Summary for Trajectory Simulations**

| Season | Trajectory Run No. | Minimum Time for Surface Oiling (hrs) | Maximum Surface Slick Area ($km^2$) | Minimum Time for Shoreline Oiling (hrs) | Impacted Length of Coastline after 190 days (km) | Fate of Released Condensate after 190 days (% of total release) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ashore | Surface | Water Column | Evaporated | Degraded | Sediment |
| Winter | 26 | 11 | 1,911.35 | 1,301 | 3.56 | 0.0 | 0.0 | 28.10 | 21.91 | 49.98 | 0.0 |
| Spring | 74 | 11 | 2,017.61 | 388 | 1 | 0.0 | 0.0 | 28.14 | 22.22 | 49.64 | 0.0 |
| Summer | 30 | 10 | 1,305.42 | 4,069 | 0.51 | 0.0 | 0.0 | 28.02 | 22.57 | 49.41 | 0.0 |
| Autumn | 5 | 11 | 1,627.09 | 1,783 | 3.54 | 0.0 | 0.0 | 28.11 | 22.09 | 49.80 | 0.0 |

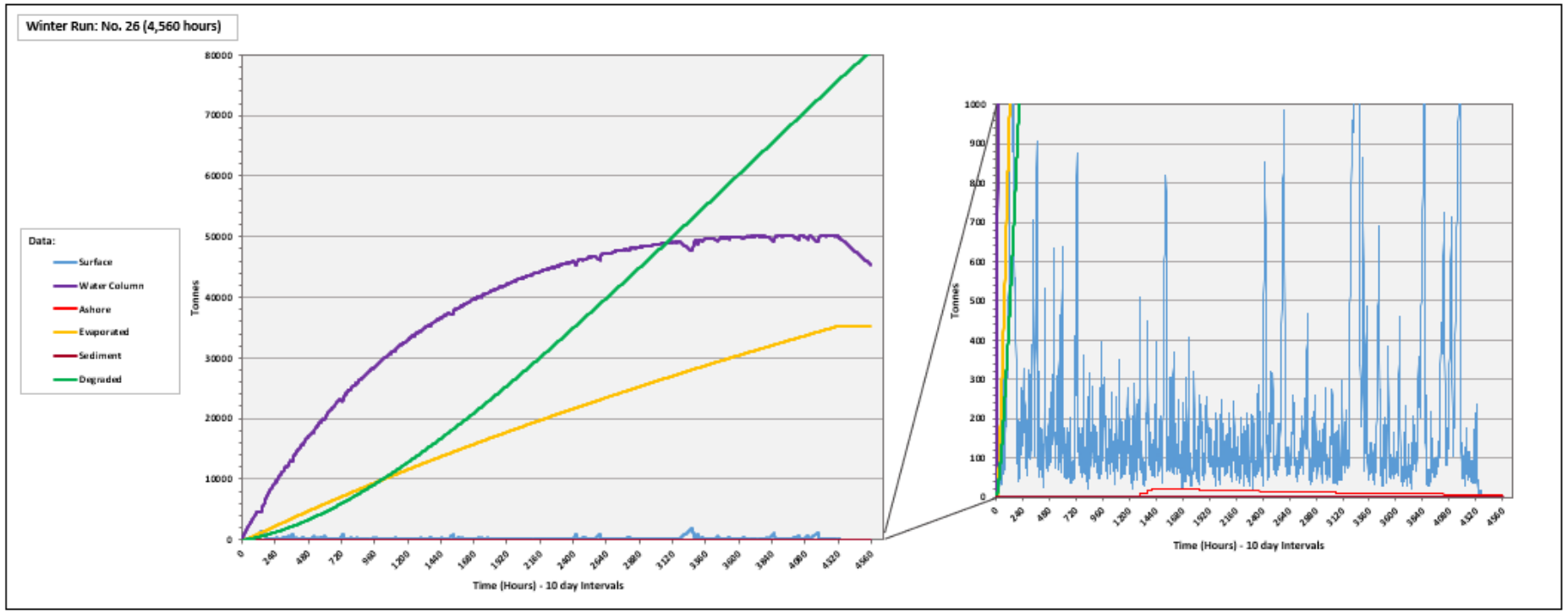



**Figure 11.6: Fate of the condensate released from Winter Run No. 26 (showing model duration 190 days)**

## 11.4 Environmental and Socio-Economic Effects

The potential effects of spills on the marine environment depend on the nature and volume of the hydrocarbons spilt, the extent of weathering in the marine environment, and the sensitivity of the species exposed to the spill (ITOPF, 2014b). Oil spills can affect the marine environment directly through physical smothering of marine organisms and toxicity impacts, and also indirectly through loss of habitat, shelter, or key species in communities, altering community structure and loss of prey (ITOPF, 2014b). The marine environment is highly dynamic and complex. Many species are exposed to fluctuating environmental conditions and therefore have a degree of intrinsic tolerance to environmental stressors, including pollution. However, chronic stressors can reduce the resilience of individuals and communities.

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 (ITOPF, 2014c).

Given the variety of factors that can affect the behaviour of spilt hydrocarbons, accurate predictions of effects before a spill has actually occurred are difficult to make. However, a summary of the potential effects that could occur in the event of a worst case blowout release from Tornado has been provided below based on the oil spill modelling results (see Section 11.3 and Appendix F) and the known environmental and socio-economic sensitivities present in the area. In this assessment, to enable a worst case assessment, it is assumed that no response or clean-up activities are implemented to mitigate the spill, noting in reality that this would not be the case.

### 11.4.1 Water Quality

There is the potential that a worst case release of hydrocarbons from the Tornado field could result in damage that would significantly adversely affect the ecological, chemical and/or quantitative status and/or ecological potential, as defined in Directive 2006/60/EC or the environmental status of marine waters as defined in Directive 2008/56/EC.

Low viscosity hydrocarbons such as the Tornado condensate are expected to disperse naturally through the water column, particularly in a subsea release scenario. The released condensate will be dispersed over a wide area by currents, wave action and wind. Once the condensate reaches the sea surface (typically 10 – 11 hours after release) it is subject to relatively high evaporation rates due to the light nature of the hydrocarbon. However, modelling does predict that surface oil may be severe in some areas, with BAOAC 5 – Continuous True Oil Colour oiling found at distances up to 332 km from the release location. However, the condensate has a low asphaltene content which prevents emulsification, reducing its persistence in the marine environment as shown in Figure 11.6.

Modelling results show that the water column would be impacted over a relatively wide area, with a hydrocarbon concentration of 1 ppb exceeded out to a maximum distance of 1,944 km from the release location. The 1 ppb hydrocarbon concentration was used as the minimum screening threshold in the oil spill modelling (refer to Table 11.7). However, although potential effects to sensitive organisms and socio-economic activity may be detectable at a 1 ppb hydrocarbon concentration, mortality to marine fauna is not expected. Nilsen *et al*. (2006) found a 58 ppb THC is a conservative lethal exposure value for marine fauna. Modelling predicts that subsurface oiling at higher concentrations (> 58 ppb to < 200 ppb) are limited to within the immediate vicinity of the release location and surrounding the north west coast of the Shetland Islands, where water depths are shallow. The maximum area at risk of oiling at these higher concentrations is 323 $km^2$ at the release location and approximately 191 $km^2$ off the coast of the Shetland Islands.

Modelling also predicts that 10 days after the end of the subsea blowout release, only around 28% of the condensate spill (equivalent to 45,306 tonnes) would remain in the water column. Further dilution, dispersion and biodegradation would continue to reduce concentrations of condensate in the water column.

In summary, the sensitivity of water quality to a worst case condensate blowout is considered to be **Medium**. The receptor has a Very High value; however, the WoS area is characterised by persistent, long-period swells, complex current regimes and rapidly changing weather conditions. The water

quality is subject to rapid refreshment rates and mixing of the water column, coupled with strong wave action on the sea surface. Therefore, the receptor resistance and resilience is Very High to condensate pollution. The magnitude of impact is considered to be **Major**, given the area which will be subject to oiling, although condensate does not persist in the marine environment, with modelling showing rapid recovery towards baseline conditions in the 10 day duration after cessation of the blowout. Effects on water quality due to the worst case blowout scenario are therefore assessed as **Moderate**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to water quality from a well blowout is considered to be **Medium**.

### 11.4.2 Sediment Quality

Modelling predicts that the seabed sediments would be subject to a negligible amount of oiling (< 1 tonne) at any one time during the spill duration, which is to be expected as the subsea oil droplets are buoyant. The condensate is light (ITOPF Group 1 - 47.6°API) and rises to the sea surface quickly, with the minimum time to surface oiling predicted to be within 10 to 11 hrs. Once in the water column, the condensate would be subject to rapid dispersion and biodegradation, which also limits the mass of condensate reaching and persisting within the seabed sediment. The trajectory simulations predict no condensate is present in the seabed sediments after completion of the model simulation completed (i.e. 10 days after the release had stopped).

The sensitivity of sediment quality to a worst case condensate blowout is considered to be **High**. The receptor has a Very High value; sediments in the region are uncontaminated and the Faroe-Shetland Sponge Belt NC MPA designated for the protection of seabed features is within 9 km of the release location. However, it is anticipated that condensate will be subject to high biodegradation within the seabed sediment and recoverability will be in the medium term. Therefore, the receptor resistance and resilience is High to condensate pollution. The magnitude of impact is considered to be **Negligible**, as the worst case oil spill modelling revealed negligible amounts of sediment oiling throughout the blowout scenario. Effects on sediment quality due to the worst case blowout scenario are therefore assessed as **Negligible**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to sediment quality from a well blowout is considered to be **Low**.

### 11.4.3 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 (Ozhan et al., 2014).

As hydrocarbons can float on the water's surface and disperse within the ocean as it weathers, plankton may be exposed to both floating hydrocarbon slicks and to small, dissolved droplets of hydrocarbon in the water column (Cormack, 1999; Almeda et al., 2013). Hydrocarbon slicks can also inhibit air-sea gas exchange and reduce sunlight penetration into the water, both essential to photosynthesis and phytoplankton growth (González et al., 2009). Zooplankton at the surface are thought to be particularly sensitive to oil spills due to their proximity to high concentrations of dissolved hydrocarbon and to the additional toxicity of photo-degraded hydrocarbon products at this boundary (Bellas *et al.*, 2013). However, the worst case modelling predicts that surface oiling will be short lived, therefore, limiting the exposure to zooplankton at the sea surface.

Studies have shown growth inhibition in phytoplankton at hydrocarbon concentrations of 100,000 ppb. Conversely, lower levels of hydrocarbons, around 100 ppb, have been found to stimulate growth (Harrison *et al.*, 1986). Subsurface oiling concentrations are highest (> 58 ppb to < 200 ppb) in the immediate vicinity of the release location and surrounding the north west coast of the Shetland Islands, where water depths are shallow. The maximum area at risk of oiling at these higher concentrations is 323 $km^2$ at the release location and approximately 191 $km^2$ off the coast of the Shetland Islands.

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, 2014b). The distribution of plankton across the UKCS is generally uniform and widespread such that it is likely that plankton numbers would recover after the impact of an oil spill and most studies have found that there is a rapid return to normal densities and community compositions once oil in

water background levels have returned (IPIECA-IOGP, 2015). In addition, there is evidence that some zooplankton (particularly copepods) can sense and actively avoid oiled areas, therefore reducing potential contact with oil (Seuront, 2010). Consequently, the potential for knock-on effects on fauna feeding at high trophic levels is not considered to be significant.

In summary, the sensitivity of plankton to a worst case blowout is considered to be **Low**. The receptor is of Medium value; the plankton community has a regional importance to the Faroe-Shetland Channel, providing a food source to higher trophic levels in this region. However, condensate does not persist within the marine environment and the plankton has high recoverability in the short-term with high reproduction rates. Therefore, the receptor resistance and resilience is Very High to condensate pollution. The magnitude of impact is considered to be **Moderate**, as the worst-case oil spill modelling predicts that maximum water column oiling (> 58 ppb to < 200 ppb) is restricted to areas within the immediate vicinity of the release location and surrounding the north west coast of the Shetland Islands and that surface oiling will be short lived, limiting the exposure to plankton at the sea surface. However, any impacts to the plankton community are predicted to be short term and temporary. Effects on plankton due to the worst case blowout scenario are therefore assessed as **Minor**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to plankton from a well blowout is considered to be **Low**.

### 11.4.4 Seabed Communities

In response to hydrocarbon exposure, benthic fauna can either move, tolerate the pollutant (with associated impacts on the overall health and fitness), or die (Gray *et al*., 1988; Lee and Page, 1997). The response to hydrocarbons by benthic species differs depending on their life history and feeding behaviour, as well as the ability to metabolise toxins, especially PAH compounds. However, severe oil pollution typically causes initial massive mortality and lowered community diversity, followed by extreme fluctuations in populations of opportunistic mobile and sessile fauna (Suchanek, 1993).

As discussed above, modelling predicts that seabed sediments would be subject to a negligible amount of oiling (< 1 tonne) at any one time during the spill duration (refer to Figure 11.6). The condensate is subject to rapid dispersion and biodegradation upon release, thus limiting the mass of condensate reaching and persisting at the seabed. It is therefore anticipated that seabed communities will be exposed to negligible volumes of condensate during and after the spill duration. Mass mortality and lowered community diversity to benthic species is not expected.

In summary, the sensitivity of seabed communities to a worst case condensate blowout is considered to be **Medium**. The receptor has a High value, as habitats and species present at the release location are typical of this region WoS. The receptor resistance and resilience is High to condensate pollution as the condensate does not persist and the benthic community does have some tolerance to hydrocarbon contamination and is expected to recover in the medium term. The magnitude of impact is considered to be **Negligible**, as the worst case oil spill modelling revealed very small amounts of seabed oiling throughout the blowout scenario. Condensate in the seabed sediment does not persist and modelling shows immeasurable / undetectable changes in baseline conditions after the model simulation had completed. Effects on seabed communities due to the worst case blowout scenario are therefore assessed as **Negligible**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to seabed communities from a well blowout is considered to be **Low**.

### 11.4.5 Fish

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, 2014b). In addition, many fish species have developed systems which can metabolise and excrete aromatic hydrocarbons and therefore most fish do not tend to accumulate high concentrations of petroleum hydrocarbons, even in heavily oil-contaminated environments (Neff, 1990). Hydrocarbons have, however, been detected in fish bile over one year after the Deepwater Horizon oil spill (Murawski et al., 2014), suggesting that adult fish may accumulate hydrocarbons after a large hydrocarbon spill event.

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. Joye et al. (2016) reported an estimated 2–5 trillion fish larvae were killed as a consequence of the Deepwater Horizon oil spill.

Studies have shown that fish tainting from oil exposure can occur at oil concentrations from 10 ppb (GESAMP, 1993). Modelling predicts that water column oiling at a concentration >10 ppb could occur at distances up to 1,520 km from the release location (refer to Figure 11.7).

The chemical components of light oils, such as the Tornado condensate, have a high biological availability and toxic impacts are more likely than from a heavy crude. The 58 ppb hydrocarbon concentration threshold used in the oil spill modelling (refer to Table 11.7), is a conservative lethal exposure value for marine fauna as it is below the $LC_{50}$ (Lethal Concentration, 50%) for 95% of species. $LC_{50}$ is a toxicological term that represents the concentration of a substance expected to kill 50% of a test animal population during a specified exposure period. It is highly unlikely that mortality to fish will occur at a 58 ppb concentration; however, toxicological effects may be long lasting and contamination may lead to sub-lethal effects such as impaired feeding and reproduction (ITOPF, 2014b). As previously noted, subsurface oiling concentrations are highest (> 58 ppb to < 200 ppb) in the immediate vicinity of the release location and surrounding the north west coast of the Shetland Islands. The maximum area at risk of oiling at these higher concentrations is 323 $km^2$ at the release location and approximately 191 $km^2$ off the coast of the Shetland Islands. Once the hydrocarbon disappears from the water column fish generally lose contamination from their tissues quickly due to their ability to metabolise accumulated hydrocarbons very rapidly (Krahn *et al*., 1993).

As noted above, a large release of condensate from Tornado could also have the potential to impact fish spawning success. The eggs and larvae of broadcast spawners, which are widely dispersed, could be exposed to condensate in the water column. Fish species that are demersal spawners are less at risk, as the worst case spill modelling predicts that seabed sediments would be subject to a negligible amount of oiling (< 1 tonne) at any one time during the spill duration (refer to Figure 11.6).

There are a number of fish spawning and nursery grounds which either overlap with the Tornado Development area or are found in the wider area (see Section 4.3.3). This includes the following species listed as PMFs in Scottish waters: blue whiting, ling, mackerel and Norway pout, halibut, Greenland halibut, and blue ling (NatureScot, 2022; Tyler-Walters et al., 2016). However, many of these species have a widespread distribution and their spawning and nursery grounds are not restricted to this area. It is important to note that any localised mortality of eggs and larvae following a spill rarely impacts wider populations. Even a large spill, coinciding with a geographically isolated spawning event, would be extremely unlikely to expose a notable proportion of the adult stock to a sustained lethal dose of hydrocarbons (IPIECA-IOGP, 2015). In addition, marine organisms are adapted to acute local impacts by the production of vast surpluses of eggs and larvae, and recruitment from outside the affected area (ITOPF, 2014b; IPIECA-IOGP, 2015).

In summary, the sensitivity of fish to a worst case condensate blowout is considered to be **Medium**. The receptor has a High value; with many species listed as PMF in Scottish waters. However, the condensate does not persist and fish do have some tolerance / ability to avoid, adapt and recover from hydrocarbon pollution. Therefore, the receptor resistance and resilience is High to condensate pollution. The magnitude of impact is considered to be **Major**, given the area which will be subject to oiling, although condensate does not persist in the marine environment, with modelling showing rapid recovery towards baseline conditions in the 10 day duration after cessation of the blowout. Effects on fish due to the worst case blowout scenario are therefore assessed as **Moderate**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to fish from a well blowout is considered to be **Medium**.

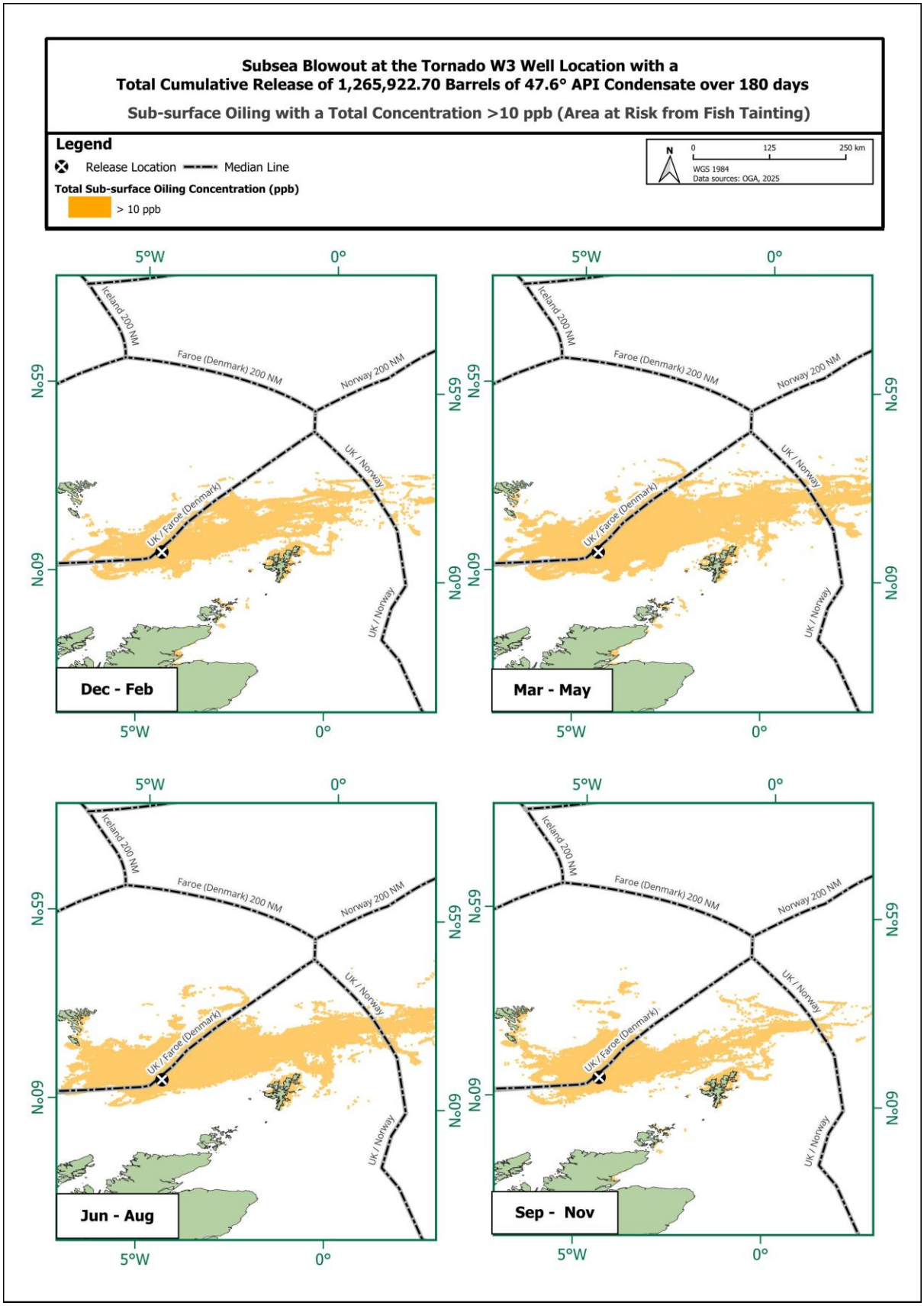



**Figure 11.7: Area at Risk of Fish Tainting (Subsurface Oil Concentration >10 ppb)**

### 11.4.6 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, 2014b). 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.

The proposed Tornado Development is located within an important area for storm petrel, northern gannet and northern fulmar in the breeding season. During the winter months, black-legged kittiwake and northern fulmar are predicted to be found in comparatively higher densities in the Faroe-Shetland Channel, with guillemot also present during the post-dispersal period. An assessment of the median SOSI scores for the UKCS Blocks making up the Tornado Development area shows that the sensitivity of seabirds to oil pollution varies throughout the year. SOSI scores within the Blocks of Interest vary between medium to low in January to April and in June, high to low in May, low in July, August and December, extremely high to low in September and October and very high to low in November (refer to Section 4.3.4). However, no periods of concern for drilling have been assigned to UKCS Block 204/13, which is the location of the proposed Tornado drill centre.

Of note, the Seas off Foula SPA, located approximately 69 km southeast of the proposed Tornado drill centre location, is an important seabird foraging site WoS, covering an area of 3,412 km$^2$. Modelling of a worst case condensate blowout release predicts that there is 37% probability of surface oil (BAOAC 5 - Continuous True Oil Colour oiling) entering the Seas off Foula SPA (refer to Table 11.10).

An oil sheen thickness >0.3 µm is the minimum thickness expected to produce negative impacts on marine fauna encountering released condensate at the sea surface. There is a 100% probability of surface oiling at a thickness >0.3 µm occurring within 125 km of the release source (as illustrated in Figure 11.3). Surface oiling with a thickness >0.3 µm may travel up to 456 km from the release source, but at much lower probabilities. In addition, the most severe surface oiling (BAOAC 5 - Continuous True Oil Colour) may occur within 332 km of the release location. Therefore, in the event of a well blowout in the Tornado field, significant volumes of hydrocarbons may surface over a wide area, potentially affecting a large number of seabirds.

Stochastic modelling shows that higher-severity surface oiling can occur across a large spatial area within the modelled probability range; however, this oiling is predicted to be transient and non-persistent.. Figure 11.8 presents the total surface oiling mass and surface slick area (with an oiling concentration >100 kg/km$^2$) over time for the winter trajectory run number 26. Figure 11.8 shows the maximum surface slick area at any one time is 1,911.35 km$^2$. However, the surface oil does not persist; once the blowout release stops at 4,320 hours (180 days) the surface oil reduces to zero in the following 10 days. The peaks and troughs shown in Figure 11.8 are a function of the time taken for released condensate to reach the sea surface and relatively high evaporation rates once at the sea surface. Therefore, the surface slick grows and shrinks at regular intervals throughout the release scenario. The relatively high evaporation rates limit the peak surface slick exposure time and the potential interaction with rafting seabirds, although only a relatively low exposure time is needed to compromise a rafting bird.

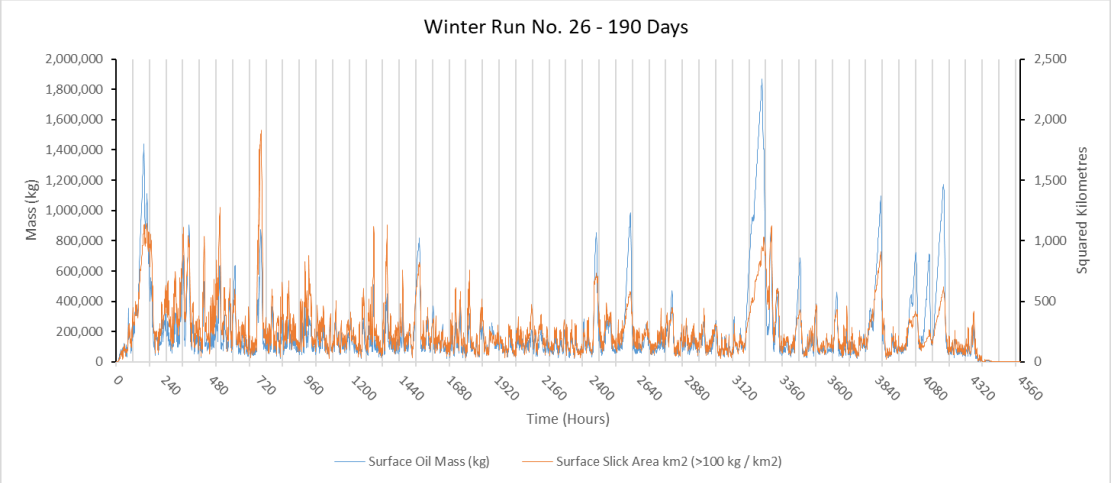



**Figure 11.8: Surface Slick Area (with a concentration >100 kg / km$^2$) and Surface Oil Mass over Time during Winter Run No. 26**

The stochastic modelling predicts that the Shetland Islands are at risk from 'light' shoreline oiling with a maximum thickness of 0.17 mm. The greatest mass of beached condensate at any one location is 23.35 tonnes. Therefore, seabirds on the shoreline are at low risk from a large scale oiling event.

In summary, the sensitivity of seabirds to a worst case condensate blowout is considered to be **Very High**. The receptor has a Very High value; the seabird assemblage in the vicinity of the Tornado Development area is of international importance. Seabirds that are exposed to oiling have very limited tolerance and recovery is unlikely. Therefore, the receptor resistance and resilience is Low to condensate pollution. The magnitude of impact is considered to be **Major** as the area around Tornado is important for seabirds and the maximum size of the slick is relatively large at up 2,017.61 km$^2$. The released condensate does, however, not persist and modelling shows rapid recovery towards baseline conditions in the 10 day duration after the blowout cessation. Effects on seabirds due to the worst case blowout scenario are therefore assessed as **Major**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to seabirds from a well blowout is considered to be **Medium**.

### 11.4.7 Marine Mammals

As discussed in Section 4.3.5, cetacean species most likely to be present in the vicinity of the proposed Tornado Development include harbour porpoise, Risso's dolphin, killer whale, pilot whale, minke whale, beaked whale, white-beaked dolphin and white-sided dolphin. All species of cetacean are listed as European Protected Species (listed in Annex IV of the EC Habitats Directive) and the harbour porpoise and bottlenose dolphin are listed under Annex II of the EC Habitats Directive.

Although marine mammals also use the sea surface in a similar manner to seabirds (refer to Section 11.5.6), they 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 also unlikely to adhere to or permeate through the skin of marine mammals where it could accumulate in tissues and have toxicity effects (Neff, 1990). While cetaceans skin is not thought to be particularly sensitive to oil, any accidental ingestion or breathing of oily fumes could cause physiological stress (Takeshita et al., 2017). Notably, following the Deepwater Horizon spill in 2010, significant health issues were identified in a resident bottlenose dolphin population located in one of the most heavily oiled area, including pulmonary disease and low reproductive success (Lane et al., 2015; Takeshita et al., 2017), however, there is still some doubt these effects were directly linked to the spill. Notwithstanding the research conducted after the Deepwater Horizon, current evidence does not suggest more than a low sensitivity to oil for most cetaceans, but resident populations of some species may be both vulnerable and sensitive to large oiling events (Kirby et al, 2018).

Both harbour and grey seals are widespread around the west coast of Shetland and Orkney (SCOS, 2022b). Seals utilising coastal waters, particularly those at haul-out and breeding sites, may be impacted in the event of shoreline oiling. These species 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, 2014b). The stochastic modelling predicts that the Shetland Islands are at risk from 'light' shoreline oiling with a maximum thickness of 0.17 mm. The greatest mass of beached condensate at any one location is 23.35 tonnes. Therefore, seal haul-out sites on the shoreline are not considered to be at significant risk from a large scale oiling event.

In summary, the sensitivity of marine mammals to a worst case condensate blowout is considered to be **High**. The receptor has a Very High value as marine mammals are of international importance. However, the condensate does not persist and marine mammals have some capacity to avoid hydrocarbon pollution. Therefore, the receptor resistance and resilience is High to condensate pollution. The magnitude of impact is considered to be **Moderate**; as the condensate is not predicted to persist in the marine environment, with modelling showing rapid recovery towards baseline conditions in the 10 day duration after cessation of the blowout. Effects on marine mammals due to the worst case blowout scenario are therefore assessed as **Moderate**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to marine mammals from a well blowout is considered to be **Medium**.

### 11.4.8 Marine Protected Areas

The MPAs at risk from surface, subsurface and shoreline oiling are detailed in Appendix F with the maximum probability, shortest arrival time and maximum severity identified for each site.

#### Shoreline Oiling

Stochastic modelling predicts that MPAs located on the Shetland coastline are at risk of low severity 'light' shoreline oiling (refer to Appendix F). Trajectory modelling revealed that up to 3.56 km of coastline could be impacted during the winter with a maximum oiling thickness of 0.17 mm (see Figure 11.5). Furthermore, the greatest mass of beached condensate at any one location is 23.35 tonnes. Modelling also found that beached condensate does not persist with relatively high rates of evaporation and degradation. After 190 days (i.e. 10 days after the blowout release has ceased), the model predicts that 0% of released condensate is expected to remain on the shoreline. As such, the protected features of coastal MPAs are at **Low** risk from a large scale shoreline oiling event.

#### Surface Oiling

The MPAs most likely to be most affected by surface oiling are those designated for the protection of seabird species or marine mammals as they are most likely to be present at the sea surface. Although modelling predicts the condensate slick does not persist, a relatively low exposure time is required to compromise seabird species. Table 11.10 therefore lists those MPAs which may be subject to surface oiling at a thickness of > 0.3 µm, with qualifying features vulnerable to surface oiling, and assesses the impact to these sites in the event of a worst case blow out scenario from Tornado. Of note, the probability of surface oil reaching the majority of these sites is relatively low.

#### Subsurface Oiling

The majority of MPAs at risk from subsurface oil are subject to low severity concentrations (<58 ppb) of condensate (refer to Appendix F). In addition, condensate does not persist within the water column, with only a moderately low proportion (circa. 28 %) of released condensate remaining within the water column after 190 days. Table 11.11 therefore lists those MPAs which could be subject to subsurface oiling at a concentration of > 58 ppb, with qualifying features vulnerable to subsurface oiling, and assesses the impact to these sites in the event of a worst case blow out scenario from Tornado. Of note, the probability of subsea oiling reaching these sites is very high.

#### Conclusion

In summary, the protected features of the following five MPAs are at **Medium** risk from a large scale oiling event, which could adversely impact the conservation objectives of these sites:

- Seas off Foula SPA;
- Bluemull and Colgrave Sounds SPA;

- Hermaness, Saxa Vord and Valla Field SPA;
- Fetlar SPA;
- Fetlar to Haroldswick MPA.

These areas are designated for the protection of seabirds, which as previously discussed, are particularly sensitive to oil pollution.

In contrast, two MPAs, namely the Faroe-Shetland Sponge Belt MPA and the North East Faroe-Shetland Channel MPA, are assessed to be at **Low** risk from a large scale oiling event. This is because the designated features of these MPAs lie on the seabed, and the buoyant nature of the oil droplets causes them to rise quickly to the surface, reducing the potential for interaction with seabed habitats. Modelling predicts that the seabed sediments would be subject to a negligible amount of oiling (< 1 tonne) at any one time during the spill duration.

**Table 11.10: Assessment of MPAs with Qualifying Features at Risk from Surface Oiling**

| Protected Area | Surface Oil | | Protected Features & Conservation Objectives at Risk from Surface Oil | Impact Assessment [Note 1] | | |
|---|---|---|---|---|---|---|
| | Probability | Maximum Severity | | Sensitivity to Surface Oiling | Magnitude of Oiling Impact | Significance Evaluation (Consequence x Likelihood) |
| Seas off Foula SPA | 37 % | BAOAC: 5 | **Protected Features:** Great skua *Stercorarius skua* (breeding and non-breeding); assemblage of breeding seabirds; assemblage of seabirds, non-breeding; northern fulmar *Fulmarus glacialis* (breeding and non-breeding); Arctic skua *Stercorarius parasiticus* (breeding); common guillemot *Uria aalge* (breeding and non-breeding); Atlantic puffin *Fratercula arctica* (breeding).<br>**Conservation Objectives:**<br>1. Avoid significant mortality, injury and disturbance of the qualifying features, so that the distribution of the species and ability to use the site are maintained in the long-term;<br>2. Maintain the habitats and food resources of the qualifying features in favourable condition. | Very High | Major | Major x Extremely Rare = **MEDIUM** |
| Bluemull and Colgrave Sounds SPA | 1 % | BAOAC: 5 | **Protected Features:** Red-throated diver *Gavia stellate* (breeding).<br>**Conservation Objectives:**<br>1. To ensure that red-throated diver at Bluemull and Colgrave Sounds SPA are in favourable condition and make an appropriate contribution to achieving Favourable Conservation Status.<br>2. To ensure that the integrity of Bluemull and Colgrave Sounds SPA is maintained in the context of environmental changes by meeting objectives 2a, 2b and 2c for red-throated diver:<br>a. The population of red-throated diver is a viable component of the site.<br>b. The distribution of red-throated diver throughout the site is maintained by avoiding significant disturbance of the species.<br>c. The supporting habitats and processes relevant to red-throated diver and their prey/food resources are maintained. | Very High | Major | Major x Extremely Rare = **MEDIUM** |

| Protected Area | Surface Oil | | Protected Features & Conservation Objectives at Risk from Surface Oil | Impact Assessment [Note 1] | | |
|---|---|---|---|---|---|---|
| | Probability | Maximum Severity | | Sensitivity to Surface Oiling | Magnitude of Oiling Impact | Significance Evaluation (Consequence x Likelihood) |
| Hermaness, Saxa Vord and Valla Field SPA | 3 % | BAOAC: 5 | **Protected Features:** Fulmar *Fulmarus glacialis* (assemblage); gannet *Morus bassana* (breeding); great skua *Stercorarius skua* (breeding); guillemot *Uria aalge* (assemblage); kittiwake *Rissa tridactyla* (breeding); puffin *Fratercula arctica* (breeding); red-throated diver *Gavia stellate* (breeding); shag *Phalacrocorax aristotelis* (assemblage); seabird assemblage.<br>**Conservation Objectives:**<br>1. To avoid deterioration of the habitats of the qualifying species or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained;<br>2. To ensure for the qualifying species that the following are maintained in the long term:<br>a. Population of the species as a viable component of the site.<br>b. Distribution of the species within site.<br>c. Distribution and extent of habitats supporting the species.<br>d. Structure, function and supporting processes of habitats supporting the species.<br>e. No significant disturbance of the species. | Very High | Major | Major x Extremely Rare = **MEDIUM** |

**Table 11.11: Assessment of MPAs with Qualifying Features at Risk from Sub-surface Oiling**

| Protected Area | Sub-surface Oil | | Protected Features & Conservation Objectives at Risk from Subsurface Oil | Impact Assessment [Note 1] | | |
|---|---|---|---|---|---|---|
| | Probability | Water Column Oil Concentration (ppb) | | Sensitivity to Sub-surface Oiling | Magnitude of Oiling Impact | Significance Evaluation (Consequence x Likelihood) |
| Fetlar SPA | 100% | >70.5 | **Protected Features:** Fulmar *Fulmarus glacialis* (breeding); Arctic tern *Sterna paradisaea* (breeding); Arctic skua *Stercorarius parasiticus* (breeding); Dunlin *Calidris alpina schinzii* (breeding); Great skua *Stercorarius skua*; Red-necked phalarope *Phalaropus lobatus*; Whimbrel *Numenius phaeopus* and Seabird assemblage<br>**Conservation Objectives:**<br>1. To avoid deterioration of the habitats of the qualifying species or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained;<br>2. To ensure for the qualifying species that the following are maintained in the long term:<br>a. Population of the species as a viable component of the site.<br>b. Distribution of the species within site.<br>c. Distribution and extent of habitats supporting the species.<br>d. Structure, function and supporting processes of habitats supporting the species.<br>e. No significant disturbance of the species. | Very High | Major | Major x Extremely Rare = **MEDIUM** |

| Protected Area | Sub-surface Oil | | Protected Features & Conservation Objectives at Risk from Subsurface Oil | Impact Assessment Note 1 | | |
|---|---|---|---|---|---|---|
| | Probability | Water Column Oil Concentration (ppb) | | Sensitivity to Sub-surface Oiling | Magnitude of Oiling Impact | Significance Evaluation (Consequence x Likelihood) |
| Hermaness, Saxa Vord and Valla Field SPA | 100% | >100 | **Protected Features:** fulmar *Fulmarus glacialis* (assemblage); gannet *Morus bassana* (breeding); great skua *Stercorarius skua* (breeding); guillemot *Uria aalge* (assemblage); kittiwake *Rissa tridactyla* (breeding); puffin *Fratercula arctica* (breeding); red-throated diver *Gavia stellate* (breeding); shag *Phalacrocorax aristotelis* (assemblage); seabird assemblage.<br>**Conservation Objectives:**<br>3. To avoid deterioration of the habitats of the qualifying species or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained;<br>4. To ensure for the qualifying species that the following are maintained in the long term:<br>f. Population of the species as a viable component of the site.<br>g. Distribution of the species within site.<br>h. Distribution and extent of habitats supporting the species.<br>i. Structure, function and supporting processes of habitats supporting the species.<br>No significant disturbance of the species. | Very High | Major | Major x Extremely Rare = **MEDIUM** |
| Faroe-Shetland Sponge Belt MPA | 100 % | >70.5 | **Protected Features:** Deep sea sponge aggregations; Ocean quahog (*Arctica islandica*) aggregations; offshore subtidal sand and gravel habitats; continental slope; Continental slope channels, iceberg plough marks, prograding wedges and slide deposits representative of the West Shetland Margin paleo-depositional system Key Geodiversity Area and; sand wave fields and sediment wave fields representative of the West Shetland Margin contourite deposits Key Geodiversity Area<br>**Conservation Objectives:**<br>1. The conservation objectives for the Faroe- Shetland Sponge Belt NC MPA are that the protected features listed above:<br>a. so far as already in favourable condition, remain in such condition; and<br>b. so far as not already in favourable condition, be brought into such condition, and remain in such condition. | Very High | Negligible | Negligible x Extremely Rare = **LOW** |

| Protected Area | Sub-surface Oil | | Protected Features & Conservation Objectives at Risk from Subsurface Oil | Impact Assessment Note 1 | | |
|---|---|---|---|---|---|---|
| | Probability | Water Column Oil Concentration (ppb) | | Sensitivity to Sub-surface Oiling | Magnitude of Oiling Impact | Significance Evaluation (Consequence x Likelihood) |
| North East Faroe-Shetland Channel MPA | 100 % | >58 | **Protected Features:** Deep sea sponge aggregations; offshore deep-sea muds; offshore subtidal sand and gravel habitats; continental slope; A wide range of features representative of the West Shetland Margin Palaeo-depositional, Miller Slide and Pilot Whale Diapirs Key Geodiversity Areas.<br>**Conservation Objectives:**<br>1. The conservation objectives for the North East Faroe-Shetland Channel NC MPA are that the protected features listed above:<br>a. so far as already in favourable condition, remain in such condition; and<br>b. so far as not already in favourable condition, be brought into such condition, and remain in such condition. | Very High | Negligible | Negligible x Extremely Rare = **LOW** |
| Fetlar to Haroldswick MPA | 100 % | > 70.5 | **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. Geodiversity: Marine Geomorphology of the Scottish Shelf Seabed.<br>**Conservation Objectives:**<br>1. The Conservation Objectives of the Fetlar to Haroldswick MPA, are that the protected features<br>• so far as already in favourable condition, remain in such condition<br>• so far as not already in favourable condition, be brought into such condition, and remain in such condition | Very High | Major | Major x Extremely Rare = **MEDIUM** |

Note 1: Refer to Section 5 for impact assessment methodology.

### 11.4.9 Socio-economic Receptors

#### Commercial Fisheries

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, 2014c).

The proposed Tornado drill centre location is located within water depths >800 m where bottom trawling is prohibited. Fishing activity is therefore more likely to be concentrated at the Tormore end of the pipeline route, where water depths are shallower. However, The Offshore Fishing (Prohibition of Fishing Methods) (Scotland) Order 2025 came into effect on 16th October 2025, which prohibits demersal gear (mobile and static) fishing practices within Scottish MPAs, including the Faroe-Shetland Sponge Belt NCMPA. The proposed Tornado pipeline route cross through the northern zone of the NCMPA for a distance of ca. 13 km, where the use of demersal mobile gear is now prohibited. As such, only ca. 5 km of the entire proposed pipeline route would potentially be exposed to demersal mobile fishing gear interaction, noting that a 500 m length of this section is located within the existing Tormore 500 m safety exclusion zone. In the wider area, where allowed, demersal (bottom) otter trawling occurs in water depths less than 700 m, with the highest intensities found between 200 m and 300 m. Hake and halibut (Greenland) are the greatest components of the fishery. There is also a higher presence of fishing vessels west of the UK EEZ boundary (refer to Section 4.4.1).

Modelling predicts that water column oiling at a concentration (>10 ppb) that causes fish tainting could occur up to a distance of 1,520 km from the Tornado release location. In addition, as previously noted, subsurface oiling concentrations are highest (> 58 ppb to < 200 ppb) in the immediate vicinity of the release location and surrounding the north west coast of the Shetland Islands. It is highly unlikely that mortality to fish will occur at a 58 ppb concentration; however, toxicological effects may be long lasting and contamination may lead to sub-lethal effects such as impaired feeding and reproduction (ITOPF, 2014b). The maximum area at risk of oiling at these higher concentrations is 323 $km^2$ at the release location and approximately 191 $km^2$ off the coast of the Shetland Islands.

Throughout the spill duration, surface oiling could temporarily displace fishing vessels from the region, with modelling indicating that the condensate slick will cover an area of 1,305.42 – 2,017.61 $km^2$ at any one point; however, surface oiling does not persist, with zero surface oil predicted 10 days after the cessation of the blowout release.

In summary, the sensitivity of commercial fisheries to a worst case blowout is considered to be **High**. The receptor has a Very High value as the area in the wider region of the proposed Tornado Development (in water depths <800m) is fished by both UK and international vessels. However, receptor resistance and resilience is High as the condensate is not predicted to persist and fishing vessels may be able to temporarily switch to alternative fishing grounds. The magnitude of impact is considered to be **Moderate**, as modelling predicts that maximum water column oiling (> 58 ppb to < 200 ppb) is restricted to areas within the immediate vicinity of the release location (where bottom trawling is prohibited) and surrounding the north west coast of the Shetland Islands. The condensate does not persist in the marine environment, with modelling showing rapid recovery towards baseline conditions in the 10 day duration after cessation of the blowout. Effects on commercial fisheries due to the worst case blowout scenario are therefore assessed as **Moderate**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to commercial fisheries from a well blowout is considered to be **Medium**.

#### Aquaculture

Aquaculture is a prominent industry along the west coast of the Shetland Islands, with salmon and mussels dominating production (refer to Figure 11.9 and Section 4.4.1). Aquaculture sites are vulnerable to the effects of oiling. Modelling predicts that subsurface oiling concentration is highest off the north west coast of the Shetland Islands, where water depths are shallow, and, as demonstrated in Figure 11.7, aquaculture sites located along the west and east coasts of Shetland are at risk from fish tainting. However, modelling predicts that 10 days after the end of the subsea blowout release, only around 28% of the condensate spill (equivalent to 45,306 tonnes) would remain in the water column.

Further dilution, dispersion and biodegradation would continue to reduce concentrations of condensate in the water column.

In summary, the sensitivity of aquaculture to a worst case blowout is considered to be **High**. The receptor has a Medium value; the aquaculture is of regional importance. Aquaculture sites are vulnerable to oiling exposure as the farmed fish / shellfish are unable to avoid or more away from pollution; therefore, the receptor resistance and resilience is Low to condensate pollution. The magnitude of impact is considered to be **Major**, as the worst case oil spill modelling revealed that inshore areas of Shetland may be exposed to harmful concentrations of subsurface oil. Effects on aquaculture due to the worst case blowout scenario are therefore assessed as **Major**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to aquaculture from a well blowout is considered to be **Medium**.

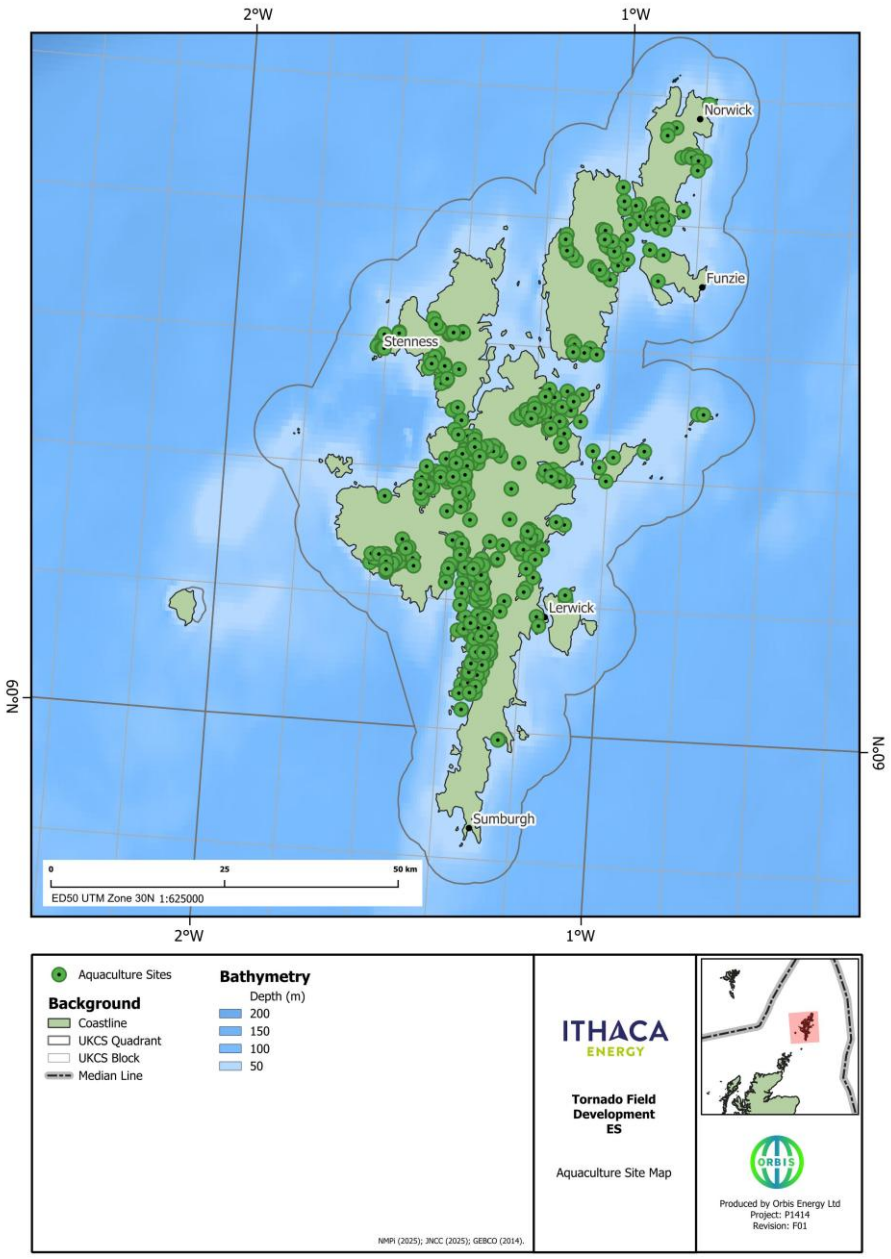



**Figure 11.9: Aquaculture Sites around the Shetland Islands**

### Recreational Activity and Tourism

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, 2014c). The smell and appearance of stranded oil may be a nuisance to people living on the affected shoreline.

Tourism and leisure activities are focused along the coastline and nearshore water of the Shetland Islands. Coastal tourism activities include wildlife watching for birds, otters, cetaceans and pinnipeds, as well as recreational and sport fishing activities. Scuba diving is also popular due to the extensive rocky shores and kelp beds which support a diverse assemblage of species (DTI, 2005; Visit Shetland, 2021).

Following a worst case release of condensate, areas with the highest probability of shoreline contamination in Shetland include the Unst (3 %), Yell (1 %) and mainland (2 %) coastlines. Other locations that make up the Shetland Islands (Papa Stour, Muckle Roe, and Vaila) have probabilities of less than 1 %. However, shoreline oiling at all locations is predicted to be of low severity (maximum thickness 0.17 mm) and will not persist (refer to Section 11.4.2 and Appendix F).

In summary, the sensitivity of recreational activity and tourism to a worst case blowout is considered to be **Medium**. The receptor has a High value; recreational activity and tourism is of importance to the local economy. However, the condensate does not persist with recreational activity and tourism expected to recovery in the short to medium term; therefore, the receptor resistance and resilience is High to condensate pollution. The magnitude of impact is considered to be **Moderate**, as shoreline oiling at all locations is predicted to be of low severity, with modelling showing rapid recovery towards baseline conditions in the 10 day duration after the blowout cessation. Effects on recreational activity and tourism due to the worst case blowout scenario are therefore assessed as **Minor**. When combined with the likelihood of the event occurring (Extremely Rare), the risk to recreational activity and tourism from a well blowout is considered to be **Low**.

## 11.5 Potential for a Major Environmental Incident

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*".

Under Directive 2004/35/EC, "*environmental damage*" is defined as:

- *"Damage to protected species and natural habitats, which is any damage that has significant adverse effects on reaching or maintaining the favourable conservation status of such habitats or species. The significance of such effects is to be assessed with reference to the baseline condition, taking account of the criteria set out in Annex I";*
- *"Water damage, which is any damage that significantly adversely affects the ecological, chemical and/or quantitative status and/or ecological potential, as defined in Directive 2000/60/EC, of the waters concerned, with the exception of adverse effects where Article 4(7) of that Directive applies";*
- *"Land damage, which is any land contamination that creates a significant risk of human health being adversely affected as a result of the direct or indirect introduction, in, on or under land, of substances, preparations, organisms or micro-organisms".*

For an event to be considered as a MEI, a major accident (as defined under SCR 2015) must be a precursor (BEIS, 2017). For the proposed Tornado Development, the major accident scenario that would result in the worst case release of hydrocarbons is:

- Loss of well control and subsequent blowout that can only be stopped by drilling a relief well.

Based on the results of the oil spill modelling (Section 11.3.2 and Appendix F) and the assessment of environmental and socio-economic effects as detailed in Section 11.4, it is considered possible that oiling from a worst case release of hydrocarbons could significantly impact ecosystems (i.e. there could

be a significant adverse impact on the favourable conservation status of relevant species and/or habitats in areas identified to be at risk from oiling); these impacts would likely constitute a MEI.

As outlined in Sections 11.4.6 and 11.4.8, the most significant threat to Annex I habitats, Annex II/IV species, and MPA features arises from the severity of surface oiling. MPAs designated for protection of seabirds are especially vulnerable due to the sensitivity of these species to oil contamination. According to Table 11.10, the protected seabird features of three SPAs are exposed to surface oiling at a level that could result in a MEI. Similarly, Table 11.11 indicates that two SPAs and one MPA with seabirds as protected features are at risk from sub-surface oiling of sufficient severity to also constitute a MEI.

It should be stressed that the identified major accident scenario is an extreme worst case; it assumes the complete failure of all control and preventative measures. In a real situation, steps would immediately be taken to stem the flow of hydrocarbons and in the event of a well control incident bring the well back under control.

## 11.6 Mitigation Measures

Ithaca's commitments to ensuring protection of the environment are set out in Ithaca's corporate HSE policy. Ithaca follow the International Standards Organisation (ISO) 14001 standard and has an externally verified EMS. The Company's EMS covers activities including exploration, drilling and production.

It is the policy of Ithaca that the Tornado Development will be designed and operations will be conducted in such a manner as to minimise the risk of accidental releases. 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.

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.

Where residual risks remain, mitigation procedures will be put in place to prevent accidental spills. Key mitigation measures for the Tornado Development are summarised in Table 11.12.

In the unlikely event that an oil pollution incident did occur, Ithaca has Oil Spill Response Limited (OSRL) membership which provides access to oil spill response equipment. Ithaca also has insurance provisions in place to cover well control/re-drill situations as well as legal liabilities, and the Company is a member of Offshore Pollution Liability Agreement (OPOL) which provides rapid compensation to parties directly affected by an oil spill.

With regards to well control during the proposed Tornado drilling operations, the MODU will be equipped with a BOP which is rated for pressures beyond the maximum pressure anticipated for the wells being drilled.

The function of the BOP will be to prevent uncontrolled flow from the wells to the surface during drilling by positively closing in the well in the event of an uncontrolled release from the reservoir into the well bore. The BOP is made up of a series of hydraulically operated rams that can be closed in an emergency from the drill floor, or from a safe location elsewhere on the rig.

The integrity of the BOP will be tested prior to usage and periodically during the drilling. Inspection and testing of the BOP will be undertaken in line with Ithaca's procedures and UK legislation.

In the event of any well control issues the Ithaca Well Incident Response Plan will be activated and used as a guide in the event of a well control emergency during operations involving a MODU. The Well Incident Response Plan provides a contingency plan and guidance for the application of equipment and procedures to various well control scenarios. These range from routine well control operations to situations involving the total loss of well control.

The available response options will include, but are not limited to, well control specialists and engineering support; specialist equipment and services; intervention procedures; well kill procedures; relief well planning and execution; ROV intervention; capping stack deployment; hydrocarbon

containment and subsea dispersant resources. A well control event may not require all of the responses listed.

The Oil Spill Prevention and Response Advisory Group (OSPRAG) capping device is available for use on the wells if it is determined to be a suitable and effective response to the incident at the time. In addition to well capping the drilling of a relief well may be required.

The suitability of a capping device strategy will be significantly dependent on the circumstances of the incident and scenario encountered. In the unlikely event of a blow out from a subsea well where the primary Blowout Prevention Equipment has failed, a well capping device may be required. Ithaca has access to the OSPRAG Capping device in the event it is required.

An approved OPEP will be in place, prepared in advance of activities commencing offshore, which will detail the spill prevention measures, response procedures and resources available to Ithaca in the event of a spill. All supporting vessels will also have a ship oil pollution emergency plan (SOPEP) onboard.

**Table 11.12: Key Spill Prevention Measures for the Tornado Development**

| Source | Spill Prevention Measures |
|---|---|
| Loss of chemicals, fuel or utility hydrocarbons during bunkering and general operations | • Liquid storage areas and areas that might be contaminated with oil are segregated from other deck areas;<br>• Bunding or additional containment will be provided around plated areas beneath equipment with significant hydrocarbon inventories;<br>• Chemicals will be stored in bunded areas where any spillages can be routed to the closed drainage system;<br>• 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;<br>• Small spill kits will be on board the MODU and subsea vessels to clean up deck spills and prevent spilt hydrocarbons and chemicals from reaching the sea;<br>• Non-return valves will be installed on transfer hoses and hoses to be tested and inspected as a part of a regular maintenance programme;<br>• 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;<br>• Crews will be adequately trained, supervised and regular exercises held to contain and clean-up deck spills;<br>• Routine equipment maintenance programme will be in place with specific emphasis on environmentally critical equipment;<br>• Effective management of chemicals to endeavour to reduce the volumes required and therefore the frequency of bunkering;<br>• Use of floating hoses;<br>• Where feasible, bunkering operations will be undertaken in daylight and in good weather conditions. |
| Loss of containment on MODU due to collision or other major event | • Consent to Locate will be in place for the MODU under Part 4A of the Energy Act 2008;<br>• 500m safety exclusion zone will be designated around the MODU;<br>• Dedicated ERRV present during drilling to monitor movements of other vessels in the area and prevent them entering the exclusion zones;<br>• Notifications made to ‘regular runners’ and local fisheries organisations via Notices to Mariners, NAVTEX / NAVAREA warnings and fisheries notices. |

| Source | Spill Prevention Measures |
|---|---|
| Well Blowout | • Crews will be adequately experienced, trained in well control techniques and supervised;<br>• Weighted drilling fluids will provide the primary barrier and the downhole pressures will be carefully controlled and monitored;<br>• The secondary barrier will be the BOP which will be regularly maintained and tested;<br>• Well design and construction reviewed by an independent well examiner;<br>• Safety and Environmental critical elements related to drilling operations will be identified, and a suitable maintenance and testing schedule applied to each;<br>• Emergency drills will be held regularly;<br>• Emergency response plans and equipment will be in place;<br>• Review spill mitigation measures of all contractors as part of the contractor selection process. |
| Loss of pipelines | • Facilities will be subject to stringent design specifications;<br>• Where practicable, pressure and leak testing will be undertaken onshore prior to infrastructure being installed. All pipelines will be pressure tested to above the planned operating pressure;<br>• The production pipeline will be protected against corrosion by the continuous injection of corrosion inhibitor;<br>• The production pipeline will be designed to resist credible fishing interaction loads.<br>• The requirement for protective measures for the MEG pipeline and control umbilical will depend on the findings of ongoing studies assessing the intensity of fishing activity and the potential for damage, but for the purposes of this ES it is assumed they will be protected in water depths <800 m;<br>• Routine monitoring of pipeline pressure and temperature will be undertaken. Automatic and manual shutdown systems in place;<br>• Regular ROV inspection of all pipelines will be undertaken. |

## 11.7 Residual Risk

Based on historical data and taking into account the spill prevention measures that will be in place, the most probable accidental releases from the proposed Tornado Development will be small in volume. It is considered to be extremely rare for a major event, such as a blowout, to 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 from the Tornado Development will vary depending on the quantity and type of hydrocarbon released, the wind speed and direction and sea state and the sensitivity of receptors depending on the time of year. A small spill of condensate or diesel would be subject to rapid dilution and dispersion and any impact on receptors in the marine environment would be short term and localised.

The Tornado condensate is an ITOPF Group 1 (47.6° API) oil which is subject to relatively high rates of evaporation and biodegradation upon release. The condensate does not persist in the water column, on the sea surface or at the shoreline. The residual risk to the marine environment from a worst case accidental release is considered to range from **Medium** to **Low**, depending on the receptor impacted, but in all cases the risk has been reduced to ALARP through mitigation measures and good industry practice and is therefore not considered to be significant.

## 11.8 Transboundary Impacts

The Tornado field lies approximately 6.5 km to the south east of the UK / Faroe Islands median. As such, modelling predicts a 100% probability of surface oil crossing the Faroe Islands median line in the event of a well blowout. There is also a very low (1 - 3 %) probability of surface oil crossing the Norwegian median line (refer to Table 11.5). The minimum time for surface oil to reach the Faroe Islands and Norwegian median lines is 16 hours and 271 hours, respectively.

In addition, there is a 100% probability of subsurface oil crossing the Faroe Islands and Norway median lines, a moderate probability of subsurface oil crossing the Jan Mayen (29- 54 %) median line and a low to moderate probability of subsurface oil crossing the Sweden (6 – 25%), Denmark (9% - 32%) and Iceland (3 – 22%) median lines.

It is important to note, however, that the scenario modelled is an extreme worst case; it assumes the complete failure of all control and preventative measures. In a real situation, steps would immediately be taken to stem the flow of hydrocarbons and bring the well back under control. A counter-pollution response strategy would also be developed and initiated.

A Local Agreement of Mutual Support exists between the UK and the Faroe Islands, with regards to spill preparedness and response. Agreements are also in existence for dealing with international releases with states bordering the UK (e.g. Bonn Agreement). These agreements would operate within the framework of the National Contingency Plans (NCPs) and are oriented towards major releases. In the event of an oil spill entering Norwegian waters, the NORBRIT Agreement (the Norway-UK Joint Contingency Plan) may be activated. Responsibility for implementing joint action with neighbouring states rests with the Action Co-ordinating Authority (ACA) of the country on whose side of the median line a spill originated. The UK's ACA is the Counter Pollution Branch of the Maritime Coastguard Agency (MCA).

Given the above, the risk of transboundary impacts is considered to range from **Medium** to **Low**, depending on the receptor impacted, but in all cases the risk has been reduced to ALARP through mitigation measures and good industry practice and is therefore not considered to be significant.

## 11.9 Cumulative Impacts

Cumulative effects from accidental releases are not anticipated. As indicated by historical data, the likelihood of one major accidental release occurring is remote or extremely remote, limiting the cumulative impact from the Tornado Development and other existing installations.

# 12 Waste Management

## 12.1 Introduction

The management of waste produced offshore on the UKCS is regulated through a framework of international and national legislation. Waste generated on offshore installations and vessels is primarily regulated by the Merchant Shipping (Prevention of Pollution by Sewage from Ships) Regulations 2020 (as amended) and Merchant Shipping (Prevention of Pollution by Garbage from Ships) Regulations 2020 (as amended). These Regulations implement Annex IV (Prevention of pollution by sewage from ships) and Annex V (Prevention of pollution by garbage from ships) of MARPOL 73/78 (The International Convention for the Prevention of Pollution from Ships).

MARPOL Annex IV and V prohibit the discharge of all garbage (including plastics) and galley waste (except for comminuted or ground food waste to < 25 mm and treated sewage) into sea from offshore installations or vessels. Once transported onshore, waste management is regulated by the Environment Protection Act 1990 (as amended), which sets out Duty of Care requirements for the containment, transfer, handling, and recording of all onshore waste through appropriately licensed carriers holding a Waste Carrier Registration. In Scotland, the Scottish Environment Protection Agency (SEPA) is responsible for regulating waste management.

Given the subsea nature of the Tornado Development, the majority of waste associated with the Tornado Development will be generated onboard the vessels, including the MODU, contracted by Ithaca to undertake the development operations. Waste handling onboard the vessels, including the MODU, will therefore be the responsibility of vessel/MODU contractors. However, Ithaca have a Duty of Care to ensure that the collection, handling, and disposal of all waste generated by the Tornado Development is achieved, in compliance with current environmental legislation, as well as in accordance with Ithaca's Waste Management Procedure.

## 12.2 The Waste Hierarchy

Ithaca is committed, and has a legal duty, to take all reasonable steps to apply the waste hierarchy (as illustrated in Figure 12.1) and promote 'high quality' recycling.

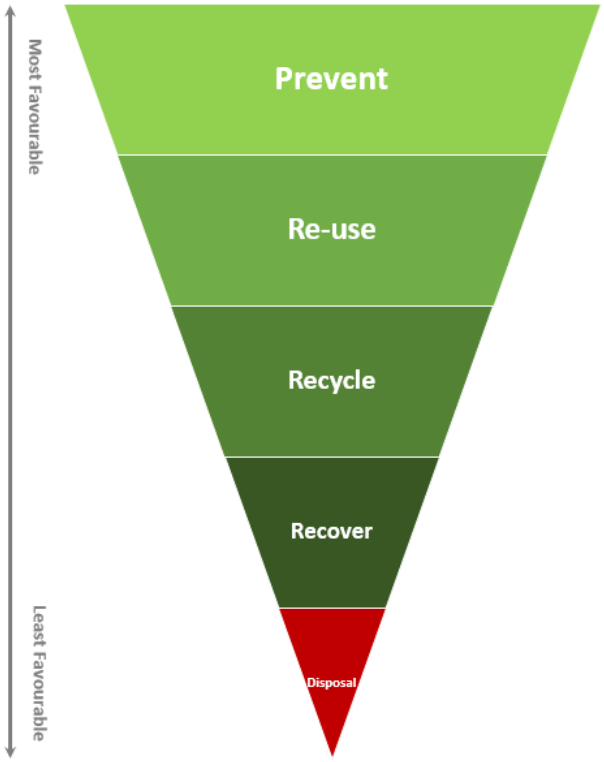



**Figure 12.1: Waste Hierarchy**

The waste hierarchy ranks waste management options according to the best environmental outcome, taking into consideration the lifecycle of the material. The lifecycle of a material is an environmental assessment of all the stages of a product's life from-cradle-to-grave (i.e. from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). Waste will only be disposed of if it cannot be prevented, re-used, recycled or recovered.

In its simplest form, the waste hierarchy gives top priority to preventing waste. When waste is created, it gives priority to preparing it for reuse, then recycling, then other recovery, and last of all disposal (i.e. landfill). For example, one tonne of food waste in landfill produces 450 kg $CO_2e$, whereas preventing one tonne of food waste saves 3,590 kg $CO_2e$. The benefits of selecting options higher up the hierarchy also extend beyond carbon savings and include reduced water consumption, protection of important raw materials, creation of jobs, and other economic opportunities (Scottish Government, 2017).

## 12.3 Duty of Care

Anyone who produces, transports, manages and treats waste has a legal Duty of Care to ensure that waste is managed correctly. This includes proper storage, only transferring it to an appropriate person and ensuring that when it is transferred it is sufficiently well described to enable its safe recovery or disposal without harming the environment.

Ithaca will ensure that all waste produced from the Tornado Development operations will be minimised through appropriate procurement controls and will be properly segregated for recycling, treatment or disposal. Bulk wastes generated offshore will be segregated by type and periodically transported to shore in an auditable manner through authorised waste contractors.

Ithaca is responsible for ensuring that waste is transferred to waste contractors in possession of a Waste Carrier Registration. All controlled waste being transferred onshore is required to have a completed Transfer Note, whilst special waste requires a Consignment Note. These Notes provide details on the type and quantity of waste that is being transferred, the parties involved in the transfer of waste, the category of authorised person in receipt of the waste, licence numbers, and time, place and date of transfer. Once onshore, waste will be managed in accordance with the waste hierarchy and will be recovered or disposed of at appropriate licensed sites by properly licensed waste disposal contractors.

## 12.4 Waste Streams

The types of wastes likely to be generated during the life of the Tornado Development are summarised in Table 12.1 and include both non-hazardous waste and hazardous waste (referred to as special waste in Scotland).

**Table 12.1: Types of Waste Likely to Generated from the Tornado Development**

| Special Waste | General Waste | Other Waste | Backloaded Cuttings [1] | NORM [2] |
|---|---|---|---|---|
| Oils, paints, adhesives, solvents, hazardous chemicals and brines, batteries, oily rags | Non-hazardous workover / completion / drilling fluids, brines<br>Segregated recyclables (e.g. scrap metal, plastics, aluminium cans, paper / cardboard, glass etc.)<br>Non-hazardous, galley waste, accommodation waste, compactor waste | Clinical materials<br>Explosives | LTOBM cuttings<br>Solid material (e.g. powder or stabilised products), oil and water generated by the treatment process | Naturally occurring radioactive material (NORM) from mineral scales which build up in pipework |

[1] For Tornado, if LTOBM cuttings are generated, they will be processed offshore using a thermal cuttings treatment unit to an acceptable overboard disposal limit (<1% OOC) and discharged to sea. LTOBM cuttings would only be backloaded for treatment onshore in the event of major equipment failure on the thermal cuttings treatment unit.
[2] May be applicable during Tornado decommissioning operations. Where NORM readings are found, the infrastructure would be subject to specific identification, handling and waste disposal at an authorised site in accordance with legislative requirements.

Given the subsea nature of the Tornado Development, the majority of waste will be generated onboard the MODU during development drilling operations and, on cessation of production, when the Tornado infrastructure is decommissioned. See further detail below.

The quantities and disposal routes of waste arising from offshore operations associated with the Tornado Development will be reported by Ithaca via the OPRED EEMS, which records measured and calculated data relating to emissions and discharges from offshore installations.

### 12.4.1 Vessel Waste

Waste will be generated onboard all vessels associated with the proposed Tornado Development activities including the MODU and support vessels, subsea installation vessels and any vessels used during inspection and maintenance activities and decommissioning. All vessel waste will be managed in compliance with the framework of Regulations discussed above and in line with individual vessel specific Waste Management Plans (WMPs). Generally, waste will either be discharged in line with MARPOL 73/78 requirements or will be segregated and stored in suitable, labelled containers for subsequent transfer to shore, where it will be treated or disposed of in accordance with the waste hierarchy.

Offshore vessels of 100 gross tonnage and above, and every ship certified to carry 15 or more persons, must have a Garbage Management Plan and maintain a Garbage Record Book (as per MCA Marine Guidance Note 632 (M+F) Amendment 2). Solid domestic waste will normally be compacted with a garbage compactor, placed in disposal bags and returned to the mainland in waste skips. Open skips will be netted.. Separate storage areas will be provided for solid and liquid waste that can be reused. Waste storage areas will be well ventilated and bunded with drainage to appropriate storage or treatment areas. Hazardous waste containers will be covered to reduce rainwater contact in the containment structure. Furthermore, segregation of recyclable materials will be implemented to avoid contamination and consequent reduction of the quality of recycled products.

### 12.4.2 Drilling Waste

MODUs generate various waste products during routine drilling operations (e.g. excess cement, used drilling fluids and chemicals etc.), in addition to waste generated from the everyday running of the MODU (e.g. general waste, food waste and sewage).

Wastes will be minimised by use of appropriate procurement controls, and all wastes will be segregated for recycling, disposal, and / or treatment. The appointed waste management contractor will supply monthly reports of all waste sent to shore and will complete Controlled Waste Transfer Notes as required, and records of monthly disposals will be maintained. Waste Management Duty of Care audits will also be carried out.

Oily waste will be generated on the MODU by a variety of sources, including waste engine oil and hydraulic oil. All waste oil will be held in designated storage tanks. The volumes of waste oils kept onboard the MODU will be kept to a minimum before being transferred to shore, keeping the possibility of spillages to a minimum. No sludge or waste oil will be discharged to sea. Lidded skips will be used for LTOBM contaminated drill cuttings (if required).

### 12.4.3 Decommissioning Waste

Onshore waste management will be in an important consideration during the decommissioning phase of the Tornado Development. A dedicated decommissioning WMP will be produced to identify all waste streams and the most appropriate removal and disposal method. All recovered waste will be brought to shore to a licenced specialist decommissioning waste facility. Where possible, materials will be sold for reuse or recycled in accordance with the waste hierarchy.

## 12.5 Mitigation Measures

The management of offshore waste generated on the UKCS is strictly regulated, ensuring a high level of mitigation from the outset, as described above. Ithaca will ensure successful implementation of the mitigation measures regarding waste management by:

- Application of the Waste Hierarchy to all produced waste;
- Compliance with Ithaca's WMP and use of a Garbage Management Plan for the management of waste produced from vessels;
- Compliance with Ithaca's Waste Management Procedures for waste produced during the proposed development activities;
- Segregation, transfer onshore and disposal of waste through licensed contractors and sites.

## 12.6 Conclusion

Several different waste streams will be generated throughout the lifespan of the Tornado Development. Waste management will be undertaken in compliance with current environmental legislation and applicable waste procedures which includes the waste hierarchy, as described above. The management of offshore waste generated on the UKCS is strictly regulated and the UK has well-established infrastructure in place to manage this waste effectively. Therefore, no significant impacts (including cumulative or transboundary impacts) are expected as a result of the Tornado Development.

# 13 Environmental Management

## 13.1 Ithaca's EMS

Ithaca SP E&P Limited is an affiliate of Ithaca Energy (UK) Limited and operates under the Group's policies. The control and management of environmental matters lies at the centre of the policies and procedures that shape Ithaca's HSE management system, as well as its corporate culture.

Ithaca operates under an EMS, which was re-certified to the ISO 14001:2015 standard on 7 April 2024 and is fully integrated into the Group Business Management System. The EMS follows the Plan-Do-Check-Act (PDCA) cycle (Figure 13.1), elements of which are embedded in the Group's day-to-day activities. Increasing awareness of environmental compliance, ensuring that the environmental considerations are embedded in everything we do and ensuring our processes and control measures are robust are just some examples of how we work to ensure continual improvement.

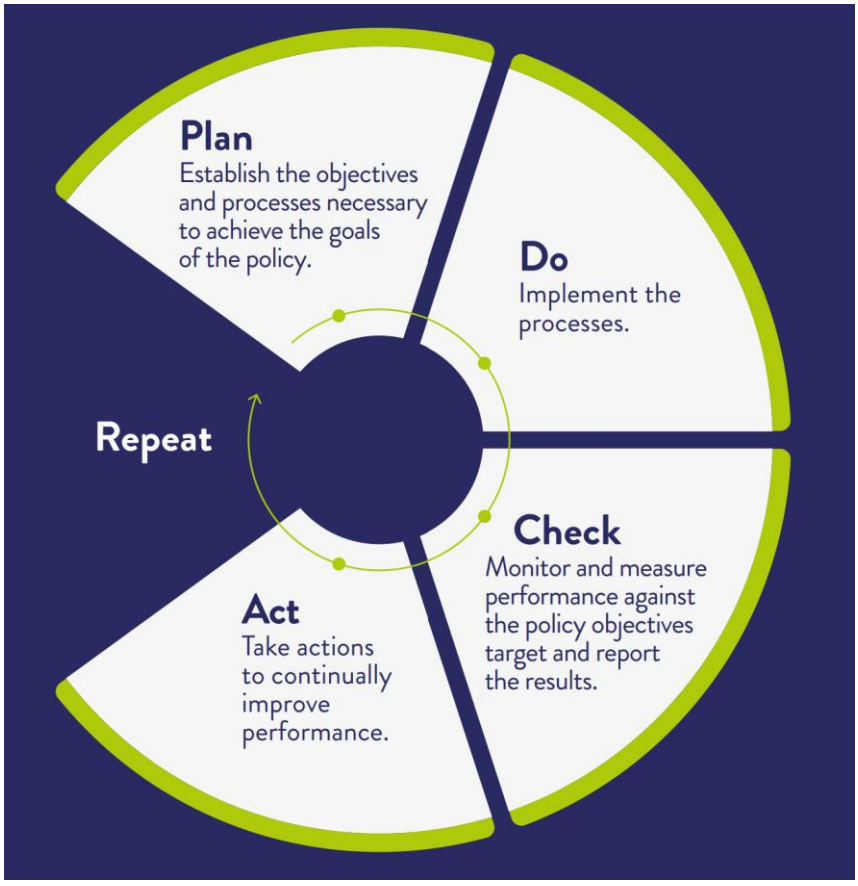



**Figure 13.1: Plan-Do-Check-Act (PDCA) Cycle**

The EMS is designed to support the implementation of the Group's HSE Policy (Figure 13.2), including the management of emissions and overall environmental impact. Ithaca strives for Industry leading levels of environmental performance. Key to this ambition is the Company's commitment to significantly reduce GHG emissions from its operations in line with the global transition to a low carbon economy and the UK Government's Net Zero targets (refer to Section 13.2).

Ithaca takes a proactive approach to managing environmental aspects by systematically identifying, monitoring, and reducing environmental impact. The Company regularly reviews its operations, sets measurable environmental objectives, and engages employees in environmental awareness and initiatives. Through this structured approach, Ithaca aims to minimize waste, reduce emissions and promote environmental stewardship while achieving business goals.

## Health, Safety and Environmental Policy Statement

### Our Vision

It is the vision of Ithaca Energy plc, its affiliates, and subsidiaries (the "**Company**") to be the highest performing UK North Sea independent oil and gas company, focused on sustainably growing value. We strive to be leaders in terms of process safety; occupational health and safety; environmental responsibility; asset reliability and efficiency.

### We will:

- Put our people, their safety and environmental responsibility at the heart of everything we do.
- Ensure no harm to our people or environment, by excelling as safety leaders.
- Ensure our operations are governed by robust procedures and management systems as described within our Business management System (BMS).
- Ensure risks related to occupational health, process safety and environment, including major accident hazards are assessed and controlled.
- Ensure the provision and maintenance of safe means of access to and egress from our facilities.
- Ensure adequate facilities and arrangements for welfare at work are in place at our facilities.
- Ensure systems are place for the safe use, handling, storage and transport of articles and substances.
- Promote a culture in which our people express themselves and can trust that our leaders will listen and act where necessary.
- Acknowledge that making mistakes is human and that focus must be on learning and supporting our frontline teams regarding strength of barriers to prevent major accident hazards.
- Protect the environment, prevent pollution, and minimise emissions, waste, and use of natural resources.
- Be considered and support physical, social, and emotional wellbeing.
- Meet legal requirements and other compliance requirements/obligations, ensuring effective stakeholder engagement.
- Set objectives and targets to focus on improvement in HSE performance.
- Ensure risks related to occupational health, process safety and environment, including major accident hazards are assessed.
- Provide appropriate HSE information, instruction, training, and supervision.
- Through audit and workplace monitoring, assess our processes and operations looking for opportunities to continually improve our HSE performance.
- Investigate and learn from near misses and incidents.
- Plan and prepare for potential emergencies.
- Provide sufficient resources for implementation of this policy.
- Ensuring everyone is empowered to stop a job if there are any concerns regarding HSE risks.

We all have a responsibility at Ithaca Energy to follow this Policy and assist the business in its implementation.

**Luciano Vasques**

**Chief Executive Officer, Ithaca Energy**

**Yaniv Friedman**

**Executive Chairman, Ithaca Energy**

**1st October 2024**

**Figure 13.2: Ithaca HSE Policy Statement**

All Ithaca operations and projects, including the proposed Tornado Development, have the potential to impact on the environment and they are all subject to strict environmental regulatory controls which require Ithaca to prepare and submit regulatory applications to gain approval before activities commence.

Ithaca is already a licenced well and installation operator under the Offshore Petroleum Licensing (Offshore Safety Directive) Regulations 2015 and will be the appointed well operator for Tornado on behalf of the JV partners. The company constantly monitors operational activities and reports ongoing emissions, discharges and waste streams to ensure regulatory requirements are met and ensure there is no significant impact on the environment. In the event of an unplanned release to sea, or a non-compliance with regulatory requirements, the relevant regulatory authorities would be notified and immediate actions taken to respond to any threat of or actual pollution. Investigations of incidents are conducted to gain any learnings or actions to prevent recurrence.

Ithaca is committed to continually improving environmental performance through responsible design, development and operations. For the Tornado Development, the environmental performance of contractors will be a key consideration. To this end, every effort will be made to select contractors with strong HSE performance and processes. Ithaca will also ensure that all parties engaged in the proposed Tornado Development operations understand the potential environmental impacts and commitments as outlined in this ES (refer to Section 13.3) and the importance of environmental compliance.

The company records and monitors their environmental data in line with regulatory reporting requirements. Environmental performance data for each of Ithaca's operated assets and associated activities is submitted to the UK environmental regulator (OPRED) via the EEMS.

Ithaca takes pride in:

- Having a relentless focus on high performance;
- Continuously reducing the HSE impact of its operations;
- Developing an engaged workforce, in an inclusive, dynamic workplace; and
- Striving for efficiency and simplicity in all that is done.

Ithaca's leadership team have set ambitious company targets and asset specific emissions reduction Key Performance Indicators (KPIs). Performance is reviewed by leadership on a monthly basis and communicated to Company employees at townhalls.

In addition, the HSE Team has an annual integrated objectives and improvement plan which outlines key elements for measuring success in progressing towards climate targets. This plan is endorsed by the Executive Leadership Team and the Board.

## 13.2 Ithaca's Net Zero Strategy

Ithaca acknowledges the transitional role of oil and gas in the national energy mix and aims to balance operational activities with decarbonisation requirements.

Key principles underpinning Ithaca's strategy include:

- Compliance with regulatory requirements and industry expectations;
- Active participation in industry collaborations aimed at decarbonising the UKCS; and
- Continuous improvement of emissions management processes, including data quality, reporting accuracy, and emissions mitigation practices.

Using the EMS process described in Section 13.1, Ithaca regularly assesses emissions abatement opportunities. Using these processes, Ithaca has overseen a net reduction in flaring and venting emissions across all assets since 2018. As a responsible JV partner, Ithaca also encourages and supports large emissions abatement projects, such as electrification, on non-operated assets.

Ithaca's strategy is aligned with the NSTD and is actively contributing to the basin achieving a 50% reduction by 2030 and Net Zero by 2050.

Ithaca's strategy includes annual asset emissions targets, operational improvement initiatives, and decarbonisation projects aligned with industry best practice.

Interim milestones include:

- Completing planned and approved emissions reduction projects;
- Continual evolvement of our ERAP, including completing ongoing new studies (refer to Section 9.5.2);
- Deploying methane detection technologies;
- Developing a supplier engagement program for emissions assessment and reduction;
- Collaborating with industry on low-carbon project collaborations.

Robust emissions reporting is central to Ithaca's Energy's environmental governance framework. The company reports atmospheric emissions under several schemes:

- UK Emissions Trading Scheme (UK ETS) — for installations regulated under emissions permits;
- EEMS — annual environmental reporting;
- Energy Savings Opportunity Scheme (ESOS) and Streamlined Energy and Carbon Reporting (SECR) — corporate-level reporting requirements;
- Carbon Disclosure Project (CDP) and Task Force on Climate-Related Financial Disclosures (TCFD) submissions — for transparency to investors and regulators; and
- OGMP 2.0 – for improving the monitoring and verification of the Company's methane emissions data, so that we may identify areas for further methane reduction and mitigation. Recently Ithaca was awarded a 'Gold Standard Pathway' certificate from OGMP 2.0 in recognition of efforts in improving methane management across its operations.

Responsibility for emissions management lies with Ithaca's Environmental & Energy Transition Manager, supported by the wider Health, Safety and Environment (HSE) Team, while Board-level accountability is maintained through quarterly HSE performance reviews.

## 13.3 ES Commitments

Table 13.1 summarises the mitigation measures and commitments identified within this ES. As described above, Ithaca will ensure these are taken into account and implemented as the proposed Tornado Development progresses.

**Table 13.1: Mitigation Measures and Commitments Register**

| Ref | Theme | Mitigation Measure / Commitment | ES Section |
|---|---|---|---|
| 1 | Physical Presence | a. 500 m safety exclusion zone will be designated around the MODU and a dedicated ERRV, equipped with AIS and/or ARPA will be present during the drilling operations to monitor movements of other vessels in the area and prevent them entering the exclusion zone.<br>b. A Vessel Traffic Survey and, if necessary, a Collision Risk Assessment, will be prepared to support the CtL permit applications required to site the MODU and subsea infrastructure at the Tornado Development location and all vessels will comply with the International Regulations for Preventing Collisions at Sea (COLREG).<br>c. Information on the location of the MODU, 500m safety zone, subsea infrastructure and vessel operations will be communicated to other sea users via the UKHO, MCA, FishSAFE, Kingfisher Information Services, Notices to Mariners and Radio Navigation Warnings.<br>d. Ithaca will continue to consult with SFF during the detailed design phase and planning process for the subsea infrastructure installation activities. A FLO will be appointed to maintain good communication with local fisheries and co-ordinate activities, particularly during installation of the pipelines and umbilical.<br>e. During installation operations, the number of vessels and length of time they are required on site will be reduced as far as practicable through careful planning.<br>f. Where water depths are less than 800 m, subject to fishing intensity and damage tolerability studies, the MEG pipeline and control umbilical may require protection from fishing interaction. In this instance, up to two guard vessels will be on location for the period between the MEG pipeline and umbilical being laid on the surface of the seabed and the lines being trenched and backfilled or protected by rock. The rock berm profile will be overtrawlable.<br>g. Where boulders (>0.5 m) are required to be removed from the pipeline lay corridors, the as-left position of any relocated boulders will be recorded and reported via Kingfisher.<br>h. Following pipeline trenching operations, Ithaca will liaise with the SFF to review any safety risks for the fishermen from mud berms being left behind and discuss potential mitigations.<br>i. A 500 m safety zone will be in place around the subsea infrastructure at the Tornado drill centre location.<br>j. At the Tormore tie-in location, the subsea structures and protection material will be designed to be overtrawlable.<br>k. During the life of the field, external inspection of the pipelines and control umbilical will take place at a frequency determined by ongoing risk assessment. Any free spans recorded that present a potential hazard to legal fishing activities will be suitably rectified. | 6 |
| 2 | Seabed Disturbance | a. A full 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 and subsea operations commencing and, as part of chemical selection and assessment process, where practicable less hazardous alternatives will be sought in preference for any chemicals identified to be high risk (e.g. those with substitution warnings).<br>b. Planned use of CAN-ductors will reduce the volume of cuttings being generated from the top hole section. | 7 |

| Ref | Theme | Mitigation Measure / Commitment | ES Section |
|---|---|---|---|
| | | c. Drill cuttings to be passed through the cuttings cleaning system on the MODU prior to discharge.<br>d. A ROV and chemical dye will be used to monitor cement returns when cementing either the CAN-ductor option or the conductor and 20" casing option to help ensure the volume of cement discharged to the seabed is kept at a minimum.<br>e. Route selection and optimisation will be based on acquired Environmental, Geophysical, and Geotechnical survey data, and minimises length through the Faroe-Shetland Sponge Belt NCMPA.<br>f. Fishing intensity study carried out to define depth to which pipeline protection is required.<br>g. Working corridors will be minimised as far as possible.<br>h. Any boulders removed from the pipeline and umbilical lay corridors will be placed appropriately on the seabed to avoid a snag hazard and their as-left position recorded.<br>i. Use of DP installation vessels as opposed to anchored vessels or anchored MODU.<br>j. Rock will be deployed from a DP rock dumping vessel using a fall pipe and the rate and locations of deployment will be controlled on board the vessel and monitored using high resolution survey / sonar equipment.<br>k. Size of subsea infrastructure will be optimised for the Tornado Development.<br>l. Subsea infrastructure layout and pipeline crossing designs optimised to minimise material deposited.<br>m. Monitoring of integrity of subsea infrastructure, including the pipeline / umbilical and stabilisation material throughout production operations and taking remedial action, if required. However, based on experience in the West of Shetland area, subsea integrity is not expected to be an issue.<br>n. Minimise amount of deposited material whilst still achieving the required level of stabilisation / protection in line with advice from the JNCC (JNCC, 2018b). | |
| 3 | Noise | a. Use the lowest practicable power levels needed to achieve the survey objectives;<br>b. Pre-shooting surveys and soft-starts will be incorporated into the survey design. A soft-start will be conducted by slowly increasing the seismic source power. The soft-start will be planned to commence during daylight hours;<br>c. A MMO and PAM operator will be onboard the MODU to monitor for the presence of marine mammals within a 500 m mitigation zone during the pre-shooting search and soft-start procedure;<br>d. All observations (MMO or PAM) will be undertaken during a pre-shooting search for 60 minutes, i.e. prior to the commencement of any use of the seismic source as water depths are greater than 200 m. The longer search period is to allow for deep diving species (e.g. sperm whale and beaked whale) which are known to dive for longer than 30 minutes. If marine mammals are detected in the 500 m mitigation zone during the pre-shooting search then operations must be delayed until their passage, or the transit of the vessel, results in the marine mammals being outside of the mitigation | 8 |

| Ref | Theme | Mitigation Measure / Commitment | ES Section |
|---|---|---|---|
| | | zone. Either way there should be a minimum of a 20-minute delay from the time of the last sighting within the mitigation zone and the commencement of the soft-start procedure, to allow animals unavailable for detection to leave the area.<br>e. In line with the JNCC guidelines, during VSP operations the breaks taken to reposition geophones are treated in the same manner as line changes. Where geophone repositioning is expected to take longer than 40 minutes:<br>• Firing is to be terminated during geophone repositioning;<br>• A pre-shooting search will be undertaken during geophone repositioning;<br>• The soft start procedure is to be delayed if marine mammals are sighted within the 500 m mitigation zone during the pre-shooting search;<br>• A full 20-minute soft-start will be undertaken before restarting VSP data collection.<br>f. For unplanned breaks of longer than 10 minutes (e.g. if the acoustic output of the survey equipment ceases due to a technical problem), a full pre-shooting search and soft-start will be carried out before the survey re-commences. For unplanned breaks of less than 10 minutes, there is no requirement for a soft-start and firing can recommence at the same power level as at prior to the break (or lower), provided no marine mammal(s) have been detected in the mitigation zone during the breakdown period. If marine mammals are detected there must be a minimum of a 20 minute delay from the time of the last detection within the mitigation zone and a soft-start must then be undertaken. For planned breaks the same procedures will be applied; however, if the planned break is for less than 10 minutes, the MMO must begin monitoring 20 minutes prior to the planned break and continue for the duration of the break. | |
| 4 | GHG Emissions | a. Ithaca's general emission reduction initiatives which will be applied to the Tornado Development project are focused on reducing indirect (Scope 3) upstream GHG emissions and include:<br>• Vessel's environmental emissions will be factored into the tender evaluation process;<br>• Compliance with International Maritime Organisation requirements on fuels;<br>• Optimise drilling, installation, maintenance and repair and decommissioning activities, including vessel movements, by careful planning to minimise optimise fuel use holistically.<br>• Well test and clean-up durations will be optimised and permitted appropriately.<br>b. With regards to direct (Scope 1) GHG emissions, responsibility for identification and implementation of emissions reduction initiatives at SGP resides with the SGP operator (TEPUK) under the regulation of SEPA and NSTA in their respective capacities as regulators of onshore Oil and Gas facilities. Ithaca, as the operator of Tornado, will support the SGP operator as they continue to assess and implement reasonable decarbonisation strategies for SGP. | 9 |

| Ref | Theme | Mitigation Measure / Commitment | ES Section |
|---|---|---|---|
| 5 | Marine Discharges | a. A chemical risk assessment will be undertaken to identify the risk profile of chemicals to be used and / or discharged in accordance with the requirements of the Offshore Chemicals Regulations 2002 (as amended). Where practicable, chemicals with a higher risk profile will be substituted out in favour of those with an improved environmental profile;<br>b. Chemical use and discharge will be minimised where practicable;<br>c. In the event WBM is used to drill the Tornado wells, cuttings / mud cleaning equipment will ensure optimal cuttings cleaning prior to discharge and recovered WBM will be reused/ re-circulated where practical. In addition, WBM will be mixed offshore to ensure that only what is required is used;<br>d. In the event that LTOBM is used to drill the Tornado wells, a thermal cuttings treatment unit will be installed on the MODU to safely treat the LTOBM contaminated cuttings to an acceptable overboard disposal limit (<1% OOC);<br>e. During the drilling and pipeline dewatering operations, any discharges of residual reservoir hydrocarbons will be treated in accordance with the conditions of the approved Oil Discharge Permit, such that oil-in-water concentrations are within the permit limits. The discharge streams will also be monitored and sampled in accordance with an approved Oil Discharge Permit. | 10 |
| 6 | Accidental Releases | a. Liquid storage areas and areas that might be contaminated with oil are segregated from other deck areas;<br>b. Bunding or additional containment will be provided around plated areas beneath equipment with significant hydrocarbon inventories;<br>c. Chemicals will be stored in bunded areas where any spillages can be routed to the closed drainage system;<br>d. 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;<br>e. Small spill kits will be on board the MODU and subsea vessels to clean up deck spills and prevent spilt hydrocarbons and chemicals from reaching the sea;<br>f. Non-return valves will be installed on transfer hoses and hoses to be tested and inspected as a part of a regular maintenance programme;<br>g. 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;<br>h. Crews will be adequately trained, supervised and regular exercises held to contain and clean-up deck spills;<br>i. Routine equipment maintenance programme will be in place with specific emphasis on environmentally critical equipment;<br>j. Effective management of chemicals to endeavour to reduce the volumes required and therefore the frequency of bunkering;<br>k. Use of floating hoses;<br>l. Where feasible, bunkering operations will be undertaken in daylight and in good weather conditions.<br>m. Consent to Locate will be in place for the MODU under Part 4A of the Energy Act 2008;<br>n. 500m safety exclusion zone will be designated around the MODU; | 11 |

| Ref | Theme | Mitigation Measure / Commitment | ES Section |
|---|---|---|---|
| | | o. Dedicated ERRV present during drilling to monitor movements of other vessels in the area and prevent them entering the exclusion zones;<br>p. Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, NAVTEX / NAVAREA warnings and fisheries notices.<br>q. Crews will be adequately experienced, trained in well control techniques and supervised;<br>r. Weighted drilling fluids will provide the primary barrier and the downhole pressures will be carefully controlled and monitored;<br>s. The secondary barrier will be the BOP which will be regularly maintained and tested;<br>t. Well design and construction reviewed by an independent well examiner;<br>u. Safety and Environmental critical elements related to drilling operations will be identified, and a suitable maintenance and testing schedule applied to each;<br>v. Emergency drills will be held regularly;<br>w. Emergency response plans and equipment will be in place;<br>x. Review spill mitigation measures of all contractors as part of the contractor selection process.<br>y. Facilities will be subject to stringent design specifications;<br>z. Where practicable, pressure and leak testing will be undertaken onshore prior to infrastructure being installed. All pipelines will be pressure tested to above the planned operating pressure;<br>aa. The production pipeline will be protected against corrosion by the continuous injection of corrosion inhibitor;<br>bb. The production pipeline will be designed to resist credible fishing interaction loads.<br>cc. The MEG pipeline and umbilical will be protected from physical damage by fishing gear in water depths < 800 m;<br>dd. Routine monitoring of pipeline pressure and temperature will be undertaken. Automatic and manual shutdown systems in place;<br>ee. Regular ROV inspection of all pipelines will be undertaken. | |
| 7 | Waste Management | a. Application of the Waste Hierarchy to all produced waste;<br>b. Compliance with applicable WMP and use of a Garbage Management Plan for the management of waste produced from vessels;<br>c. Compliance with applicable Waste Management Procedures for waste produced during the proposed development activities;<br>d. Segregation, transfer onshore and disposal of waste through licensed contractors and sites. | 12 |

# 14 Conclusions

The key findings of the EIA process for the proposed Tornado Development can be summarised as follows:

- **Physical Presence:** No significant residual effects on other sea users are predicted as a result of the physical presence of the DP MODU and vessels during drilling, installation, inspection and maintenance and decommissioning activities or the long-term presence of the Tornado subsea infrastructure, pipelines, umbilical and associated protection / stabilisation material.

  It is likely that commercial shipping will have to adjust their routes to avoid the MODU, vessels and exclusion zone but there is ample sea room for shipping to re-route or avoid the Tornado location, as necessary, particularly given the low density of vessel traffic in the area. A number of measures will be in place to ensure advance notification of the operations is provided. Residual effects on shipping from the physical presence of the DP MODU and vessels during drilling, installation, inspection and maintenance and decommissioning activities, are therefore assessed as **Minor** and not significant. A Vessel Traffic Survey will be undertaken by Ithaca to inform the CtL permit applications, required to site the MODU and subsea infrastructure at the Tornado location. If necessary, a Collision Risk Assessment may also be undertaken.

  Fishing vessels may be temporarily displaced from the Tornado Development area during the drilling and installation phases, with an area of 0.8 $km^2$ at the Tornado drill centre location lost for the life of the development. This is considered to be a very small area in comparison to the alternative fishing grounds available in the wider WoS area. In addition, fishing activity in the Tornado Development area is low, with bottom trawling prohibited in water depths greater than 800 m. As such, the risk of snagging is low, with overtrawlable protection only utilised as part of the Development at depths less than 800 m, along approximately 20% of the length of the entire pipeline route. The likelihood of fishing interaction in water depths less than 800 m has been reduced further by the recent introduction of The Offshore Fishing (Prohibition of Fishing Methods) (Scotland) Order 2025, which currently prohibits mobile demersal fishing gear within the northern zone of the Faroe-Shetland Sponge Belt NCMPA. The proposed Tornado drill centre and the majority of the proposed pipeline route (ca. 68 km) are located in water depths greater than 800 m. In addition, the proposed pipeline route crosses through the northern zone of the NCMPA. Given the above, overtrawable protection is considered worst case and may not be required following risk based assessment. Residual effects on commercial fishing from physical presence are therefore **Minor** and not significant.

- **Seabed Disturbance:** No significant residual effects on seabed sediments, seabed communities or fish are predicted as a result of disturbance to the seabed during the life of the Tornado Development. The worst case total area of seabed that will be impacted temporarily by the Tornado Development is estimated at around 8.24 $km^2$, and the worst case total area of seabed that will be subject to long term / permanent impacts as a result of the Tornado Development is estimated at around 0.53 $km^2$. This is a relatively small area in comparison to the seabed available WoS region, with similar water depths, sediment types and benthic communities.

  Temporary disturbance of the seabed is attributed to the discharge of drill cuttings and muds, disturbance from certain subsea installation, pre-installation and post-lay protection activities, where only temporary short to medium term effects are predicted. The discharge of drill cuttings and muds from the Tornado Development wells will initially alter the seabed topography and sediment structure of a small area close to the wells (1.9 $km^2$ surrounding all three wells). Cuttings mounds in the Tornado drilling location can be expected to disperse, typically over a time scale of 1 – 10 years. The accumulation of drill cuttings and mud at the Tornado drill centre is likely to change the benthic community in the immediate area by burying some animals and impairing the feeding and respiration of others. It is expected that the communities in the immediate vicinity of the well will be lost, and that increased concentrations of suspended particles near the seabed may also impair respiratory and feeding processes, inducing metabolic stress and reducing growth and survival rates. Field studies in the United States of America have shown however that recovery

of benthic communities impacted with water based drilling discharges is likely to be very rapid (i.e. within a few months).

It is, however, recognised that some aspects associated with the Tornado Development (i.e. formation of cement patios, installation of the subsea structures, pipeline and umbilical and associated protection material) will have long term impacts on sediment communities, due to permanent habitat change, although direct physical injury of benthic species will only occur when the infrastructure or material is first placed on the seabed. This impact will last the duration of the Tornado Development (ca. 6 to 10 years) and beyond depending on how the infrastructure is decommissioned.

An Annex I habitat stony reef assessment (after Irving, 2009) conducted over the Tornado Development area found two occurrences of 'Low Reef' at the site survey area. There were no occurrences of 'Medium Reef' or 'High Reef'. The pipeline survey area found occurrences of 'low reef' across 13 transects. However, only one patch was observed to exceed 25 $m^2$ and was thus classed as 'low reef'. Patches of 'medium' stony reef were observed along sections of four transects, but the size of these areas did not exceed 25 $m^2$. There were no occurrences of 'High Reef' (Fugro, 2025a; 2025b). Research has shown that stony reefs have a limited tolerance to direct physical pressures, with recovery not expected for an extended period. The closest stony reefs were recorded 0.6 km and 1.7 km respectively from the proposed well locations, thus it is unlikely the discharge of cuttings, mud and cement or the installation of subsea infrastructure will affect these recorded reefs. The cement patio additionally will only extend 14.2 m radially from each well and thus it is unlikely that these incidences of 'Low Reef' will be affected.

Ocean quahog is on the OSPAR list of threatened and/or declining species and a PMF in Scottish waters, although not recorded within the Tornado site and pipeline survey areas, is known to be present in the wider area. Moreover, the Faroe-Shetland Sponge Belt NCMPA is designated for the conservation of ocean quahog, in which part of the Tornado Development is located (approximately 18 km of the proposed Tornado pipeline). The ocean quahog is highly sensitive to physical pressures and changes in seabed habitat types (i.e. the introduction of new hard substrata). Any impacts will, however, be in a very localised area, such that any effects on the population of ocean quahog in the wider WoS region are not predicted to be significant.

In the Tornado site survey area, the sponge aggregations observed were sporadic and of low abundance and therefore did not reach the criteria for further assessment. However, due to observations of demosponges, the presence of 'Deep-sea sponge aggregations' was considered along the proposed pipeline route. The assessment found that along two sections of one transect, the density of demosponges satisfied the density criteria for the OSPAR threatened and/or declining habitat 'Deep-sea sponge aggregations'. In the Tornado survey, the faunal assemblages associated with sponges were not different from the surrounding assemblages. Additionally, the areas where sponges satisfied the density criterion did not exceed 25 $m^2$ and therefore no qualifying criteria were met. Therefore due to the limited aggregations of deep sea sponges recorded within the proposed development area, the Tornado Development will not directly significantly impact the objective to recover the extent, distribution, structure or function of deep sea sponge aggregations.

The habitat assessment results for Tornado highlighted the presence of 'Offshore subtidal sands and gravels'. 'Offshore subtidal sands and gravels' are part of the protected features of the Faroe-Shetland Sponge Belt NCMPA and is listed as a PMF in Scottish waters. There will be temporary disturbance within the NCMPA arising from the potential trenching and backfill operations, and installation of subsea infrastructure at Tormore estimated to amount to approximately 1.81 $km^2$ (0.034% of the NCMPA). It is likely that a proportion of the sediments displaced for the purpose of pipeline laying and burial and temporarily deconstructing GRP structures at Tormore will become suspended in the bottom few metres of the water column. Within the vicinity of the proposed seabed infrastructure, the sediments are relatively coarse (sandy and gravelly) in nature which means that plumes or re-suspended sediment will tend to re-settle quickly and will not be prolonged or affect large areas. The potential trench and burial operations will also result in the temporary formation of mounds either side of the pipeline during the potential trenching phase which will be replaced during the burial phase. Due to the temporary nature of these effects, no

permanent changes to offshore subtidal sands and gravels are expected to occur as a result of the temporary impacts.

Approximately 18 km of the Tornado to Tormore pipeline route is located within the Faroe-Shetland Sponge Belt NCMPA. The proposed installation of the subsea infrastructure, pipelines, umbilical, protection / stabilisation / stabilisation materials and use of temporary laydown areas have the potential to impact the designated features of the NCMPA. Any long term disturbance caused by the proposed Tornado Development will result in a very small, permanent reduction in protected habitat type (0.007% of the Faroe-Shetland Sponge Belt NCMPA). Any other impacts are deemed temporary and of a small scale (0.034% of the Faroe-Shetland Sponge Belt NCMPA). The long-term habitat loss by other projects within the Faroe-Shetland Sponge Belt NCMPA, represents a relatively small percentage of the NCMPA at ca. 0.02%. Of note, for Tornado although a small amount of new hard substrate may be introduced into the Faroe-Shetland Sponge Belt NCMPA if protection / stabilisation material is required, alongside the placement of the subsea infrastructure. Based on the small area of seabed that will be impacted (0.386 $km^2$), in comparison to the overall NCMPA area (5,278 $km^2$), no likely significant effects on the qualifying features or their conservation objectives are predicted as a result of the proposed activities either alone or in-combination with other plans or projects.

Residual effects from seabed disturbance are therefore predicted to be **Minor** on water quality, seabed sediments and seabed communities and **Negligible** on other receptors impacted and are not significant.

- **Underwater Noise Emissions:** No significant residual effects are predicted as a result of noise generated from the proposed Tornado drilling, vessels operations or contingent VSP survey operations. It is possible that short term behavioural effects may be observed among marine mammals and fish as a result of the underwater noise emissions generated during development of the Tornado field. However, Ithaca will implement a range of measures to mitigate any potential impacts including optimising the duration of drilling and installation activities to minimise vessel usage and adhering to the JNCC guidelines for minimising injury and disturbance to marine mammals. As a result, any residual effects are predicted to be **Minor** and not significant.
- **Greenhouse Gas Emissions:** Combustion of hydrocarbons for power generation on the MODU, vessels, and helicopters during the development of the Tornado field, as well as flaring of hydrocarbons during the well flow test, will result in GHG emissions. During the production phase, gas from the Tornado field will be processed at the SGP with processing equipment and support facilities shared with several other producing assets. This minimises the incremental energy demand caused by the development. Tornado Scope 3 downstream emissions are the indirect emissions which will be generated once the Tornado hydrocarbons have been processed at the SGP and sold, including from further processing at the Sullom Voe and St Fergus terminals, transportation and distribution and from the end use of the sold product (namely, the worst case presumption that all end use Tornado hydrocarbons are eventually combusted).

  It is recognised that development of the Tornado field will contribute to overall volumes of GHG emissions in the atmosphere in combination with the other projects and activities emitting GHG emissions. Ithaca is therefore commited to minimising the amount of GHG emission produced. During drilling and installation operations, vessel days and fuel consumption will be reduced, as far as practicable. The well test and well clean-up activities will be designed not only to achieve their goals but to provide an optimal duration and reduce flaring to minimise the GHG emissions produced. Ithaca's Emissions Reduction Action Plan (ERAP) demonstrates its commitment to the NSTD in reducing emissions from the sector in line with the Net Zero targets of the UK. However, Tornado as a subsea development will not be incorporated into the Ithaca ERAP once operational. Instead, responsibility for identification and implementation of Tornado Scope 1 emissions reduction initiatives will reside with the operator of SGP, where the Tornado production fluids will be processed.

  In summary, the worst-case total gross GHG emissions generated over the life of the Tornado Field are estimated to be ca. 35,692.81 kilotonnes of $CO_2e$, based on the Max production case, which represents a 'worst case' emissions profile, without partial electrification of SGP.

The GHG emissions associated with the Tornado Development are aligned with global climate targets and pathways, including those set out by The Paris Agreement. The Paris Agreement is a legally binding international treaty adopted in 2015 that commits countries to limit global warming to well below 2°C, ideally 1.5°C, through emissions reductions and climate adaptation.

The GHG emissions associated with the Tornado Development represent a small proportion of GHG emissions typically arising from oil and gas developments in the UKCS and will contribute a small fraction of $CO_2e$ emissions towards future UK carbon budget targets (ca. 0.04201% to 1.37644%). Tornado will also contribute a very small percentage towards predicted global oil and gas production rates in international pathways consistent with limiting warming 2°C (ca. 0.082% in 2030 and ca. 0.027% in 2035 of global gas production and ca. 0.00495% in 2030 and ca. 0.00038% in 2035 of global oil production). In 2030, Tornado's projected GHG emissions are estimated to represent between 0.01211% and 0.02605% of median global GHG emissions, depending on the SSP pathway considered. The SSPs are baseline narrative scenarios that identify socio-economic and geopolitical assumptions and economic and technological trends. The proportion is highest under the SSP1-1.9 (very low) scenario, where global GHG emissions are projected to decline rapidly to around 33 $GtCO_2e$ (median) per year in 2030, and lowest under the SSP5-8.5 (very high) scenario, where emissions reach approximately 71 $GtCO_2e$ (median) per year in 2030.

In a national context, the Tornado Development is aligned with UK government climate policies and strategies. The GHG emissions generated by the Tornado Development would have no material influence on the UK's ability to meet its statutory carbon budget targets or NDC emissions reduction targets. Tornado when produced via SGP has a forecasted carbon intensity below the UKCS average and significantly lower than the average GHG intensity of imported LNG. Development of Tornado will therefore provide the UK with low carbon, indigenous gas. At its peak production in 2030, Tornado could account for up to 20.90% of UK gas production (based on August 2025 NSTA forecasts), providing critical energy security during the transition to Net Zero.

Residual effects of the Tornado Development's GHG emissions on the global climate, in a Paris Aligned oil and gas production pathway, is therefore considered to be **Minor** and not significant.

- **Marine Discharges:** No significant residual effects on water quality, plankton or fish are predicted as a result of routine marine discharges during the development of the Tornado Development.

  The main operational discharges into the marine environment from the proposed Tornado Development will occur as a result of the discharge of drill cuttings, muds and cement, residual hydrocarbons when drilling through the payzone, chemicals during drilling, installation, hook-up and commissioning activities, completion brine during well clean-up activities, discharge of water-based hydraulic fluid for subsea valve activation during production, discharge of chemicals and hydrocarbons during subsea intervention activities and during decommissioning. Upon release, these discharges will be subject to rapid dilution and dispersion and are not expected to persist within the marine environment. Additionally, a number of studies have shown that any impacts will be limited to the local area in the immediate vicinity of the release location.

  Ithaca will implement a range of measures to mitigate any potential impacts including undertaking a chemical risk assessment to identify the risk profile of chemicals being used and / or discharged in accordance with the requirements of the Offshore Chemicals Regulations 2002 (as amended). Where practicable, chemicals with a higher risk profile will be substituted out in favour of those with an improved environmental profile. During the proposed drilling operations, any discharges of residual reservoir hydrocarbons will be treated to meet oil-in-water limits of less than or equal to 30 mg/l. The discharge stream will also be monitored and sampled in accordance with an approved Oil Discharge Permit.

  Residual effects from marine discharges are therefore predicted to be **Minor** on water quality and seabed communities and **Negligible** on other receptors impacted and are not significant.

- **Accidental Releases:** All offshore activities associated with the Tornado 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, Ithaca'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 hydrocarbon released, 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 Tornado Development would be an uncontrolled flow of light condensate from the proposed Tornado W03 Development well (i.e. a well blowout). Oil spill modelling has been conducted to determine the fate of Tornado hydrocarbons released from this worst case scenario. There is a low potential for a surface slick of condensate to cross the UK/Norwegian median line. However there is a very high potential for a surface slick of condensate to cross the UK/Faroe Islands median line. There is a low possibility shoreline oiling will occur across the United Kingdom. However, the Tornado condensate is a light hydrocarbon 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 Tornado 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 Tornado subsea facilities once operational will be covered in approved oil pollution 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 Tornado Development is considered to range from **Medium** to **Low**, depending on the receptor impacted, but in all cases the risk has been reduced to ALARP through mitigation measures and good industry practice and is therefore not considered to be significant.

In summary, it is concluded that the proposed Tornado Development will not result in any significant environmental effects (including transboundary and cumulative effects).

# 15 References

Abbriano, R.M., Carranza, M.M., Hogle, S.L., Levin, R.A., Netburn, A.N., Seto, K.L., Snyder, S.M. and Franks, P.J.S. (2011) Deepwater Horizon oil spill: A review of the planktonic response. *Oceanography,* 24 (3): 294-301.

Acona (2012) *Blowout Risk Evaluation in the Labrador Sea*, Technical Report, Acona, Revision No.: 2.3 – Revised version, Revision date: 23.03.2012. Available at: http://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Appendix_2_Blowout_risk_in_the_Labrador_Sea.pdf [Accessed April 2025].

AFEN, 2000. Environmental Surveys of the Seafloor of the UK Atlantic Margin [CD-ROM]. Available from Geotek Limited, Daventry, Northants NN11 5EA, UK. ISBN 09538399-0-7

Aguilar de Soto, N., Gillespie, D., Hammond, P., Johnson, M., Reyes, C. and Tyack, P. (2016) Beaked whales: a review of distribution and abundance in UK waters and new information on life history, diving behaviour and ecology, noise impacts, approaches to monitoring and options for mitigation. Report for the DECC Offshore Energy SEA programme by the Sea Mammal Research Unit, University of St Andrews. Cited in DECC (2016).

Aires, C., González-Irusta, J.M. and Watret, R. (2014) Updating Fisheries Sensitivities Maps in British Waters. Scottish Marine and Freshwater Science Report. Vol. 5, No. 10. [Online] Available at: http://www.gov.scot/Topics/marine/science/MSInteractive/Themes/fish-fisheries/fsm [Accessed March 2025].

Almeda, R., Wambaugh, Z., Wang, Z., Hyatt, C. Liu, Z. and Buskey, E.J. (2013). Interactions between zooplankton and crude oil: toxic effects and bioaccumulation of polycyclic aromatic hydrocarbons. PLoS ONE 8(6): e67212. Available at https://doi.org/10.1371/journal.pone.0067212

Auld, A.H. and Schubel, J.R. (1978) Effects of suspended sediment on fish eggs and larvae: a laboratory assessment. Estuarine, Coastal and Shelf Science, 6 (2): 153-164.

AUMS (1987) An Environmental Benthic Survey around Three North Sea Single Well Sites. Aberdeen University Marine Studies. Unpublished Report for the United Kingdom Offshore Operators Association (UKOOA).

Bakke, T., Klungsøyr, J., Sanni, S. (2013) Environmental impacts of produced water and drilling waste discharges from the Norwegian offshore petroleum industry. Marine Environmental Research. Vol. 92. 154-169

Barham R, Mason T (2022). Underwater noise propagation modelling of seismic airgun array noise at the North Eigg field. Subacoustech Report Ref P311R0101.

Baxter, J.M., Boyd, I.L., Cox, M., Donald, A.E., Malcolm, S.J., Miles, H., Miller, B. and Moffat, C.F. (eds) (2011) Scotland's Marine Atlas: Information for the National Marine Plan. Edinburgh: The Scottish Government. Available from: http://scotgov.publishingthefuture.info/publication/marine-atlas [Accessed March 2025]

BEIS (2016) Record of the Habitats Regulations Assessment undertaken under Regulation 5 of the Offshore Petroleum Activities (Conservation of Habitats) regulations 2001 (as amended): East Shetland Platform (Inshore) 2D Seismic Survey. BEIS July 2016.

BEIS (2017) *Environmental Information for Offshore Safety Directive Submissions – A Guide*. BEIS Offshore Environment Unit (OEU): Aberdeen.

BEIS (2019a) Offshore Oil & Gas Licensing 31st Seaward Round. Habitats Regulations Assessment Draft Appropriate Assessment: Moray Firth. February 2019. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/777002/31st_Round_AA_MF_-_Consultation_Draft.pdf [Assessed April 2025].

BEIS (2019b). The Climate Change Act 2008 (2050 Target Amendment) Order 2019 [Online]. Available from: https://www.legislation.gov.uk/ukdsi/2019/9780111187654 [Accessed October 2025].

BEIS (2021) *North Sea Transition Deal.* March 2021. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/972520/north-sea-transition-deal_A_FINAL.pdf [Accessed March 2025]

BEIS (2022) UK Offshore Energy Strategic Environmental Assessment. Future Leasing/Licensing for Offshore Renewable Energy, Offshore Oil & Gas and Gas Storage and Associated Infrastructure. OESEA4 Environmental Report.

Bellas, J., Saco-Álvarez, L., Nieto, Ó., Bayona, J. M., Albaigés, J., and Beiras, R. (2013) Evaluation of artificially-weathered standard fuel oil toxicity by marine invertebrate embryo-genesis bioassays. *Chemosphere*, 90: 110.-1108.

Bett B.J. (2000) Benthic ecology of the Faeroe-Shetland Channel. Section 4.3.1 in Environmental Surveys of the Seafloor of the UK Atlantic Margin, Atlantic Frontier Environmental Network [CD-ROM]. Available from Geotek Limited, Daventry, Northants, NN11 5EA, UK. ISBN 09538399-0-7

Bett, B.J. (2003) An introduction to the benthic ecology of the Faroe-Shetland Channel (SEA4). Southampton: DEEPSEAS Group, George Deacon Division, Southampton Oceanography Centre. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/197362/SEA4_TR_Benthos_SOC.pdf [Accessed March 2025].

Bett, B.J., & Rice, A.L. (1992) The influence of hexactinellid sponge (*Pheronema carpenteri*) spicules on the patchy distribution of macrobenthos in the porcupine seabight (*bathyal ne atlantic*). Ophelia, 36, Pp. 217-226.

BGS (2001) North Sea Geology – Technical Report 008 Rev1 – Geology [Online] Available from: https://assets.publishing.service.gov.uk/media/5a7a2a8340f0b66a2fc005f6/TR_SEA3_Geology.pdf [Accessed March 2025]

BGS (2015) Offshore marine information products – WMS. Available from: http://www.bgs.ac.uk/data/services/offprodwms.html [Accessed March 2025].

BGS (2025) Offshore seismic Hazard in UK waters [Online] Available from: https://www.earthquakes.bgs.ac.uk/hazard/hazard_offshore.html [Accessed March 2025]

Black, K., & Parry, G., (1999). Entrainment, dispersal, and settlement of scallop dredge sediment plumes: Field measurements and numerical modelling. Canadian Journal of Fisheries and Aquatic Sciences. 56. 2271-2281.

Blix, A.S., Folkow, L.P. (1995) Daily energy expenditure in free living minke whales. Acta Physiologica Scandinavica: 153 (1). https://doi.org/10.1111/j.1748-1716.1995.tb09834.x

BRIG (2011). Biodiversity Reporting and Information Group UK Biodiversity Action Plan: Priority Habitat Descriptions. Joint Nature Conservation Committee [JNCC]. https://hub.jncc.gov.uk/assets/2728792c-c8c6-4b8c-9ccd-a908cb0f1432

Bryan, G.W. and Langston, W.J. (1992) Bioavailability, accumulation and effects of heavy metals in sediments with special reference to United Kingdom estuaries: a review. Environmental Pollution, 76: 89-131.

Burnell, D., Perkins, A. J., Newton, S. F., Bolton, M., Tierney, T. D., & Dunn, T. E. (2023) Seabirds Count: a census of breeding seabirds in Britain and Ireland (2015–2021). Lynx Edicions, Barcelona.

Camphuysen, K.C.J., Chardine, J., Frederiksen, M. and Nunes, M. (2005) Review of the impacts of recent major oil spills on seabirds. In: Anonymous (ed.) *Report of the Working Group on Seabird Ecology*, 29 March - 1 April 2005, Texel, Netherlands. Copenhagen, Denmark: International Council for the Exploration of the Sea (ICES). Report No.: ICES CM 2005/C:05, Ref. ACME+E.

Carter, M.I.D., Boehme, L., Cronin, M.A., Duck, C.D., Grecian, W.J., Hastie, G.D., Jessopp, M., Matthiopoulos, J., McConnell, B.J., Miller, D.L., Morris, C.D., Moss, S.E.W., Thompson, D., Thompson, P.M., & Russell, D.J.F. (2022) Sympatric seals, satellite tracking and protected areas: habitat-based distribution estimates for conservation and management. Frontiers in Marine Science, Vol. 9, 875869.

Cefas (2001) Contaminant status of the North Sea. Technical report produced for Strategic Environmental Assessment – SEA-2. Report No. TR_004. Available from: https://www.gov.uk/government/publications/strategic-environmental-assessment-2-supporting-documents [Accessed March 2025].

Chambers S. and Solandt J. (2005). MCS Basking Shark Annual Report. A report of sightings gathered from the general public in 2005. Report for the Marine Conservation Society.

Charif, R.A. and Clark, C.W. (2000) Acoustic monitoring of large whales off north and west Britain and Ireland: a two year study. October 1996 to September 1998. Peterborough: Joint Nature Conservation Committee, Report No. 313.

CIEEM (2018) Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine. Chartered Institute of Ecology and Environmental Management, Winchester.

CIN (2017) CHARM - Chemical Hazard Assessment and Risk Management. For the use and discharge of chemicals used offshore – User Guide Version 1.5. Charm Implementation Network – CIN 2017, Pages 1-77.

Clark, C.W. (1990) Acoustic behavior of mysticete whales. In Sensory abilities of cetaceans. Springer, Boston, MA, 571-583.

Climate Change Committee (CCC (2020) The Sixth Carbon Budget The UK's path to Net Zero. December 2020. [Online] Available from: https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf [Accessed November 2025].

Climate Change Committee (CCC) (2024). COP29: Key outcomes and next steps for the UK. [Online]. Available from: https://www.theccc.org.uk/publication/cop29-key-outcomes-and-next-steps-for-the-uk/ [Accessed October 2025]

Climate Change Committee (CCC) (2025a) The Seventh Carbon Budget: This statutory report provides advice to the UK Government on the level of the Seventh Carbon Budget (2038 to 2042). Published 26 February 2025. [Online] Available at: https://www.theccc.org.uk/publication/the-seventh-carbon-budget/ [[Accessed April 2025].

Climate Change Committee (CCC (2025b) Progress in adapting to climate change. 2025 report to Parliament. April 2025. [Online] Available from: https://www.theccc.org.uk/wp-content/uploads/2025/04/Progress-in-adapting-to-climate-change-2025-1.pdf [Accessed November 2025].

Collie, J.S., Hall, S.J., Kaiser, M.J. and Poiner, I.R., 2000. A quantitative analysis of fishing impacts on shelf-sea benthos. Journal of animal ecology, 69(5), pp.785-798.

Collins, M.A., Yau, C., Allcock, L., & Thurston, M.J. (2001) Distribution of deep water benthic and bentho-pelagic cephalopods from the NE Atlantic. Journal of the Marine Biological Association of the UK. Vol. 85, pp. 105 – 117.

CONCAWE (2001) Report 01/54 Environmental classification of petroleum substances - summary data and rationale.

Cordes, E.E., Jones, D.O.B., Schlacher, T.A., Amon, D.J., Bernadino, A.F., Brooke, S., Carney, R., DeLeo, D.M., Dunlop, K.M., Escobar-Briones, E.G., Gates, A.R., Genio, L., Gobin, J., Henry, L.A., Herrera, S., Hoyt, S., Joye, M., Kark, S., Mestre, N.C., Metaxas, A., Pfeifer, S., Sink, K., Sweetman, A.K. and Witte, U., (2016). Environmental impacts of the deep-water oil and gas industry: a review to guide management strategies. *Frontiers in Environmental Science*, vol. 4, no. 58. DOI: 10.3389/fenvs.2016.00058.

Cormack, D., 1999. Response to marine oil pollution – review and assessment. Dordrecht, The Netherlands.

Coull, K.A., Johnstone, R. and Rogers, S.I. (1998) Fisheries Sensitivity Maps in British Waters. Aberdeen: UKOOA Ltd.

Cranmer, G J (1988) Environmental Survey of the Benthic Sediments Around Three Exploration Well Sites. Report 88/02, prepared for UKOOA by Aberdeen University Marine Studies Ltd.

Crown Estate Scotland (2024) The Crown Estate Scotland Spatial Hub. [Online] Available from: https://crown-estate-scotland-spatial-hub-coregis.hub.arcgis.com/ [Accessed March 2025].

Cummings, J.A. (2005) Operational multivariate ocean data assimilation. Quart. J. Royal Met. Soc., Part C, 131(613), 3583-3604

Cummings, J.A. and Smedstad., O. M. (2013) Variational Data Assimilation for the Global Ocean. Data Assimilation for Atmospheric, Oceanic and Hydrologic Applications vol II, chapter 13, 303-343.

Daan, R. and Mulder, M (1993) Long term effects of OBM cutting discharges at a drilling site on the Dutch Continental Shelf. NIOZ-report 1993-15, NIOZ, Texel, The Netherlands: 1-27

Dahl, P.H., de Jong C.A., Popper, A.N. (2015) The underwater sound field from impact pile driving and its potential effects on marine life. Acoustics Today, Spring 2015, Volume 11, Issue 2.

Dale, A.C., Boulcott, P., Sherwin, T.J. (2011) Sedimentation patterns caused by scallop dredging in a physically dynamic environment. Marine Pollution Bulletin. 62 (11). pp. 2433-2441

De Robertis, A. and Handegard, N.O. (2013), Fish avoidance of research vessels and the efficacy of noise-reduced vessels: a review, ICES Journal of Marine Science, Volume 70, Issue 1, January 2013, Pages 34–45, https://doi.org/10.1093/icesjms/fss155.

Debes, H.H., 2000. *Plankton in the Faroe-Shetland Channel: a review*. The Faroese Fisheries Laboratory.

DECC (2009) UK Offshore Energy Strategic Environmental Assessment. Future Leasing for Offshore Wind Farms and Licensing for Offshore Oil & Gas Storage. Environmental Report. Aberdeen: Department of Energy and Climate Change (DECC).

DECC (2011) OESEA2 Environmental Report. Future Leasing/Licencing for Offshore Renewable Energy, Offshore Oil & Gas, Hydrocarbon Gas and Carbon Dioxide Storage and Associated Infrastructure. February 2011.

DECC (2016) UK Offshore Energy Strategic Environmental Assessment 3 (OESEA3). Aberdeen: Department of Energy and Climate Change (DECC). Available from: https://www.gov.uk/government/consultations/uk-offshore-energy-strategic-environmental-assessment-3-oesea3 [Accessed March 2025].

Dee, D.P., Uppala, S.M., Simmons, A.J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M.A., Balsamo, G., Bauer, D.P. and Bechtold, P. (2011). The ERA-Interim reanalysis: Configuration and performance of the data assimilation system. Quarterly Journal of the royal meteorological society, 137(656), pp.553-597.

Defra (2010) Charting Progress 2. An assessment of the state of UK seas. Prepared by the UK Marine Monitoring and Assessment Strategy (UKMMAS) community, July 2010.

Delvigne, G.A.L., and C.E., Sweeney (1988) Natural dispersion of oil, Oil and Chemical Pollution 4:281-310.

Delvigne, G.A.L., and L.J.M., Hulsen (1994) Simplified laboratory measurement of oil dispersion coefficient – Application in computations of natural oil dispersion. Proceedings of the Seventeenth Arctic and Marine Oil Spill Program, Technical Seminar, June 8-10, 1994, Vancouver, British Columbia, Canada, pp. 173-187.

Dernie, K.M., Kaiser. M.J., Richardson, E.A. and Warwick, R.M. (2003) Recovery of soft sediment communities and habitats following physical disturbance. Journal of Experimental Marine Biology and Ecology, 285-286: 415-434.

DESNZ (2021a) *The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020 – A Guide*. July 2021. Available from: https://assets.publishing.service.gov.uk/media/60f961e68fa8f50429f0e6d1/The_Offshore_Oil_and_Gas_Exploration__Production__Unloading_and_Storage__Environmental_Impact_Assessment__Regulations_2020_-_A_Guide__July_2021.pdf [Accessed March 2025]

DESNZ (2021b) North Sea Transition Deal. March 2021. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/972520/north-sea-transition-deal_A_FINAL.pdf [Accessed April 2025].

DESNZ (2023a). Carbon Budget Delivery Plan, March 2023. [Online]. Available from: https://assets.publishing.service.gov.uk/media/6424b2d760a35e000c0cb135/carbon-budget-delivery-plan.pdf [Accessed October 2025].

DESNZ (2023b). Powering Up Britain: Net Zero Growth Plan [Online]. Available from: https://www.gov.uk/government/publications/powering-up-britain/powering-up-britain-net-zero-growth-plan [Accessed October 2025].

DESNZ (2024a) Clean Power 2030 Action Plan: A new era of clean electricity. [Online] Available at: https://www.gov.uk/government/publications/clean-power-2030-action-plan [Accessed November 2025].

DESNZ (2024b). Statutory Security of Supply Report 2024. [Online]. Avalable at : https://www.gov.uk/government/publications/statutory-security-of-supply-report-2024/statutory-security-of-supply-report-2024 [Accessed November 2025].

DESNZ (2025a) Environmental Impact Assessment (EIA) – Assessing effects of downstream scope 3 emissions on climate. Supplementary guidance for assessing the effects of downstream scope 3 emissions on climate from offshore oil and gas projects. June 2025. Available from: https://assets.publishing.service.gov.uk/media/6853fa3d1203c00468ba2b15/Supplementary_guidance_-_Effects_of_Scope_3_Emissions.pdf [Accessed July 2025]

DESNZ (2025b) *Building the North Sea's Energy Future Consultation*. March 2025. Available from: https://assets.publishing.service.gov.uk/media/67d0005ed107f3a16e028796/building-the-north-sea-energy-future-consultation.pdf [Accessed March 2025]

DESNZ (2025c) Energy Trends. UK, October to December 2024 and 2024. Statistical Release 27 March 2025. [Online] Available at: https://assets.publishing.service.gov.uk/media/67e4f7c49c9de963bc39b526/Energy_Trends_March_2025.pdf [Accessed April 2025].

DESNZ. (2025d). 2023 UK Greenhouse Gas Emissions, Final Figures. [Online]. Available from: https://assets.publishing.service.gov.uk/media/67a30e4f7da1f1ac64e5feb1/2023-final-greenhouse-gas-emissions-statistical-release.pdf [Accessed April 2025].

DESNZ. (2025e). UK Greenhouse Gas Reporting Emission Factors. [Online]. Available from: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2025 [Accessed August 2025].

DESNZ. (2025f). North Sea Future Plan for fair, managed and prosperous transition. [Online]. Available from: https://www.gov.uk/government/news/north-sea-future-plan-for-fair-managed-and-prosperous-transition [Accessed January 2026].

DESNZ and BEIS, 2022. North Sea Transition Deal. Updated: March 2022. [Online]. Available from: https://www.gov.uk/government/publications/north-sea-transition-deal [Accessed October 2025].

DOER (2000) Assessment of Potential Impacts of Dredging Operations Due to Sediment Resuspension. Massachusetts: Department of Energy Resources. [Online] Available from: http://www.dtic.mil/docs/citations/ADA377325 [Accessed May 2025].

Dooling, R.J. and Therrien, S.C. (2012) Hearing in Birds: What changes from air to water. In A.N. Popper and A. Hawkins (eds.), The Effects of Noise on Aquatic Life. Pp. 77-82. Advances in Experimental Medicine and Biology 730, DOI 10.1007/978-1-4419-7311-5_17.

DOSITS (2017) Discovery of Sound in the Sea. Available from: http://www.dosits.org/ [Accessed April 2025].

DTI (2000) Consultation on the habitats directive with regards to oil and gas activities, and SEA for an area to the west of the Shetland Islands (SEA 1). Department of Trade and Industry. Available from: https://www.gov.uk/government/consultations/consultation-on-the-habitats-directive-with-regards-

to-oil-and-gas-activities-and-sea-for-an-area-to-the-west-of-the-shetland-islands-sea-1 [Accessed March 2025]

DTI (2001) Strategic Environmental Assessment 2 (SEA 2). Department of Trade and Industry. Available from: https://www.gov.uk/government/consultations/strategic-environmental-assessment-2-sea-2 [Accessed March 2025].

DTI (2003) Strategic Environmental Assessment 4 (SEA 4). Department of Trade and Industry. Available from: https://www.gov.uk/government/consultations/strategic-environmental-assessment-4-sea-4 [Accessed March 2025].

DTI (2005) Strategic Environmental Assessment 5 (SEA 5). Department of Trade and Industry. Available from: https://www.gov.uk/government/consultations/strategic-environmental-assessment-5-sea-5 [Accessed March 2025].

Duck, C.D. (1997) Seals. In: Barne, J.H., Robson, C.F., Kaznowska, S.S., Doody, J.P., Davidson, N.C. and Buck, A.L. (eds.). Coasts and Seas of the United Kingdom. Region 1 Shetland. Peterborough: Joint Nature Conservation Committee.

Dulvey, N., Stuart, K., Rogers, I., Jennings, S., Stelzenmuller, V., Dye, S.R. and Skjoldal, H.R., (2008). Climate change and deepening of the North Sea fish assemblage: a biotic indicator of warming seas. *Journal of Applied Ecology,* **45**, pp. 1029-1039.

Dyndo, M., Wisniewska, D.M., Rojano-Donate, L. & Madsen, P.T. (2015) Harbour porpoises react to low levels of high frequency vessel noise. Scientific Reports, 5: 11083.

Edds-Walton, P.L. (1997) Acoustic communication signals of mysticete whales. Bioacoustics, 8(1-2), 47-60.

Edwards, R. and White, I. (1999) *The Sea Empress Oil Spill: Environmental Impact and Recovery.* Paper presented at The International Oil Spill Conference 1999, 7-12 March 1999, Seattle, USA. Available from: http://www.itopf.com/knowledge-resources/documents-guides/document/the-sea-empress-oil-spill-environmental-impact-and-recovery-1999/ [Accessed April 2025].

EEMS (2008). EEMS Atmospheric Calculations. [Online]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/136461/atmos-calcs.pdf [Accessed August 2025].

Eggett, A., Johnson, G., Johnston, C., Chaniotis, P. & Robertson, M. (2018) MRV Scotia 15/12S Cruise Report: Survey of Wyville Thomson Ridge cSAC/SCI and Faroe-Shetland Sponge Belt Proposed NCMPA. JNCC Report No. 610, JNCC, Peterborough.

Ellis, J.R., Cruz-Martínez, A., Rackham, B.D. and Roger, S.I. (2004) The Distribution of Chondrichthyan Fishes around the British Isles and Implications for Conservation. Journal of Northwest Atlantic Fishery Science, 25: 195-213

Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J. (2012) Spawning and nursery grounds of selected fish species in UK waters. Lowestoft: Centre for Environment, Fisheries and Aquaculture Science (CEFAS). Report No. 147.

Emissions Database for Global Atmospheric Research (EDGAR) (2025). Global Greenhouse Gas Emissions: EDGAR Community GHG Database, a collaboration between the European Commission, Joint Research Centre (JRC), the International Energy Agency (IEA), and comprising IEA-EDGAR CO2, EDGAR CH4, EDGAR N2O, EDGAR F-GASES version EDGAR_2025_GHG (2025) European Commission, JRC (Datasets) [Online]. Available from: https://edgar.jrc.ec.europa.eu/dataset_ghg2025 [Accessed October 2025]

EMODnet (2024a). Seabed Habitats. Available from: http://www.emodnet-seabedhabitats.eu [Accessed March 2025]

EMODnet (2024b) EMODnet Map Viewer [Online] Available from: https://emodnet.ec.europa.eu/geoviewer/ [Accessed March 2025]

Equinor (2022) Rosebank Environmental Statement. ES/2022/001.

Erbe, C., Marley, S.A., Schoeman, R.P., Smith, J.N., Trigg, L.E., Embling, C.B. (2019) The effects of ship noise on marine mammals – a review. Frontiers in Marine Science, 6.

Etter, P.C. (2013) Underwater acoustic modelling and simulation. 4th edn., CRC Press.

European Commission (EC) (2017) Environmental Impact Assessment of Projects Guidance on the Preparation of the Environmental Impact Assessment Report (Directive 2011/92/EU as amended by 2014/52/EU). European Union.

European Environment Agency [EEA]. (2022a). EUNIS habitat type hierarchical view (marine version 2022 & terrestrial version 2021). https://eunis.eea.europa.eu/habitats-code-browser-revised.jsp?expand=30000,31361#level_31361

European Environment Agency [EEA]. (2022b). Arctic upper bathyal mixed sediment. [Online] Available from: https://eunis.eea.europa.eu/habitats/31478 [Accessed March 2025]

Fanneløp, T.K. and Sjøen, K. (1980) Hydrodynamics of underwater blowouts. AIAA 8th Aerospace Sciences Meeting, January 14-16, Pasadena, California. AIAA paper, pp. 80-0219.

Fernandes, P.G. (2010) Estimates of the abundance of anglerfish (*Lophius* spp.) on the European Northern Shelf: 2005-2010. Edinburgh: Marine Scotland Science.

Finneran, J.J., Schlundt, C.E., Carder, D.A., Clark, J.A., Young, J.A., Gaspin, J.B. and Ridgway, S.H. (2000) Auditory and behavioural response of bottlenose dolphins (Tursiops truncatus) and a beluga whale (Delphinapterus leucas) to impulsive sounds resembling distant signatures of underwater explosions. J. Acoust. Soc. Am. 108 (1): 417 – 431.

Fischer, R. (2000) Bow Thruster Induced Noise and Vibration. Paper presented at the Dynamic Positioning Conference, Houston, October 17 – 18, 2000.

FishBase (2021) Species Information Network. Available from: https://fishbase.se/search.php [Accessed March 2025].

Folk, R.L., (1954) The Distinction Between Grain size and Mineral Composition in Sedimentary Rock Nomenclature. Journal of Geology 62: 344-349.

Forster, P. et al (2024) Indicators of Global Climate Change 2023: annual update of key indicators of the state of the climate system and human influence. Earth Syst. Sci. https://doi.org/10.5194/essd-16-2625-2024

Forster, P. et al., (2025). Indicators of Global Climate Change 2024: annual update of key indicators of the state of the climate system and human influence. Supplement of Earth Syst. Sci. Data, 17, pp. 2641 – 2680. https://doi.org/10.5194/essd-17-2641-2025-supplement [Accessed October 2025]

French-McCay, D., Reich, D., Michel, J., Etkin, D., Symons, L., Helton, D., and J. Wagner. (2012) Oil Spill Consequence Analyses of Potentially-Polluting Shipwrecks. In Proceedings of the 34th AMOP Technical Seminar on Environmental Contamination and Response, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada.

French-McCay, D., Reich, D., Rowe, J., Schroeder, M., and E., Graham. (2011) Oil Spill Modelling Input to the Offshore Environmental Cost Model (OECM) for USBOEMRE's Spill Risk and Cost Evaluations. In Proceedings of the 34th AMOP Technical Seminar on Environmental Contamination and Response, Emergencies Science Division, Environment Canada, Ottawa, ON, Canada.

French-McCay, D.P. (2002) Development and application of an oil toxicity and exposure model, OILTOXEX. Environmental Toxicology and Chemistry. 21(10): 2080-2094.

French-McCay, D.P. (2004) Oil spill impact modelling: Development and validation. Environmental Toxicology and Chemistry 23(10): 2441-2456.

Frost, M., Diele, K. (2022). Essential spawning grounds of Scottish herring: current knowledge and future challenges. *Rev Fish Biol Fisheries* **32**, 721–744. https://doi.org/10.1007/s11160-022-09703-0

Fugro (2011) HESS Cambo Environmental Survey UKCS Block 204/05 – Habitat Investigation Results. September 2011. Report No. 00650V2.0

Fugro (2018) Updated Metocean Criteria for the Cambo Development. Report No. 173504-1-R3

Fugro (2019) Cambo Development, UKCS Blocks 204/4a, 204/5, 204/9a & 204/10a – FPSO and Drill Centre Site Geophysical Results Report. December 2019. Report No. 192374V1.1

Fugro (2024a) Tornado Site Survey and Route Survey from Tornado to Tormore – Tornado Site Survey Geophysical Report. October 2024. Ithaca Report No. TOR-SF-FU-SU-RE-0001

Fugro (2024b) Tornado Site Survey and Route Survey from Tornado to Tormore – Tornado to Tormore Route Survey Geophysical Report. October 2024. Ithaca Report No. TOR-SF-FU-SU-RE-0002

Fugro (2024c) Tornado Site Survey and Route Survey from Tornado to Tormore – Marine Mammal Mitigation Report. September 2024. Report No. F248567-REP-012

Fugro (2025a) Tornado Site Survey and Route Survey from Tornado to Tormore – Tornado Site Habitat Assessment Report. January 2025. Ithaca Report No. TOR-SF-FU-SU-RE-0009

Fugro (2025b) Tornado Site Survey and Route Survey from Tornado to Tormore – Tornado to Tormore Route Habitat Assessment Report. January 2025. Ithaca Report No. TOR-SF-FU-SU-RE-0010

Fugro (2025c) Tornado Site Survey and Route Survey from Tornado to Tormore – Tornado Site Environmental Baseline Survey Report. February 2025. Ithaca Report No. TOR-SF-FU-SU-RE-0007

Fugro (2025d) Tornado Site Survey and Route Survey from Tornado to Tormore – Tornado to Tormore Route Environmental Baseline Survey Report. February 2025. Ithaca Report No. TOR-SF-FU-SU-RE-0008

Gardline (2001) Environmental baseline survey of the UKCS 204/10. August to October 2001. Gardline project ref 5694.

Genesis (2011) Review and assessment of underwater sound produced by oil and gas activities and potential reporting requirements under the Marine Strategy Framework Directive. Aberdeen: Genesis Oil and Gas Consultants, Report No. J71656-Final Report-G2.

GESAMP (1993) *Impact of oil and related chemicals and wastes on the marine environment*. Joint Group of Experts on the Scientific Aspects of Marine Pollution. London: IMO. Reports No. 50.

GHG Protocol (2024). Corporate Standard. [Online]. Available from: https://ghgprotocol.org/corporate-standard#supporting-documents [Accessed October 2025].

Gilles, A, Authier, M, Ramirez-Martinez, NC, Araújo, H, Blanchard, A, Carlström, J, Eira, C, Dorémus, G, Fernández- Maldonado, C, Geelhoed, SCV, Kyhn, L, Laran, S, Nachtsheim, D, Panigada, S, Pigeault, R, Sequeira, M, Sveegaard, S, Taylor, NL, Owen, K, Saavedra, C, Vázquez-Bonales, JA, Unger, B, Hammond, PS (2023). Estimates of cetacean abundance in European Atlantic waters in summer 2022 from the SCANS-IV aerial and shipboard surveys. Final report published 29 September 2023. 64 pp. https://tinyurl.com/3ynt6swa

Global Carbon Project (GCP) (2024) Global Carbon Budget 2024 Presentation. Published on 13 November 2024. Available from: GCP_CarbonBudget_2024_slides_v1.0.pptx.pdf [Accessed July, 2025] 'Used with permission of the Global Carbon Project under the Creative Commons Attribution 4.0 International license'. [Accessed October 2025]

Goertner, J. F. (1978) Dynamical model for explosion injury to fish. Naval Surface Weapons Center, White Oak Lab, Silver Spring, MD. Report No. NSWC/WOL.TR-76-155.

Goertner, J. F., Wiley M L, Young G A, McDonald W W (1994) Effects of underwater explosions on fish without swim bladders. Naval Surface Warfare Center. Report No. NSWC/TR-76-155.

González, J., Figueiras, F.G., Aranguren-Gassis, M., Crespo, B., Fernández, E., Morán, X.A.G., Nieto-Cid, M. (2009). Effect of a simulated oil spill on natural assemblages of marine phytoplankton enclosed in microcosms. Estuarine, Coastal and Shelf Science. 83. 265-276. 10.1016/j.ecss.2009.04.001.

González-Irusta, J.M. and Wright, P.J. (2016) Spawning grounds of Atlantic cod (*Gadus morhua*) in the North Sea, ICES Journal of Marine Science, Volume 73, Issue 2, pp 304-315.

Gordon J.D.M. (2003) Fish and Fisheries in the SEA4 Area. Report to the Department of Trade and Industry. Scottish Association for Marine Science Research Services.

Gordon J.D.M. and Swan S.C. (1997). The Distribution and Abundance of Deep-Water Sharks on the Continental Slope to the West of the British Isles. ICES CM 1997/BB: 11. 23 pages.

Gore M.A., Rowat D., Hall J., Gell F.R. and Ormond R.F. (2008) Transatlantic migration and deep mid-ocean diving by basking shark. Biol Lett 4: Pages 395−398.

Gray, J. S., Aschan, M., Carr, M. R., Clarke, K. R., Green, T. H., Pearson, R., and Warwick, R. M. (1998) Analysis of community attributes of the benthic macro-fauna of Frierfjord-Langesundfjord and in a mesocosm experiment. *Marine Ecology Progress Series*, 46: 151-165.

Greenhouse Gas Protocol (GHGP) (2024). IPCC Global Warming Potential Values. [Online]. Available from: https://ghgprotocol.org/sites/default/files/2024-08/Global-Warming-Potential-Values%20%28August%202024%29.pdf [Accessed April 2025]

Gubbay, S. (2003) Marine aggregate extraction and biodiversity. Information, issues and gaps in understanding. Report to the Joint Marine Programme of the Wildlife Trusts and WWF-UK.

Halvorsen, M.B., Casper, B.C., Matthew, D., Carlson, T.J., and Popper, A.N. (2012) Effects of exposure to pile driving sounds on the lake sturgeon, Nila tilapia, and hogchoker. Proc. Roy. Soc. B, 279, 4705-4714.

Hammond, P.S., Gordon, J.C.D., Grellier, K., Hall, A.J., Northridge, S.P., Thompson, D. and Harwood, J. (2001) Background information on marine mammals relevant to SEA 2. Report to the DTI from the Sea Mammal Research Unit, University of St. Andrews, UK, 70pp.

Harper, Hugh & Sandwell, David. (2024). Global Predicted Bathymetry Using Neural Networks. Earth and Space Science. 11. 10.1029/2023EA003199.

Harrison, P.J., Cochlan, W.P., Acreman, J.C., Parsons, T.R., Thompson, P.A. and Dovey, H.M. (1986) The effects of crude oil and Corexit 9527 on marine phytoplankton in an experimental enclosure. *Marine Environmental Research*, 18: 93-109.

Hartley Anderson Ltd (2005) UKOOA Report to the Government/Industry Offshore Environmental Monitoring Committee 2004 Single Well Site Survey.

Haug, T., 1990 Biology of the Atlantic halibut, *Hippoglossus hippoglossus* (L., 1758). *Advances in Marine Biology*, **26**, pp. 1–70.

Hawkins, A.D. (1993) Underwater Sound and Fish Behaviour IN: Pitcher, T.J. (ed.) Behavior of Teleost Fishes. London: Chapman & Hall: 129-169.

Henry, L.A., & Roberts, J.M. (2014a) Applying the OSPAR habitat definition of deep-sea sponge aggregations to verify suspected records of the habitat in UK waters (JNCC Report No. 508). Joint Nature Conservation Committee (JNCC).

Henry, L.A., & Roberts, J.M. (2014b) Developing an interim technical definition for Coral Gardens specific for UK waters and its subsequent application to verify suspected records (JNCC Report No. 507). Joint Nature Conservation Committee (JNCC).

Hermannsen, L., Beedholm, K., Tougaard, J. and Madsen, P. T. (2014) High frequency components of ship noise in shallow water with a discussion of implications for harbour porpoises (Phocoena phocoena). J. Acoust. Soc. Am., 138, 1640–1653.

Highlands and Islands Enterprise (HIE) (2025) About Shetland [Online] Available from: https://www.hie.co.uk/our-region/shetland/ [Accessed March 2025]

Hirata, K. (1999) Swimming speeds of some common fish. National Maritime Research Institute (Japan). Data sourced from Iwai T, Hisada M (1998). Fishes – Illustrated book of Gakken (in Japanese). Accessed on 8th March 2017 at http://www.nmri.go.jp/eng/khirata/fish/general/ speed/speede/htm.

Hislop, J.R.G., Gallego, A., Heath, M.R., Kennedy, F.M., Reeves, S.A. and Wright, P.J. 2001 A synthesis of the early life history of the anglerfish, Lophius piscatorius (Linnaeus, 1758) in Northern British waters. ICES Journal of Marine Science, 58, pp. 70–86.

HM Government (2008). Climate Change Act 2008. [Online]. Available from: https://www.legislation.gov.uk/ukpga/2008/27/contents [Accessed October 2025].

HM Government (2020) *Energy White Paper: Powering our Net Zero Future.* December 2020. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf [Accessed March 2025].

HM Government (2021) Net Zero Strategy: Build Back Greener. October 2021. Accessed from: https://assets.publishing.service.gov.uk/media/6194dfa4d3bf7f0555071b1b/net-zero-strategy-beis.pdf [Accessed October 2025]

HM Government (2022) *British Energy Security Strategy. Secure, clean and affordable British energy for the long term*. April 2022. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1069969/british-energy-security-strategy-web-accessible.pdf [Accessed March 2025]

HM Government (2024) Final Statement for the Third Carbon Budget. [Online]. Available from: https://assets.publishing.service.gov.uk/media/664356ef4f29e1d07fadc6e9/third-carbon-budget-statement.pdf#:~:text=The%20UK%20met%20its%20first%20%282008-2012%29%20and%20second,2022%20with%20an%20emissions%20cap%20of%202%2C544%2C000%2C000%20tCO2e. [Accessed April 2025].

HM Government (2025) Carbon Budget and Growth Delivery Plan. Available from: https://assets.publishing.service.gov.uk/media/6901d0c2a6048928d3fc2b55/carbon-budget-and-growth-delivery-plan-report.pdf [Accessed November 2025].

Howell, K.L., Davies, J.S. & Narayanaswamy, B.E., 2010. Identifying deep-sea megafaunal epibenthic assemblages for use in habitat mapping and marine protected area network design. Journal of the Marine Biological Association of the United Kingdom, 90 (01), 33.

Hughes, S.L., Turrell, W.R. (2006) FINAL REPORT OF ROAME AE1190 Oceanic transport around Scotland April 2002 – March 2006. Fisheries Research Services Internal Report No 11/06. Fisheries Research Services, Marine Laboratory, Victoria Road, Aberdeen, AB11 9DB.

Hyland, J., Balthis, L., Karakassis, I., Magni, P., Petrov, A., Shine, J., Vestergaard, O., Warwick, R. (2005) Organic carbon content of sediments as an indicator of stress in the marine benthos. Marine Ecology Progress Series. Vol. 295: 91-103

Hyland, J., D. Hardin, M. Steinhauer, D. Coats, D. R. Green, R., and J. Neff. (1994) Environmental impact of offshore oil development on the outer continental shelf and slope off Point Arguello, California. Mar. Environ. Res. 37:195-229.

IAMMWG (2013) Management Units for Marine Mammals in UK waters (June 2013). Peterborough: Inter-Agency Marine Mammal Working Group, Joint Nature Conservation Committee.

IAMMWG (2022) Updated abundance estimates for cetacean Management Units in UK waters. JNCC Report No. 680 (Revised March 2022), JNCC Peterborough, ISSN 0963-8091.

ICES (2009). Report of the ICES-NAFO Working Group on Deep-Water Ecology (WGDEC), 9–13 March 2009. ICES Advisory Committee [online]. Available at: http://vme.ices.dk/download/WGDEC_2009.pdf [Accessed January 2026].

ICES CIEM (2023) Aquaculture Overview for Faroes ecoregion. March 2023. Available from: https://www.ices.dk/news-and-events/news-archive/news/Pages/FaroesAO.aspx

IEA (2018). The Future of Petrochemicals. [Online]. Available from: https://www.iea.org/reports/the-future-of-petrochemicals [Accessed October 2025].

IEA (2021). Net Zero by 2050: A Roadmap for the Global Energy Sector. Online]. Available from: https://www.iea.org/reports/net-zero-by-2050 [Accessed November 2025].

IEA (2023a). World Energy Outlook 2023. [Online]. Available from: https://www.iea.org/reports/world-energy-outlook-2023 [Accessed November 2025].

IEA (2023b). Energy Unit Converter. [Online]. Available from: https://www.iea.org/data-and-statistics/data-tools/unit-converter [Accessed November 2025].

IEA (2024). World Energy Outlook 2024. [Online]. Available from: https://www.iea.org/reports/world-energy-outlook-2024 [Accessed October 2025].

IEA (2025). World Energy Outlook 2025. [Online]. Available from: https://iea.blob.core.windows.net/assets/af5ac385-8fce-4cc7-8c73-107a3aade95e/WorldEnergyOutlook2025.pdf [Accessed November 2025].

IEMA (2016) Environmental Impact Assessment Guide to: Delivering Quality Development, July 2016. Institute of Environmental Management and Assessment.

IMO (2018) Adoption of the Initial IMO Strategy on Reduction of GHG Emissions from Ships and Existing IMO Activity Related to Reducing GHG Emissions in the Shipping Sector. London: IMO headquarters. Available from: https://unfccc.int/sites/default/files/resource/250_IMO%20submission_Talanoa%20Dialogue_April%202018.pdf [Accessed April 2025].

Institution of Civil Engineers (IoCE). (2023). Guidance Document for Publicly Available Standard (PAS) 2080. [Online]. Available from: https://www.ice.org.uk/media/vm0nwehp/2023-03-29-pas_2080_guidance_document_april_2023.pdf [Accessed April 2025].

Intergovernmental Panel on Climate Change (IPCC) (2006). IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2 Energy. [Online]. Available from: https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html [Accessed November 2025].

Intergovernmental Panel on Climate Change (IPCC) (2019a). Special Report on Climate Change and Land / Intergovernmental Panel on Climate Change. [Online]. Available from: https://www.ipcc.ch/report/srccl/ [Accessed July 2025].

Intergovernmental Panel on Climate Change (IPCC) (2019b). Special Report on the Ocean and Cryosphere in a Changing Climate / Intergovernmental Panel on Climate Change. [Online]. Available from: https://www.ipcc.ch/srocc/home/ [Accessed July 2025].

Intergovernmental Panel on Climate Change (IPCC) (2020). The concept of risk in the IPCC Sixth Assessment Report: a summary of cross-Working Group discussion. [Online]. Available from: https://www.ipcc.ch/site/assets/uploads/2021/02/Risk-guidance-FINAL_15Feb2021.pdf [Accessed October 2025].

Intergovernmental Panel on Climate Change (IPCC) (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. [Online]. Available from: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport.pdf [Accessed July 2025].

Intergovernmental Panel on Climate Change (IPCC) (2022). Sixth Assessment Report (AR6). Riahi, K., R. Schaeffer, J. Arango, K. Calvin, C. Guivarch, T. Hasegawa, K. Jiang, E. Kriegler, R. Matthews, G.P. Peters, A. Rao, S. Robertson, A.M. Sebbit, J. Steinberger, M. Tavoni, D.P. van Vuuren, 2022: Mitigation pathways compatible with long-term goals. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.005 Intergovernmental Panel on Climate Change. [Online]. Available from: https://www.ipcc.ch/assessment-report/ar6/ [Accessed April 2025].

Intergovernmental Panel on Climate Change (IPCC) (2023a). IPCC Working Group 1 (WG1) Sixth Assessment Report (AR6) Annex III Extended Data. [Online]. Available from: https://zenodo.org/records/5705391 [Accessed October 2025]

Intergovernmental Panel on Climate Change (IPCC). (2023b). Sixth Assessment Report (AR6). [Online]. Available from: https://www.ipcc.ch/assessment-report/ar6/ [Accessed July 2025].

Intergovernmental Panel on Climate Change (IPCC) (2023c). Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental

Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.

IOC-UNESCO. 2024. State of the Ocean Report. Paris, IOC-UNESCO. (IOC Technical Series, 190). https://doi.org/10.25607/4wbg-d349 [Accessed July 2025].

IOGP (2019) RISK ASSESSMENT DATA DIRECTORY Blowout Frequencies. September 2019. Report 434-02.

IPIECA-IOGP (2015) Impacts of oil spills on marine ecology. Good practice guidelines for incident management and emergency response personnel. IOGP Report 525.

Irving, R. (2009) The identification of the main characteristics of stony reef habitats under the habitats directive: summary report of an inter-agency workshop (JNCC Report No. 432). Joint Nature Conservation Committee (JNCC). Available from: https://doi.org/10.13140/2.1.2278.5283 [Accessed March 2025]

Isaji, T., Howlett, E., Dalton, C., and Anderson, E. (2001a) Stepwise-Continuous-Variable-Rectangular Grid Hydrodynamic Model, Environment Canada's 24th Arctic and Marine Oilspill (AMOP) Technical Seminar.

Isaji, T., Howlett, E., Dalton, C., and Anderson, E. (2001b) Stepwise-Continuous-Variable-Rectangular Grid Hydrodynamic Model, Environment Canada's 24th Arctic and Marine Oilspill (AMOP) Technical Seminar.

ITOPF (2014a) TIP 06: Recognition of oil on shorelines. Available at: https://www.itopf.org/knowledge-resources/documents-guides/document/tip-06-recognition-of-oil-on-shorelines/ [Accessed April 2025].

ITOPF (2014b) Technical Information Paper 13: Effects of Oil Pollution on the Marine Environment. London: The International Tanker Owners Pollution Federation Limited.

ITOPF (2014c) TIP 12: Effects of Oil Pollution on Social and Economic Activities. Available at: https://www.itopf.org/knowledge-resources/documents-guides/tip-12-effects-of-oil-pollution-on-social-and-economic-activities/ [Accessed April 2025].

IUCN (2025) The IUCN Red List of Threatened Species. [Online] Available at: https://www.iucnredlist.org/ [Accessed March 2025].

Jacobson, A.R. et al. (2023). CarbonTracker CT2022. Retrieved from NOAA Global Monitoring Laboratory: https://doi.org/10.25925/Z1GJ-3254

JNCC (2010) The Protection of Marine European Protected Species from Injury and Disturbance. Guidance for the Marine Area in England and Wales and the UK Offshore Marine Area. Peterborough: Joint Nature Conservation Committee (JNCC).

JNCC (2014a) Faroe-Shetland Sponge Belt Marine Protected Area. Site Summary Document. Peterborough: Joint Nature Conservation Committee. Available from: http://jncc.defra.gov.uk/page-6479 [Accessed March 2025].

JNCC (2014b) Faroe-Shetland Sponge Belt Marine Nature Conservation MPA. Site Assessment against the MPA Selection Guidelines. Peterborough: Joint Nature Conservation Committee. Available from: http://jncc.defra.gov.uk/pdf/Faroe-Shetland_Sponge_Belt_Application_of_the_MPA_Selection_Guidelines_v5_0.pdf [Accessed March 2025].

JNCC (2016) SPA Site Selection Document. The Scientific Case Supporting Site Selection. Seas off Foula proposed SPA. Peterborough: Joint Nature Conservation Committee, Version 13.

JNCC (2017a) 1355 Otter *Lutra lutra*. Annex II Species Accounts. Available from: http://jncc.defra.gov.uk/protectedsites/sacselection/species.asp?FeatureIntCode=S1355 [Accessed March 2025].

JNCC (2017b) JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys (August 2017). Peterborough: Joint Nature Conservation Council (JNCC). Available online: http://jncc.defra.gov.uk/marine/seismic_survey [Accessed April 2025].

JNCC (2018a) Faroe-Shetland Sponge Belt MPA – Conservation Advice [Online] Available from: https://hub.jncc.gov.uk/assets/1422e961-edfb-40e8-b1ad-2eaf67cf21f0 [Accessed March 2025]

JNCC (2018b) Supplementary Advice On Conservation Objectives For Faroe-Shetland Sponge Belt Nature Conservation Marine Protected Area [Online] Available From: Https://Data.Jncc.Gov.Uk/Data/1422e961-Edfb-40e8-B1ad-2eaf67cf21f0/Fssb-3-Saco-V1.0.Pdf [Accessed January 2026]JNCC (2019) At Sea Densities for Seabirds, by Season. [Shapefiles] Available from: https://data.gov.uk/search?filters%5Bformat%5D=&filters%5Bpublisher%5D=&filters%5Btopic%5D=&q=krigged [Accessed March 2025]

JNCC (2020) Statements on conservation benefits, condition & conservation measures for Faroe-Shetland Sponge Belt Nature Conservation Marine Protected Area [Online] Available from: https://data.jncc.gov.uk/data/1422e961-edfb-40e8-b1ad-2eaf67cf21f0/FSSB-4-ConservationStatements-V1.0.pdf [Accessed March 2025]

JNCC (2023) Seabird Monitoring Programme. Available from: https://jncc.gov.uk/our-work/seabird-monitoring-programme/ [Accessed March 2025].

JNCC (2025) About Marine Protected Areas [Online] Available at: https://jncc.gov.uk/our-work/about-marine-protected-areas/ [Accessed March 2025]

JNCC and Natural England, 2016. Review of the MCZ Features of Conservation Importance. May 2016. 43pp.

JNCC, DEFRA and NE (2020) Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (England, Wales & Northern Ireland).

Johns, D. and Wooton, M. (2003) Plankton report for Strategic Environment Assessment Area 4. Plymouth: Sir Alistair Hardy Foundation for Ocean Science, Plymouth Marine Laboratory. Report to the Department of Trade and Industry.

Joint Research Council - Institute for Environment and Sustainability of the European Commission. (2010). ILCD Handbook [Online]. Available from: https://eplca.jrc.ec.europa.eu/uploads/ILCD-Handbook-General-guide-for-LCA-DETAILED-GUIDANCE-12March2010-ISBN-fin-v1.0-EN.pdf [Accessed April 2025].

Jones, D.O.B., Gates, A.R. (2010) Recovery at Morvin: SERPENT final report. Research and Consultancy Report No. 86. National Oceanography Centre, Southampton.

Jones, D.O.B., Gates, A.R. and Lausen, B., (2012). Recovery of deep-water megafaunal assemblages from hydrocarbon drilling disturbance in the Faroe-Shetland channel. *Marine Ecology Progress Series*, 461, pp. 71-82.

Jones, E.L., McConnell. B.J., Smout, S., Hammond, P.S., Duck, C.D., Morris, C.D., Thompson, D., Russell, D.J.F., Vincent, C., Cronin, M., Sharples, R.J. & Matthiopoulos, J. (2015) Patterns of space use in sympatric marine colonial predators reveal scales of spatial portioning. Marine Ecology Progress Series. 534: 235-249.

Joye, S.B., Bracco, A., Ozgokmen, T.M., Chanton, J.P., Grosell, M., MacDonald, I.R., Cordes, E.E., Montoya, J.P. and Passow, U. (2016). The Gulf of Mexico Ecosystem, six years after the Macondo Oil Well Blowout. Deep Sea Research Part II: Topical Studies in Oceanography. 129(1): 4–19. Available at: https://doi.org/10.1016/j.dsr2.2016.04.018

Kafas, A., Jones, G., Watret, R., Davies, I. and Scott, B. (2012) Representation of the use of marine space by commercial fisheries in Marine Spatial Planning. ICES Annual Science Conference, Bergen, Norway. International Council for the Exploration of the Sea, 1-2.

Kazanadis, G., Vad, J., Henry, L-A., Neat, F., Berx, B., Georgoulas, K. and J. Roberts, M. (2019). Distribution of Deep-Sea Sponge Aggregations in an Area of Multisectoral Activities and Changing Oceanic Conditions. Frontiers in Marine Science, 6, pp196-.

Kiørboe, T., Frantsen, E., Jensen, C. and Sørensen, G. (1981) Effects of suspended sediments on development and hatching of herring (Clupea harengus) eggs. Estuarine, Coastal and Shelf Science, 13 (1): 107-111.

Kirby, M.F., Brant, J., Moore, J., Lincoln, S., (eds) (2018). PREMIAM - Pollution Response in Emergencies - Marine Impact Assessment and Monitoring: Post-incident monitoring guidelines. Second Edition. Science Series Technical Report. Cefas, Lowestoft.

KIS-ORCA (2025) Interactive Map. [Online] Available from: https://kis-orca.org/map/ [Accessed March 2025].

Kober, K., Webb, A., Win, I., Lewis, M., O'Brien, S., Wilson, L.J. and Reid, J.B. (2010) An analysis of the numbers and distribution of seabirds within the British Fishery Limit aimed at identifying areas that qualify as possible marine SPAs. JNCC report No. 431.

Kohler, N.E. Turner, P.A. Hoey, J.J. Natason, L.J. and Briggs, R. (2002) Tag and recapture data for three pelagic shark species: blue shark (*Prinoace glauca*) shortfin mako (*Isurus xyrinchus*), and porbeagle (*Lamna nasus*) in the North Atlantic Ocean. Collected Volumes of Scientific papers of the international commission for the conservation of Atlantic Tunas, 54, 1231 – 1260.

Kostylev, V.E. (2012) Benthic habitat mapping from seabed acoustic surveys: do implicit assumptions hold? In: Sediments, Morphology and Sedimentary Processes on Continental Shelves. Li, M.Z., Sherwood, C.R. and Hill, P.R. (Eds). International Association of Sedimentologists Special Publication ##, Blackwell Publishing Ltd, Oxford.

Krahn, M.M., G.M. Ylitalo, J. Buzitis, S. Chan, and U. Varanasi. (1993) Rapid High-performance Liquid Chromatographic Methods that Screen for Aromatic Compounds in Environmental Samples. *Journal of Chromatography*. Vol. 642, pp. 15-32.

Laist, D.W., Knowlton, A.R., Mead, J.G. Collet, A.S. & Podesta, M. (2001) Collisions between ships and whales. Marine Mammal Science, 17(1), pp.35-75.

Lan, X., Thoning, K.W., Dlugokencky, E.J. (2025). Trends in globally-averaged CO2, CH4, N2O, and SF6 determined from NOAA Global Monitoring Laboratory measurements. Version 2025-06. Retrieved from https://gml.noaa.gov/ccgg/trends/ [Accessed July 2025]

Lane, S.M., Smith, C.R., Mitchell, J., Balmer, B.C., Barry, K.P., McDonald, T., Mori, C.S., Rosel, P.E., Rowles, T.K., Speakman, T.R., Townsend, F.I., Tumlin, M.C., Wells, R.S., Zolman, E.S. and L.H. Schwacke (2015). Reproductive outcome and survival of common bottlenose dolphins sampled in Barataria Bay, Louisana, USA, following the Deepwater Horizon oil spill. Proceedings Royal Society B 282:1994-2001.

Large, P.A., Diez, G., Drewery, J., Laurans, M., Pilling, G.M., Reid, D.G., Reinert, J., South, A.B. and Vinnichenko, V.I., 2010. Spatial and temporal distribution of spawning aggregations of blue ling (Molva dypterygia) west and northwest of the British Isles. *ICES Journal of Marine Science*, **67**, pp. 494–501.

Larsen, K.M.H., Conzales-Pola, C., Fratantoni, P., Beszxzynska-Moller, A. and Hughes, S.L., 2016. ICES report on ocean climate 2014. ICES Cooperative Research Report No. 329. pp. 139.

Lee, R. F., and Page, D. S. (1997) Petroleum hydrocarbons and their effects in subtidal regions after major oil spills. *Marine Pollution Bulletin.* 34 (11): 928-940.

Lindsey, R. (2025). Climate Change: Atmospheric Carbon Dioxide. Retrieved from Climate.gov: https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide [Accessed July 2025].

Løkkeborg, S., (2005). Impacts of trawling and scallop dredging on benthic habitats and communities. FAO Fisheries Technical Paper 472.

Lonergan, M., Duck, C.D., Thompson, D., Mackey, B.L., Cunningham, L., & Boyd, I.L. (2007) Using sparse survey data to investigate the declining abundance of British harbour seals. Journal of Zoology, Vol. 271, 3. Pp. 261-269.

Lonergan, M., McConnell, B., Duck, C. and Thompson, D. (2010) An estimate of the UK grey seal population based on summer haul out counts and telemetry data. Special Committee on Seals (SCOS), Briefing paper: 10/04.

Mackay, D., S. Paterson, and K. Trudel. (1980) A mathematical model of oil spill behaviour, Department of Chemical Engineering, University of Toronto, Canada, 39 pp.

Mackay, D., W. Shui, K. Houssain, W. Stiver, D. McCurdy, and S., Paterson. (1982) Development and calibration of an oil spill behavior model, Report No. CG-D027-83, US Coast Guard Research and Development Center, Groton, CT.

MacLeod, C.D. (2005) Niche partitioning, distribution and competition in North Atlantic beaked whales. PhD thesis, University of Aberdeen.

Macleod, K. (2004) Abundance of Atlantic white-sided dolphin (*Lagenorhynchus acutus*) during summer off northwest Scotland. Journal of Cetacean Research and Management, 6:33-40.

Macleod, K., Simmonds, M. and Murray, L. (2006) Abundance of fin (*Balaenoptera physalus*) and sei whales (*B. Borealis*) amid oil exploration and development off northwest Scotland. Journal of cetacean research and management, 8: 247-254.

Malcolm I.A., Godfrey J & Youngson A.F. (2010). Review of migratory routes and behaviour of Atlantic salmon, sea trout and European eel in Scotland's coastal environment: implications for the development of marine renewables. Scottish Marine and Freshwater Science. Vol 1 No 14.

Marine Scotland (2013) FEAST – Feature Activity Sensitivity Tool. Available from: http://www.marine.scotland.gov.uk/FEAST/ [Accessed May 2025].

Marine Scotland (2016) Scottish Sea Fisheries Statistics 2015. [Online] Available from: https://www.gov.scot/publications/scottish-sea-fisheries-statistics-2015-9781786524300/documents/ [Accessed March 2025]

Marine Scotland (2021) 2020 Scottish Sea Fisheries Statistics - Fishing Effort and Quantity and Value of Landings by ICES Rectangles [Online] Available from: https://data.marine.gov.scot/dataset/2020-scottish-sea-fisheries-statistics-fishing-effort-and-quantity-and-value-landings-ices [Accessed March 2025]

Mason, T. (2013) Modelling of Subsea Noise During the Proposed Piling Operations at the Dudgeon Wind Farm. Report submitted to Royal Haskoning DHV. Bishop's Waltham: Subacoustech Environmental Ltd. Report Ref: E438R0106.

Massey, K., Cosgrove, P., Massey, F., Jackson, D., & Chapman, M. (2016) Habitat characteristics of breeding Eurasian Whimbrel Numenius phaeopus on Mainland Shetland, Scotland, UK, Bird Study, 63:4, 500-508.

Masson, D.G., Bas, T.P.L., Bett, B.J., Huehnerbach, V., Jacobs, C.L. & Wynn, R.B. (2003) Seafloor sediments and sedimentary processes on the outer continental shelf, continental slope and basin floor. Strategic Environmental Assessment: SEA 4. Consultation Document. Department of Trade and Industry, London, p. 51pp.

McCauley, R. D. (1994) "Seismic surveys" in Environmental Implications of Offshore Oil and Gas Development in Australia – The Findings of an Independent Scientific Review, edited by J. M. Swan, J. M. Neff, and P. C. Young. Australian Petroleum Exploration Association, Sydney, pp. 19–122.

McDougall, J. (2000) The significance of hydrocarbons in surficial sediments from the Atlantic Margin regions. IN: Hydrocarbons in environmental surveys of the seafloor of the UK Atlantic Margin. [CD-ROM. Atlantic Frontier Environmental Network, Geotek Ltd.

McDougall, T.J. (1978) Bubble plumes in stratified environments. Journal of Fluid Mechanics 85(4): 655-672.

McLeese, D. W., Sprague, J. B., and Ray, S. (1987) Effects of cadmium on marine biota. p. 171-198. In: Nriagu, J.O. and J.B. Sprague (eds.). Cadmium in the Aquatic Environment. Advances in Environmental Science and Technology, Volume 19. John Wiley & Sons, New York. 272 pp.

Melle, W., Rungeb, J., Head, E., Plourded, S., Castellanie, C., Licandroe, P., Piersonf, J., Jonasdottirg, S., Johnson, C., Bromsa, C., Debesh, H., Falkenhauga, T., Gaardh, E., Gislasoni, A., Heathj, M., Niehoffk, B., Nielseng, T.G., Pepinl, P., Stenevika, E.K. and Chustm, G. (2014) The North Atlantic Ocean as habitat for *Calanus finmarchicus*: Environmental factors and life history traits. Progress in Oceanography, 129 (Part

B): 244-284.Metoc (2002) Description of currents West of Shetland. Briefing note prepared for BP, Deepwater Upstream Technology.

Miller, C.B. and Wheeler, P.A. (2012) Biological Oceanography. 2nd Edition. London: Wiley Blackwell.

Mission Zero (2023). Independent Review of Net Zero, Final Report, 13 January 2023, 340 pp. [Online]. Available from: https://www.gov.uk/government/publications/review-of-net-zero [Accessed October 2025].

MMO (Marine Management Organisation) (2017) UK Sea Fisheries Annual Statistics report 2015. [Online] Available at: https://www.gov.uk/government/statistics/uk-sea-fisheries-annual-statistics-report-2015 [Accessed March 2025]

MMO (Marine Management Organisation) (2021) UK Sea Fisheries Annual Statistics report 2020. [Online] Available at: https://www.gov.uk/government/statistics/uk-sea-fisheries-annual-statistics-report-2020 [Accessed March 2025]

MMO (Marine Management Organisation) (2024) UK Sea Fisheries Annual Statistics report 2023. [Online] Available at: https://www.gov.uk/government/statistics/uk-sea-fisheries-annual-statistics-report-2023 [Accessed March 2025]

MMT (2019) Cambo Field Development Survey – Geophysical, Benthic and Geotechnical Site and Route Survey. March 2019. Report No. 102998-MMT-SPE-REP-ENVIRO.

Moyle, P.B. and Cech, J.J. (2004) Fish: an introduction to ichthyology, 3rd ed. Cloth: Pearson.

Munk, W.H. and Zachariasen (1991) Refraction of sound by islands and seamounts. Journal of Atmospheric and Oceanic Technology. 8(4), pp.554-574.

Murawski, S. A. et al. (2014) 'Prevalence of External Skin Lesions and Polycyclic Aromatic Hydrocarbon Concentrations in Gulf of Mexico Fishes, Post-Deepwater Horizon'. Transactions of the American Fisheries Society. 143(4) 1084–1097. Available at: 10.1080/00028487.2014.911205.

Muus B.J. and Dahlstrøm P. (1985) Collins guide to Sea Fishes of Britain and North-Western Europe. Collins, London.

Myrberg, A.A. (2001) The acoustical biology of elasmobranchs. Environmental Biology of Fishes. 60: 31 – 45.

Nash, R.D.M., Wright, P.J., Matejuvosa, I., Dimitrov, S.P., O' Sullivan, M., Augley, J. and Höffle, H. (2012) Spawning location of Norway pout (*Trisopterus esmarkii*) in the North Sea. ICES Journal of Marine Science, 69 (8): 1338–1346.

National Marine Fisheries Service (NMFS) (2018). 2018 Revisions to: Technical guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum, NMFS-OPR-59. Available from: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-acoustic-technical-guidance [Accessed April 2025].Nedwell, J.R. and Edwards, B. (2004) A review of the measurement of underwater man made noise. Hampshire: Subacoustech Limited. Report No. 534R0109.

National Research Council (NRC) (1983) Drilling discharges in the marine environment. Washington DC: National Academy. p1–180.

Nature Scot (2020) List of Nature Scot Priority Marine features. Available from: https://www.nature.scot/sites/default/files/2020-10/Priority%20Marine%20Features%20in%20Scotlands%20seas.pdf [Accessed March 2025].

Nature Scot (2022) List of Nature Scot Priority Marine features. Available online at: https://www.nature.scot/sites/default/files/2020-10/Priority%20Marine%20Features%20in%20Scotlands%20seas.pdf [Accessed April 2025].

NatureScot (2021) Otters. Available from: https://www.nature.scot/plants-animals-and-fungi/mammals/land-mammals/otter/ [Accessed March 2025].

Neal, K.J. & Avant, P. (2008) Owenia fusiformis A tubeworm. In Tyler-Walters H. and Hiscock K. Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [online]. Plymouth: Marine Biological Association of the United Kingdom. Available from: https://www.marlin.ac.uk/species/detail/1703 [Accessed May 2025].

Neff J.M., Hillman R.E. and Waugh J.J (1989) Bioaccumulation of trace metals from drilling mud barite by benthic animals. In Engelhardt F.R., Ray J.P. & Gillam A.H. (eds.) Drilling Wastes. Proceedings of the 1988 International Conference on Drilling Wastes, Calgary, Alberta, Canada, 461 to 479.

Neff, J.M. (1990). Composition and fate of petroleum and spill-treating agents in the marine environment. In: Sea Mammals and Oil: Confronting the risks. Geraci, J.R. and St. Aubin, D.J. (eds.) San Diego: Academic Press.

Neff, J.M. (2005) Composition, Environmental Fates, and Biological Effects of Water Based Drilling Muds and Cuttings Discharged to the Marine Environment: A synthesis and annotated bibliography. PERF report prepared by Battelle Ltd.

Neff, J.M. (2010) Fate and Effects of Water Based Drilling Muds and Cuttings in Cold Water Environments. Prepared for Shell Exploration and Production Company. Houston, Texas. May 2010.

Neilson, J. L., Gabriele, C.M., Jensen, A. S., Jackson, K., and Straley, J.M. 2012. Summary of reported whale-vessel collisions in Alaskan waters. Journal of Marine Biology, 2012: 18.

Nelson, D.S., McManus, J., Richmond, R.H., King Jr, D.B., Gailani, J.Z., Lackey, T.C. and Bryant, D. (2016) 'Predicting dredging-associated effects to coral reefs in Apra Harbor, Guam – Part 2: Potential coral effects', Journal of Environmental Management, vol. 168, pp. 111–122.

Nicholls, P., Hewitt, J. and Haliday, J. (2003) Effects of Suspended Sediment Concentrations on Suspension and Deposit Feeding Marine Macrofauna. NIWA Client Report ARC03267.

Nilsen, H., Greiff Johnsen H., Nordtug, T., Johansen, Ø. (2006) Threshold values and exposure to risk functions for oil components in the water column to be used for risk assessment of acute discharges (EIF Acute). Statoil contract no.: C.FOU.DE.B02.

NMPi (2024) National Marine Plan Interactive. [Online] Available from: https://marinescotland.atkinsgeospatial.com/nmpi/ [Accessed March 2025].

NSTA (2021) *NSTA Net-Zero Asset Stewardship Expectation 11.* March 2021. Available from: https://www.nstauthority.co.uk/media/7184/se11_net-zero.pdf [Accessed March 2025]

NSTA (2023) Natural gas carbon footprint analysis. [Online] Available at: https://www.nstauthority.co.uk/the-move-to-net-zero/net-zero-benchmarking-and-analysis/natural-gas-carbon-footprint-analysis/ [Accessed April 2025].

NSTA (2024a) *OGA Plan to reduce UKCS greenhouse gas emissions*. March 2024. Available from: https://www.nstauthority.co.uk/regulatory-information/regulatory-framework/the-oga-strategy/oga-plan-emissions-reduction/ [Accessed March 2025]

NSTA (2024b) North Sea Transition Authority Open Data [Online] Available at: https://opendata-nstauthority.hub.arcgis.com/search [Accessed March 2025].

NSTA (2024c) Emissions Monitoring Report 2024. [Online]. Available from: https://www.nstauthority.co.uk/media/nugh4i0q/emissions-monitoring-report-2024.pdf [Accessed April 2025].

NSTA (2025a) *NSTA Overview 2025*. Available from: https://www.nstauthority.co.uk/media/5wwaedil/nsta-overview-2025.pdf [Accessed March 2025]

NSTA (2025b) Emissions Monitoring Report 2025. North Sea Transition Authority. 2 September 2025. Available at: https://www.nstauthority.co.uk/news-publications/emissions-monitoring-report-2025/ [Accessed October 2025].

NSTA (2025c) Production and expenditure projections. [Online] Available at: https://www.nstauthority.co.uk/data-and-insights/insights-and-analysis/production-and-expenditure-projections/ [Accessed April 2025].

NSTD, 2021. North Sea Transition Deal. Published by the Department of Business, Energy and Industrial Strategy under the Conservative government. [Online]. Available from: https://www.gov.uk/government/publications/north-sea-transition-deal#full-publication-update-history [Accessed October 2025].

OEUK (2024a). Emissions Reduction Report 2024. [Online]. Available from: https://oeuk.org.uk/product/emissions-reduction-report-2024/ [Accessed April 2025].

OEUK (2024b) ENVIRONMENTAL INSIGHT. September 2024. Offshore Energies UK. Available from: https://oeuk.org.uk/wp-content/uploads/2024/09/Environmental-Insight-September-2024-Offshore-Energies-UK-OEUK.pdf.

OEUK (2025a) Environmental Insight 2025 [Online] Available from: https://oeuk.org.uk/wp-content/uploads/woocommerce_uploads/2025/09/Environment-Insight-Report-2025-Final-bqvql2.pdf [Accessed November 2025].

OEUK (2025b). OEUK Business Outlook 2025. [Online]. Available from: https://oeuk.org.uk/product/business-outlook-report-2025/ [Accessed November 2025].

Offshore Norge (2024) Species and habitats of environmental concern - mapping, risk assessment, mitigation and monitoring. - in relation to oil and gas activities. Available from : https://www.offshorenorge.no/contentassets/13d5d06ec9464156b2272551f0740db0/handbook-species-and-habitats-of-environmental-concern-2024-rev1.pdf [Accessed March 2025]

OGA (2016) 29th Licensing Round Information – Levels of Shipping Activity. Available from: https://www.ogauthority.co.uk/media/2213/other_regulatory_issues-230816.pdf [Accessed March 2025].

OGA (2019) 32nd Licencing Round Information – Other Regulatory Issues. (Version dated 11th July 2019).

OGA (2020) *The Oil and Gas Authority Strategy.* December 2020. Available from: https://www.nstauthority.co.uk/media/6980/annex-2-the-oga-strategy.pdf [Accessed March 2025]

OGP (2005) Fate and effects of naturally occurring substances in produced water on the marine environment. Report No. 364.

OGP (2010) Risk Assessment Data Directory – Major Accidents. London: International Association of Oil & Gas Producers. Report No. 434-17. Available at: http://www.ogp.org.uk/pubs/434-17.pdf [Accessed April 2025].

OGUK (2014) Environment Report 2014, Oil & Gas UK.

OGUK (2019) Environment Report 2018, Oil & Gas UK (OGUK).

OPRED (2022) UK Offshore Energy Strategic Environmental Assessment. Future Leasing/Licensing for Offshore Renewable Energy, Offshore Oil & Gas and Gas Storage and Associated Infrastructure. OESEA4 Environmental Report. March 2022.

OPRED (2025). EIA – Assessing effects of downstream scope 3 emissions on climate - Supplementary guidance. June 2025.

Oslo and Paris Commission (OSPAR) (2010a) Background document for deep-sea sponge aggregations (Publication Number: 485/2010). OSPAR Commission. Available from: https://www.ospar.org/work-areas/bdc/species-habitats/list-of-threatened-declining-species-habitats [Accessed March 2025]

Oslo and Paris Commission (OSPAR) (2010b). Background document for sea pens and burrowing megafauna. OSPAR Commission biodiversity series (Publication Number: 481/2010). OSPAR Commission. Available from : https://www.ospar.org/work-areas/bdc/species-habitats/list-of-threatened-declining-species-habitats [Accessed March 2025]

Oslo and Paris Commission (OSPAR) (2021) OSPAR List of Threatened and / or Declining Species and Habitats. Available at: http://www.ospar.org/work-areas/bdc/species-habitats/list-of-threatened-declining-species-habitats [Accessed March 2025].

Oslo and Paris Commission (OSPAR) Agreement 2014-05. Establishment of a list of Predicted No Effect Concentrations (PNECs) for naturally occurring substances in produced water.

OSPAR (2006) *OSPAR Recommendation 2006/5 on a Management Regime for Offshore Cuttings Piles.*

OSPAR (2009a) CEMP Assessment Manual. Co-ordinated Environmental monitoring Programme Assessment Manual for contaminants in sediments and biota. No. 379/2008. Available from: http://qsr2010.ospar.org/media/assessments/p00390_2009_CEMP_assessment_report.pdf [Accessed March 2025].

OSPAR (2009b) Overview of Impact of anthropogenic underwater sound in the marine environment. Biodiversity Series. London: OSPAR Commission. Available from: http://qsr2010.ospar.org/media/assessments/p00441_Noise_background_document.pdf [Accessed April 2025].

OSPAR (2014) Agreement 2014-05. Establishment of a list of Predicted No Effect Concentrations (PNECs) for naturally occurring substances in produced water.

OSPAR Commission (2023) Climate Change. In: Quality Status Report 2023 – Thematic Assessments: Pelagic Habitats [Online] Available from: https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/thematic-assessments/pelagichabitats/climate-change/

Otani, S., Naito, Y., Kato, A. and Kawamura, A. (2000) Diving behaviour and swimming speed for free-ranging harbour porpoise, Phocoena phocoena. MARINE MAMMAL SCIENCE, 6(4):811-814.

Ozhan, K., Parsons, M.L. and Bargu, S. (2014). How were phytoplankton affected by the Deepwater Horizon oil spill? Bioscience. 64(9): 829–836. Available at: https://doi.org/10.1093/biosci/biu117

Palka, D.L., Hammond, P.S. (2001) Accounting for responsive movement in like transect estimates of abundance. Canadian Journals of Fisheries and Aquatic Sciences, 58.

PARLOC (2012) Pipeline and Rise Loss of Containment 2001 – 2012 (PARLOC, 2012). PARLOC Report Series, London: Energy Institute and Oil & Gas UK, March 2015, 6th Edition.

PARLOC (2024) Pipeline and riser loss of containment 2001 – 2020 (PARLOC 2020). 7th edition.

Perez, M., Munilla, I., López-Alonso, M. and Velando, A. (2009) Sub-lethal effects on seabirds after the Prestige oil-spill are mirrored in sexual signals. *Biology Letters,* 6: 33-35.

PFML (2016) Lancaster Drilling Operations - Well 205/21a-G (Pilot Well) and Well 205/21a-GZ (Horizontal Sidetrack): Environmental Assessment. Petrofac Facilities Management Limited, Rev 0; 03.06.16.

PhysE (2018) Metocean Criteria for the Cambo Field. Report No. C753 - R 867-18 (2F)

PhysE (2024) Cambo-Tornado-Tormore Regional Severity – Technical Report. Report No. C949-R1059-24 (1D).

Pidduck, E., Jones, R., Daglish, P., Farley, A., Morley, N., Page, A. and Soubies, H., (2017). *Identifying the possible impacts of rock dump from oil and gas decommissioning on Annex I mobile sandbanks.* JNCC Report No. 603. JNCC, Peterborough.

Pierce, G.J. and Santos, M.B., 2003. Diet of harbour seals (*Phoca vitulina*) in Mull and Skye (Inner Hebrides, W. Scotland, UK). Journal of the Marine Biological Association of the United Kingdom.

Pollock, C.M., Mavor, R., Weir, C.R., Reid, A., White, R.W., Tasker, M.L., Webb, A. and Reid, J.B. (2000) The distribution of seabirds and marine mammals in the Atlantic Frontier, north and west of Scotland. Aberdeen: Joint Nature Conservation Committee, Cited in DECC (2016).

Popper, A.N. (2012) Laboratory of Aquatic Bioacoustics. Available from: http://www.life.umd.edu/biology/popperlab/ [Accessed April 2025].

Popper, A.N., Hawkins, A.D., Fay, R.R., Mann, D.A., Bartol, S., Carlson, T.J., Coombs, S., Ellison, W.T., Gentry, R.L., Halvorsen, M.B., Løkkeborg, S., Rogers, P.H., Southall, B.L., Zeddies, D.G. and Tavolga, W.N. (2014) Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report Prepared by ANSI

Accredited Standards Committee S3/SC1 and registered with ANSI. Cham, Switzerland: Springer and ASA Press.

Priede, I.G., 2018. *Deep-sea fishes literature review*. A JNCC report No: 619.

Production Gap Report (PGR). (2023). The Production Gap Report 2023: Phasing down or phasing up? Top fossil fuel producers plan even more extraction despite climate promises. [Online]. Available from: https://www.sei.org/publications/production-gap-report-2023/ [Accessed November 2025].

Production Gap Report (PGR). (2025). 2025 Report. [Online]. Available from: https://productiongap.org/2025report/#2025downloads [Accessed November 2025].

Reed, M., E. Gundlach, and T. Kana, (1989) A coastal zone oil spill model: development and sensitivity studies, Oil and Chemical Pollution 5:411-449.

Reid, J. B., Evans, P. G. H. and Northridge, S. P. (2003) Atlas of Cetacean distribution in north-west European waters. Peterborough: Joint Nature Conservation Committee (JNCC).

Richardson, W.J., Greene, C.R. Jr., Malme, C.I. and Thomson, D.H. (1995) Marine Mammals and Noise. San Diego: Academic Press.

Robinson, S.P., Lepper, P.A., and Hazelwood, R.A. (2014) Good practice guide for underwater noise measurement. National Measurement Office, Marine Scotland, The Crown Estate. NPL Good Practice Guide No. 133, ISSN: 1368-6550.

Rogers, C.S. (1990) Reponses of coral reefs and reef organisms to sedimentation. Marine Ecology Progress Series, 62, 185 – 202.

Rolland, R.M., Parks, S.E., Hunt, K.E., Castellote, M., Corkeron, P.J., Nowacek, D.P., Wasser, S.K. & Kraus, S.D. (2012) Evidence that ship noise increases stress in right whales. Proceedings of the Royal Society B 279: 2363-2368.

Rouse, S., Hayes, P. and Wilding, T.A., (2020). Commercial fisheries losses arising from interactions with offshore pipelines and other oil and gas infrastructure and activities. ICES Journal of Marine Science, 77,1148-1156.

RPS (2025a) TORNADO FIELD (CONCEPT 1), Drill Cuttings and Muds Dispersion Modelling – Rev 4. GOC389447. 17 June 2025.

RPS (2025b) TORNADO FIELD, Hydrotest Discharge Dispersion Modelling – Rev 2. GOC389447. 13 June 2025.

RPS (2025c) Tornado Field (Concept 2 - OBM) – Drill Cuttings and Muds Dispersion Modelling. GOC389447. June 2025.

RSPB (2024) Birds and Wildlife. Available from: https://www.rspb.org.uk/birds-and-wildlife [Accessed March 2025]

Rust, A.J., Burgess, R.M., Brownawell, B.J. and McElroy, A.E. (2004) Relationship between metabolism and bioaccumulation of benzo[a]pyrene in benthic invertebrates. Environmental Toxicology and Chemistry. 23 (11): 2587 – 2593.

Sabatini, M., Pizzolla, P. and Wilding, C. (2008) Icelandic cyprine (*Arctica islandica*). Marine life information network: Biology and sensitivity key information sub-programme [online]. Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/species/detail/1519 [Accessed March 2025].

Santos, M.B., Clarke, M.R. & Pierce, G.J. (2001a) Assessing the importance of cephalopods in the diets of marine mammals and other top predators: problems and solutions. Fisheries Research 52, 121-139.

Santos, M.B., Pierce, G.J., Boyle, P.R., Reid, R.J., Ross, H.M., Patterson, I.A.P., Kinze, C.C., Tougaard, S., Lick, R., Piatkowski, U. & Hernández-García, V. (1999). Stomach contents of sperm whales (*Physeter macrocephalus*) stranded in the North Sea 1990-1996. Marine Ecology Progress Series 183: 281-294.

Santos, M.B., Pierce, G.J., Garcia Hartmann, M., Smeenk, C., Addink, M.J., Kuiken, T., Reid, R.J., Patterson, I.A.P., Lordan, C., Rogan, E. & Mente, E. (2002). Additional notes on stomach contents of

sperm whales (*Physeter macrocephalus*) stranded in the NE Atlantic. Journal of the Marine Biological Association of the United Kingdom 82: 501-507.

Santos, M.B., Pierce, G.J., Herman, J., López, A., Guerra, A., Mente, E. & Clarke, M.R. (2001b) Feeding ecology of Cuvier's beaked whale (Ziphius cavirostris): a review with new information on the diet of this species. Journal of the Marine Biological Association of the United Kingdom 81, 687-694.

Sarnocińska, J., Teilmann, J., Dalgaard Balle, J., Beest, F., Delfosse, M., and Tougaard, J. (2020) Harbor Porpoise (Phocoena phocoena) Reaction to a 3D Seismic Airgun Survey in the North Sea, Frontiers in Marine Science, 6:824.

Saunders, P.M., 1990. Cold outflow from the Faroe Bank Channel. Journal of Physical Oceanography 20, pp. 28-43.

SCANS-II (2008) Small Cetaceans in the European Atlantic and North Sea. ASCOBANS Advisory Committee Meeting. Report No. LIFE04NAT/GB/000245. Cited in DECC (2009).

SCOS (2005) Scientific advice on matters related to the management of seal populations: 2005. Special Committee on Seals. Available from: https://www.smru.st-andrews.ac.uk/research-policy/scos/ [Accessed March 2025].

SCOS (2014) Scientific advice on matters related to the management of seal populations: 2014. Special Committee on Seals. Available from: https://www.smru.st-andrews.ac.uk/research-policy/scos/ [Accessed March 2025].

SCOS (2021) Scientific Advice on Matters Related to the Management of Seal Populations: 2021. Available from: www.smru.st-andrews.ac.uk/files/2022/08/SCOS-2021.pdf [Accessed March 2025].

SCOS (2022a) Scientific Advice on Matters Related to the Management of Seal Populations: 2022. Available from: http://www.smru.st-andrews.ac.uk/files/2023/09/SCOS-2022.pdf [Accessed March 2025].

SCOS (2022b). August Seal Counts – England. [Online]. Available from: http://www.smru.st-andrews.ac.uk/scos/scos-data/august-seal-counts/august-seal-counts-england/ [Accessed April 2025].

Scottish Government (2017) Guidance on applying a waste hierarchy under Section 34 of the Environmental Protection Act 1990. Published 29 November 2017. Available from: https://www.gov.scot/publications/guidance-applying-waste-hierarchy/documents/ [Accessed July 2025]

Scottish Government (2025) Offshore Marine Protected Areas - fisheries management measures: supporting guidance on coordinates and restrictions [Online] Available from: https://www.gov.scot/publications/supporting-guidance-fisheries-management-measures-offshore-marine-protected-areas-coordinates-restrictions/ [Accessed September 2025]

Seafood Shetland (2025) Mussels [Online] Available from: https://seafoodshetland.co.uk/mussels-3/ [Accessed March 2025]

SERPENT (2009a) Rosebank report including Cambo sediment analysis. SERPENT, June and July. 2009.

SERPENT (2009b) Rosebank North visit report.

Seuront, L. (2010) *Fractals and Multifractals in Ecology and Aquatic Science.* Florida, USA: CRC Press.

SGMD (2024) Fishing Effort and Quantity and Value of Landings by ICES Rectangle. [Online] Available at: https://www.gov.scot/collections/sea-fisheries-statistics/ [Accessed March 2025].

Shelton R.G.J., Turrell W.R., Macdonald A., McLaren I.S., and Nicoll N.T. (1997). Records of post-smolt Atlantic salmon, Salmo salar L., in the Faroe-Shetland Channel in June 1996. Fisheries Research, 31, 159 - 162.

Siccar Point Energy (2021) Cambo Oil Field, UKCS Blocks 204/4a, 204/5a, 204/9a and 204/10a - Environmental Statement – D/4261/2021

Sims, D.W., Southall, E.J., Richardson, A.J., Reid, P.C. and Metcalfe, J.D. (2003). Seasonal movements and behaviour of basking sharks from archival tagging: no evidence of winter hibernation. Marine Ecology Progress Series, 248, Pages 187-196.

Slabbekoorn, H., Bouton, N., van Opzeeland, I., Coers, A., ten Cate, C. and Popper, A. N. (2010) A noisy spring: the impact of globally rising underwater sound levels on fish. Trends in Ecology and Evolution, 25: 419-427.

Smit, M.G.D., Bechmann, R.K., Hendriks, A.J., Skadsheim, A., Larsen, B.K., Baussant, T., Sanni, S. (2009) Relating effect levels to whole-organism effects using species sensitivity distributions: A pilot study for marine species exposed to oil. Environmental Toxicology and Chemistry 28(5):1104-9.

SNH (2009) Whales, Dolphins & Porpoises. Available from: http://www.snh.org.uk/pdfs/publications/naturallyscottish/whales.pdf [Accessed March 2025].

SNH (2014) Priority Marine Features in Scotland's Seas. Available from: http://www.snh.gov.uk/docs/A1327320.pdf [Accessed March 2025].

SNH (2021) Otter. Available from https://www.nature.scot/plants-animals-and-fungi/mammals/land-mammals/otter [Accessed March 2025].

SNH and HES (2018) Environmental Impact Assessment Handbook - Guidance for competent authorities, consultation bodies, and others involved in the Environmental Impact Assessment process in Scotland. Version 5, April 2018. Scottish Natural Heritage and Historic Environment Scotland.

SOTEAG (2015) Ornithological Monitoring. Available from: https://www.soteag.org.uk/environmental-monitoring/ornithological-monitoring/ [Accessed March 2025].

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene Jr., C.R., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A. and Tyack, P.L. (2007) Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals, 33: 411–521.

Southall, B.L., Finneran, J.J., Reichmuth, C., Nachtigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P., and Tyack, P.L., (2019) Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. Aquatic Mammals, 45(2), 125-232

Spaulding, M.L. (1982) User's manual for a simple gas blowout plume model. Continental Shelf Institute, Trondheim, Norway.

SSMEI (2013) A Marine Spatial Plan for the Shetland Islands, Fourth edition. Edinburgh: Scottish Government and Scottish Sustainable Marine Environment Initiative. Available from: https://www.gov.scot/seag/seagDocs/SEA-00818/13822.pdf [Accessed March 2025].

Stein, J.E., Oliver, J.E. and Schwaab, E.C. (2010) Metabolism of PAHs by teleost fish, scientific findings Memorandum to Eric Schwaab, Assisstant Administrator for Fisheries, National Marine Fisheries Service and John Oliver, Deputy Assisstant Administrator for Operations, National Marine Fisheries Service, from /s/ John E. Stein, Deputy Director Northwest Fisheries Science Center, NMFS. [Online] Available at: https://repository.library.noaa.gov/view/noaa/114 [Accessed May 2025].

Stephenson, J. R., Gingerich, A.J., Brown, R.S., Pflugrath, B.D., Deng, Z., Carlson, T.J., Langeslay, M.J., Ahmann, M.L., Johnson, R.L., Seaburg, A.G. (2010) Assessing barotrauma in neutrally and negatively buoyant juvenile salmonids exposed to simulated hydro-turbine passage using a mobile aquatic barotrauma laboratory. Fisheries Research, Volume 106, Issue 3, pp 271-278.

Stoker, M.S. (1997). Submarine debris flows on a glacially-influenced basin plain, FaroeShetland Channel. In: T.A. Davies et al. (Eds.), Glaciated Continental Margins - An Atlas of Acoustic Images. Chapman and Hall, London, pp. 126-127.

Stoker, M.S. and Holmes, R. (1991). Submarine end-moraines as indicators of Pleistocene ice limits off northwest Britain. Journal of the Geological Society, London 148, 431-434

Stoker, M.S., Akhurst, M.C., Howe, J.A. and Stow, D.A.V. (1998). Sediment drifts and contourites on the continental margin off northwest Britain. Sedimentary Geology 115, 33-51.

Stoker, M.S., Harland, R. and Graham, D.K. (1991). Glacially influenced basin plain sedimentation in the southern Faroe-Shetland Channel, northwest United Kingdom continental margin. Marine Geology 100, 185-199.

Stone, C.J. (1998) Cetacean observations during seismic surveys in 1997. Peterborough: Joint Nature Conservation Committee, Report No. 278.

Subacoustech (2025) Vertical Seismic Profiling – UCKS Block 204/13b (West of Shetland): Underwater Noise Modelling Assessment. 4th April 2025. Report No. P421R0102

Suchanek, T.H., (1993) Oil impacts on marine invertebrate populations and communities. *American Zoologist,* 33, 510-523.

Swift, R.J., Hastie, G.D., Barton, T.R., Clark, C.W., Tasker, M.L and Thompson, P.M. (2002) Studying the Distribution and Behaviour of Cetaceans in the Northeast Atlantic using Passive Acoustic Techniques. Report for the Atlantic Frontier Environmental Network (AFEN).

Takeshita, R., Sullivan, L., Smith, C., Collier, T., Hall, A., Brosnan, T., Rowles, T., Schwacke, L. 2017. The Deepwater Horizon oil spill marine mammal injury assessment. Endangered Species Research, 33, 95-106

Tangye, T., Albrecht, J. & Stirling, D. (2022). Faroe-Shetland Sponge Belt MPA Survey Report (1121S). JNCC-MSS Partnership Report No. 8. JNCC, Peterborough, ISSN 2634-2081.

Taylor, A.C. (1976). Burrowing behaviour and anaerobiosis in the bivalve Arctica islandica. Journal of the Marine Biological Association, 56:95-109.

Tesch F.W. (2003). The Eel (3rd edition, Thorpe, J.E. ed), Blackwell Science, Oxford, pp 408. Cited in Malcolm et al 2010.

Thompson, P.M., Brookes, K.L., Cheney, B. and Graham, I.M. (2013) Assessing the Potential Impact of Oil and Gas Exploration Operations on Cetaceans in the Moray Firth. Final Report for DECC, Scottish Government, COWRIE and Oil & Gas UK. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/261936/Moray_Firth_Final_Report_-_November_2013.pdf#page=102 [Accessed March 2025].

Thompson, P.M., Cheney, B., Ingram, S., Stevick, P., Wilson, B., Hammond, P.S. (Eds) (2011) Distribution, abundance and population structure of bottlenose dolphins in Scottish waters. Scottish Government and Scottish Natural Heritage funded report. Scottish Natural Heritage Commissioned Report No. 354.

Thorarinsdóttir, C.G. and Einarsson, S.T. (1996) Distribution, abundance, population structure and mean yield of the Ocean quahog, Arctica islandica. Journal of Shellfish Research, 15: 729-733.

Tillin, H. & Tyler-Walters, H., (2014). Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities. Phase 2 Report – Literature review and sensitivity assessments for ecological groups for circalittoral and offshore Level 5 biotopes. JNCC Report No. 512B, 260 pp. Available from https://www.marlin.ac.uk/publications

Tillin, H. and Tyler-Walters, H. (2013) Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities. Phase 1 Report: Rationale and proposed ecological groupings for Level 5 biotopes against which sensitivity assessments would be best undertaken. Peterborough: Joint Nature Conservation Committee. Report No. 512A Available from: http://jncc.defra.gov.uk/PDF/Report%20512-A_phase1_web.pdf [Accessed May 2025].

Tillin, H.M., Hull, S.C. & Tyler-Walters, H. (2010). Development of a sensitivity matrix (pressures-MCZ/MPA features). Report to the Department of the Environment, Food and Rural Affairs from ABPmer, Southampton and the Marine Life Information Network (MarLIN) Plymouth: Marine Biological Association of the UK. Defra Contract no. MB0102 Task 3A, Report no. 22. London, 145 pp.

Tozer, B, Sandwell, D. T., Smith, W. H. F., Olson, C., Beale, J. R., & Wessel, P. (2019) Global bathymetry and topography at 15 arc sec: SRTM15+. Earth and Space Science. 6.

Tremlett, C. J., Morley, N., & Wilson, L. J. (2024) UK Seabird Colony Counts in 2023 Following the 2021/22 Outbreak of Highly Pathogenic Avian Influenza. RSPB Research Report 76. RSPB, Sandy.

Trudel, B.K., R.C. Belore, B.J. Jessiman and S.L., Ross. (1989) A Mico-computer Based Spill Impact Assessment System for Untreated and Chemically Dispersed Oil Spills in the U.S. Gulf of Mexico. 1989 International Oil Spill Conference.

Turnpenny, W. H. and Nedwell J. R. (1994) The Effects on Marine Fish, Diving Mammals and Birds of Underwater Sound Generated by Seismic Surveys. Southampton: Fawley Aquatic Research Laboratories Ltd / Subacoustech Ltd.

Turrell, W.R., Slesser, G., Adams, R.D., Payne, R. & Gillibrand, P.A. (1999) Decadal variability in the composition of Faroe Shetland Channel bottom water. Deep-Sea Research Part I-Oceanographic Research Papers, vol. 46, no. 1, pp. 1-25. https://doi.org/10.1016/S0967-0637(98)00067-3

Tuvikene, A. (1995) Responses of fish to polycyclic aromatic hydrocarbons (PAHs). Annales Zooligici Fennici. 32 (3): 295-309.

Tyack, P. L. and Clark, C.W. (2000) Communication and acoustic behavior of dolphins and whales. In Hearing by whales and dolphins. Springer New York, pp.156-224.

Tyler-Walters, H. and Sabatini, M. (2017) *Arctica islandica* Icelandic cyprine. In TylerWalters H. and Hiscock K. (eds) Marine life information network: Biology and sensitivity key information reviews [online]. Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/species/detail/1519 [Accessed March 2025].

Tyler-Walters, H., James, B. (eds.), Wilding, C., Durkin, O., Lacey, C., Philpott, E., Adams, L., Chaniotis, P.D., Wilkes, P.T.V., Seeley, R., Neilly, M., Dargie, J. and Crawford-Avis, O.T. (2012) MPA search feature descriptions catalogue. A report produced by MarLIN (Marine Life Information Network), SMRU Ltd., Scottish Natural Heritage and the Joint Nature Conservation Committee, for the Scottish Marine Protected Areas Project.

Tyler-Walters, H., Jamesm B., Carruthers, M. (eds.), Wilding, C., Durkin, O., Lacey, C., Philpott, E., Adams, L., Chaniotis, P.D., Wilkes, P.T.V., Seeley, R., Neilly, M., Dargie, J. and Crawford-Avis, O.T. (2016) Descriptions of Scottish Priority Marine Features (PMFs). Scottish Natural Heritage, Report No. 406.

UK Government (2025). United Kingdom of Great Britain and Northern Ireland's 2035 Nationally Determined Contribution Presented to Parliament by the Secretary of State for Energy Security and Ne Zero by Command of His Majesty January 2025. 74 pp. [Online]. Available from: https://unfccc.int/sites/default/files/2025-01/UK%27s%202035%20NDC%20ICTU.pdf [Accessed October 2025].

UKHO (2024) ADMIRALITY Marine Data Portal [Online] Available at: https://datahub.admiralty.co.uk/portal/apps/sites/?_gl=1*1j24oc6*_ga*MjY0MTE4NjAxLjE2ODg3NDQwODg.*_ga_8PTW8GJL1R*MTY5MjExMDgzMC44LjAuMTY5MjExMDgzMC4wLjAuMA..#/marine-data-portal/items/c5afebefad5c49008b8ffc36523a953a [Accessed March 2025]

United Nations (2025) 17 Goals of Sustainable Development. [Online] Available from: https://sdgs.un.org/goals [Accessed November 2025]

United Nations Environment Programme (UNEP) (2024). Emissions Gap Report 2024: No more hot air … please! With a massive gap between rhetoric and reality, countries draft new climate commitments. Nairobi. Available from: Emissions Gap Report 2024 | UNEP - UN Environment Programme.

United Nations Framework Convention on Climate Change (UNFCCC) (2024) Nationally determined contributions under the Paris Agreement. Synthesis report by the secretariat. https://unfccc.int/documents/641792.

United Nations Framework Convention on Climate Change (UNFCCC). (2016). The Paris Agreement. Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T. I. A. S. No 16-1104, 3156 U. N. T. S.

United Nations Framework Convention on Climate Change (UNFCCC). (2021). The Glasgow Climate Pact – Key Outcomes from COP26. [Online]. Available from: https://unfccc.int/process-and-meetings/the-paris-agreement/the-glasgow-climate-pact-key-outcomes-from-cop26 [Accessed October 2025].

United Nations Framework Convention on Climate Change (UNFCCC). (2022). Sharm el-Sheikh Climate Change Conference - November 2022. [Online]. Available from: https://unfccc.int/node/568190 [Accessed October 2025].

United Nations Framework Convention on Climate Change (UNFCCC). (2023). UN Climate Change Conference - United Arab Emirates. [Online]. Available from: https://unfccc.int/cop28 [Accessed October 2025].

Vad, J., Kazanidis, G., Henry, L., Jones, D., Tendal, O. S., Christiansen, S., Henry, T. B., and Roberts, J., M. (2018). Potential Impacts of Offshore Oil and Gas Activities on Deep-Sea Sponges and the Habitats They Form. In: Sheppard, C., ed. 2021. Advances in Marine Biology (Chpt 2, Vol 79). London: Academic Press.

Veirs, S., Veirs, V. & Wood, J.D. (2016) Ship noise extends to frequencies used for echolocation by endangered killer whales. Peer J4: e1657.

Vik, E.A., Blytt, L.D., Stang, P., Henninge, L.B. and Kjønnø,O (2014). Characterising thermal treated OBM drill cuttings. Sampling, characterisation, environmental analysis and risk assessment of offshore discharges. Prepared for the Norwegian Oil and Gas Association.

Vikebø, F.B., Rønningen, P., Lien, V.S., Meier, S., Reed, M., Ådlandsvik, B., Kristiansen, T. (2013) Spatio-temporal overlap of oil spills and early life stages of fish. ICES Journal of Marine Science, October 14, 2013, doi: 10.1093/icesjms/fst131.

Visit Shetland (2021) Visit Shetland. Available from: http://visit.shetland.org/ [Accessed March 2025].

Waggitt, J.J., Evans, P.G.H., Andrade, J. et al (2019). Distribution maps of cetacean and seabird populations in the North-East Atlantic. Journal of Applied Ecology, 57, 253-269.

Webb, A., Elgie, M., Irwin, C., Pollock, C. and Barton, C. (2016) Sensitivity of offshore seabird concentrations to oil pollution around the United Kingdom: Report to Oil & Gas UK. Available from: http://jncc.defra.gov.uk/page-7373 [Accessed March 2025]

Weir, C.R., Pollock, C., Cronin, C. and Taylor, S. (2001) Cetaceans of the Atlantic Frontier, north and west of Scotland. Continental Shelf Research, 21: 1047-1071.

Witt M.J., Hardy T., Johnson L., McClellan C.M., Pikesley S.K., Ranger S., Richardson P.B., Solandt J., Speedie C., Williams R. and Godley B.J. (2012) Basking sharks in the northeast Atlantic: spatio-temporal trends from sightings in UK waters. Marine Ecology Progress Series, 459, Pages 121-134.

WMO (World Meteorological Organization (WMO) (2025) State of the Global Climate 2024. Available from: https://library.wmo.int/records/item/69455-state-of-the-global-climate-2024 [Accessed August 2025]

Woodward, I., Thaxter, C., Owen, E., Aonghais, S., Cook (2019) Desk-based revision of seabird foraging ranges used for HRA screening, BTO Research Report No. 724, December 2019.

World Meteorological Organization (WMO) (2019). The Global Climate in 2015–2019 / World Meteorological Organization. [Online]. Available from: https://library.wmo.int/index.php?lvl=notice_display&id=21522#.Xd7FaOhKjcs [Accessed July 2025].

World Meteorological Organization (WMO) (2023). WMO Greenhouse Gas Bulletin. [Online]. Available from: https://wmo.int/resources/publications/wmo-greenhouse-gas-bulletin-no-19 [Accessed July 2025].

World Nuclear Association (WNA). 2025. Heat Values of Various Fuels. [Online]. Available from: https://world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels [Accessed November 2025]

Wyatt, R. (2008) Review of existing data on underwater sounds produced by the oil and gas industry. Seiche Measurements Limited. Report No. S186.

Wynn, R.B., Masson, D.G. and Bett, B.J. (2002). Hydrodynamic significance of variable ripple morphology across deep-water barchan dunes in the Faroe-Shetland Channel. *Marine Geology,* 192, 309-319.

Yapa, P.D., Zheng, L., and Chen, F.H. (2001) A model for deepwater oil/gas blowouts. Marine Pollution Bulletin 43: 234–241.

Zheng , L. and Yapa, P.D. (2002) Modeling gas dissolution in deepwater oil/gas spills. J. Mar. Syst. 31(4):299–309.

Zheng, L., Yapa, P.D. and Chen, F.H. (2003) A model for simulating deepwater oil and gas blowouts – Part I: Theory and model formulation. J. Hydraul. Res. 41(4):339–351.

# 16 Glossary

| Term | Description |
|---|---|
| Atmospheric Emissions | A collective term for gases and particulates released to the atmosphere. |
| Attenuation Loss | The physical processes in the sea that distort the mathematical spreading laws relating to sound. |
| Automatic Identification System | A marine navigation safety system that uses transponders on ships and shore-based stations to automatically transmit and receive real-time data about a vessel's identity, position, course, and speed to aid collision avoidance and vessel tracking. |
| Barrel of Oil Equivalent | A unit of energy equating to the approximate energy released by burning one barrel of crude oil. |
| Bioaccumulation | The process where a substance, such as a pesticide or heavy metal, builds up in the tissues of an individual organism over its lifetime because the rate of intake and storage (from the environment, food, and water) is faster than the rate at which the organism can break it down and excrete it. |
| Blowout | A blowout occurs when gas, oil or saltwater escapes in an uncontrolled manner from a well. |
| Blowout Preventer | A high-pressure safety valve or series of valves installed at the wellhead that is designed to seal the wellbore to prevent uncontrolled flow of oil, gas, or drilling fluid from the well |
| Bottom Hole Assembly | The section of the drill string located at the very bottom of the wellbore, immediately above the drill bit, which contains specialised tools like measurement and logging devices, motors, and stabilisers to control the direction and performance of the drilling operation. |
| Bumper Bar | A tool used to nudge / clear objects such as boulders from the pipeline installation corridor. |
| Carbon Budget | Legally binding milestone of anthropogenic $CO_2$ emissions proposed every 5 years to achieve Net Zero targets. |
| Casing | Steel pipe cemented in place during the construction process to stabilise the wellbore. |
| Carbon Dioxide Equivalent | A metric used to compare the climate impact of different greenhouse gases by converting the amount of each gas into the amount of carbon dioxide that would have the equivalent global warming potential. |
| Conductor | The casing string that is usually put into the well first to prevent the sides of the hole from caving into the wellbore. |
| Conductor Anchor Nodes | A large-diameter steel can driven into the seabed, used to securely anchor subsea structures or act as a foundation for conductors. |
| Cone Penetration Test | An in-situ geotechnical investigation method where an instrumented cone tip is pushed into the seabed at a constant rate, measuring the resistance and pore water pressure to determine the seabed's stratigraphy and engineering properties. |
| Cumulative Weighted Sound Exposure Level | An advanced measure of the total received acoustic energy over a specified period where the sound levels are weighted according to the hearing sensitivity of the specific marine species being studied. |
| Cuttings | Rock chips produced by chipping and crushing action of the drill bit. |
| Decibel | Denoted by dB, a logarithmic unit used to express the ratio of two values of a physical quantity used to measure the intensity of sound. |
| Decibels relative to one micro-Pascal | Denoted by dB re 1µPa @ 1 m, a specialized unit of measurement for underwater acoustics that defines the sound pressure level by comparing the measured acoustic pressure to a standard reference pressure of one micropascal. |

| Term | Description |
|---|---|
| Degrees Latitude | The angular distance, measured in degrees North or South of the Equator, used as the primary geographical coordinate to specify the north-south position of a point on the Earth's surface |
| Degrees Longitude | The angular distance, measured in degrees East or West of the Prime Meridian (Greenwich, UK), used as the primary geographical coordinate to specify the east-west position of a point on the Earth's surface. |
| Demersal | Organisms (primarily fish like cod or haddock) that live on or near the seabed (the benthic zone) and often feed on benthic invertebrates, contrasting with organisms that live entirely in the open water. |
| Drill Bit | The cutting tool at the very end of the drill string that rotates to grind, shear, or crush rock, creating the wellbore. |
| Drill String | The entire length of connected steel pipe, including the drill pipe, drill collars, and bottom hole assembly, that rotates the drill bit and provides a conduit for drilling fluid from the drilling rig to the bottom of the wellbore. |
| Dynamic Positioning | A computer-controlled system that automatically maintains a vessel's heading and position solely by using its own thrusters and propellers, without the need for anchors. |
| Easting | Easting is the distance, measured in meters or kilometres, eastward from a defined north-south line or origin point in a specific coordinate system |
| Effects Range Low | A sediment quality guideline concentration that represents the level below which adverse biological effects are rarely observed. |
| Electrical Flying Lead | A short, flexible cable assembly used subsea to provide a temporary or permanent electrical connection between two pieces of equipment, such as a subsea control module and a distribution unit |
| Emissions Reduction Action Plan | A company's specific strategies, targets, and scheduled activities designed to measure, manage, and significantly reduce greenhouse gas emissions and other atmospheric pollutants across its operations. |
| Environmental Aspect | An element of an organization’s activities, products, or services that can interact with the environment. |
| Environmental Baseline Survey | a systematic collection and analysis of physical, chemical, and biological data in a specific area to establish the existing environmental conditions. |
| Environmental Impact Assessment | A systematic process of evaluating the likely environmental consequences of a proposed project or development, aiming to ensure that environmental considerations are integrated into decision-making. |
| Environmental Impact Identification | A structured, systematic review process used to identify potential environmental hazards, impacts, and risks associated with all phases of a development project or activity. |
| Environmental Statement | The report on the environmental impact assessment for proposed project or development. |
| Epifauna | Benthic organisms that live on the surface of the seabed, either sessile or free moving. |
| European Protected Species | Animal and plant species listed in the Habitats Directive of the European Union, afforded strict legal protection against deliberate capture, injury, killing, or disturbance, and the damage or destruction of their breeding and resting sites |
| Exclusive Economic Zone | The sea zone extending up to 200 nautical miles from a country's coastline, within which the coastal state has special sovereign rights for the exploration and use of marine resources. |
| Far-field | The region of a propagating wave distant enough from the source that the waves behave as planar, and the intensity falls off predictably (e.g., inversely with the square of the distance from the source). |
| Favourable Reference Population | The ideal minimum population size for a species within a given region that is needed to ensure its long-term survival and healthy status, as defined for conservation under the EU Habitats Directive. |

| Term | Description |
|---|---|
| Field | An accumulation of hydrocarbons in the subsurface. Consists of a reservoir in a shape that will trap hydrocarbons and that is covered by an impermeable, sealing rock. |
| Flare | A vent to safely and quickly burn off unwanted or excess combustible gases to the atmosphere. |
| Flow Induced Pulsation | A dynamic phenomenon where unstable flow conditions inside a pipe or component create pressure waves or vibrations that propagate through the system, often leading to noise and mechanical fatigue |
| Flowline End Termination Structure | A subsea structure installed at the end of a flowline, typically containing connections, valves, and manifolding to tie the flowline into another pipeline or a subsea manifold/tree |
| Front-End Engineering Design | The stage in an engineering project where all technical requirements are fully defined and the necessary documentation is prepared to provide a solid foundation for the subsequent detailed design, procurement, and construction phases. |
| Gas Condensate | A low-density mixture of liquid hydrocarbons that separates from natural gas when the reservoir pressure or temperature drops below a certain point (dewpoint) |
| Glass Fibre Reinforced Polymer | A strong, lightweight composite material made from a polymer matrix reinforced with fine fibers of glass. |
| Global Warming Potential | An index that measures how much a specific mass of a greenhouse gas will warm the Earth over a defined time period (usually 100 years) relative to the warming caused by the same mass of carbon dioxide, which is set as the baseline with a GWP of 1. |
| Greenhouse Gas | Any gaseous compound in the atmosphere, such as carbon dioxide, methane, or nitrous oxide, that is capable of absorbing and re-emitting infrared radiation, thereby trapping heat and contributing to the warming of the Earth's surface known as the 'Greenhouse Effect' |
| Habitat Assessment | A survey and evaluation process used to determine the type, quality, condition, and distribution of habitats present in a specific area. |
| Harmonised Mandatory Control Scheme | A regulatory framework established by the OSPAR Commission to protect the marine environment requiring all chemicals used and discharged during offshore oil and gas operations to be tested, risk-assessed, and authorised. |
| High Case hydrocarbon profile | Reflects the high estimate anticipated volume of hydrocarbon production from a two production well scenario (at least P10). |
| High Frequency | A wave or periodic event that repeats a large number of times within a specific period. |
| Hydraulic Flying Lead | A short, flexible hose assembly used subsea to transmit hydraulic power and/or control fluid between components, such as a subsea control module and a tree or manifold. |
| ICES Rectangle | A standard geographical unit defined by the International Council for the Exploration of the Sea used primarily for the reporting and management of fisheries, environmental monitoring, and research within the North Atlantic and adjacent seas, with each rectangle typically measuring 1˚of longitude by 0.5˚of latitude. |
| Intergovernmental Panel on Climate Change (IPCC) | The United Nations body that regularly assesses the scientific basis of climate change, its impacts, future risks, and options for adaptation and mitigation, providing policymakers with comprehensive and authoritative scientific reports. |
| Intermediate-field | The transitional zone where the energy characteristics of the propagating wave shift from the complex, non-propagating dynamics of the near-field to the predictable, planar dynamics of the far-field |

| Term | Description |
|---|---|
| International Union for the Conservation of Nature | A global authority and membership union composed of both governmental and civil society organisations dedicated to addressing the world's most pressing environment and development challenges. |
| IPCC Assessment Report | A comprehensive scientific evaluation of the state of knowledge on climate change, its physical science basis, impacts, adaptation, vulnerability, and options for mitigation, published every five to seven years by the IPCC. |
| Joint Nature Conservation Committee | UK public body that advises the UK Government and the devolved administrations on UK-wide and international nature conservation, providing scientific evidence and data on biodiversity status and trends. |
| Laggan-Tormore Pipeline System | A subsea-to-shore infrastructure that includes flowlines transporting gas condensate from the deepwater Laggan and Tormore fields, West of Shetland, to the Shetland Gas Plant (SGP) for processing. |
| Liquified Natural Gas | Natural gas that has been cooled, turning it into a liquid for easier, safer, and more economical storage and transportation. |
| Low Case hydrocarbon profile | Reflects the low estimate anticipated volume of hydrocarbon production from a two production well scenario (at least P90). |
| Low Frequency | A wave or periodic event that repeats a low number of times within a specific period. |
| Low Toxicity Oil Based Mud | An invert emulsion mud with synthetic oil as the external phase instead of oil |
| Lower Marine Riser Package | The bottom section of the marine drilling riser assembly, which contains key equipment like an annular Blowout Preventer |
| Lowest Astronomical Tide | The lowest predictable water level that can occur under any combination of astronomical conditions (Sun, Moon, and Earth alignment), excluding extreme meteorological effects like storms. |
| Marine Conservation Zone | A type of Marine Protected Area that is designated to protect nationally important, rare, or threatened marine wildlife, habitats, geology, and ecological processes within its boundaries. |
| Marine Drilling Riser | The large-diameter pipe that extends from a drilling vessel to the subsea wellhead, providing a conduit for the drill string, returning drilling fluid, and maintaining pressure control. |
| Marine Mammal Management Units | Specific geographical areas defined by UK conservation bodies to represent distinct population segments of highly mobile marine mammals (i.e. dolphins, seals and porpoises). |
| Marine Protected Area | A clearly defined geographical zone in the sea that receives long-term protection of its marine life, habitats, and cultural heritage. |
| Max Case hydrocarbon profile | Reflects the highest anticipated volume of hydrocarbon production from a three production well scenario (at least P10). The Max case hydrocarbon profile is based on an contingency accelerated production scenario where additional capacity ullage is made available (subject to commercial negotiations) in the GLA flowline system, and the Tornado project can maximise production rates to fill the available ullage by drilling and producing from a third well at Tornado. The availability of ullage to support the Max case is uncertain at this time but has been included as a basis for the EIA as it represents the worst-case scenario in terms of total production volume, and resulting in emissions, albeit at a lower GHG intensity than all other cases. |
| Mid Case hydrocarbon profile | Reflects the best estimated volume of hydrocarbon production from a two production well scenario. |
| Mobile Offshore Drilling Unit | Any vessel or structure, such as a jack-up rig or semi-submersible, capable of engaging in drilling operations for exploring or developing offshore oil and gas reserves. |

| Term | Description |
|---|---|
| Multibeam Echosounder | An advanced sonar system that transmits multiple beams of sound waves in a fan shape perpendicular to the vessel's movement, allowing it to measure and map a wide area of the seafloor simultaneously to create high-resolution, 3D bathymetric maps. |
| National Transmission System | The high-pressure gas pipeline network that transmits natural gas throughout Great Britain, connecting terminals and storage facilities to the regional distribution networks. |
| Nationally Determined Contribution | A country's self-defined national climate action plan under the Paris Agreement, outlining its specific commitments and policies to reduce greenhouse gas emissions. |
| Natural Gas | A naturally occurring mixture of gaseous hydrocarbons, primarily methane, often found in underground reservoirs and used as a major source of energy |
| Nature Conservation Marine Protected Area | A designated site within the UK's marine environment, protected under the Marine and Coastal Access Act 2009, established to conserve nationally important marine flora, fauna, habitats, and geological or geomorphological features. |
| Nautical Mile | A unit used for measuring distances at sea. |
| Near-field | The region of a propagating wave closest to the source where the waves are complex and energy is dominated by non-propagating effects, meaning the intensity relationship is not simple or predictable |
| Nominal bore | A standard, non-exact number used to label the size of a pipe or pipe fitting for easy referencing and consistent sizing |
| North Sea Transition Authority | Previously known as the Oil and Gas Authority (OGA) until March 2022, it is the UK government body responsible for regulating and enabling the effective and responsible development of oil, gas, and carbon storage within the UK Continental Shelf, while driving the transition to net zero. |
| Northing | Northing is the distance, measured in meters or kilometres, northward from a defined east-west line or origin point in a specific coordinate system. |
| Octanol-water partition coefficient | A ratio used to describe how a chemical distributes itself between two immiscible phases, providing a critical indicator of a chemical's potential to bioaccumulate in organisms. |
| Offshore Chemical Notification Scheme | A regulatory system in the UK that manages and controls the use and discharge of all chemicals used by the offshore oil and gas industry, ensuring that they are assessed for their environmental impact before use. |
| Offshore Petroleum Regulator for Environment and Decommissioning | UK Government regulator responsible for regulating the environmental and decommissioning aspects of offshore oil and gas operations and carbon capture and storage in the UK. |
| Oil On Cuttings | The concentration of residual oil or synthetic drilling fluid that remains adsorbed or trapped on the rock fragments (cuttings) after they are brought to the surface during drilling operations. |
| Optical Flying Lead | A short, flexible fibre-optic cable assembly used subsea to transmit data and communication signals between subsea equipment, often connecting a sensor to a subsea control module. |
| OSPAR Commission | An intergovernmental body formed by 15 Governments and the European Union to implement the OSPAR Convention and cooperate on measures to protect the marine environment of the North-East Atlantic Ocean |
| Paris Agreement | Adopted at COP21 in 2015 and requires all major greenhouse gas emitting countries to reduce their emissions. The aim of the Paris Agreement is to restrict global temperature change to well under 2°C above pre-industrial levels and pursue efforts to keep it below 1.5°C. |

| Term | Description |
|---|---|
| Particle Size Analysis | A laboratory technique used to determine the distribution of different sized grains within a sample of sediment, which is crucial for understanding the material's properties. |
| Particle Size Distribution | A fundamental characteristic of any material composed of particles, such as powders, granules, or particles dispersed. It is a statistical description that defines the relative amount of particles present according to their size. |
| Passive Acoustic Monitoring | The technique of using underwater hydrophones or terrestrial microphones to listen to the environment and record sounds of marine species and background marine environments.. |
| Pelagic | The zone of the water column in a sea or ocean that is neither near the shore nor close to the seabed. |
| Permanent Threshold Shift | An irreversible, long-term or permanent reduction in hearing sensitivity caused by exposure to sufficiently loud noise |
| Pipeline End Manifold | A fixed subsea structure installed at the end of a pipeline, which acts as a distribution and connection point, allowing the flow to be directed to multiple flowlines or other subsea facilities. |
| Pipeline Integrity Gauge | A tool sent through a pipeline to perform various tasks such as cleaning, inspecting, or separating different products, ensuring the line's structural integrity and operational efficiency. |
| Plankton | Any aquatic organisms, including tiny plants, animals, and bacteria, that drift in the water column and cannot swim strongly enough to counteract currents, forming the base of most marine and freshwater food webs. |
| Polycyclic Aromatic Hydrocarbons | A group of organic chemical compounds that are naturally present in fossil fuels, a leading indicator to monitor environmental pollutants of this nature. |
| Priority Marine Feature | A habitat or species of particular conservation importance, identified in Scotland, to focus marine nature conservation efforts, guide planning and licensing decisions. |
| Propagating Wave | A wave that is spreading, moving, or being transmitted through a medium or space over time, transferring energy without permanent displacement of the medium itself. |
| Representative Concentration Pathway | A greenhouse gas concentration trajectory adopted by the IPCC for climate modelling, representing a possible future level of carbon dioxide emissions and resulting climate change. |
| Reservoir | The underground formation where oil and gas has accumulated. It consists of a porous rock to hold the oil or gas, and a cap rock that prevents its escape. |
| Root Mean Square Sound Pressure Level | The time-averaged measure of the sound pressure level over a specific duration. |
| Scope 1 Emissions | Greenhouse gas emissions categorised as Scope 1 emissions are those that a company makes directly. |
| Scope 2 Emissions | Greenhouse gas emissions categorised as Scope 2 emissions are those that a company makes indirectly such as the purchase of energy for heating buildings |
| Scope 3 Emissions | Greenhouse gas emissions which include all other indirect emissions that occur in the upstream and downstream activities of an organisation |
| Scottish Fishermen's Federation | A non-profit organization representing the interests of fishermen's associations and fishing companies across Scotland. |
| Shellfish | Any aquatic invertebrate with a shell or shell-like exoskeleton. |
| Sidescan Sonar | An acoustic device towed behind a vessel that transmits sound pulses to the seafloor on both sides, creating a photographic-like, high-resolution image of the seabed surface that highlights variations in texture and features |
| Similarity Profile Analysis (SIMPROF) | A statistical permutation test used in ecology to objectively determine if a set of samples, which are not grouped beforehand, contain any genuine structure or statistically distinct groups. |

| Term | Description |
|---|---|
| Sound Exposure Level | A cumulative measure of the total acoustic energy of a sound event over a given time period. |
| Sound Exposure Level, single strike ($SEL_{ss}$) | The measurement of the total acoustic energy contained within a single, distinct impulsive sound event |
| Sound Pressure Level peak ($SPL_{peak}$) | The highest absolute value of the instantaneous acoustic pressure measured during a sound event. |
| Special Area of Conservation | A protected site designated under the Habitats Directive to protect and conserve specific, threatened habitats (like reefs or saltmarshes) and non-bird species that are considered to be of European importance. |
| Special Protected Area | A protected site designated under the Birds Directive specifically for the conservation of rare, vulnerable, or regularly migrating species of birds and their habitats. |
| Species Distribution Model | A mathematical tool that uses species occurrence data and environmental variables (i.e. temperature and elevation) to predict the geographic area where a species is most likely to be found. |
| Spool | Short segment of rigid pipe with a flange or other connecting fitting at either end and is commonly used to connect flowlines and / or subsea facilities together, e.g. a subsea tree to a subsea manifold. |
| Statutory Nature Conservation Bodies | Public sector organizations in the UK and its devolved nations that advise the government and enforce laws concerning nature and wildlife protection. |
| Sub-bottom Profiler | A geophysical sonar system used to map and image the geological structure of the material below the seafloor, providing detailed cross-sectional views of the shallow layers of sediment and rock. |
| Threshold Shift | A measurable change in an species hearing sensitivity. |
| Total Hydrocarbon Concentration | The sum measurement of all individual hydrocarbon compounds present in a sample. |
| Total Organic Carbon | The amount of carbon found in an organic compound within a sample (e.g., soil or water. |
| Total Organic Matter | A measurement of the organic material in a soil or sediment sample, typically derived using a loss on ignition technique. |
| Total Suspended Solids | A measurement of the dry weight of solid particles (i.e. sediment, organic matter) that remain suspended in a water sample. |
| Transboundary line | The officially established line separating the Exclusive Economic Zones or Continental Shelves of two adjacent or opposing countries in a shared sea area, such as the North Sea. |
| True Vertical Depth Sub Sea | The vertical distance measured from a fixed reference point down to a specific point within the wellbore. |
| United Kingdom Continental Shelf (UKCS) | The United Kingdom Continental Shelf is the area of the continental shelf over which the United Kingdom exercises sovereign rights for the purpose of exploring it and exploiting its natural resources, primarily oil and gas. |
| UKCS Block | Sub-division of territorial seas for the purpose of licensing to a company or group of companies for exploration and production rights. Each block has a standard size of 10 minutes of Latitude by 12 minutes of Longitude, ~200 – 250 $km^2$. |
| Umbilical End Termination | A subsea structure installed at the end of an umbilical, which functions as the mechanical, electrical, and hydraulic connection point to link the umbilical to a subsea tree or manifold. |
| Vertical Seismic Profile | A high-resolution geophysical well logging technique using sensors at various depths to record seismic waves generated by a source at the surface. |
| Volatile Organic Compounds | A large group of carbon-containing chemicals that easily become vapours or gases at room temperature that largely contribute to air pollution, smog formation, and have adverse effects on human health. |

| Term | Description |
|---|---|
| Water Based Mud | A drilling fluid that uses water as the continuous phase, mixed with various clays, polymers, and chemical additives to control well pressure, cool and lubricate the drill bit, and carry rock cuttings to the surface |
| Wellbore | The drilled hole that extends from the surface or seabed into the earth, used to access and produce hydrocarbons from a subsurface reservoir. |
| Xmas Tree | A complex arrangement of valves, spools, and fittings installed at the wellhead of an oil or gas well to control the flow of fluids from the wellbore, manage pressure, and allow access for monitoring and intervention |
| Zooplankton | The animal components of the plankton community, consisting mostly of tiny crustaceans, protozoans, and the eggs and larvae of larger animals, which feed on phytoplankton and are themselves prey for fish and larger animals |

# Appendix A: Legislation and Marine Policy

## A.1 Applicable Environmental Legislation

Table A.1 provides an overview of key environmental legislation pertinent to the proposed Tornado Development.

**Table A.1. Key Legislation Pertinent to the Proposed Tornado Development**

| Legislation | Summary of Requirements | Relevance to Tornado Development |
|---|---|---|
| The Petroleum Act 1998 | The Petroleum Act 1998 vests all rights to the UK's petroleum resources in the Crown and provides the NSTA with the power to grant licences that confer exclusive rights to 'search and bore for and get' petroleum. The Act provides the legislative basis for the OGA Strategy (OGA, 2020) and the requirement for the NSTA and industry to act in accordance with the Strategy, which sets out how, in practice, the principal objective should be achieved by the NSTA and industry. It is supplemented by the Energy Act 2016, the Infrastructure Act 2015 and various environmental and health and safety legislative provisions. | The Tornado discovery sits within Licence P.2403, which is jointly held by Ithaca (50%) and Adura Operations Limited (50%). The proposed Tornado Development concept has been selected and defined with consideration to the central obligation of the OGA Strategy (refer to Section 2). Ithaca is operator on behalf of the Joint Venture and will ensure all consents and permits required for the Tornado Development will be in place prior to the commencement of operations offshore. |
| The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020 and associated guidance dated July 2021 | There is a mandatory requirement for an EIA and the application for consent must be supported by an ES where the development falls within the scope of a Schedule 1 project, namely where the extraction of oil and natural gas for commercial purposes exceeds 500 tonnes per day in the case of oil and 500,000 cubic metres per day in the case of natural gas and/or where the project involves a pipeline with a diameter of more than 800 mm and a length of more than 40 km. | The Tornado Development meets the criteria for a mandatory ES as Tornado production rates are anticipated to peak at 9,462,562 cubic metres of gas per day and 619.1 tonnes of condensate per day (Max case, based on a three well development scenario). The production pipeline is also over 40 km in length. |
| The Offshore Chemicals Regulations 2002 (as amended) | These regulations implement OSPAR Decision 2000/2 and a number of subsidiary OSPAR Recommendations and Agreements relating to the adoption of a harmonised mandatory control system for the use and discharge of offshore chemicals. All activities that involve the use and/or discharge of chemicals during the course of offshore operations require a Chemical Permit issued under the regulations | Applications for Chemical Permits will be made via the DESNZ UK Energy Portal in advance of the proposed Tornado drilling operations, pipeline operations, well intervention (if applicable) and plug and abandonment activities commencing. |

| Legislation | Summary of Requirements | Relevance to Tornado Development |
|---|---|---|
| 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'. | When drilling through the pay zone with WBM, it is anticipated that the drill cuttings and muds may contain residues of reservoir hydrocarbons. During the well test, formation water potentially contaminated with residual reservoir hydrocarbons may also be discharged to sea. An application for an Oil Discharge Permit will therefore be made via the DESNZ UK Energy Portal in advance of the proposed Tornado drilling operations commencing. Any produced water generated during processing of the Tornado fluids will be disposed at the SGP via the existing produced water system and is therefore outside of the scope of this ES. |
| 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. | Applications for Consent to Locate permits will be made via the DESNZ UK Energy Portal in advance of the proposed Tornado drilling operations commencing and installation of the Tornado subsea infrastructure and pipelines. |
| The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (as amended) | These Regulations require consent for geological surveys related to oil and gas activities. In addition, under these Regulations, it is the responsibility of the Competent Authority (OPRED) to make an Appropriate Assessment of the implications of a plan, programme or project, alone or in combination, on a Special Area of Conservation (SAC) or Special Protection Area (SPA) in view of the site's conservation objectives and the overall integrity of the site. | An application for a Geological Survey Consent will be made via the DESNZ UK Energy Portal in advance of a VSP survey being conducted. |
| The Conservation of Offshore Marine Habitats and Species Regulations 2017 | These Regulations implement the species protection requirements of the Habitats and Birds Directives offshore (more than 12 nautical miles from the coast). The Regulations also include provisions for the designation and protection of areas that host important habitats and species in the offshore marine area (i.e. SACs and SPAs). Part 5 provides powers to OPRED to issue licences for specific activities that could result in the injury or disturbance of European Protected Species (EPS injury or disturbance licences) and the potential to issue wild birds licences (providing certain licensing tests are met). | This ES has concluded that the Tornado Development activities will not kill or injure EPS, or deliberately disturb EPS in such a way as to be likely to impair their ability to survive, breed, or rear or nurture their young, or significantly affect the local distribution or abundance of EPS. |

| Legislation | Summary of Requirements | Relevance to Tornado Development |
|---|---|---|
| The Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation) Regulations 1998 (as amended) | These Regulations require that every offshore installation and oil-handling facility must have an approved oil pollution emergency plan (OPEP) in place, 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). | Approved OPEPs will be in place for all lifecycle phases of the Tornado Development in advance of operations commencing offshore. |
| The Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations 2015 | These Regulations aim to reduce the risks from major accident hazards to the health and safety of the workforce employed on offshore installations or in connected activities. The Regulations also aim to increase the protection of the marine environment and coastal economies against pollution and ensure improved response mechanisms in the event of such an incident | The risk of a major environmental incident occurring from the Tornado Development has been identified and its environmental consequence assessed in Section 11. |
| The Climate Change Act 2008 (as amended) | The Climate Change Act (2008) establishes a legally binding target for the UK to reduce greenhouse gas (GHG) emissions by at least 80% by 2050 from 1990 levels. In 2019 this target was revised with the UK planning to reduce all GHG emissions to net zero by 2050. The Act also provides a system of carbon budgeting, to help the UK meet its targets through a series of five-year carbon budgets. | The potentially significant effects on climate from GHG emissions generated by the proposed Tornado Development are assessed in Section 9. The GHG emissions have been evaluated in the context of a global baseline scenario of GHGs, with consideration given to the impact the emissions will have on global climate change agreements, UK carbon policies and targets and associated emissions reduction pathways. The assessment has been undertaken with reference to the new DESNZ supplementary guidance for assessing the effects of downstream Scope 3 emissions on climate from offshore oil and gas projects (DESNZ, 2025), published following the Finch judgment, 2024 and the Jackdaw / Rosebank judgment, 2025. |
| The Offshore Petroleum Licensing (Offshore Safety Directive) Regulations 2015 | These Regulations introduce the specific licensing requirements of the EU Offshore Safety Directive. 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. | Ithaca will be the appointed Well and Pipeline Operator for the Tornado Development on behalf of the Joint Venture (licensees), subject to approval by the NSTA. |

| Legislation | Summary of Requirements | Relevance to Tornado Development |
|---|---|---|
| Marine and Coastal Access Act 2009 (as amended) / The Marine (Scotland) Act 2010 | The Marine (Scotland) Act 2010 and Marine and Coastal Access Act 2009 (known as the 'Marine Acts') established a new legislative and management framework for the marine environment, allowing the competing demands on the sea to be managed in a sustainable way across all of Scotland's seas. Marine planning matters in Scotland's inshore waters are governed by the Marine (Scotland) Act 2010, and by the Marine and Coastal Access Act 2009 for Scotland's offshore waters. The Acts also define powers to establish marine protected areas to protect natural and cultural marine features | The proposed Tornado Development, as described in this ES, has been assessed against all relevant Scottish National Marine Plan objectives and policies, as well as relevant policies in The Shetland Islands Regional Marine Plan, to confirm that the Project will not adversely impact them (refer to Sections A.2 and A.3 below). Under Section 126 of the Marine and Coastal Access Act (2009), given that approximately 18 km of the proposed Tornado pipeline route is located within the Faroe-Shetland Sponge Belt NCMPA, the ES includes information to enable OPRED (as the Competent Authority) to determine that there is no significant risk that the Project will hinder the achievement of the conservation objectives stated for the NCMPA (refer to Section 7). |
| OSPAR Recommendation 2003/5 to Promote the Use and Implementation of Environmental Management Systems by the Offshore Industry | In line with the convention and reporting requirements, all operators controlling the operation of offshore installations on the UKCS should have in place an independently verified environmental management system (EMS) designed to:<br>• Achieve the general objectives of the OSPAR Offshore Strategy;<br>• 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<br>• Maintain continual improvement in environmental performance. | The Tornado field will be developed in accordance with Ithaca's EMS, which is certified to ISO 14001 (refer to Section 13). |
| 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, the Tornado field will be decommissioned in accordance with the requirements of the prevailing UK and international law (refer to Section 3.6). |

| Legislation | Summary of Requirements | Relevance to Tornado Development |
|---|---|---|
| The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) | The MARPOL Convention is the main international convention covering prevention of pollution of the marine environment by ships. It is a combination of two treaties adopted in 1973 and 1978 respectively and updated by amendments through the years.<br>The Convention is made up of six annexes:<br>• Annex I – sets out regulations regarding the discharge of oil into the sea and requires ships to have efficient oil separation and removal equipment onboard (transposed into UK legislation through the Merchant Shipping (Prevention of Oil Pollution) Regulations 2019 ( as amended) and Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulation 2005 as amended;<br>• Annex II – addresses the prevention of pollution by noxious liquid substances carried in bulk on ships (transposed into UK legislation through The Merchant Shipping (Dangerous or Noxious Liquid Substances in Bulk) Regulations 2018);<br>• Annex III – addresses the prevention of pollution by harmful substances carried in packaged form (transposed into UK legislation through Merchant Shipping (Carriage of Dangerous Goods and Harmful Substances) Regulations 2024);<br>• Annex IV – concerned with the prevention of pollution by sewage from ships (transposed into UK legislation through The Merchant Shipping (Prevention of Pollution by Sewage from Ships) Regulations 2020) (as amended);<br>• Annex V – concerned with the prevention of pollution by garbage from ships (transposed into UK legislation through The Merchant Shipping (Prevention of Pollution by Garbage from Ships) Regulations 2020) (as amended);<br>• Annex VI – covers prevention of air pollution from ships setting limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibiting deliberate emissions of ozone depleting substances (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, sewage, garbage and emissions to air. Further information on Ithaca's Waste Management strategy for the Tornado Development is provided in Section 12. |

## A.2 Scottish National Marine Plan

The Marine and Coastal Access Act 2009 and The Marine (Scotland) Act 2010 establish the legislative and management framework for the marine environment allowing the competing demands on the sea to be managed in a sustainable way across all of Scotland's seas. The framework includes Scotland's National Marine Plan (NMP), published in March 2015. The NMP sets out strategic policies for the sustainable development of Scotland's marine resources out to 200 nautical miles, 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'.

When designing, planning and assessing the potential environmental impacts from the proposed Tornado Development, Ithaca has paid due regard to the General Policies outlined in Chapter 4 of the NMP, the Sectoral Policies for Oil and Gas detailed in Chapter 9 of the NMP, which outline how oil and gas activities are expected to develop in the longer term and the issues to be addressed to ensure they are grown sustainably, and the Strategic Objectives outlined in Annex B of the NMP.

Tables A.2 confirms that the proposed Tornado Development will not have a significant adverse impact on the General Policies of the NMP and Table A.3 confirms that the proposed Tornado Development will not have a significant adverse impact on the Sectoral Oil and Gas Policies of the NMP.

**Table A.2. General Policies Contained within Scotland's NMP that are of Relevance to the Proposed Tornado Development**

| Policy | Addressed by the Tornado Development Project |
|---|---|
| **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. | Ithaca will ensure that the proposed Tornado Development complies with all legal requirements and does not result in a significant adverse impact on the policy goals and objectives of the NMP. |
| **GEN 2 Economic benefit:** Sustainable development and use which provides economic benefit is encouraged when consistent with the objectives and outcomes of the Plan. | It is widely acknowledged that on the pathway to Net Zero emissions, oil and gas will continue to play an important part of the energy mix for the foreseeable future. Moreover, according to the Climate Change Committee (CCC), the UK will require 13–15 billion barrels of oil and gas equivalent in the period 2025 to 2050 but is currently only forecast to produce 4 billion (CCC, 2025; NSTA, 2025a). In a time of historically low domestic energy production with more than 40% of the UK's energy now imported (DESNZ, 2025), responsible development of UKCS oil and gas fields ensures that the UK meets its energy demand while retaining control over emissions. The selected Development concept for Tornado makes maximum use of existing oil and gas infrastructure and will be a contributor in the life extension of GLA pipeline system. While residual operational emissions are unavoidable, the Development represents one of the lowest carbon intensity means of recovering remaining hydrocarbons in the Tornado field. Opportunities for further emissions reductions, including electrification of offshore assets and low-carbon logistics, will be assessed as part of ongoing asset stewardship and future investment planning. In addition, the Project aligns with the UK Government's strategy to maintain domestic production to preserve critical infrastructure, skills, and supply chain capacity for the energy transition. |
| **GEN 3 Social benefit:** Sustainable development and use which provides social benefits is encouraged when consistent with the objectives of the Plan | |

| Policy | Addressed by the Tornado Development Project |
|---|---|
| **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. | Currently, there are no planned, consented or operational offshore wind farms or carbon capture and storage sites that would be adversely impacted by the Tornado Development. In addition, there are no commercial or capital dredging activities undertaken in the area or any sites licenced for disposal of dredged material. Shipping activity in the waters WoS is relatively low and there is ample sea room for shipping to re-route or avoid the Tornado Development location. There is a ban on the use of all bottom trawling below 800 m depth in UK waters. As such, fishing activity in the Tornado Development area is low, with effort concentrated in the shallower water at the Tormore end of the pipeline route (refer to Section 4.4).<br>The proposed Tornado pipeline route crosses the Farice and Shefa-2 Seg 7 (active) cables and will cross the proposed Rosebank gas export pipeline. Crossings will be designed to be overtrawable, as described in Section 3.4.4, in order to reduce snagging risks.<br>Ithaca has undertaken a scoping exercise with key stakeholders to ensure that the expectations of concerned parties have been incorporated into the Project at an early stage. The feedback received and how this has been considered by the Project is detailed in Section 1.7 of this ES. Continued liaison with other users of the area will be undertaken throughout the Project 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. | The Tornado Development has a forecasted GHG intensity of between 16.0 kg $CO_2$e/boe and 18.6 kg $CO_2$e/boe (depending on the production case). This is significantly below the UKCS average of 28 kg $CO_2$e/boe, and less than a fifth of the average GHG intensity of imported LNG (85 kg $CO_2$/boe).<br>The potentially significant effects on climate from GHG emissions generated by the proposed Tornado Development are assessed in Section 9. The GHG emissions have been evaluated in the context of a global baseline scenario of GHGs, with consideration given to the impact the emissions will have on global climate change agreements, UK carbon policies and targets and associated emissions reduction pathways. The assessment has been undertaken with reference to the new DESNZ supplementary guidance for assessing the effects of downstream Scope 3 emissions on climate from offshore oil and gas projects (DESNZ, 2025), published following the Finch judgment, 2024 and the Jackdaw / Rosebank judgment, 2025. |
| **GEN 6 Historic Environment:** Development and use of the marine environment should protect and, where appropriate, enhance heritage assets in a manner proportionate to their significance. | The Tornado Development is not anticipated to impact on any marine heritage features. No wrecks were observed during the 2024 survey operations (refer to Section 4.4.6). |

| Policy | Addressed by the Tornado Development Project |
|---|---|
| **GEN 9 Natural heritage:** Development and use of the marine environments must:<br>a) Comply with legal requirements for protected areas and protected species;<br>b) Not result in significant impact on the national status of PMFs;<br>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 in Section 4 of the ES. The ES has concluded that the Tornado Development will not result in any significant environmental effects to the marine environment provided that all identified mitigation measures are implemented (refer to assessment detailed in Sections 6 – 11). Of note, approximately 18 km of the proposed Tornado pipeline route is located within the Faroe-Shetland Sponge Belt NCMPA. Section 7 of this ES therefore includes sufficient information to enable OPRED (as the Competent Authority) to determine that there is no significant risk that the Project will hinder the achievement of the conservation objectives stated for the NCMPA. |
| **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. | The MODU and all other contracted vessels will comply with the IMO Ballast Water Management Convention throughout all stages of the Project. |
| **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. | Ithaca and its contractors will adhere to the Waste Hierarchy Principles and will minimise the generation of waste as a priority (refer to Section 12). Vessels 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. The main discharges into the marine environment from the proposed Tornado Development will occur as a result of the discharge of drill cuttings, muds, cement, completion and rig chemicals during drilling operations, residual hydrocarbons when drilling through the payzone, chemicals during drilling, chemicals during hook-up and commissioning of subsea infrastructure, including commissioning and preservation fluids and discharge of chemicals or hydrocarbons during subsea intervention activities. 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 is often detectable chemically (refer to Section 7). All other discharges will be subject to rapid dilution and dispersion and are not expected to persist within the marine environment (refer to Section 10). No significant residual effects on the marine environment are predicted as a result of routine marine discharges during the development of the Tornado field. All chemicals will be risked assessed prior to use and any discharges of residual reservoir hydrocarbons will be treated to meet oil-in-water limits of less than |

| Policy | Addressed by the Tornado Development Project |
|---|---|
| | or equal to 30 mg/l. Note that the WFD applies to inshore waters only and is therefore not applicable to the Tornado 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, fish and seabirds) that may arise from underwater noise emissions generated by the Tornado Development are assessed in Section 8 of this ES. This has concluded that sensitive marine fauna may experience short term behavioural effects, but significant impacts are not predicted provided that in the event a VSP survey is conducted, the Project adheres to the JNCC protocol for minimising the risk of injury to marine mammals from geophysical surveys (JNCC, 2017). |
| **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. | Impacts to air quality arising from the atmospheric emissions generated during the proposed Tornado Development operations are predicted to be Negligible. Emissions will disperse rapidly from source given the open and dynamic metocean environment in the WoS region (refer to Section 9). |
| **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 the scoping exercise, as reported in Section 1.7 of this ES. In addition, Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020 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 the environmental baseline survey and habitat assessment undertaken at the Tornado Development location in 2024 (refer to Section 4.1.1). |
| **GEN 20 Adaptive management:** Adaptive management practices should take account of new data and information in decision making, informing future decisions and future iterations of policy. | As noted above, this ES has been based on robust data sources to inform the EIA process. Ithaca will ensure the continued use of the most up-to-date data and research when assessing the impact of the proposed Tornado Development. |
| **GEN 21 Cumulative impacts:** Cumulative impacts affecting the ecosystem of the marine plan area | Cumulative impacts have been considered during the EIA process and are assessed in the Sections 6 to 11 of this ES. No significant cumulative impacts are predicted provided that all identified mitigation measures are implemented. |

| Policy | Addressed by the Tornado Development Project |
|---|---|
| should be addressed in decision-making and plan implementation. | |

**Table A.3. Sector Policies Related to Oil and Gas Developments According to Scotland's National Marine Plan**

| Policy | Supported Strategic Objectives | Addressed by the Tornado Development Project |
|---|---|---|
| **OIL & GAS 1:** The Scottish Government will work with OPRED, the NSTA 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<br>Social<br>Climate Change – Adaptation<br>Marine Ecosystem | The proposed Tornado Development concept has been selected and defined with consideration to the central obligation of the OGA Strategy (refer to Section 2). It comprises a subsea development, tied back to the TotalEnergies E&P UK Limited operated, Greater Laggan Area (GLA) infrastructure, thereby minimising the impact on the environment and other users of the sea. Key environmental risks have been identified in the assessment sections of this ES (Sections 6 – 11). |
| **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<br>Social | On cessation of production, the Tornado field will be decommissioned in accordance with the requirements of the prevailing UK and international law (refer to Section 3.6). |
| **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<br>Marine Ecosystem | The development concept for Tornado comprises a subsea development, tied back to the TotalEnergies E&P UK Limited operated, Greater Laggan Area (GLA) infrastructure, thereby minimising the impact on the environment and other users of the sea (refer to Section 2). |
| **OIL & GAS 5:** Consenting and licensing authorities should have regard to the potential risks, both now and under future climates, to oil and gas operations in Scottish waters, and be satisfied that installations are appropriately sited and designed to take account of current and future conditions. | Social<br>Marine Ecosystem | The Tornado field will be developed in a way that will not result in significant effects to the marine environment. With respect to future climate conditions, the Tornado field is expected to produce hydrocarbons for ca. six to ten years, whilst design considerations have accounted for 100-year extreme weather events. In this context, the Tornado Development is appropriately designed for the location for which it is proposed. |

| Policy | Supported Strategic Objectives | Addressed by the Tornado Development Project |
|---|---|---|
| **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<br>Marine Ecosystem | Accidental events that may arise during the Tornado Development have been assessed in Section 11 this ES, along with measures in order prevent their occurrence or to minimise any potentially significant adverse effects. |

## A.3 The Shetland Islands Regional Marine Plan

The Shetland Islands Regional Marine Plan (SIRMP) reflects the requirements for regional marine planning under the Marine (Scotland) Act 2010 and associated Delegation of Functions (Regional Marine Plan for the Scottish Marine Region for the Shetland Isles) Direction 2016. The policy framework is in line with Scotland's NMP. The SIRMP includes all territorial waters seaward of the mean high water of the spring tide, out to 12 nautical miles. Although the proposed Tornado Development is located further offshore, approximately 153 km west of the closest landfall on the Shetland Islands, the SIRMP is relevant to any impacts that may occur in the inshore area. Table A.4 confirms that the proposed Tornado Development will not have a significant adverse impact on the objectives and policies of the SIRMP.

**Table A.4: General Policies Contained within the Shetland Islands Regional Marine Plan (SIRMP) that are of Relevance to the Proposed Tornado Development**

| Policy | Addressed by the Tornado Development Project |
|---|---|
| **DEV1 Marine Developments:** Proposals for marine-related developments must comply with all policies included in Policy Framework Section (a) and (b), Policies MP DEV2 and Policy MP FISH1. | The proposed Tornado Development will consider the requirements of Shetland Islands Regional Marine Plan and will be consistent with the sustainable use of the marine environment and will consider the environmental and socio-economic sensitivities in the potential zone of influence of the project throughout operations. |
| **DEV2 Decommissioning of Assets:** Applications for marine-related developments should, where directed by the consenting authority or regulator, be supported by a decommissioning plan to ensure the removal of redundant infrastructure. | On cessation of production, the Tornado field will be decommissioned in accordance with the requirements of the prevailing UK and international law (refer to Section 3.6). |
| **WAT1 Water Ecology:** Development shall not cause any water body to deteriorate in ecological status nor prevent the achievement of established objectives set out in the Scotland River Basin Management Plan. | No significant residual effects on the marine environment are predicted as a result of routine marine discharges during the development of the Tornado field (refer to Sections 7 and 10). |
| **WST1 Waste Minimisation:** All applications shall include a waste minimisation and management plan to ensure the safe disposal of waste material and debris associated with the construction, operation and decommissioning stages of the development. | Ithaca and its contractors will adhere to the Waste Hierarchy Principles and will minimise the generation of waste as a priority (refer to Section 12). Vessels 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. |

| Policy | Addressed by the Tornado Development Project |
|---|---|
| **NOISE1 Minimising Levels of Surface and Underwater Noise and Vibration:** Applications for marine-related development and use should, where directed by the consenting authority or regulator:<br>a) submit a surface and underwater noise and vibration impact assessment or supporting information to describe the duration, type and level of noise and vibration expected to be generated at all stages of the development (construction, operation, decommissioning); and<br>b) include mitigation measures to minimise the adverse impacts associated with the duration and level of noise and vibration activity. | The potentially significant environmental impacts on sensitive marine fauna (specifically marine mammals, fish and seabirds) that may arise from underwater noise emissions generated by the Tornado Development are assessed in Section 8 of this ES. This has concluded that sensitive marine fauna may experience short term behavioural effects, but significant impacts are not predicted provided that in the event a VSP survey is conducted, the Project adheres to the JNCC protocol for minimising the risk of injury to marine mammals from geophysical surveys (JNCC, 2017). |
| **CLIM1 Climate Change Mitigation:** Applications for marine-related developments should demonstrate, in a format approved by the consenting authority or regulator, that:<br>a) resource use;<br>b) energy use; and<br>c) emissions have been assessed and minimised as part of the overall development proposal. | The Tornado Development has a forecasted GHG intensity of between 16.0 kg $CO_2e$/boe and 18.6 kg $CO_2e$/boe (depending on the production case). This is significantly below the UKCS average of 28 kg $CO_2e$/boe, and less than a fifth of the average GHG intensity of imported LNG (85 kg $CO_2$/boe).<br>The potentially significant effects on climate from GHG emissions generated by the proposed Tornado Development are assessed in Section 9. The GHG emissions have been evaluated in the context of a global baseline scenario of GHGs, with consideration given to the impact the emissions will have on global climate change agreements, UK carbon policies and targets and associated emissions reduction pathways. The assessment has been undertaken with reference to the new DESNZ supplementary guidance for assessing the effects of downstream Scope 3 emissions on climate from offshore oil and gas projects (DESNZ, 2025), published following the Finch judgment, 2024 and the Jackdaw / Rosebank judgment, 2025. |
| **CLIM2 Climate Change Adaptation:** Applications for marine-related developments should demonstrate that the impacts of climate change over the lifetime of the development have been considered and minimised as part of the overall development proposal. | |
| **MPA1 Plans or projects that may affect SACs, SPAs (collectively known as European sites) and Ramsar Sites:** Developments or uses that might affect a European site must comply with legal requirements for these protected areas and must be subject to a Habitats Regulations Appraisal (HRA) undertaken by a competent authority (normally the licensing or consenting authority/body). | The only risk to SACs, SPAs and Ramsar sites from the proposed Tornado Development is in the event of a worst case hydrocarbon release, namely a well blow out. However, the risk has been reduced to ALARP through mitigation measures and good industry practice and is therefore not considered to be significant (refer to Section 11). |

| Policy | Addressed by the Tornado Development Project |
|---|---|
| **MPA2 Nature Conservation Marine Protected Areas (NCMPAs):** Development capable of affecting any Nature Conservation MPA will only be permitted where it has been adequately demonstrated, to the satisfaction of the consenting authority and SGMD and with advice from NatureScot, that the proposal has had due regard to the conservation objectives of the designated site and either:<br>a) there will be no significant risk of hindering the conservation objectives of the Nature Conservation MPA, or<br>b) there is an urgent need for the development to be approved, or<br>c) the benefit to the public outweighs the risk of damage to the environment and there are no alternative solutions. | Approximately 18 km of the proposed Tornado pipeline route is located within the Faroe-Shetland Sponge Belt NCMPA. Section 7 of this ES therefore includes sufficient information to enable OPRED (as the Competent Authority) to determine that there is no significant risk that the Project will hinder the achievement of the conservation objectives stated for the NCMPA. |
| **SPCON2 Protection of Wild Birds and Their Habitats Outside Designated Sites:** If a wild bird protected under the Wildlife and Countryside Act 1981 (as amended), the Nature Conservation (Scotland) Act 2004 or listed in Annex 1 of the EC Birds Directive is present on site, or may be affected by a proposed development a plan should be provided to avoid or mitigate any adverse effects on the species. | No significant adverse effects to wild birds are predicted as result of the proposed Tornado Development (refer to Section 5, 8 and 11). |
| **SPCON1 Development and European Protected Species and Schedule 5 Species**<br>Development or uses that could affect a European Protected Species (EPS) or Schedule 5 species will be permitted only if:<br>a) it can be shown that the development is not likely to result in an offence being committed under Regulation 39 of The Conservation (Natural Habitats, &c.) Regulations 1994 (the Habitats Regulations) or Section 9 of the Wildlife and Countryside act 1981 (as amended); or<br>b) if an offence might result, it is determined that a licence would be, or has been, issued by the appropriate authority (either NatureScot or SGMD). | The ES has concluded that the Tornado Development activities will not kill or injure EPS, or deliberately disturb EPS in such a way as to be likely to impair their ability to survive, breed, or rear or nurture their young, or significantly affect the local distribution or abundance of EPS (refer to Section 8). |
| **SPCON4 Priority Marine Features:** Developments or uses must demonstrate they will have no significant adverse direct or indirect effect on a Priority Marine Feature (PMF) unless:<br>a) there is no reasonable alternative at a less ecologically damaging location and;<br>b) mitigation is included to minimise impact and;<br>c) the reasons for the development clearly outweigh the value of the feature by virtue of social or economic benefits of regional importance. | The ES has concluded that the Tornado Development will not result in any significant environmental effects to the marine environment provided that all identified mitigation measures are implemented (refer to assessment detailed in Sections 6 – 11). |

| Policy | Addressed by the Tornado Development Project |
|---|---|
| **BIOD1 Furthering the Conservation of Biodiversity:** Development and use of the marine environment will be considered against public bodies' obligation to further the conservation of biodiversity and the ecosystem services it delivers. Development and use of the marine environment must protect, and where appropriate enhance the health of the Shetland marine area. | |
| **FISH1 Safeguarding Fishing Opportunities:** Developments will only be permitted where it can be demonstrated that:<br>a) there will be no significant negative impact or permanent significant obstruction to an important fishing area;<br>b) there will be no significant environmental impact to a known/designated spawning, nursery area or habitats or species which are important for commercially important species of fish;<br>c) it will not cause a navigational hazard for commercial fishermen;<br>d) there will be no significant negative effect to the cultural importance of fishing, particularly for vulnerable coastal communities; and<br>e) there is no reasonable alternative and any such adverse effects are clearly outweighed by social, environmental or economic benefits of national importance. | No significant residual effects to commercial fishing are predicted to occur from the Tornado Development (refer to Section 6). Fishing vessels will be temporarily displaced from the Tornado Development area during the drilling and installation phases, with an area of 0.8 $km^2$ at the Tornado drill centre location lost for the life of the field development. This is considered to be a very small area in comparison to the alternative fishing grounds available in the wider WoS area. In addition, fishing activity in the Tornado Development area is low, with bottom trawling prohibited in water depths greater than 800 m. As such, the risk of snagging is low, with overtrawlable protection only utilised as part of the Development at depths less than 800 m, along approximately 20% of the length of the entire pipeline route. |
| **OAG1 Oil and Gas Proposals:** Exploration and extraction for oil and gas within 12 nautical miles of the coast will only be permitted where:<br>a) the proposal complies with all policies included in Policy Framework Section (a) and (b) and Policy MP DEV1;<br>b) there will be no adverse effects on the integrity of a European site or a proposed site;<br>c) an acceptable Emergency Response Plan is provided in agreement with the appropriate consenting authority for any accidental release of oil or gas and related hazardous substances is provided;<br>d) the proposal includes all elements such as connections to shore base and infrastructure; and<br>e) an appropriate monitoring programme and detailed restoration and maintenance proposals are included. | N/A |

# Appendix B: ENVID Registers

To inform the Tornado Development EIA, an ENVironmental and socio-economic impact IDentification (ENVID) workshop was undertaken to identify those Project activities (or aspects) which should be subject to detailed assessment in the ES. The ENVID used the Ithaca 'Risk Prioritisation Matrix' (see Figure B.1) to assign a Risk Level to each aspect, by assessing the likelihood of an impact occurring and the potential consequence to the receptor. For the purposes of this assessment, a Risk Level score of 1 to 4 was considered to be significant in EIA terms, and therefore these aspects were taken forward for detailed assessment in the ES. The results of the ENVID workshop are documented in the ENVID Registers provided in this Appendix, refer to Tables B.1 to B.4.

| Likelihood Descriptions & Index | | | | Legend | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | **Risk Levels 1-4**: Risk reduction is required. General Manager approval required if residual risk cannot be reduced. CEO and HES Manager approval required if potential **HES Consequence 1 or 2** is identified. | | | | |
| | | | | **Risk Level 5**: Risk reduction is required. Applicable Asset Manager or Wells Manager approval required if residual risk cannot be reduced. General Manager and HES Manager approval required if potential **HES Consequence 1 or 2** is identified. | | | | |
| | | | | **Risk Level 6**: Confirm that risk reduction measures are in place. Add further risk reduction measures unless unreasonable. Responsible Manager / Supervisor (e.g., OIM / OMTL / Drilling Supt) approval required if residual risk cannot be reduced. HES Manager approval required if potential **HES Consequence 2** is identified. | | | | |
| | | | | **Risk Levels 7+**: Manage risk. Further risk reduction discretionary. | | | | |
| **Likelihood Descriptions** | **Likelihood Indices** | | | | | | | |
| Expected to occur | 1 | Likely | Decreasing Likelihood | 5 | 4 | 3 | 2 | 1 |
| Conditions may allow to occur | 2 | Occasional | | 6 | 5 | 4 | 3 | 2 |
| Exceptional conditions may allow to occur | 3 | Seldom | | 7 | 6 | 5 | 4 | 3 |
| Reasonable to expect will not occur | 4 | Unlikely | | 8 | 7 | 6 | 5 | 4 |
| Rare or unheard of | 5 | Remote | | 9 | 8 | 7 | 6 | 5 |
| Consequences Descriptions & Index (without safeguards) | **Consequence Indices** | | | Decreasing Consequence / Impact | | | | |
| | | | | 5 | 4 | 3 | 2 | 1 |
| | | | | **Minor** | **Moderate** | **Major** | **Severe** | **Catastrophic** |
| | Consequence Descriptions (Decreasing order of priority) | **People (Health & Safety)** | | One or more illness or injuries requiring treatment but not severe | One or more severe illnesses or loss time injuries | One to four illnesses with significant life shortening effects or fatalities (1-4) | Multiple illnesses resulting in significant life shortening effects or multiple fatalities (5-50) | Multiple illnesses resulting in significant life shortening effects or multiple fatalities (>50) |
| | | **Environment** | | Localized, short term (less than a day) reversable environmental impact<br>PON 1 <1t<br>PON 2 and 10<br>OPPC, OCR, PPC Non-compliance<br>F-gas/ODS permit NCN (>250 $CO_2eq$)<br>ETS permit NC | Short-medium term reversable environmental impact<br>PON 1 >1t<br>Cumulative NC of permits (OPPC, OCR, PPC)<br>Cumulative ETS permit NC with potential civil penalties.<br>OPEP Tier 1 | Medium-long term reversable environmental impact<br>OPEP Tier 2 mobilised | Severe but reversible widespread environmental damage; widespread impacts to land, water, air<br>OPEP Tier 2/3mobilised | Persistent/ irreversible landscape scale environmental impact. With widespread impacts to sensitive environments and/or major water bodies, land and/or air<br>OPEP Tier 3 mobilised |
| | | **Asset** (Facility damage, Facility Downtime, Loss of Product, Lost Production Opportunity, Clean-up and Remedial Costs, Project Delay, or other Project Impact) | | Some asset loss, damage to facility or project impact, remediation cost and/or downtime.<br>**Cost <£500K** | Serious asset loss, damage to facility or project impact, remediation cost and/or downtime.<br>**Cost £500K to <£5Million** | Major asset loss, damage to facility or project impact, remediation cost and/or downtime.<br>**Cost £5MM to <£50MM** | Severe asset loss or project impact, damage to facility. Significant downtime or remediation with appreciable economic impact.<br>**Cost £50 MM to <£500MM** | Extensive remediation, permanent loss of production, project or potential for asset write off.<br>**Cost >£500MM** |
| | | **Wells** (e.g., rig / equipment damage / downtime, mechanical damage / downtime) | | Up to 1/2 day lost and/or<br>**Up to £250K** | Up to 1 day lost and/or<br>**£250K to 1MM** | Loss of a hole section and/or<br>**£1MM to £5MM** | Loss of more than one hole section and/or<br>**£5MM to £10MM** | Loss of a well or<br>**Over £10MM** |
| | | **Reputation & Business** (Business impacts related to obtaining or maintaining permits or approvals, regulatory changes or orders, reputational issues, stakeholder challenges, or legal actions) | | Business or reputation impact but does not present longer term issues. | Moderate business or reputation impact. Letter Item issued by regulator or Notification by regulator to investigate | Major impacts to reputation, business impact. Improvement Notice issued regulator. | Severe impacts to reputation or business plan. Prohibition Notice issued by regulator. | Impact on ability to operate longer term. Prohibition Notice issued by regulator suspending all Company operations. |
| | | **Security** (Impact to people, property. Cyber security.) | | Incident that does not require additional intervention measures. | Limited scope incident that necessitates intervention. | Limited scope incident that necessitates significant intervention | Companywide disruption, significant intervention required | Companywide long-term disruption, significant intervention required |

**Figure B.1: Ithaca Risk Prioritisation Matrix**

**Table B.1: Drilling ENVID Matrix**

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| 1.1 | Physical Presence | Presence of DP vessel during CAN-ductor installation operations | Shipping | 1 | 4 | 4 | Potential for vessel to be a navigation hazard. | Adherence to Marine law, vessel radar and AIS, Notices to Mariners, Kingfisher Bulletin. | **Yes** |
| | | | Commercial Fishing | 1 | 4 | 4 | | | |
| 1.2 | | Physical presence of CAN-ductors (prior to commencement of drilling operations) | Commercial Fishing | 4 | 4 | 7 | Potential for obstruction to fishing operations resulting from the presence of CAN-ductors. | Screening Direction and Consent to Locate will be in place. There is an EU-wide ban on bottom trawling at depth >800m. Given the water depth at Tornado (ca. 1,060m) trawling activity is not expected. | **No** |
| 1.3 | | Physical presence of the DP MODU and support vessels during the drilling operations. | Shipping | 3 | 2 | 4 | MODU / vessels will present a navigational hazard and cause displacement of commercial fisheries. | A 500 m safety exclusion zone will be in place, which will be patrolled by a dedicated ERRV; MODU / vessel radar and AIS; Notice to Mariners; Reporting of the rig move will take place in line with the requirements of Part 4a of the Energy Act and HSE Operations Notice 6 guidance ;Site-specific collision risk management plan to be developed; Consent to Locate will be in place. | **Yes** |
| | | | Commercial Fishing | 3 | 2 | 4 | | | |
| 1.4 | | Physical presence of the DP MODU and support vessels during the drilling operations. | Marine Mammals | 5 | 5 | 9 | Potential for collision between moving vessels and marine mammals. | | **No** |
| | | | Seabirds | 2 | 5 | 6 | Potential for disturbance / displacement from foraging areas. | | |
| 1.5 | | Artificial light emitted from the MODU and support vessels | Seabirds | 2 | 5 | 6 | Seabirds are easily disorientated by intense sources of artificial light. | Temporary disturbance, metocean conditions drive drilling operations to target summer weather (when hours of darkness are shorter). | **No** |
| 1.6 | | Physical presence of wellheads | Commercial Fishing | 3 | 4 | 6 | Potential snagging hazard to fishing gears towed along the seabed. | Wellheads will be located within 500 m safety zone and will be marked as hazards on Navigational charts and entered into the FishSafe system; There is an EU-wide ban on bottom trawling at depth >800m. Given the water depth at Tornado (ca. 1,060m) trawling activity is not expected. | **No** |

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| 1.7 | Seabed Disturbance | Installation of the CAN-ductors | Seabed Sediments | 1 | 4 | 4 | Physical disturbance of seabed sediments. Physical disturbance and smothering of benthic fauna. | Size of the CAN-ductors will be optimised for the Tornado project;<br>Less seabed disturbance then if using a conventional conductor;<br>Screening Direction will be in place. | Yes |
| | | | Benthic Communities | 1 | 4 | 4 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |
| 1.8 | | Discharge of WBM cuttings and excess cement on the seabed. | Seabed Sediments | 1 | 3 | 3 | Cuttings pile will alter the seabed topography and sediment structure. Physical disturbance and smothering of benthic communities. Impacts to foraging behaviour of fish and displacement from spawning and nursery areas. | Minimise chemical use, use less hazardous chemicals;<br>Planned use of CAN-ductors will prevent cuttings being generated from the top hole section;<br>Conventional drilling mud/cuttings treatment/cleaning equipment will be used, as required, to meet regulatory requirements;<br>Screening Direction and Chemical Permit will be in place. | Yes |
| | | | Benthic Communities | 1 | 3 | 3 | | | |
| | | | Fish & Shellfish | 1 | 3 | 3 | | | |
| 1.9 | Underwater Noise Emissions | Use of propellers / DP thrusters on vessels/ MODU | Marine Mammals | 1 | 5 | 5 | Potential behavioural disturbance or physiological impacts to sensitive marine fauna species. | Schedule optimisation to minimise vessel and MODU offshore durations. | No |
| | | | Fish & Shellfish | 1 | 5 | 5 | | | |
| | | | Seabirds | 1 | 5 | 5 | | | |
| 1.10 | | Operation of equipment on MODU (e.g. rotating machinery) | Marine Mammals | 1 | 5 | 5 | | Operational and maintenance procedures will aim to optimise the efficiency of equipment. | No |
| | | | Fish & Shellfish | 1 | 5 | 5 | | | |
| | | | Seabirds | 1 | 5 | 5 | | | |
| 1.11 | Airborne noise emissions | Well Testing | Seabirds | 1 | 5 | 5 | Potential for disturbance / displacement from foraging areas. | Well testing operations will be of short duration. | No |
| 1.12 | | Use of helicopters | Seabirds | 1 | 5 | 5 | | Optimise helicopter movements by careful planning. | No |

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| 1.13 | Atmospheric Emissions | Fuel burnt for power generation on the MODU, vessels and helicopters | Air Quality | 1 | 5 | 5 | Emissions of combustion products (particularly $CO_2$, $CH_4$, $N_2O$) contribute to the pool of greenhouse gases in the atmosphere resulting in global warming and potential climate change. Inputs of contaminants (particulate matter, CO, NOx, $SO_2$, VOCs) can contribute to the formation of local tropospheric ozone and photochemical smog, resulting in a reduction in local air quality. | Vessel's environmental emissions will be factored into the tender evaluation process; Use of low sulphur fuels according to International Maritime Organisation requirements;<br>Optimise drilling programme, including vessel movements, by careful planning to minimise fuel use. | Yes |
| | | | Climate | 1 | 2 | 2 | | | |
| 1.14 | | Flaring of hydrocarbons during well test and well clean-up operations | Air Quality | 1 | 5 | 5 | | The well test and well clean-up durations will be optimized and permitted appropriately. | Yes |
| | | | Climate | 1 | 2 | 2 | | | |
| 1.15 | Marine Discharges | Discharge of WBM cuttings at the sea surface | Water Quality | 1 | 4 | 4 | Decline in water quality, including temporary increase in suspended sediment levels and turbidity in the water column, which could have toxic effects on marine biota particularly phytoplankton, zooplankton and fish. | Conventional drilling mud/cuttings treatment/cleaning equipment will be used, as required, to meet regulatory requirements;<br>Screening Direction and Chemical Permit will be in place. | Yes |
| | | | Plankton | 1 | 4 | 4 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |
| 1.16 | | Discharge of drilling, cementing, completion and rig chemicals | Water Quality | 1 | 4 | 4 | Decline in water quality which could have toxic effects on marine biota particularly phytoplankton, zooplankton and fish. | Chemical use and discharge will be minimised to as low as practically possible;<br>Where practicable, chemicals with a higher risk profile will be substituted out in favour of those with an improved environmental profile. A Chemical Risk Assessment will be undertaken in advance of drilling ops to support the Chemical Permit as per the requirements of the Offshore Chemicals Regulations 2002 (as amended). | Yes |
| | | | Plankton | 1 | 4 | 4 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |
| 1.17 | | Discharge of payzone cuttings | Water Quality | 1 | 4 | 4 | | Conventional drilling mud/cuttings treatment/cleaning equipment will be used, as required, to meet regulatory compliance;<br>Tornado is a gas reservoir which minimises risk of oil being discharged;<br>An Oil Discharge Permit will be in place for all reservoir hydrocarbon discharges . | Yes |
| | | | Plankton | 1 | 4 | 4 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| 1.18 | | CAN-ductor installation vessel, MODU and support vessels - discharge of grey/blackwater | Water Quality | 1 | 5 | 5 | Increased BOD (from organic and other nutrient matter in detergents and human waste) may ultimately lead to an increase in opportunistic species. | Waste water will be disposed of in accordance with the requirements of the MARPOL convention and UK regulations | **No** |
| | | | Plankton | 1 | 5 | 5 | | | |
| | | | Fish & Shellfish | 1 | 5 | 5 | | | |
| 1.19 | | CAN-ductor installation vessel, MODU and support vessels - release of food waste | Water Quality | 1 | 5 | 5 | Increased BOD (from organic and other nutrient matter) may ultimately lead to an increase in opportunistic species. | Food waste will be disposed of to meet the requirements of MARPOL convention and UK regulations. | **No** |
| | | | Plankton | 1 | 5 | 5 | | | |
| | | | Fish & Shellfish | 1 | 5 | 5 | | | |
| | | | Seabirds | 1 | 5 | 5 | | | |
| 1.20 | | Oily water discharges from deck drains on MODU | Water Quality | 1 | 5 | 5 | Decline in water quality which could have toxic effects on marine biota particularly phytoplankton, zooplankton and fish. | Deck drainage water will be sampled prior to discharge to ensure the oil in water concentration is <40 mg/l;<br>An Oil Discharge Permit will be in place. | **No** |
| | | | Plankton | 1 | 5 | 5 | | | |
| | | | Fish & Shellfish | 1 | 5 | 5 | | | |
| | | | Seabirds | 1 | 5 | 5 | | | |
| | | | Marine Mammals | 1 | 5 | 5 | | | |
| 1.21 | | CAN-ductor installation vessel, MODU and support vessels - discharge of ballast water | Water Quality | 2 | 5 | 6 | Potential to introduce alien species, which could alter the local and possibly the wider ecosystem. | Compliance with the IMO Ballast Water Management Convention | **No** |
| | | | Plankton | 2 | 5 | 6 | | | |
| | | | Fish & Shellfish | 2 | 5 | 6 | | | |
| | | | Seabirds | 2 | 5 | 6 | | | |
| | | | Marine Mammals | 2 | 5 | 6 | | | |
| 1.22 | Solid Waste | General operational waste - non-hazardous & hazardous | Population & Human Health | 2 | 5 | 6 | Effects of onshore disposal of waste depends on the nature of waste and disposal site. Potential effects on future land use options for waste | Waste will be dealt with in accordance with regulatory requirements. The principles of the Waste Management Hierarchy will be followed, licensed waste contractors will be used and Waste Management Duty of Care audits will be carried out. | **No** |

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | disposal sites. Potential for localised land and air contamination. | Vessels will conform to their own Waste Management Plans. | |
| 1.23 | Use of Resources | Resource use during drilling operations | Population & Human Health | 2 | 5 | 6 | Depletion of natural resources leading to climate change, biodiversity loss and pollution, as well as socio-economic consequences for the world wide population | Minimise the use of natural resources, as far as practicable | **No** |

**Table B.2: Subsea Installations and Commissioning ENVID Matrix**

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| 2.1 | Physical Presence | Physical presence of DP installation and commissioning vessels | Shipping | 3 | 2 | 4 | Potential for the vessels to be a navigational hazard as during installation activities/ pipelay vessel manoeuvrability will be restricted. | Adherence to Marine law, vessel radar and AIS, Notices to Mariners, Kingfisher Bulletin, Fishing Liaison Officer (FLO) onboard as appropriate. Installation vessels subject to Company Marine Assurance | Yes |
| | | | Commercial Fishing | 3 | 2 | 4 | | | |
| 2.2 | | Physical presence of DP installation and commissioning vessels | Marine Mammals | 5 | 5 | 9 | Potential for collision between moving vessels and marine mammals. | | No |
| | | | Seabirds | 2 | 5 | 6 | Potential for disturbance / displacement from foraging areas. | | |
| 2.3 | | Presence of subsea infrastructure and associated protection material | Commercial Fishing | 1 | 4 | 4 | Loss of sea area for other users (i.e. loss of access to fishing grounds) and potential snagging hazard. | Current EU ban on bottom trawling in water depths >800m. EU action plan to phase out mobile bottom fishing in all MPAs by 2030 at the latest.<br>Selected route minimises footprint in <800m WD;<br>Subsea structures installed within existing Tormore 500m safety exclusion zone;<br>Subsea facilities at Tormore will be designed for fishing interaction;<br>Tornado site sits in 1,060m WD beyond EU legal limit for on bottom trawling;<br>Tornado 500m safety exclusion zone will be requested post installation operations and marked on Navigational charts; fishing intensity study to inform fishing interaction protection requirements. | Yes |
| 2.4 | | Artificial light emitted from MODU and Vessels | Seabirds | 2 | 5 | 6 | Seabirds are easily disorientated by intense sources of artificial light. | Temporary disturbance, metocean conditions drive operations to target summer weather (when hours of darkness are shorter). | No |

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| 2.5 | Seabed Disturbance | Laying of Production pipeline on the seabed | Water Quality | 1 | 4 | 4 | Potential to disturb seabed sediments, affect benthic communities and impact the protected features of the Faroe-Shetland Sponge Belt NC MPA, with pipeline on the seabed introducing a novel hard substrata. | Route selection and optimisation based on acquired Environmental, Geophysical, and Geotechnical survey data;<br>Minimise working corridors, as far as possible;<br>Pipeline route selection minimises length through NC MPA. | Yes |
| | | | Seabed Sediments | 1 | 4 | 4 | | | |
| | | | Benthic Communities | 1 | 4 | 4 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |
| | | | Marine Protected Areas | 1 | 3 | 3 | | | |
| 2.6 | | Trenching and burial of MEG pipeline and control umbilical | Water Quality | 1 | 4 | 4 | Potential to disturb seabed sediments, affect benthic communities and impact the protected features of the Faroe-Shetland Sponge Belt NC MPA. | Route selection and optimisation based on acquired Environmental, Geophysical, and Geotechnical survey data;<br>Fishing intensity study carried out to define depth to which pipeline protection is required; Minimise working corridors a, as far as possible;<br>Route selection minimises length through NC MPA. | Yes |
| | | | Seabed Sediments | 1 | 4 | 4 | | | |
| | | | Benthic Communities | 1 | 4 | 4 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |
| | | | Marine Protected Areas | 1 | 3 | 3 | | | |
| 2.7 | | Installation of tie-in spools, jumpers and electrical flying leads at Tornado | Water Quality | 1 | 4 | 4 | Potential to disturb seabed sediments and affect benthic communities. | Subsea infrastructure layout optimised to minimise footprint/seabed disturbance. | |
| | | | Seabed Sediments | 1 | 4 | 4 | | | |
| | | | Benthic Communities | 1 | 4 | 4 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |
| 2.8 | | Installation of PLEMs and FLET structures and associated temporary initiation anchors | Water Quality | 1 | 4 | 4 | Potential to disturb seabed sediments, affect benthic communities and impact the protected features of the Faroe-Shetland Sponge Belt NC MPA. | | Yes |
| | | | Seabed Sediments | 1 | 4 | 4 | | | |
| | | | Benthic Communities | 1 | 4 | 4 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |
| | | | Marine Protected Areas | 1 | 3 | 3 | | | |

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| 2.9 | | Use of Glass Fibre Reinforced Polymer (GRP) structures and rock at Tormore for protection | Water Quality | 1 | 4 | 4 | Potential to disturb seabed sediments, affect benthic communities and impact the protected features of the Faroe-Shetland Sponge Belt NC MPA, with GRP structures and rock introducing a novel hard substrata. | Minimise amount of deposited material whilst still achieving the required level of stabilisation / protection. | Yes |
| | | | Seabed Sediments | 1 | 3 | 3 | | | |
| | | | Benthic Communities | 1 | 3 | 3 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |
| | | | Marine Protected Areas | 1 | 3 | 3 | | | |
| 2.10 | | Pipeline Prelay Boulder Clearance by pick and grab or boulder clearance plough | Water Quality | 1 | 4 | 4 | Potential to disturb seabed sediments, affect benthic communities and impact the protected features of the Faroe-Shetland Sponge Belt NC MPA. | Route selection and optimisation based on acquired Environmental, Geophysical, and Geotechnical survey data;<br>Subsea relocation of boulders, with boulders moved the minimal required distance. | Yes |
| | | | Seabed Sediments | 1 | 4 | 4 | | | |
| | | | Benthic Communities | 1 | 4 | 4 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |
| | | | Marine Protected Areas | 1 | 3 | 3 | | | |
| 2.11 | | Pipeline and Cable Crossing Construction / Pipeline corridor preparation (rock carpet) / Structure foundation preparation (rock carpet). | Water Quality | 1 | 4 | 4 | Potential to disturb seabed sediments, affect benthic communities and impact the protected features of the Faroe-Shetland Sponge Belt NC MPA, with rock berm introducing a novel hard substrata. | Route selection and optimisation based on acquired Environmental, Geophysical, and Geotechnical survey data;<br>Crossing designs optimised to minimise material deposited. | Yes |
| | | | Seabed Sediments | 1 | 3 | 3 | | | |
| | | | Benthic Communities | 1 | 3 | 3 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |
| | | | Marine Protected Areas | 1 | 3 | 3 | | | |
| 2.12 | | Pipeline protection of Production Pipeline if <16", 6" Meg Flowline and Control Umbilical in WD<800m | Water Quality | 1 | 4 | 4 | Potential to disturb seabed sediments, affect benthic communities and impact the protected features of the Faroe-Shetland Sponge Belt NC MPA, with rock berm introducing a novel hard substrata. | Fishing intensity study carried out to define depth to which pipeline protection is required; Pipeline protection methodology selected based on acquired Environmental, Geophysical, and Geotechnical survey data; Minimise quantity of rock deposited, as far as possible. | Yes |
| | | | Seabed Sediments | 1 | 3 | 3 | | | |
| | | | Benthic Communities | 1 | 3 | 3 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |
| | | | Marine Protected Areas | 1 | 3 | 3 | | | |

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| 2.13 | Underwater Noise Emissions | Use of propellers / DP thrusters on installation and support vessels, including general noise and vibration of equipment whilst operating | Marine Mammals | 2 | 5 | 6 | Potential behavioural disturbance or physiological impacts to sensitive marine fauna species. | Scheduling will minimise vessel offshore durations | **No** |
| | | | Fish & Shellfish | 2 | 5 | 6 | | | |
| | | | Seabirds | 2 | 5 | 6 | | | |
| 2.14 | Atmospheric Emissions | Fuel burnt for power generation on installation and commissioning vessels | Air Quality | 1 | 5 | 5 | Emissions of combustion products (particularly $CO_2$, $CH_4$, $N_2O$) contribute to the pool of greenhouse gases in the atmosphere resulting in global warming and potential climate change. Inputs of contaminants (particulate matter, CO, NOx, $SO_2$, VOCs) can contribute to the formation of local tropospheric ozone and photochemical smog, resulting in a reduction in local air quality. | Vessel's environmental emissions will be factored into the tender evaluation process; Use of low sulphur fuels according to International Maritime Organisation requirements;<br>Optimise installation programme, including vessel movements, by careful planning to minimise fuel use. | **Yes** |
| | | | Climate | 1 | 2 | 2 | | | |
| 2.15 | Marine Discharges | Use and discharge of chemicals during hook-up and commissioning of subsea infrastructure, including commissioning and preservation fluids | Water Quality | 1 | 4 | 4 | Decline in water quality which could have toxic effects on marine biota particularly phytoplankton, zooplankton and fish. | Chemical use and discharge will be minimised to as low as practically possible;<br>Where practicable, chemicals with a higher risk profile will be substituted out in favour of those with an improved environmental profile. A Chemical Risk Assessment will be undertaken in advance of installation ops to support the Chemical Permit as per the requirements of the Offshore Chemicals Regulations 2002 (as amended). | **Yes** |
| | | | Plankton | 1 | 4 | 4 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |
| 2.16 | | Installation and commissioning vessels - discharge of grey/blackwater | Water Quality | 1 | 5 | 5 | Increased BOD (from organic and other nutrient matter in detergents and human waste) may ultimately lead to an increase in opportunistic species. | Waste water will be disposed of in accordance with the requirements of the MARPOL convention and UK regulations | **No** |
| | | | Plankton | 1 | 5 | 5 | | | |
| | | | Fish & Shellfish | 1 | 5 | 5 | | | |

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| 2.17 | | Installation and support vessels - release of food waste | Water Quality | 1 | 5 | 5 | Increased BOD (from organic and other nutrient matter) may ultimately lead to an increase in opportunistic species. | Food waste will be disposed of to meet the requirements of MARPOL convention and UK regulations. | **No** |
| | | | Plankton | 1 | 5 | 5 | | | |
| | | | Fish & Shellfish | 1 | 5 | 5 | | | |
| | | | Seabirds | 1 | 5 | 5 | | | |
| 2.18 | | Installation and commissioning vessels - discharge of ballast water | Water Quality | 2 | 5 | 6 | Potential to introduce alien species, which could alter the local and possibly the wider ecosystem. | Compliance with the IMO Ballast Water Management Convention | **No** |
| | | | Plankton | 2 | 5 | 6 | | | |
| | | | Fish & Shellfish | 2 | 5 | 6 | | | |
| | | | Seabirds | 2 | 5 | 6 | | | |
| | | | Marine Mammals | 2 | 5 | 6 | | | |
| 2.19 | Solid Waste | General operational waste - non-hazardous & hazardous | Population & Human Health | 2 | 5 | 6 | Effects of onshore disposal of waste depends on the nature of waste and disposal site. Potential effects on future land use options for waste disposal sites. Potential for localised land and air contamination. | Waste will be dealt with in accordance with regulatory requirements. The principles of the Waste Management Hierarchy will be followed, licensed waste contractors will be used and Waste Management Duty of Care audits will be carried out. Vessels will conform to their own Waste Management Plans. | **No** |
| 2.20 | Use of Resources | Resource use during subsea installation and commissioning operations | Population & Human Health | 2 | 5 | 6 | Depletion of natural resources leading to climate change, biodiversity loss and pollution, as well as socio-economic consequences for the world wide population | Minimise the use of natural resources, as far as practicable; subsea structures design with consideration to decommissioning. Decommissioned structures will be recovered and recycled onshore. | **No** |

**Table B.3: Production, Inspection and Maintenance ENVID Matrix**

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| 3.1 | Physical Presence | Ongoing presence of subsea infrastructure and protection material | Commercial Fishing | 1 | 4 | 4 | Loss of sea area for other users (i.e. loss of access to fishing grounds) and potential snagging hazard. | Tornado safety exclusion zone and seabed infrastructure will be clearly marked on navigation charts; Subsea facilities at Tormore will be designed for fishing interaction; Wellheads will be located within 500 m safety zone and will be marked as hazards on navigational charts and entered into the FishSafe system; There is an EU-wide ban on bottom trawling at depth >800m. Given the water depth at Tornado (ca. 1,060m) trawling activity is not expected. | Yes |
| 3.2 | | Presence of vessels for inspection, maintenance and repair of subsea infrastructure | Shipping | 3 | 2 | 4 | Potential for the vessels to be a navigational hazard as during inspection, maintenance and repair activities manoeuvrability will be restricted | Adherence to Marine law, vessel radar and AIS, Notices to Mariners, Kingfisher Bulletin, Fishing Liaison Officer (FLO) onboard as appropriate. Installation vessels subject to Company Marine Assurance | Yes |
| | | | Commercial Fishing | 3 | 2 | 4 | | | |
| 3.3 | | Presence of vessels for inspection, maintenance and repair of subsea infrastructure | Marine Mammals | 5 | 5 | 9 | Potential for collision between moving vessels and marine mammals. | | No |
| | | | Seabirds | 2 | 5 | 6 | Potential for disturbance / displacement from foraging areas. | | |
| 3.4 | | Artificial light emitted from vessels | Seabirds | 2 | 5 | 6 | Seabirds are easily disorientated by intense sources of artificial light. | Temporary disturbance, metocean conditions drive operations to target summer weather (when hours of darkness are shorter). | No |
| 3.5 | Seabed Disturbance | Deposit of additional rock to rectify free spans and interaction with fishing gear | Water Quality | 2 | 4 | 5 | Potential to disturb seabed sediments, affect benthic communities and impact the protected features of the Faroe-Shetland Sponge Belt NC MPA, with | Minimise quantity of rock deposited, as far as possible. | Yes |
| | | | Seabed Sediments | 2 | 3 | 4 | | | |
| | | | Benthic Communities | 2 | 3 | 4 | | | |

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| | | | Fish & Shellfish | 2 | 3 | 4 | rock introducing a novel hard substrata. | | |
| | | | Marine Protected Areas | 2 | 3 | 4 | | | |
| 3.6 | | Inspection, maintenance and repair of subsea infrastructure | Water Quality | 1 | 5 | 5 | Potential to disturb seabed sediments, affect benthic communities and impact the protected features of the Faroe-Shetland Sponge Belt NC MPA. | | No |
| | | | Seabed Sediments | 1 | 5 | 5 | | | |
| | | | Benthic Communities | 1 | 5 | 5 | | | |
| | | | Fish & Shellfish | 1 | 5 | 5 | | | |
| | | | Marine Protected Areas | 1 | 5 | 5 | | | |
| 3.7 | Underwater Noise Emissions | Use of propellers / DP thrusters on production, maintenance and repair vessels, including general noise and vibration of equipment whilst operating | Fish & Shellfish | 2 | 5 | 6 | Potential behavioural disturbance or physiological impacts to sensitive marine fauna species. | Scheduling will minimise vessel offshore durations | No |
| | | | Marine Mammals | 2 | 5 | 6 | | | |
| | | | Seabirds | 2 | 5 | 6 | | | |
| 3.8 | Atmospheric Emissions | Fuel burnt for power generation on maintenance and repair vessels | Air Quality | 1 | 5 | 5 | Emissions of combustion products (particularly $CO_2$, $CH_4$, $N_2O$) contribute to the pool of greenhouse gases in the atmosphere resulting in global warming and potential climate change. Inputs of contaminants (particulate matter, CO, NOx, $SO_2$, VOCs) can contribute to the formation of local tropospheric ozone and photochemical smog, resulting in a reduction in local air quality. | Vessel's environmental emissions will be factored into the tender evaluation process; Use of low sulphur fuels according to International Maritime Organisation requirements; Optimise maintenance and repair programme, including vessel movements, by careful planning to minimise fuel use. | Yes |
| | | | Climate | 1 | 2 | 2 | | | |
| 3.9 | | Incremental atmospheric emissions at the SGP as a result of Tornado coming online | Air Quality | 1 | 5 | 5 | | Standard emission mitigation measures; Host facility ERAP; Facility subject to a SEPA Pollution Prevention and Control (PPC) permit. | Yes |
| | | | Climate | 1 | 2 | 2 | | | |

| Ref No. | Environmental Issue | Project Activity | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|---|
| 3.10 | | End use emissions from burning the extracted hydrocarbons as a result of Tornado coming online | Air Quality | 1 | 5 | 5 | | Development of the Tornado gas discovery, which will have a comparatively low carbon footprint, will help meet the UK's energy requirements and ensure energy security during the UK's transition to Net Zero. | Yes |
| | | | Climate | 1 | 2 | 2 | | | |
| 3.11 | Marine Discharges | Production, maintenance and repair vessels - discharge of grey/blackwater | Water Quality | 1 | 5 | 5 | Increased BOD (from organic and other nutrient matter in detergents and human waste) may ultimately lead to an increase in opportunistic species. | Waste water will be disposed of in accordance with the requirements of the MARPOL convention and UK regulations | No |
| | | | Plankton | 1 | 5 | 5 | | | |
| | | | Fish & Shellfish | 1 | 5 | 5 | | | |
| 3.12 | | Production, maintenance and repair vessels - release of food waste | Water Quality | 1 | 5 | 5 | Increased BOD (from organic and other nutrient matter) may ultimately lead to an increase in opportunistic species. | Food waste will be disposed of to meet the requirements of MARPOL convention and UK regulations. | No |
| | | | Plankton | 1 | 5 | 5 | | | |
| | | | Fish & Shellfish | 1 | 5 | 5 | | | |
| | | | Seabirds | 1 | 5 | 5 | | | |
| 3.13 | | Production, maintenance and repair vessels - discharge of ballast water | Water Quality | 2 | 5 | 6 | Potential to introduce alien species, which could alter the local and possibly the wider ecosystem. | Compliance with the IMO Ballast Water Management Convention | No |
| | | | Plankton | 2 | 5 | 6 | | | |
| | | | Fish & Shellfish | 2 | 5 | 6 | | | |
| | | | Seabirds | 2 | 5 | 6 | | | |
| | | | Marine Mammals | 2 | 5 | 6 | | | |
| 3.14 | | Discharge of chemicals or hydrocarbons during subsea intervention activities (IRM) | Water Quality | 1 | 4 | 4 | Decline in water quality which could have toxic effects on marine biota particularly phytoplankton, zooplankton and fish. | Chemical use and discharge will be minimised to as low as practically possible;<br>Chemicals with a higher risk profile will be substituted out in favour of those with an improved environmental profile, where possible;<br>A Chemical Risk Assessment will be undertaken in advance of IRM ops to support the Chemical Permit as per the requirements of the Offshore Chemicals Regulations 2002 (as amended). | Yes |
| | | | Plankton | 1 | 4 | 4 | | | |
| | | | Fish & Shellfish | 1 | 4 | 4 | | | |

**Table B.4: Unplanned Events ENVID Matrix**

| Ref No. | Unplanned Event | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|
| 4.1 | Dropped Objects | Oil & Gas | 2 | 5 | 6 | Dropped objects may pose a risk to subsea infrastructure or present a snagging risk to trawlers. | Any dropped objects to be immediately reported to the regulator (via a PON2) and procedures will be in place to recover objects, where possible;<br>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;<br>Subsea infrastructure to be designed for dropped objects as applicable. | **No** |
| | | Commercial Fishing | 2 | 5 | 6 | | | |
| 4.2 | Small release of hydrocarbons / chemicals to sea (e.g. from drains, bunkering operations etc.) during drilling, installation and commissioning or maintenance and well intervention activities | Water Quality | 2 | 5 | 6 | May temporarily affect water quality and impact species within the water column. | MODU / vessels will be designed, managed and maintained to prevent spills;<br>Crews will be adequately trained and regular exercises held;<br>Bunkering procedures will be put in place. | **No** |
| | | Seabed Sediments | 2 | 5 | 6 | | | |
| | | Benthic Communities | 2 | 5 | 6 | | | |
| | | Fish & Shellfish | 2 | 5 | 6 | | | |
| | | Marine Mammals | 2 | 5 | 6 | | | |
| | | Marine Protected Areas | 2 | 5 | 6 | | | |
| 4.3 | Small release of hydraulic fluid, e.g. from ROV operations / hydraulic equipment / subsea control system failure | Water Quality | 2 | 5 | 6 | May temporarily affect water quality and impact species within the water column. | Appropriate maintenance, and pre-use checks on hydraulic equipment and ROVs | **No** |
| | | Plankton | 2 | 5 | 6 | | | |
| | | Fish & Shellfish | 2 | 5 | 6 | | | |
| | | Seabirds | 2 | 5 | 6 | | | |
| | | Marine Mammals | 2 | 5 | 6 | | | |
| | | Marine Protected Areas | 2 | 5 | 6 | | | |

| Ref No. | Unplanned Event | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|
| 4.4 | MODU or vessel collision (loss of diesel inventory) | Water Quality | 3 | 2 | 4 | Release of fuel oil to sea may impact species within the water column, on the sea surface and in coastal habitats. | Consent to Locate will be in place for the MODU;<br>500m safety exclusion zone will be designated around the MODU and dedicated ERRV present;<br>Notifications made to 'regular runners' and local fisheries organisations via Notices to Mariners, NAVTEX / NAVAREA warnings and fisheries notices; Adherence to Marine law;<br>Vessel radar and AIS;<br>Approved OPEP in place. | Yes |
| | | Seabed Sediments | 3 | 2 | 4 | | | |
| | | Plankton | 3 | 2 | 4 | | | |
| | | Benthic Communities | 3 | 2 | 4 | | | |
| | | Fish & Shellfish | 3 | 2 | 4 | | | |
| | | Seabirds | 3 | 2 | 4 | | | |
| | | Marine Mammals | 3 | 2 | 4 | | | |
| | | Marine Protected Areas | 3 | 2 | 4 | | | |
| | | Shipping | 3 | 2 | 4 | | | |
| | | Commercial Fishing | 3 | 2 | 4 | | | |
| | | Tourism & Leisure | 3 | 2 | 4 | | | |
| | | Population & Human Health | 3 | 2 | 4 | | | |
| 4.5 | Well blowout (releasing large quantities of hydrocarbons) in the event of a loss of well control | Water Quality | 4 | 1 | 4 | Release of hydrocarbons to sea may impact species within the water column, on the sea surface and in coastal habitats. | Well design and construction reviewed by an independent well examiner;<br>Safety and Environmental Critical Elements will be identified, and a suitable maintenance and testing schedule applied to each;<br>Crews will be adequately experienced, trained in well control techniques and supervised;<br>During drilling ops, weighted drilling fluids will provide the primary barrier and the downhole pressures will be carefully controlled and monitored, with the secondary barrier, the BOP, regularly maintained and tested;<br>Emergency drills will be held regularly;<br>An approved OPEP, emergency response plans and equipment will be in place;<br>OSRL Tier 2/3 support and OSPRAG capping device available. | Yes |
| | | Seabed Sediments | 4 | 1 | 4 | | | |
| | | Plankton | 4 | 1 | 4 | | | |
| | | Benthic Communities | 4 | 1 | 4 | | | |
| | | Fish & Shellfish | 4 | 1 | 4 | | | |
| | | Seabirds | 4 | 1 | 4 | | | |
| | | Marine Mammals | 4 | 1 | 4 | | | |
| | | Marine Protected Areas | 4 | 1 | 4 | | | |
| | | Shipping | 4 | 1 | 4 | | | |
| | | Commercial Fishing | 4 | 1 | 4 | | | |
| | | Tourism & Leisure | 4 | 1 | 4 | | | |
| | | Population & Human Health | 4 | 1 | 4 | | | |

| Ref No. | Unplanned Event | Receptor | Likelihood | Consequence | Risk | Potential Impacts | Mitigation Measures | Scoped into EIA |
|---|---|---|---|---|---|---|---|---|
| 4.6 | Pipeline rupture, releasing large quantities of hydrocarbons to sea | Water Quality | 3 | 2 | 4 | Release of hydrocarbons to sea may impact species within the water column, on the sea surface and in coastal habitats. | Facilities will be subject to stringent design specifications; Routine monitoring of export pipeline pressure and temperature will be undertaken; Automatic and manual shutdown systems in place; Periodic ROV inspection of the pipeline will be undertaken. | Yes |
| | | Seabed Sediments | 3 | 2 | 4 | | | |
| | | Plankton | 3 | 2 | 4 | | | |
| | | Benthic Communities | 3 | 2 | 4 | | | |
| | | Fish & Shellfish | 3 | 2 | 4 | | | |
| | | Seabirds | 3 | 2 | 4 | | | |
| | | Marine Mammals | 3 | 2 | 4 | | | |
| | | Marine Protected Areas | 3 | 2 | 4 | | | |
| | | Shipping | 3 | 2 | 4 | | | |
| | | Commercial Fishing | 3 | 2 | 4 | | | |
| | | Tourism & Leisure | 3 | 2 | 4 | | | |
| | | Population & Human Health | 3 | 2 | 4 | | | |
| 4.7 | Large release of gas due to loss of gas pipeline inventory | Air Quality | 3 | 4 | 6 | Atmospheric emissions due to gas release | Facilities will be subject to stringent design specifications; Routine monitoring of export pipeline pressure and temperature will be undertaken; Automatic and manual shutdown systems in place; Periodic ROV inspection of the pipeline will be undertaken. | Yes |
| | | Climate | 3 | 2 | 4 | | | |

# APPENDIX C:
# Drill Cuttings Modelling

# TORNADO FIELD (CONCEPT 1 - WBM)

## Drill Cuttings and Muds Dispersion Modelling



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# EXECUTIVE SUMMARY

## Project Background

Ithaca SP E&P Limited (Ithaca) are operators of the Tornado Field, West of Shetland. The Tornado Field includes UK Continental Shelf (UKCS) Block 204/13b, within which Ithaca is proposing to drill up to three development wells. The Tornado Field is located 160 km west of the Shetland Islands in a water depth of approximately 1,060 m.

To support the environmental impact assessment for proposed drilling activities within the Tornado Field, Ithaca commissioned RPS to undertake a detailed drill cuttings and muds dispersion modelling study to quantify the distribution and sediment thicknesses on the seabed and the total suspended solids (TSS) concentrations in the water column resulting from proposed associated drilling concepts (discharge programs).

## Methodology

The modelling study was conducted in stages. Firstly, 10-years of three-dimensional (3D) current data (2010–2019) for the study site was generated to represent the combined influence of ocean drift currents and tidal currents. Secondly, the current data and discharge characteristics were input into a three-dimensional sediment dispersion model, MUDMAP, to predict the movement and initial settlement of cuttings and drilling muds based on the proposed discharge program. Thirdly, as the spud date can vary, 50 simulations were modelled with varying start dates to assess a range of current conditions. Results from all 50 simulations, per release location, were combined to identify the maximum thicknesses on the seabed, and overlayed to determine the maximum (100$^{th}$ percentile) the 95$^{th}$ percentile TSS concentrations, in each grid cell. Additionally, all 150 simulations were combined to provide a cumulative assessment of the proposed drilling and discharge operations.

A thickness of 0.1 mm was used as the minimum reporting threshold for bottom deposition, while 1-10 mm and above 10 mm were used to define low and high exposure (biological effect), respectively. Additionally, the minimum reporting threshold for TSS was 5 mg/L, while concentrations of 10-1,830 mg/L and above 1,830 mg/L were used to define low and high exposure, respectively.

## Key Results

- The near-bottom riserless discharges from the release locations were responsible for the greatest thicknesses of deposited cuttings on the seafloor given the proximity of discharge (2 m) to the seabed. The maximum bottom deposition thicknesses of >2 m for all release locations were predicted to occur within the immediate vicinity of the near-bottom discharges (within 20 m).

- Based on the assessment of 50 simulations per well the maximum distances from the release location to the edge of the minimum reporting threshold (0.1 mm) ranged between 2.1 km (W1) and 2.5 km (N1). The maximum distances to the low (1 mm) and high (10 mm) exposure thresholds were 1.0 km and 0.2 km for N1, 0.8 km and 0.1 km for W1, and 0.9 km and 0.1 km for W3, respectively. The total area of coverage for the minimum reporting threshold ranged between 2.4 km$^2$ (W1) and 3.6 km$^2$ (W3). The total area of coverage for the low and high exposure thresholds were 0.4 km$^2$ and 0.02 km$^2$ for N1, 0.4 km$^2$ and 0.02 km$^2$ for W1, and 0.7 km$^2$ and 0.03 km$^2$ for W3, respectively.
- Based on the combined assessment of all 150 simulations the maximum distances, measured from the mid-point between N1, W1 and W3, to the edge of the minimum reporting threshold, and the low and high exposure thresholds were 2.6 km, 1.5 km and 0.2 km, respectively. Additionally, the total area of coverage for the minimum reporting threshold, and the low and high exposure thresholds were 4.1 km$^2$, 1.9 km$^2$ and 0.06 km$^2$, respectively.
- Elevated TSS concentrations were predicted to occur in the immediate vicinity of the release locations (50 m). Predicted maximum 95$^{th}$ and 100$^{th}$ percentile TSS concentrations arising from the discharge of cuttings and muds from the release locations were 311.5 mg/L and 304.0 mg/L (N1), 311.0 mg/L and 298.3 mg/L (W1), and 313.7 mg/L and 303.7 mg/L (W3), respectively.

- Based on the assessment of 50 simulations per well and 95$^{th}$ percentile analysis, maximum distances from the release location to the edge of the minimum reporting threshold (5 mg/L) ranged between 1.5 km (W3) and 3.3 km (W1). The maximum distances to the low exposure thresholds (10 mg/L) were 1.1 km for N1 and W1, and 0.7 km for W3, respectively. The total area of coverage for the minimum reporting threshold (5 mg/L) ranged between 2.3 km$^2$ (W3) and 4.6 km$^2$ (W1). Additionally, the total area of coverage for the low exposure thresholds (10 mg/L) ranged from 0.6 km$^2$ (W3) to 1.2 km$^2$ (N1 and W1).
- The discharge of cuttings and muds will lead to relatively short-lived increased TSS concentrations, which is expected to dilute and reduce with distance from the release locations. Based on the temporary elevated concentrations of TSS concentrations at the low exposure threshold, and the limited occurrence of the very localised high exposure, the impact likelihood is thus considered low.

# 1 INTRODUCTION

Ithaca are operators of the Tornado Field, West of Shetland. The Tornado Field includes UK Continental Shelf (UKCS) Block 204/13b, within which Ithaca is proposing to drill up to three development wells. The Tornado Field is located 160 km west of the Shetland Islands in a water depth of approximately 1,060 m.

To support the environmental impact assessment for proposed drilling activities within the Tornado Field, Ithaca commissioned RPS to undertake a detailed drill cuttings and muds dispersion modelling study to quantify the distribution and sediment thicknesses on the seabed and the total suspended solids (TSS) concentrations in the water column resulting from proposed associated drilling concepts (discharge programs).

Two proposed drilling concepts are being investigated including:

1. To drill with water-based muds (WBM) with the cuttings and associated reservoir hydrocarbons discharged to sea (some oil from the reservoir section will remain attached to the cuttings, whilst the remainder will be carried in the WBM fluid); and
2. To drill with oil-based muds and use a thermal cuttings treatment unit to treat the low toxic oil-based mud (LTOBM) contaminated cuttings to <1% oil on cuttings prior to discharge at the surface.

This report represents the modelling assessment based on the proposed drilling Concept 1.

Drilling and discharges are proposed for three nearby locations. The coordinates for the well release locations are presented in Table 1.1 and illustrated in Figure 1.1.

The purpose of the modelling is to provide an understanding of a conservative 'outer envelope' of the potential area of deposited bottom thickness and total suspended solids concentrations (TSS) resulting from the proposed drilling and discharge program.

Modelling was performed using an advanced three-dimensional dispersion model; MUDMAP. The MUDMAP model calculates the transport, spreading, and deposition of discharged cuttings and muds solids over time, based on the prevailing current conditions, the proposed drilling and discharge program, and physical properties of the discharged cuttings and muds solids.

As the spud date may vary, 50 simulations were modelled for each release location with varying start dates to assess a range of current conditions.

**Table 1.1 Coordinates for the drill cuttings and muds discharge modelling release locations.**

| Well name | Latitude* | Longitude* | Water depth (m) |
|---|---|---|---|
| N1 | 60° 33' 43.86'' N [6,715,103 N] | 4° 25' 52.15'' W [421,585 E] | ~1,060 |
| W1 | 60° 33' 40.68'' N [6,715,004 N] | 4° 25' 54.03'' W [421,606 E] | |
| W3 | 60° 33' 43.86'' N [6,715,016 N] | 4° 25' 55.55'' W [421,635 E] | |

*Datum: WGS 1984 [ED50 Zone 30 North]

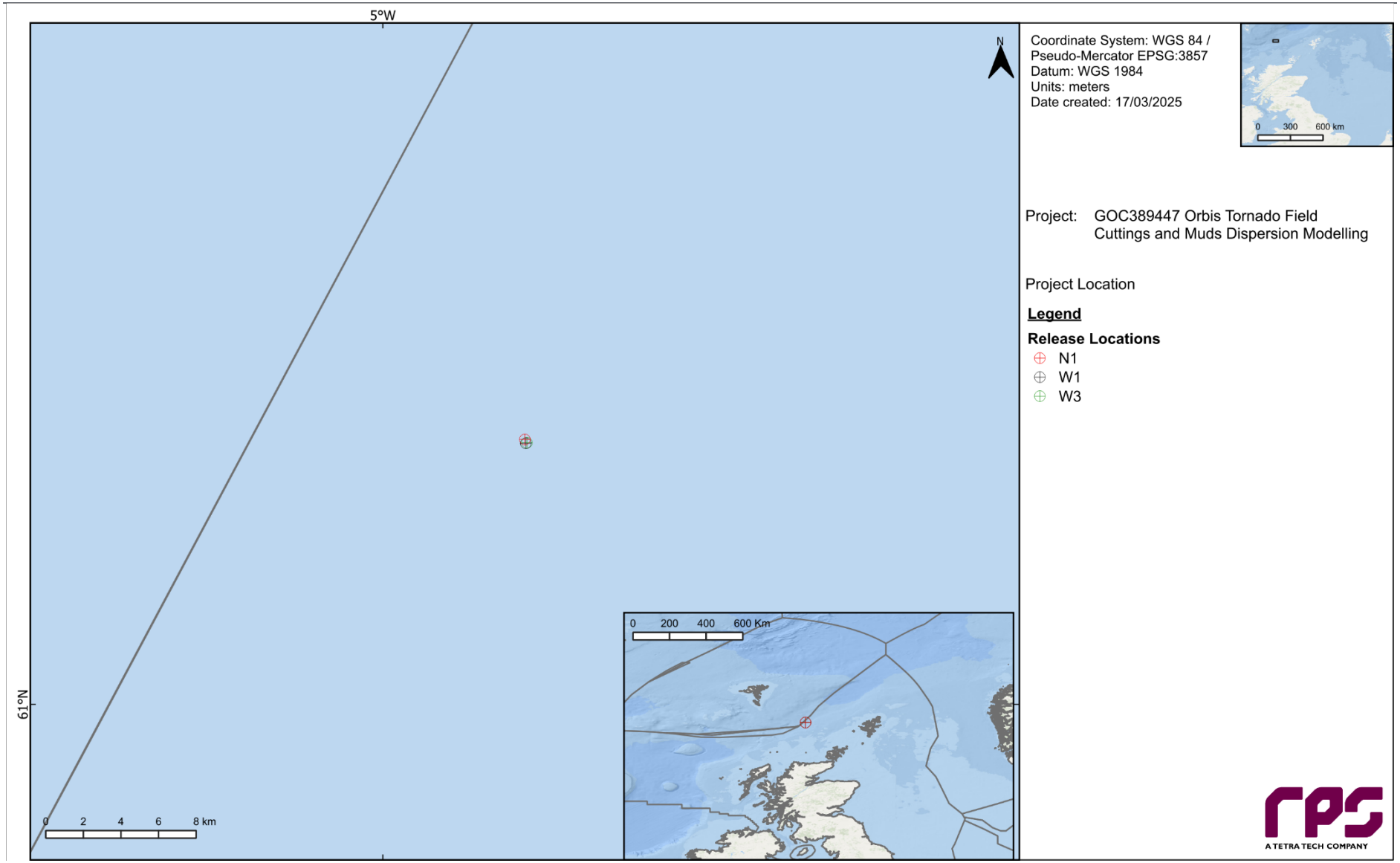



**Figure 1.1 Tornado Field drill cuttings and muds discharge modelling release locations.**

# 2 SCOPE OF WORK

The scope of work included the following components:

1. Ten years (2010 to 2019 (inclusive)) of current data were generated, which included the combined influence of ocean and tidal currents. The current data is suitably long enough to be indicative of interannual variability in ocean currents;

2. The current data and the defined discharge program specifics were input into the three-dimensional dispersion model (MUDMAP) with a total of 50 simulations modelled per release location (i.e. well) that included discharges at the seafloor and sea surface Each simulation per release location had different start times to ensure a range of current conditions were assessed;

3. Present example deterministic modelling results of the near-seabed and sea surface discharges for the drilling program at each of the three release locations (i.e., Ni, W1 and W3); and

4. Results from all 50 simulations from each of the three release locations (i.e., Ni, W1 and W3) and the combined release location results were determined to identify the maximum deposition thicknesses on the seabed, and overlayed to determine the maximum (100$^{th}$ percentile) and 95$^{th}$ percentile TSS concentrations, in each grid cell.

# 3 REGIONAL CURRENTS

The release locations are located within the northeastern region of the North Atlantic Ocean. The North Atlantic Ocean is a large ocean bounded by the Arctic Ocean to the north, the equator to the south, and the continents of North and South America to the west, and Europe and Africa to the east. The ocean has an average depth of 3,646 m (Eakins and Sharman, 2010) and is known for its powerful ocean currents, such as the Gulf Stream and the North Atlantic Current.

Specifically, the study region is located within the area of influence of the North Atlantic Drift Current (NADC), an extension of the North Atlantic Current. The NADC is a slow-moving body of water located between approximately 50°-64°N and 10°-30°W, recognised as a shallow, widespread and variable wind-driven surface movement of warm water that covers a large part of the eastern subpolar North Atlantic and slowly spills into the Nordic Seas (Bischof et al., 2003).

The northward flow of surface waters of the NADC which replace the sinking waters in the North Atlantic polar seas (Bischof et al., 2003) has a volumetric rate of transport calculated to range between 2 – 16 Sv (Krauss, 1996; Bacon, 1997).

Readers are referred to Reid (1994), Rossby (1996) and Reverdin at al. (2003) for details reviews of the physical oceanography of the North Atlantic Ocean.

To accurately describe the variability in currents both horizontally and vertically, data based on the combination of ocean currents and tides were included as part of this study. Below is a summary of the combined datasets.

## 3.1 Tidal Currents – HYDROMAP

The effects of tides were generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world for over 35 years (Isaji and Spaulding, 1984; Isaji et al., 2001; Zigic et al., 2003; Makarynskyy et al., 2010), whilst being used for a wide variety of disciplines within marine environments (e.g. Zigic et al., 2003; 2009; Talouli et al., 2009; King et al., 2010; Makarynskyy et al., 2010, 2015). In fact, HYDROMAP tidal current data have been used as input for the OILMAP hydrocarbon spill modelling system, which forms part of the Incident Management System (IMS) operated by Maritime New Zealand (MNZ), Australian Maritime Safety Authority (AMSA) and the United Kingdom Maritime and Coastguard Agency, as well as several major oil and gas companies.

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji and Spaulding (1984) and Isaji et al. (2001).

### 3.1.1 Grid Setup

RPS has a seamless global tidal model. The tidal domains are sub-gridded to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grid cells are allocated in a step-wise fashion to more accurately resolve flows along the coastline, around islands and over regions with more complex bathymetry. Figure 3.1 shows a zoomed in image of the North Atlantic Ocean and North Sea model regions.

A combination of datasets was used to describe the shape of the seabed within the high-resolution grid. Depths for the region were extracted from nautical charts and the SRTM30_PLUS dataset (see Becker et al., 2009), which provides a 30-arc second, or approximately 1 km, resolution.

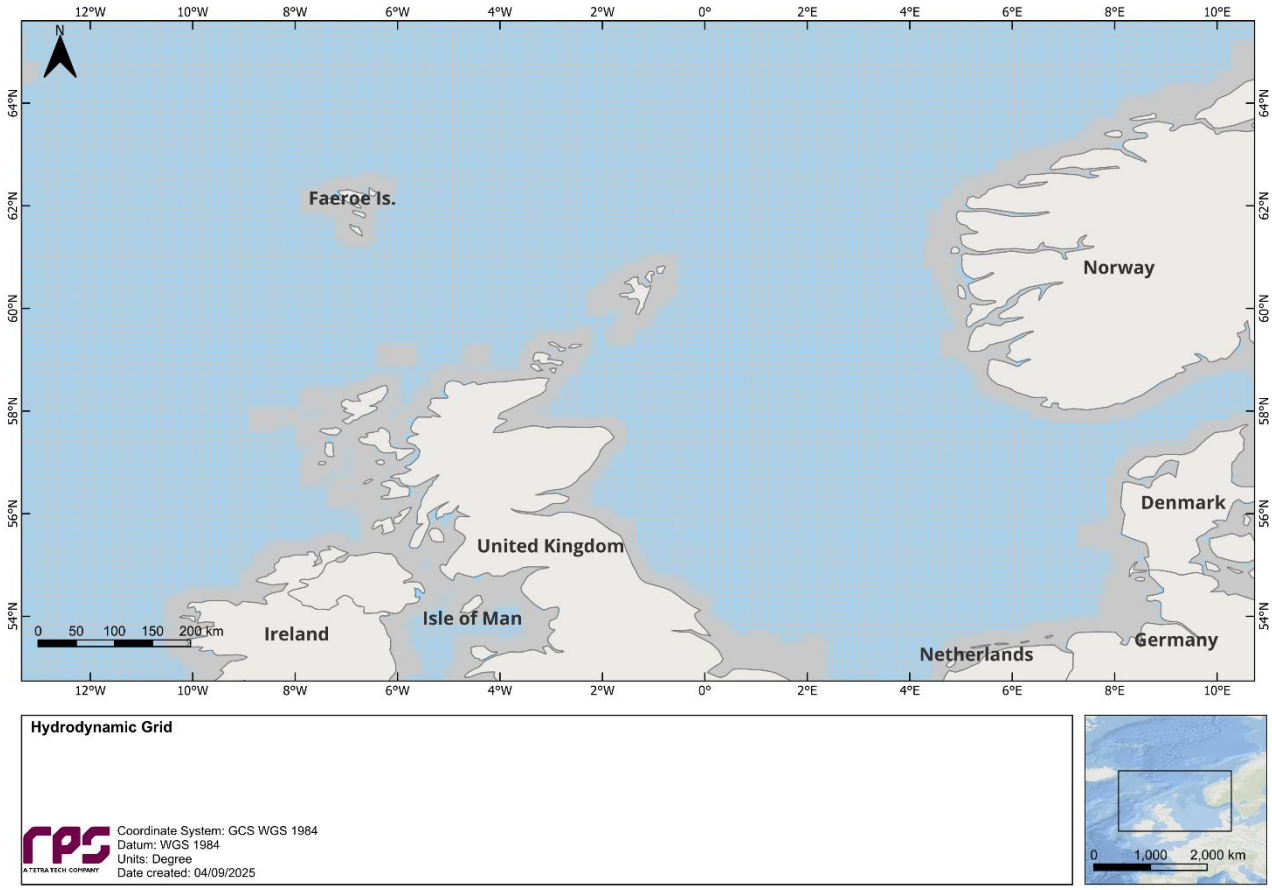



**Figure 3.1 Map showing the regions of sub-gridding for the study area and example nearshore resolution.**

### 3.1.2 Tidal Conditions

The ocean boundary data for the regional model were obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were $K_2$, $S_2$, $M_2$, $N_2$, $K_1$, $P_1$, $O_1$

and $Q_1$. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The Topex-Poseidon satellite data are produced, and quality controlled by National Aeronautics and Space Administration (NASA). The satellites, equipped with two highly accurate altimeters, capable of taking sea level measurements accurate to less than ± 5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total these satellites carried out 62,000 orbits of the planet. The Topex-Poseidon tidal data have been widely used amongst the oceanographic community, being the subject of more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010; Amores et al., 2019; Sagnieres et al., 2020; Veng et al., 2021; Zeitlhöfler et al., 2023). As such the Topex/Poseidon tidal data are considered suitably accurate for this study.

### 3.1.2 Surface Elevation Validation

To ensure that tidal predictions were accurate, predicted surface elevations were compared to data observed at twelve (12) locations situated across the study region (Figure 3.2).

Figure 3.3 to Figure 3.6 illustrate a comparison of the predicted and observed surface elevations for each location for January 2014. As shown on the graph, the model accurately reproduced the phase and amplitudes throughout the spring and neap tidal cycles well.

To provide a statistical measure of the model's performance, the Index of Agreement (IOA – Willmott, 1981) and the Mean Absolute Error (MAE – Willmott, 1982; Willmott and Matsuura, 2005) were used.

The MAE is the average of the absolute values of the difference between the model-predicted (P) and observed (O) variables. It is a more natural measure of the average error and more readily understood (Willmott and Matsuura, 2005).

$$MAE = N^{-1} \sum_{i=1}^{N} |P_i - O_i|$$

The Index of Agreement (IOA) is determined by:

$$IOA = 1 - \frac{\sum |X_{model} - X_{obs}|^2}{\sum (|X_{model} - \overline{X_{obs}}| + |X_{obs} - \overline{X_{obs}}|)^2}$$

Where: *X* represents the variable being compared and the time mean of that variable. A perfect agreement exists between the model and field observations if the index gives an agreement value of 1 and complete disagreement will produce an index measure of 0 (Wilmott, 1981). Willmott et al., (1985) also suggests that values meaningfully larger than 0.5 represent good model performance. Clearly, a greater IOA and lower MAE represent a better model performance.

Table 3.1 shows the IOA and MAE values for the selected locations.




**Figure 3.2 Location of the tide stations around used to demonstrate the accuracy of the tidal model.**

**Table 3.1 Statistical comparison between the observed and HYDROMAP predicted surface elevations data from the 1st to 31st January 2014.**

| Tide Station | IOA | MAE (m) |
|---|---|---|
| Aberdeen | 0.99 | 0.13 |
| Arendal | 0.92 | 0.03 |
| Belfast | 0.99 | 0.15 |
| Concarneau | 1.00 | 0.09 |
| Dover | 0.95 | 0.50 |
| Galway | 0.99 | 0.14 |
| Hvalba | 0.99 | 0.32 |
| Immingham | 0.91 | 0.66 |
| Kristiansund | 0.96 | 0.91 |
| Lerwick, Shetland Islands | 0.99 | 0.06 |
| Milford Haven | 0.98 | 0.32 |
| Wierumergronden | 0.92 | 0.28 |
| **Average** | **0.97** | **0.30** |

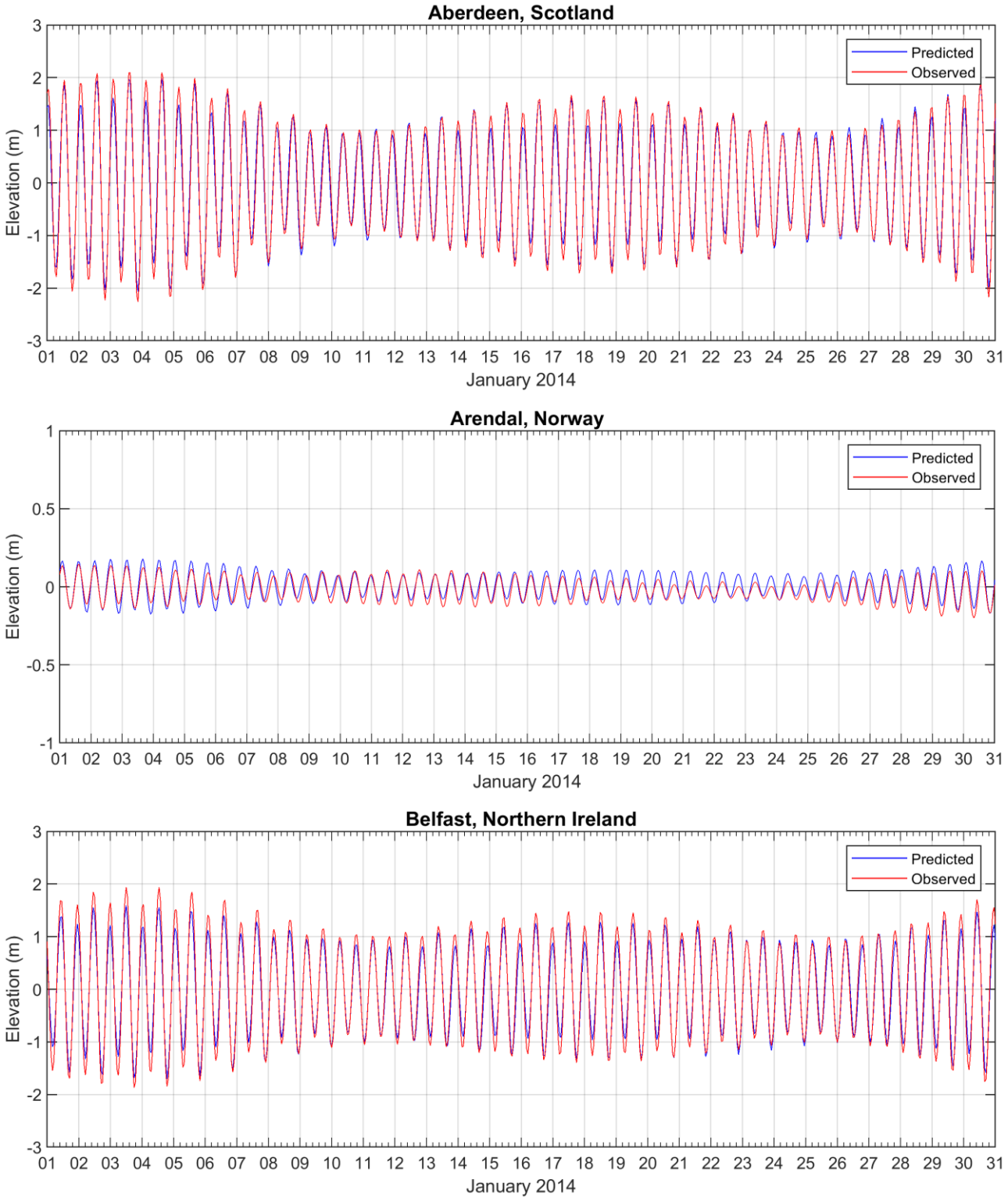



**Figure 3.3 Comparison between predicted (blue line) and observed (red line) surface elevation variation at Aberdeen (top), Arendal (middle) and Belfast (bottom), between the 1st and the 31st of July 2014.**

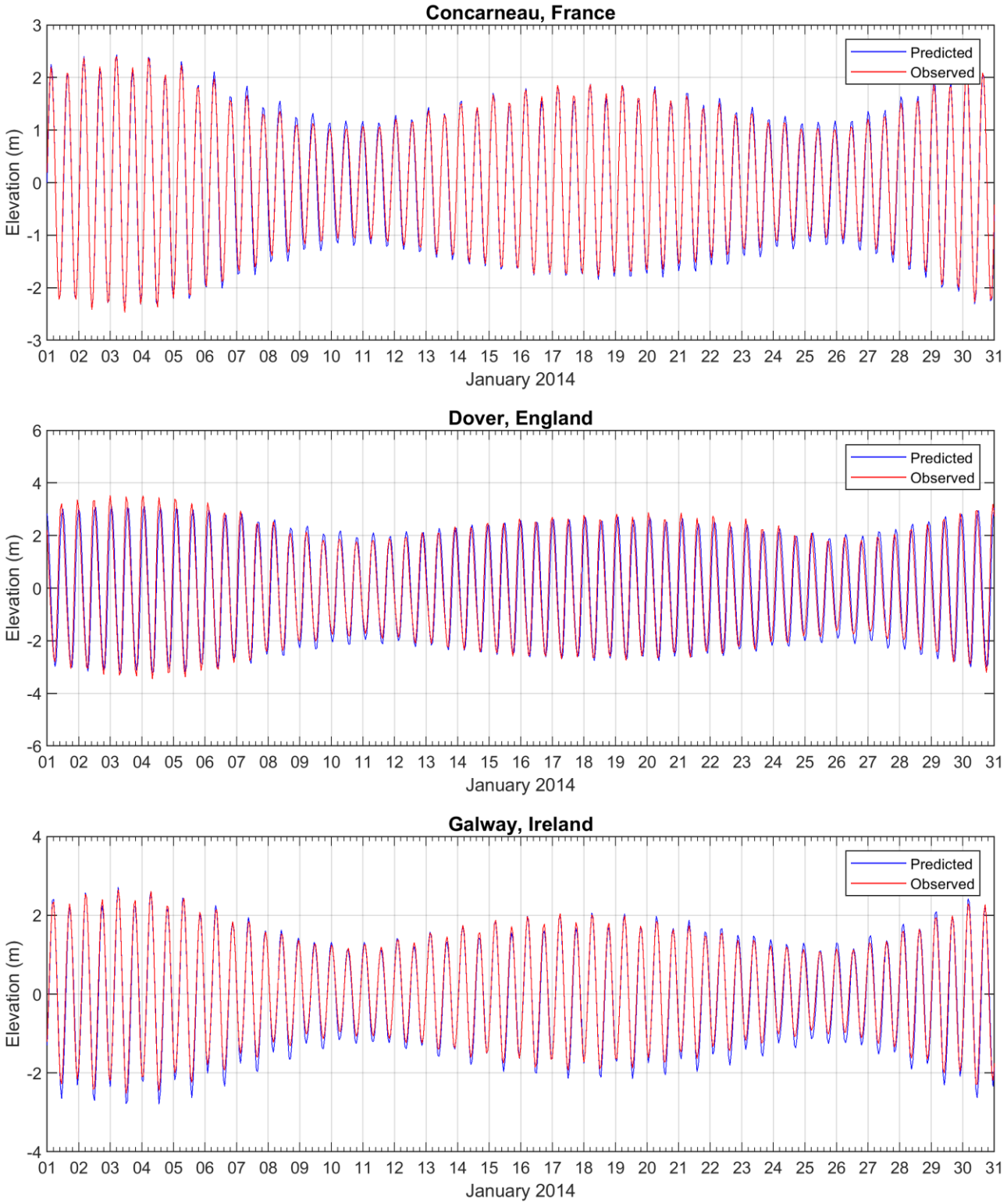



**Figure 3.4 Comparison between predicted (blue line) and observed (red line) surface elevation variation at Concarneau (top), Dover (middle) and Galway (bottom), between the 1st and the 31st of July 2014.**

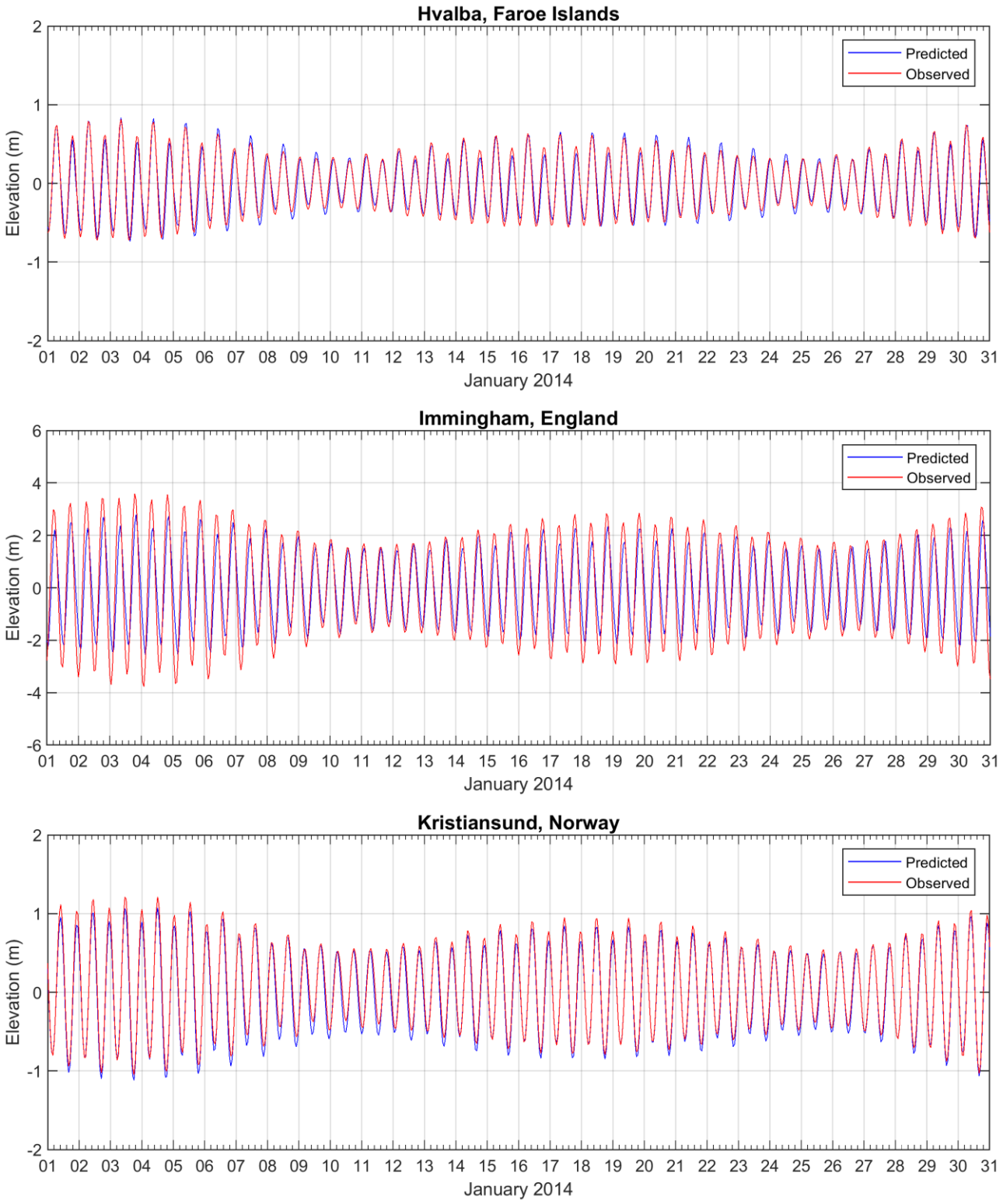



**Figure 3.5 Comparison between predicted (blue line) and observed (red line) surface elevation variation at Hvalba (top), Immingham (middle) and Kristiansund (bottom), between the 1st and the 31st of July 2014.**

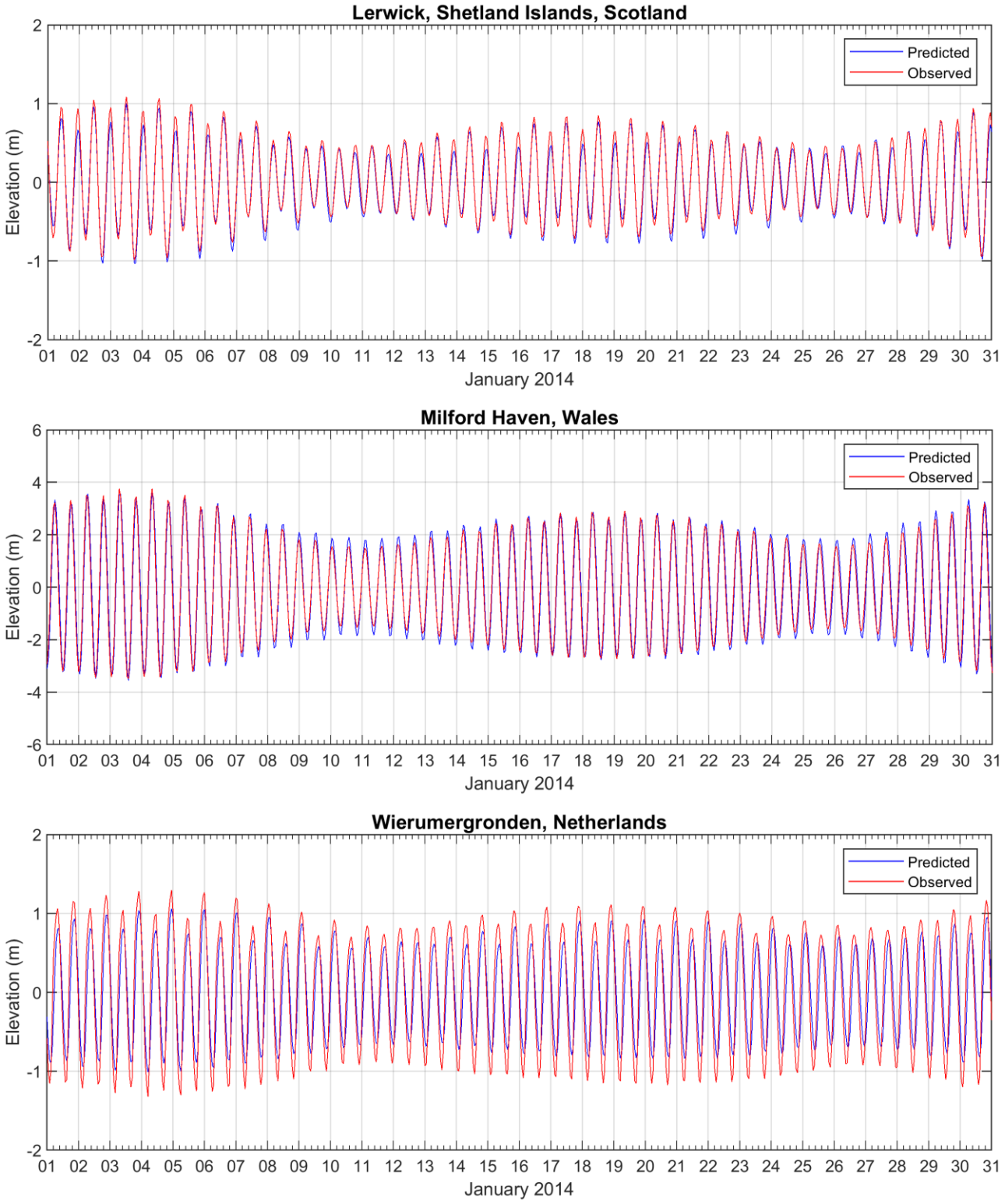



**Figure 3.6 Comparison between predicted (blue line) and observed (red line) surface elevation variation at Lerwick (top), Milford Haven (middle) and Wierumergronden (bottom), between the 1st and the 31st of July 2014.**

## 3.2 Three-Dimensional Ocean Currents – HYCOM

The three-dimensional ocean current data from 2010 to 2019 (inclusive) were obtained from the Hybrid Coordinate Ocean Model (HYCOM; see Chassignet et al., 2007), which is operated by the HYCOM Consortium, and sponsored by the Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a three-dimensional ocean model and is self-validating, meaning that it automatically integrates actual observations of sea surface heights, sea surface and in-situ temperatures and salinity measurements (Chassignet et al., 2009). Hence, the automatic integration of available measurements makes the predictions more reliable. The ocean current data are at a horizontal spatial resolution of approximately 8.25 km (1/12$^{th}$ of a degree) over the region, at a frequency of 3 hourly.

HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas.

The HYCOM model has been extensively documented through many publications which are available online[1]. The HYCOM data have also been used within the North Sea region for various application (e.g., Melsom, 2005; Winther and Johannessen, 2006; Winther and Evensen, 2006; Akinbamini et al., 2022).

For this study, the HYCOM hindcast currents were obtained for the year 2010-2019. Figure 3.7 provides an example of the modelled surface ocean currents (HYCOM) for the region.

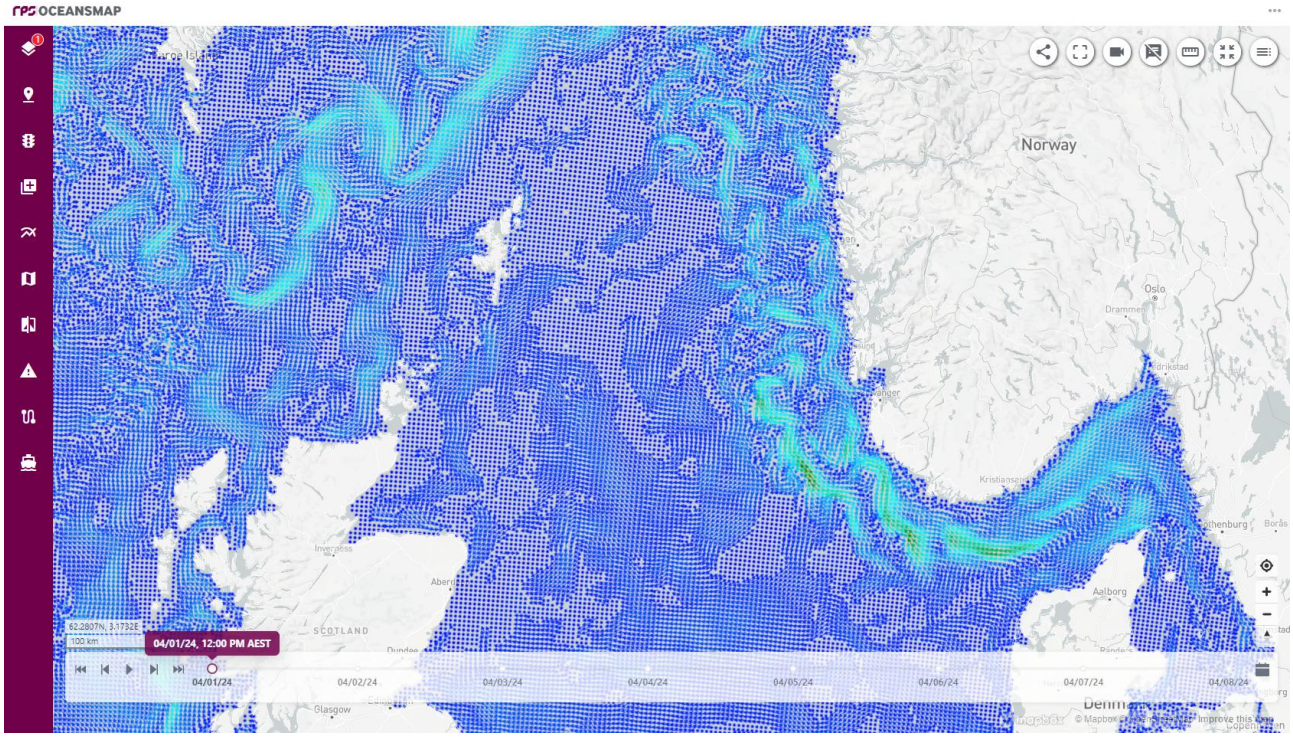



**Figure 3.7 Snapshot example of the predicted HYCOM ocean surface currents in the region. Colour and size of individual arrows indicate current speed (m/s).**

[1] https://hycom.org/publications

## 3.3 Surface and Near-Bottom Currents Nearby the Release Locations

Figure 3.8 and Figure 3.9 present the monthly surface and near-bottom current roses nearby the release locations, respectively. Note the convention for defining current direction is the direction the current flows towards, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are predominantly used in these current roses. The length of each coloured segment is relative to the proportion of currents flowing within the corresponding speed and direction.

Table 3.2 and Table 3.3 present the surface and near-bottom monthly current speeds and directions nearby the release locations, respectively.

The monthly average surface current speeds ranged from 0.23 m/s (June) to 0.41 m/s (December). Additionally, the monthly maximums reached speeds ranging between 0.77 m/s (June) and 1.69 m/s (January; Table 3.2). The surface current directions were generally consistent with currents typically flowing towards the northeast (Figure 3.8).

In comparison, the monthly average near-bottom current speeds were relatively consistent ranging from 0.15 m/s (October and December) to 0.17 m/s (September), whilst near-bottom monthly maximum current speeds ranged between 0.42 m/s (June) and 0.58 m/s (April; Table 3.3). Additionally, the near-bottom current direction predominantly occurred towards the southwest (Figure 3.9).

**Table 3.2 Monthly average and maximum surface current speeds nearby the release locations. The data was derived by combining the HYCOM ocean data and HYDROMAP tidal data for 2010-2019.**

| Month | Average current speed (m/s) | Maximum current speed (m/s) | General direction |
|---|---|---|---|
| January | 0.40 | 1.69 | Northeast |
| February | 0.35 | 1.40 | |
| March | 0.34 | 1.46 | |
| April | 0.33 | 1.10 | |
| May | 0.28 | 1.10 | |
| June | 0.23 | 0.77 | |
| July | 0.26 | 0.80 | |
| August | 0.29 | 1.04 | |
| September | 0.34 | 1.24 | |
| October | 0.39 | 1.30 | |
| November | 0.34 | 1.21 | |
| December | 0.41 | 1.52 | |
| **Minimum** | **0.23** | **0.77** | - |
| **Maximum** | **0.41** | **1.69** | |

**Table 3.3 Monthly average and maximum near-bottom current speeds nearby the release locations. The data was derived by combining the HYCOM ocean data and HYDROMAP tidal data for 2010-2019.**

| Month | Average current speed (m/s) | Maximum current speed (m/s) | General direction |
|---|---|---|---|
| January | 0.16 | 0.49 | Southwest |
| February | 0.16 | 0.52 | |
| March | 0.16 | 0.51 | |
| April | 0.16 | 0.58 | |
| May | 0.16 | 0.55 | |
| June | 0.16 | 0.42 | |
| July | 0.16 | 0.50 | |
| August | 0.16 | 0.45 | |
| September | 0.17 | 0.51 | |
| October | 0.15 | 0.50 | |
| November | 0.16 | 0.50 | |
| December | 0.15 | 0.53 | |
| **Minimum** | **0.15** | **0.42** | - |
| **Maximum** | **0.17** | **0.58** | |

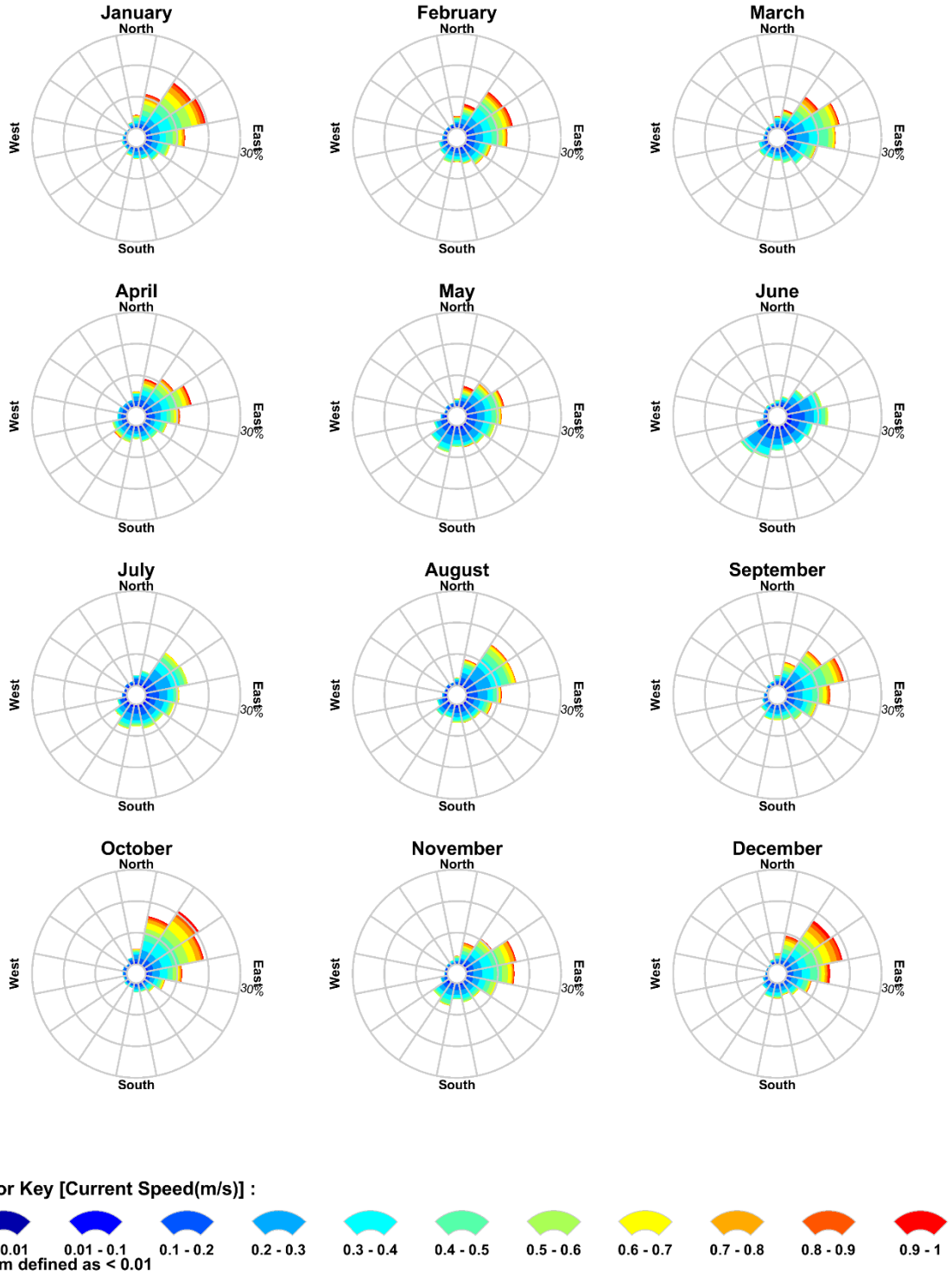



**Figure 3.8 Monthly surface current rose distributions nearby the release locations, derived from the 2010 to 2019 modelled dataset.**

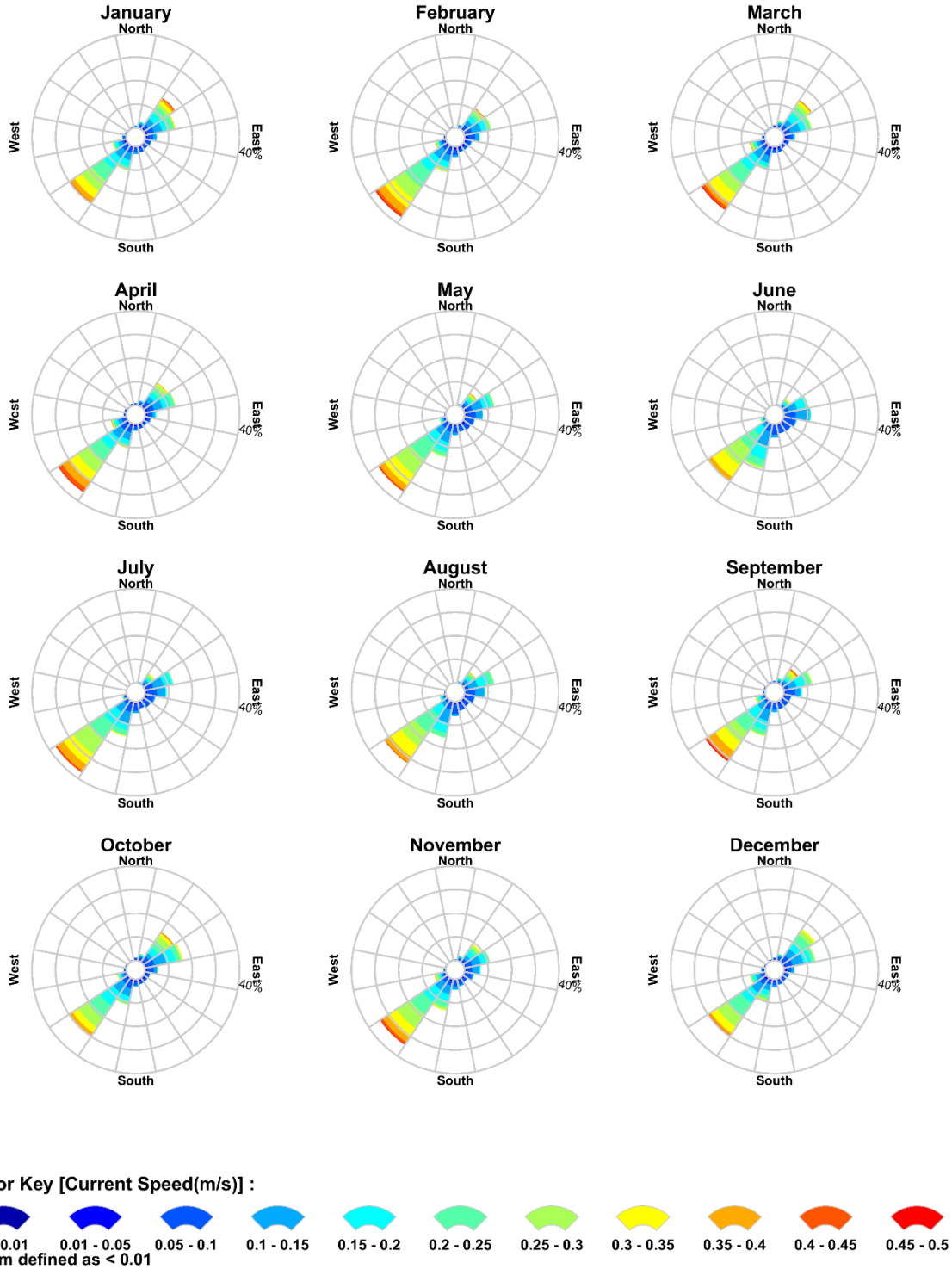



**Figure 3.9 Monthly near-bottom current rose distributions nearby the release locations, derived from the 2010 to 2019 modelled dataset.**

# 4 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release locations were obtained from the HYCOM dataset (see Section 3.2).

The three-dimensional salinity and temperature datasets are used in the model domain to inform water density in through the water column layers.

Table 4.1 presents the monthly average sea temperature and salinity of the surface and near-bottom layers nearby the release locations. Monthly average surface water temperature ranged from 8.5ºC (March) to 12.5ºC (August). In contrast, near-bottom waters ranged from -1.0ºC (May) to -0.8ºC (January to April, August to October). Salinity remained relatively consistent through the water column ranging between 34.9 psu to 35.2 psu.

Figure 4.1 presents depth profiles of water temperature and salinity nearby the release locations.

**Table 4.1 Monthly average sea surface temperature and salinity nearby the release locations.**

| Month | Temperature (ºC) | | Salinity (psu) | |
|---|---|---|---|---|
| | Surface | Near-bottom | Surface | Near-bottom |
| January | 8.9 | -0.8 | 35.3 | 34.9 |
| February | 8.7 | -0.8 | 35.3 | 34.9 |
| March | 8.5 | -0.8 | 35.3 | 34.9 |
| April | 8.6 | -0.8 | 35.3 | 34.9 |
| May | 9.2 | -1.0 | 35.3 | 34.9 |
| June | 10.9 | -0.9 | 35.3 | 34.9 |
| July | 11.8 | -0.9 | 35.2 | 34.9 |
| August | 12.5 | -0.8 | 35.2 | 34.9 |
| September | 11.7 | -0.8 | 35.2 | 34.9 |
| October | 10.3 | -0.8 | 35.2 | 34.9 |
| November | 9.1 | -0.9 | 35.2 | 34.9 |
| December | 8.9 | -0.9 | 35.3 | 34.9 |
| **Minimum** | **8.5** | **-1.0** | **35.2** | **34.9** |
| **Maximum** | **12.5** | **-0.8** | **35.3** | **34.9** |

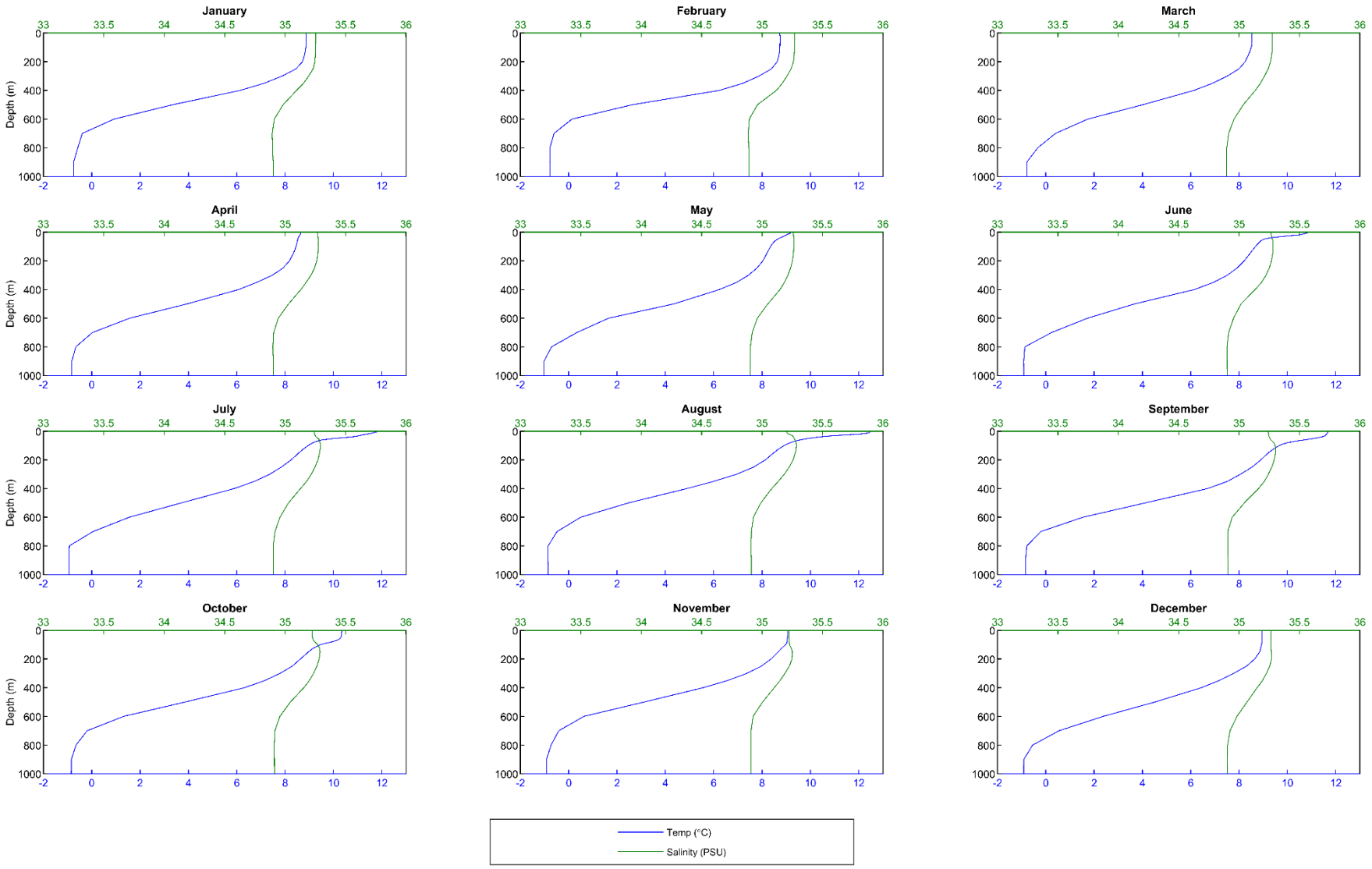



**Figure 4.1 Monthly average depth profiles of water temperature and salinity nearby the release locations.**

# 5 SEDIMENT DISPERSION MODELLING

## 5.1 Sediment Dispersion Model Description – MUDMAP

MUDMAP is a three-dimensional plume model used by industry and regulators to aid in assessing the potential environmental effects from operational discharges such as drill cuttings, drilling fluids (muds) and produced water. The model has been applied to hundreds of assessments in over 35 countries, including Scotland.

The far-field calculation (passive dispersion stage) employs a particle-based, random walk procedure. The model predicts the dynamics of the discharge material and resulting seabed concentrations and bottom thicknesses over the near-field (i.e. the immediate area of the discharge) and the far-field (the wider region). Figure 5.1 shows a conceptual diagram of the dispersion and fates of drill cuttings and muds discharge to the ocean and an idealized representation of the three discharge phases.

Settling under currents is selective for particle size, with the larger particles (rock chips to sand) tending to settle quickly, forming a pile that aligns with the predominant current axis. Smaller particles (especially silts and clays) will remain suspended for longer periods and will therefore be dispersed more widely by the ambient current conditions. Dispersion of the finer discharged material will tend to be enhanced with increased current speeds and water depth and with greater variation in current direction over time and depth.

Along with the advanced analyses tools, MUDMAP can simulate six classes of material (or 36 sub-categories), each with unique density and particle-size distribution. During the dispersion stage, the model particles are transported in three-dimensions according to the current data and horizontal and vertical mixing coefficients at each time step according to the governing equations.

MUDMAP has been extensively reported, validated and applied for discharge operations (e.g. Burns et. al., 1999; King and McAllister, 1997; 1998; Spaulding, 1994; Albert and Prosser, 2023).

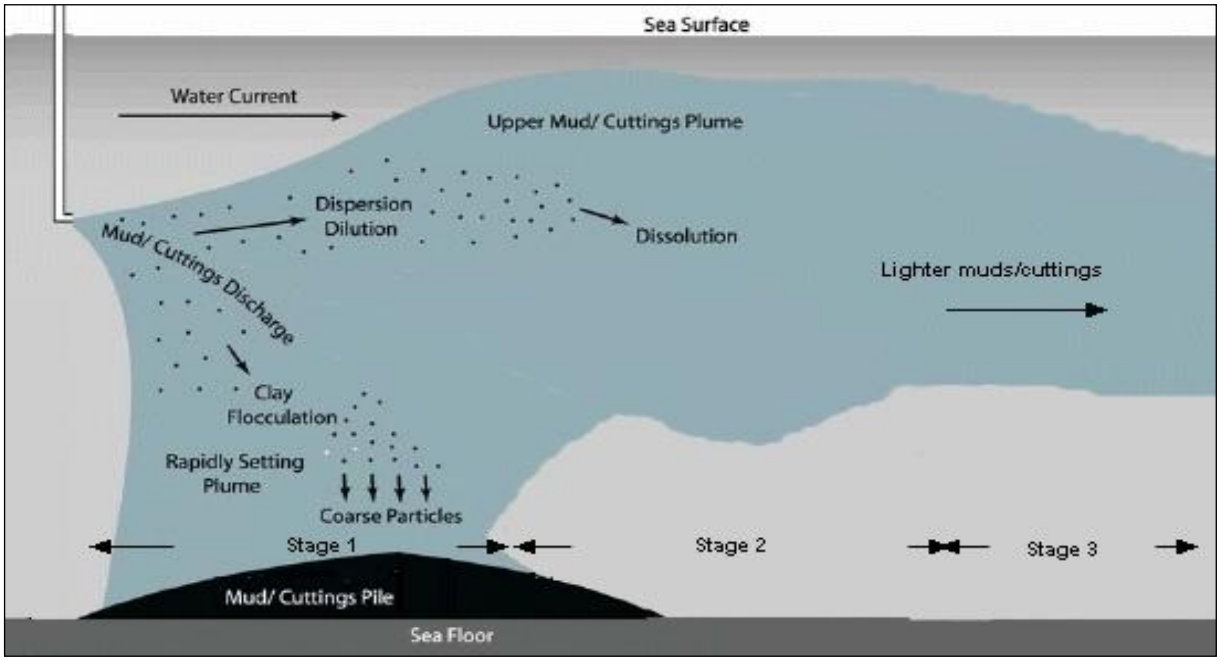



**Figure 5.1 Conceptual diagram showing the general behaviour of cuttings and muds following the discharge to the ocean (Neff, 2005) and the idealised representation of the three discharge phases.**

## 5.2 Drilling and Discharge Program

Ithaca indicated that the proposed drilling will likely use CAN-ductors[2] rather than a conventional top-hole section and associated conductor. However, as a worst-case scenario, in case problems are encountered when installing the CAN-ductors, it is assumed that the wells will be drilled conventionally.

This modelling assessment is therefore based on drilling a 42" × 36" diameter top-hole section into which a 36" × 30" diameter conductor pipe will be cemented. The second (26") section will then be drilled through the conductor and a 20" surface casing installed and cemented into place. The deeper 17½", 12¼" and 8½" sections of the wells will then be drilled with the drilling fluids circulated back to the mobile offshore drilling unit (MODU). Note, the 8½" reservoir sand section will be underreamed to 12¼" (i.e. enlarged past its originally drill size), as illustrated in Figure 5.2.

As such modelling included five intervals ranging between 8.5" to 36" hole sections at each of the release locations (i.e., N1, W1 and W3). Additionally, the potential for a re-spud scenario and mechanical sidetracks at release location well W3 was included as part of the assessment.

Proposed Concept 1 drilling and discharge activities at N1 and W1 activities will be drilled consisting of five intervals with bore diameters ranging between 8.5" and 36". Drilling and discharges at W3 will also be drilled consisting of five intervals with bore diameters also ranging between 8.5" and 36" and additionally considers side-track drilling and re-spudding. At all release locations (i.e., N1, W1 and W3) the 36" and 26" bore diameter intervals will be drilled using seawater sweeps with the extracted drill cuttings being returned directly to the seafloor.

Drilling of the 17.5", 12.25" and 8.5" intervals is anticipated to utilise WBM with the cuttings and muds from these intervals being brought to the mobile offshore drilling unit (MODU) via a marine riser that will be situated between the well and the drilling deck so that cuttings and the drilling fluid are circulated back up to the MODU before the muds are discharged to the sea surface. Figure 5.2 presents a schematic of proposed well designs for intervals 12.25" and 8.5".




**Figure 5.2 Schematic of 8½" hole section underreamed to 12¼"**

The total active discharge durations for N1, W1 and W3 are anticipated to be 5.36 days, 5.27 days and 11.75 days, respectively.

Table 5.1 to Table 5.3 presents summaries of the estimated discharge of volume of drill cuttings and unrecoverable mud solids for N1, W1 and W3, respectively, considered in this study.

[2] https://www.neodrill.com/technology-can-ductor

**Table 5.1 Summary of the estimated discharge of volume of drill cuttings and unrecoverable mud solids for each well interval for N1.**

| Bore Diameter (inches) | Discharge method | Volume of cuttings solids ($m^3$) | Fluid Type | Volume of muds liquid and solids ($m^3$) | Volume of solids in the muds ($m^3$) | Discharge Duration (days) |
|---|---|---|---|---|---|---|
| 36 | Returned directly to seabed | 94.59 | Seawater sweeps | 141.88 | 14.19 | 0.33 |
| 26 | | 252.03 | | 378.04 | 37.80 | 1.68 |
| 17.5 | Cuttings and drilling fluid brought to MODU via marine riser | 111.75 | WBM | 848.75 | 84.88 | 1.64 |
| 12.25 | | 35.87 | | 651.32 | 65.13 | 1.08 |
| 8.5 (underreamed to 12¼") | | 10.88 | | 481.20 | 48.12 | 0.64 |
| **Total** | | **505.12** | | **2,501.19** | **250.12** | **5.36** |

**Table 5.2 Summary of the estimated discharge of volume of drill cuttings and unrecoverable mud solids for each well interval for W1.**

| Bore Diameter (inches) | Discharge method | Volume of cuttings solids ($m^3$) | Fluid Type | Volume of muds liquid and solids ($m^3$) | Volume of solids in the muds ($m^3$) | Discharge Duration (days) |
|---|---|---|---|---|---|---|
| 36 | Returned directly to seabed | 94.59 | Seawater sweeps | 141.88 | 14.19 | 0.33 |
| 26 | | 252.03 | | 378.04 | 37.80 | 1.68 |
| 17.5 | Cuttings and drilling fluid brought to MODU via marine riser | 111.75 | WBM | 848.75 | 84.87 | 1.64 |
| 12.25 | | 35.87 | | 651.32 | 65.13 | 1.08 |
| 8.5 (underreamed to 12¼") | | 9.06 | | 479.38 | 47.94 | 0.55 |
| **Total** | | **503.30** | | **2,499.37** | **249.94** | **5.27** |

**Table 5.3 Summary of the estimated discharge of volume of drill cuttings and unrecoverable mud solids for each well interval for W3, including the potential for a re-spud scenario and mechanical sidetracks.**

| Bore Diameter (inches) | Discharge method | Volume of cuttings solids ($m^3$) | Fluid Type | Volume of muds liquid and solids ($m^3$) | Volume of solids in the muds ($m^3$) | Discharge Duration (days) |
|---|---|---|---|---|---|---|
| 36 | Returned directly to seabed | 189.18 | Seawater sweeps | 283.76 | 28.38 | 0.66 |
| 26 | | 504.06 | | 756.08 | 75.61 | 3.35 |
| 17.5 | Cuttings and drilling fluid brought to MODU via marine riser | 223.50 | WBM | 1,697.50 | 167.75 | 3.28 |
| 12.25 | | 71.74 | | 1,302.64 | 130.26 | 2.15 |
| 8.5 (underreamed to 12¼") | | 31.70 | | 972.33 | 97.23 | 2.31 |
| **Total** | | **1,020.18** | | **5,012.31** | **501.23** | **11.75** |

## 5.3 Discharge Input Data

The input data used to setup the dispersion model included:

- Volume and discharge duration of the cuttings and unrecovered muds solids;
- Particle size distributions (PSD) and associated settling velocities of discharged cuttings and unrecoverable muds solids;
- Bulk density of the discharged cuttings and unrecoverable muds solids;
- Temperature and salinity profile of the receiving waters;
- The size and orientation of the discharge pipe;
- The height/depth of the discharge point relative to mean sea level; and
- Depth-varying current data to represent local physical forcing.

Table 5.4 provides a summary of the discharge configuration and the estimated volume of cuttings and muds solids input into the discharge model. Simulations were run for an additional period after the completed discharges to allow sediments to disperse through the water column and potentially deposit on the seafloor (see Table 5.4).

**Table 5.4 Input data used for the drill cuttings and muds modelling.**

| Parameter/description | N1 | W1 | W3 |
|---|---|---|---|
| Total volume of cuttings discharged ($m^3$) | 505.12 | 503.30 | 1,020.18 |
| Total volume of muds solids discharged ($m^3$) | 250.12 | 249.94 | 501.23 |
| Discharge duration (days) [model duration] | 5.36 [6.5] | 5.27 [6.5] | 11.75 [13.5] |
| Depth of surface discharge (m) | 0 (sea surface) | | |
| Height of riserless discharge above seafloor (m) | 2 | | |
| Water depth (m) | ~1,060 | | |
| Discharge pipe orientation | Vertically downwards | | |
| Number of simulations | 50 (randomly selected start simulation dates and times between 2010–2019, inclusive) | | |

Ithaca has indicated that well intervals will be drilled using a typically conventional drilling approach. Model input included particle sizes for cuttings returned to the seafloor and cuttings and drilling muds solids brought to MODU via marine riser varying between 0.026 mm and 6 mm in diameter as presented in Table 5.5. The PSD is representative of data previously used for well intervals drilled using WBM (e.g. Koh & Teh, 2011; IOGP, 2016). The PSD are based on the relative contribution of cuttings and drilling muds discharge volumes.

It is important to note that grain size has a greater influence on the rate of settling than density (Neff, 2005). The fall velocities for the various size classes were derived from empirical data provided by Dyer (1986).

**Table 5.5 Cuttings and muds sediment grain sizes, settling velocities and percentage distributions.**

| Class | Grain size (mm) | Settling velocity (cm/s) | Percentage Distributions |
|---|---|---|---|
| *Medium cuttings* | 6 | 53.62 | 8.6 |
| | 5 | 49.46 | 8.6 |
| | 2 | 28.55 | 8.6 |
| | 1 | 12.73 | 5.8 |
| | 0.5 | 7.5 | 5.8 |
| | 0.45 | 6.6 | 2.9 |
| *Light cuttings* | 0.4 | 6 | 2.9 |
| | 0.35 | 5 | 2.8 |
| | 0.3 | 4 | 2.8 |
| | 0.25 | 3.1 | 2.8 |
| | 0.2 | 2.3 | 2.8 |
| | 0.15 | 1.6 | 2.8 |
| *Very light cuttings* | 0.1 | 0.8 | 2.8 |
| | 0.05 | 0.22 | 2.8 |
| | 0.04 | 0.15 | 2.9 |
| | 0.03 | 0.08 | 2.9 |
| | 0.02 | 0.04 | 2.9 |
| *Drilling mud solids* | 0.063 | 0.34 | 0.4 |
| | 0.05 | 0.22 | 1.6 |
| | 0.035 | 0.11 | 3.7 |
| | 0.026 | 0.06 | 6 |
| | 0.02 | 0.038 | 7.4 |
| | 0.016 | 0.026 | 9.4 |

## 5.4 Grid Configuration

A grid covering a 50 km (longitude, x-direction) by 50 km (latitude, y-direction) region with varying depths was employed. The grid consisted of cells with a horizontal resolution of 50 m to calculate the thickness of deposited drill cuttings and muds on the seabed and a vertical resolution of 10 m to estimate the TSS concentrations.

## 5.5 Mixing Parameters

The horizontal and vertical dispersion coefficients are used in dispersion modelling to represent the mixing and diffusion processes caused by turbulence, which are sub-grid processes at the scale of the hydrodynamic model drivers. The dispersion coefficients are expressed in units of rate of area change ($m^2/s$). Increasing the horizontal dispersion coefficient will increase the horizontal spread of the discharge plume and decrease the centreline concentrations. Increasing the vertical dispersion coefficient spreads the discharge further across the vertical layers.

The horizontal turbulent diffusion of the plume is dependent on the hydrodynamic conditions (i.e. wind, wave and current) and the physical scale of the plume compared to the scales of the oceanic processes that disperse the plume. For a plume of approximately 10-100 m width, dispersion occurs primarily through small-scale horizontal swirling motions and vertical mixing, with a horizontal dispersion rate of the order of

0.1 $m^2/s$. As the plume grows to a scale of 1-10 km, it begins to be subject to mesoscale eddies and horizontal dispersion rate becomes of the order of a few to tens of $m^2/s$.

A horizontal coefficient value of 0.1 $m^2/s$ was used to account for the turbulence as the sediment is transported from the release location for the near-bottom discharges. Additionally for the near-seabed discharges a low vertical coefficient value was employed (0.0001 $m^2/s$). In comparison, sea surface discharges employed horizontal and vertical coefficients of 0.2 $m^2/s$ and 0.002 $m^2/s$, respectively.

## 5.6 Reporting Thresholds

The MUDMAP model can predict bottom thicknesses and TSS concentrations to very low levels that may not be ecologically significant; therefore, thresholds were carefully selected for reporting the model-predicted outcomes.

Based on available literature, thresholds of 1 mm and above 10 mm were used to define low and high exposure levels for this study, respectively (see Table 5.6). The thresholds are supported by studies from Trannum et al. (2009) which found a significant decrease in species count, abundance of individuals, and biomass of marine animals with deposited cuttings 3-24 mm. Furthermore, a study by Kjeilen-Eilertsen et al. (2004) reports that depositional thicknesses greater than 9.6 mm are likely to cause smothering impacts on benthic ecosystems, including corals. It is also worth noting that a study by Smit et al. (2008) established that a thickness threshold of greater than 6.5 mm would be needed before potential harm to benthic macrofauna occur.

As a conservative measure, a thickness of 0.1 mm was employed as a minimum reporting threshold for the modelling results (Table 5.6). Additionally, as part of the study, it was assumed newly settled cuttings and drilling muds will be less compact due to incorporation of water between grains of the newly deposited solids, therefore a bulking factor of 2.5 was applied to predicted bottom thicknesses to account for porosity.

The minimum reporting threshold for TSS concentrations used for this study is 5 mg/L. Nelson et al. (2016) reports concentrations less than 10 mg/L as a minimal or no effect concentration, whilst concentrations above 10 mg/L have a sublethal effect to pelagic biota. Furthermore, IOGP (2016) cite that very high concentrations (>1,830 mg/L) of TSS have been shown to result in mortality of pelagic biota. Hence, a threshold range of 10-1,830 mg/L and above 1,830 mg/L were used to define low and high TSS exposures, respectively.

**Table 5.6 Reporting thresholds for sediment thickness and TSS concentrations for the drill cuttings and unrecoverable muds discharge modelling.**

| Reporting criteria | Total sediment thickness (mm) | Total suspended solids concentration (mg/L) |
|---|---|---|
| Minimum reporting threshold | 0.1 | 5 |
| Low exposure | 1 – 10 | 10 – 1,830 |
| High exposure | Above 10 | Above 1,830 |

# 6 Results

## 6.1 Deterministic Modelling Results

Deterministic modelling results of the near-seabed and near-sea surface discharges for the drilling and discharge programs at N1, W1 and W3 are presented below.

Figure 6.1 to Figure 6.6 present model screenshots of the predicted TSS concentrations during the modelled drilling and discharge operations at N1, W1 and W3 release locations, respectively, for a single surface (8.5" to 17.5" well intervals (see Section 5.2)) example discharge simulation (i.e., 1 out of the 50 per release location). The model screen shots illustrate the dynamic nature and TSS plume and provide both an aerial (plan) view illustrating the predicted TSS concentrations within the water column (cross section) along a given transect. These images have been included to provide an example “snapshot” of the predicted orientation and size of the TSS plume influenced by the time-varying current directions and speeds.

Figure 6.7 to Figure 6.9 presents the maximum thicknesses in each grid cell based on the surface and near-seabed (discharges of drill cuttings and muds at each of the three release locations, N1, W1 and W3 for the presented example single deterministic model simulations.

Due to the height of the surface discharges (~1,060 above the seabed) the currents had a greater influence of the distribution of the settling cuttings and muds solids and ultimate location of deposition compared to the near-seabed discharge. The larger particle sizes (i.e., medium and light cuttings, see Table 5.5) were predominantly deposited along the path of predominate current directions. The smaller particles demonstrated greater variability in location and deposition patterns.

Given the seabed discharges occur 2 m above the seabed, the currents had minimal influence on the larger, faster settling, sediments, which generally settled within 50 m from the release site in the direction of the predominant currents. The currents did have an increased influence of the smaller, slower settling, sediments (i.e., very light cuttings and drilling muds), which were carried and deposited up to 5 km from the release site (at thicknesses below the 0.1 mm minimum threshold).

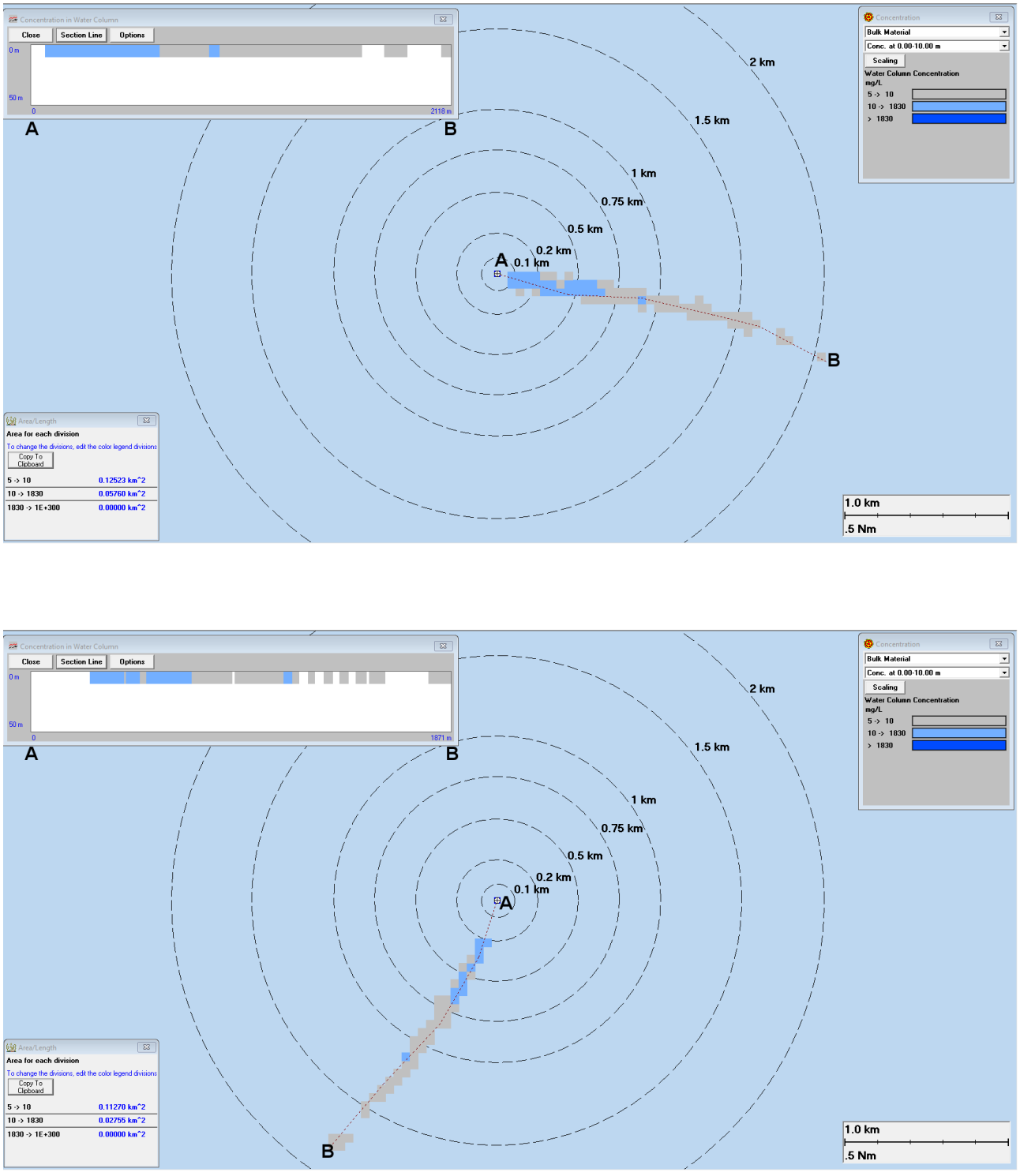



**Figure 6.1** **Example plan-view and water column (cross section) screenshots of the predicted TSS concentrations (in each grid cell) 6 hours (top image) and 12 hours (bottom image) into the surface discharge of drill cuttings and muds at N1 during July conditions. Screenshot results are from 1 simulation of the 50 modelled as part of the study at N1.**

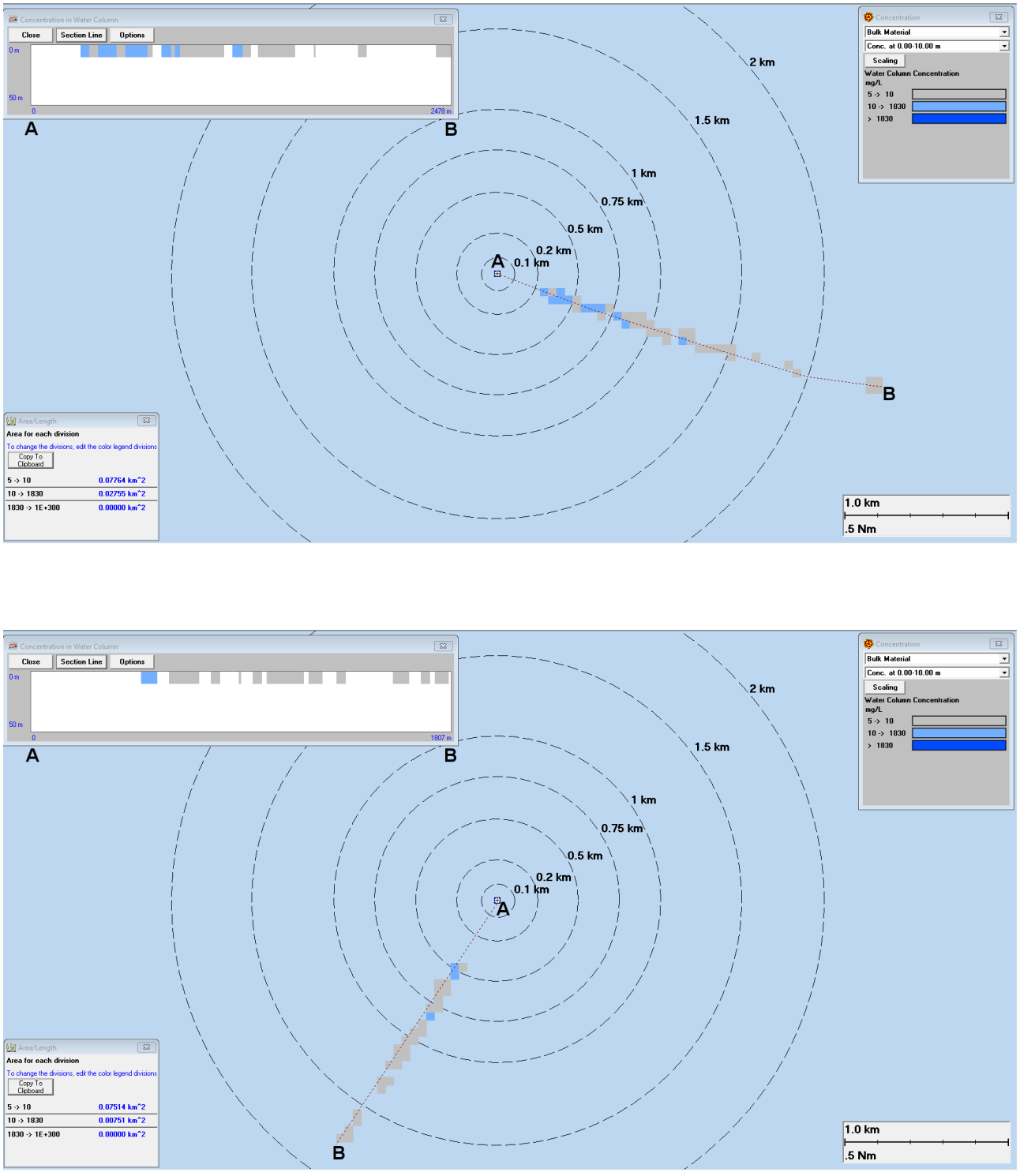



**Figure 6.2** **Example plan-view and water column (cross section) screenshots of the predicted TSS concentrations (in each grid cell) 18 hours (top image) and 24 hours (bottom image) into the surface discharge of drill cuttings and muds at N1 during July conditions. Screenshot results are from 1 simulation of the 50 modelled as part of the study at N1.**

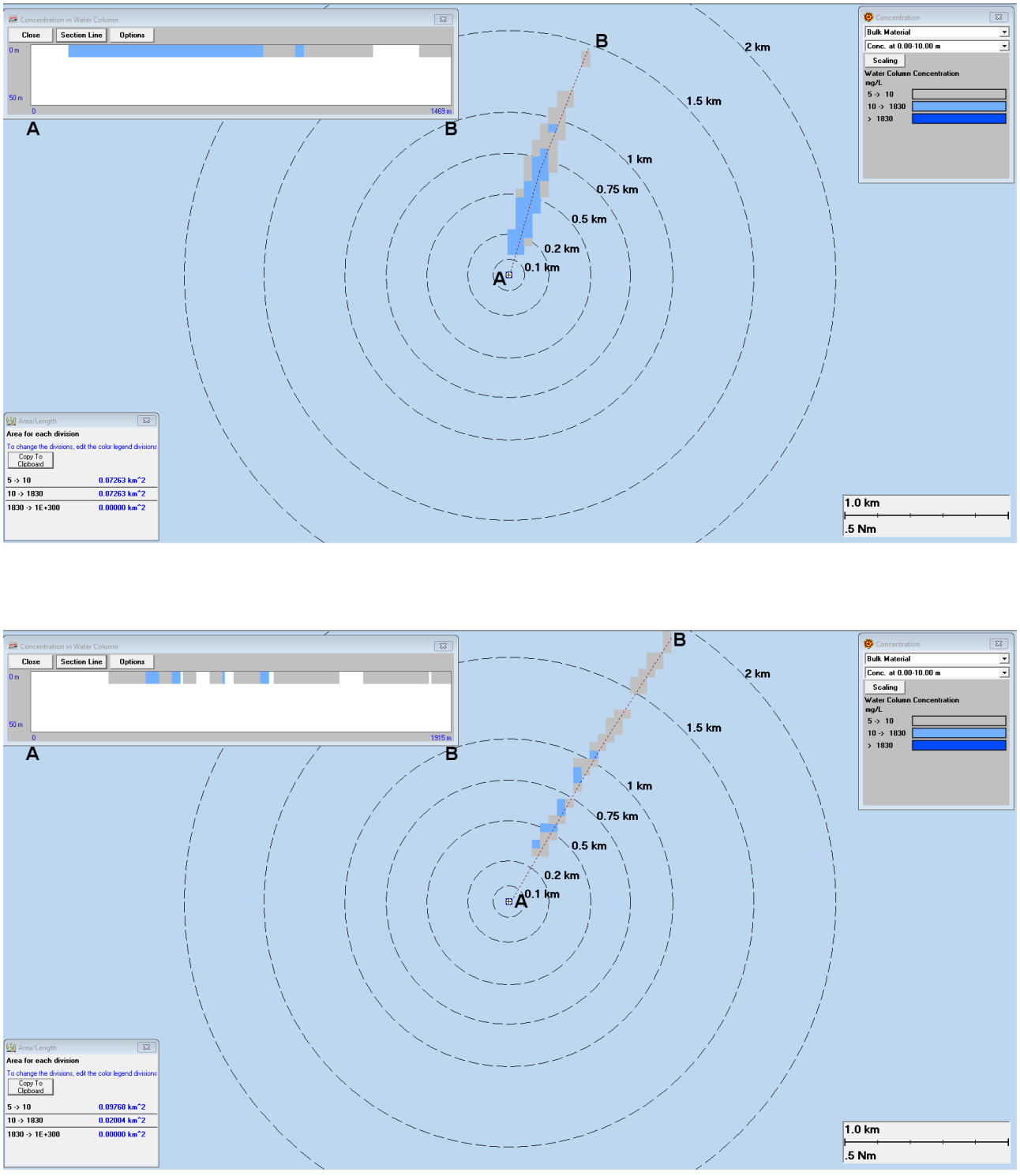



**Figure 6.3** **Example plan-view and water column (cross section) screenshots of the predicted TSS concentrations (in each grid cell) 11 hours (top image) and 17 hours (bottom image) into the surface discharge of drill cuttings and muds at W1 during September conditions. Screenshot results are from 1 simulation of the 50 modelled as part of the study at W1.**

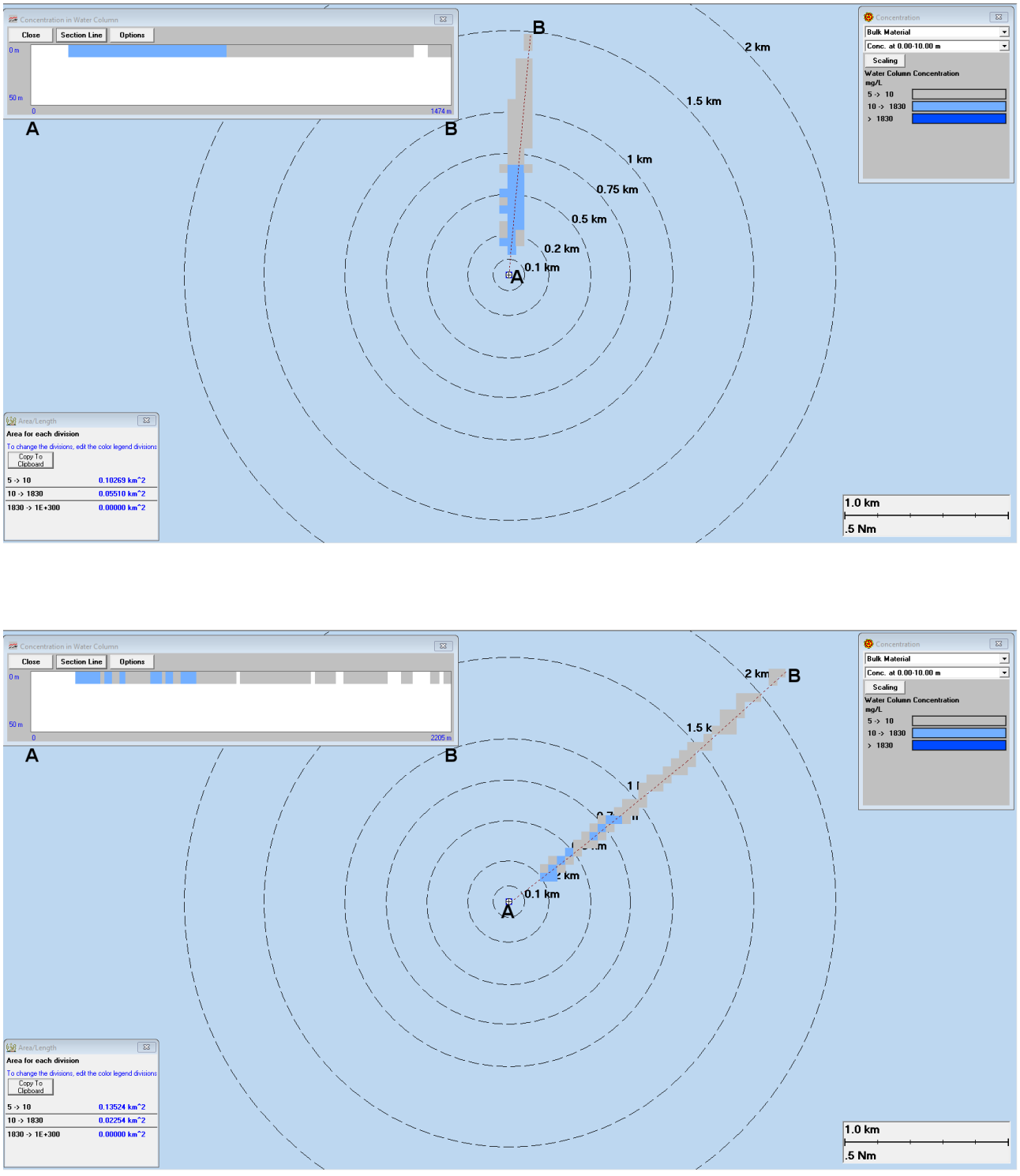



**Figure 6.4** **Example plan-view and water column (cross section) screenshots of the predicted TSS concentrations (in each grid cell) 23 hours (top image) and 29 hours (bottom image) into the surface discharge of drill cuttings and muds at W1 during September conditions. Screenshot results are from 1 simulation of the 50 modelled as part of the study at W1.**

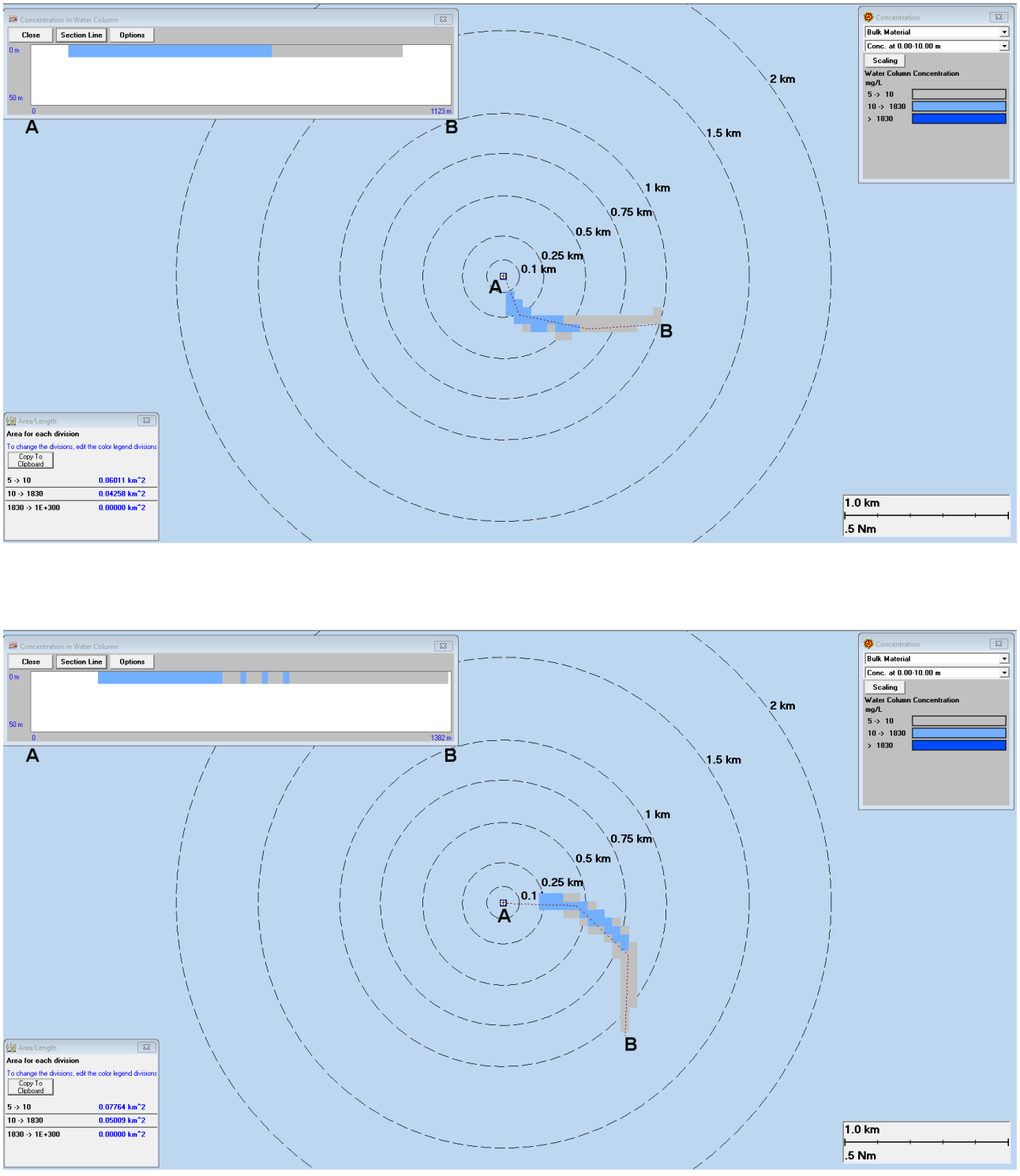



**Figure 6.5** **Example plan-view and water column (cross section) screenshots of the predicted TSS concentrations (in each grid cell) 2 hours (top image) and 8 hours (bottom image) into the surface discharge of drill cuttings and muds at W3 during October conditions. Screenshot results are from 1 simulation of the 50 modelled as part of the study at at W3.**

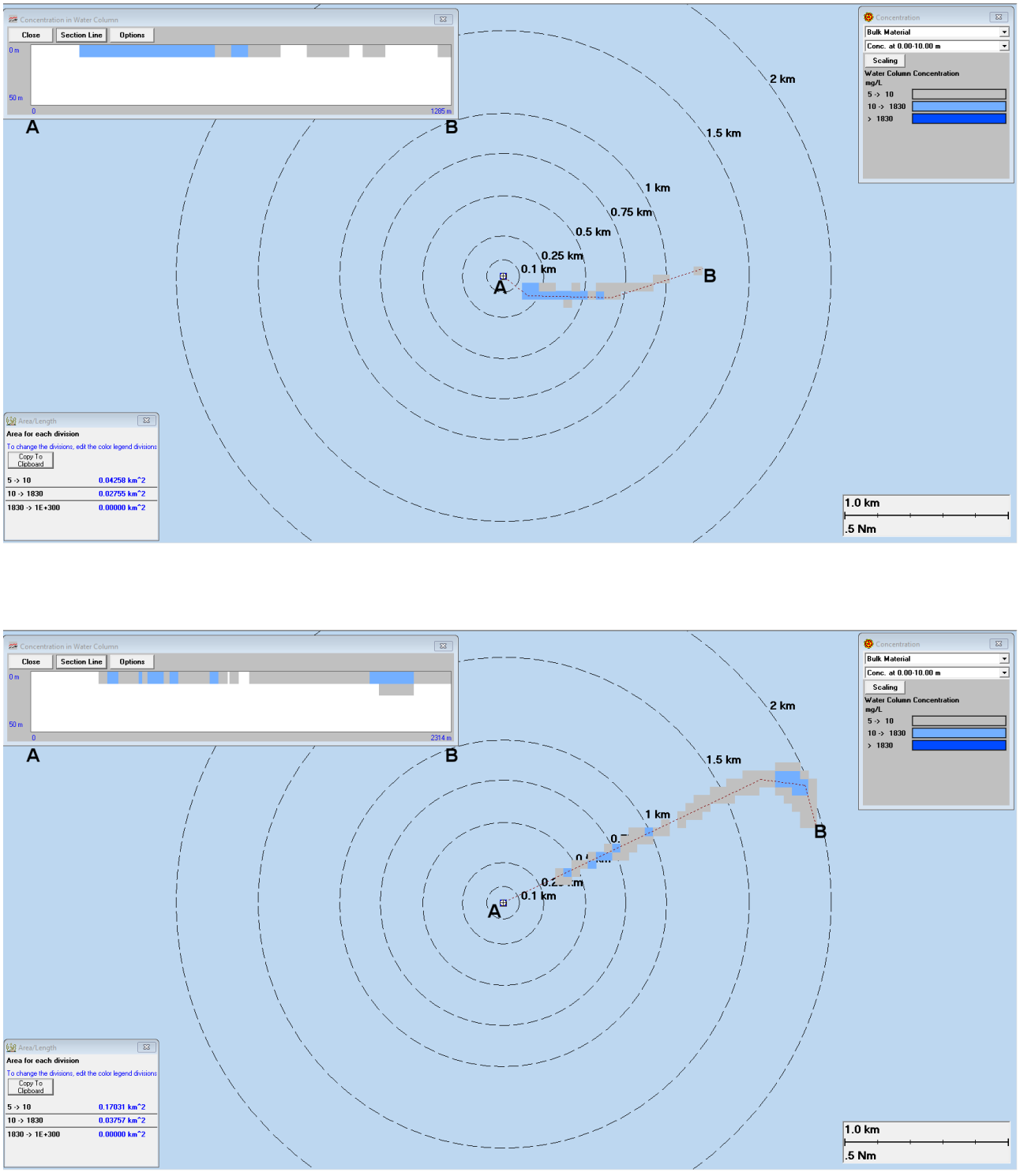



**Figure 6.6** **Example plan-view and water column (cross section) screenshots of the predicted TSS concentrations (in each grid cell) 14 hours (top image) and 22 hours (bottom image) into the surface discharge of drill cuttings and muds at W3 during October conditions. Screenshot results are from 1 simulation of the 50 modelled as part of the study at W3.**

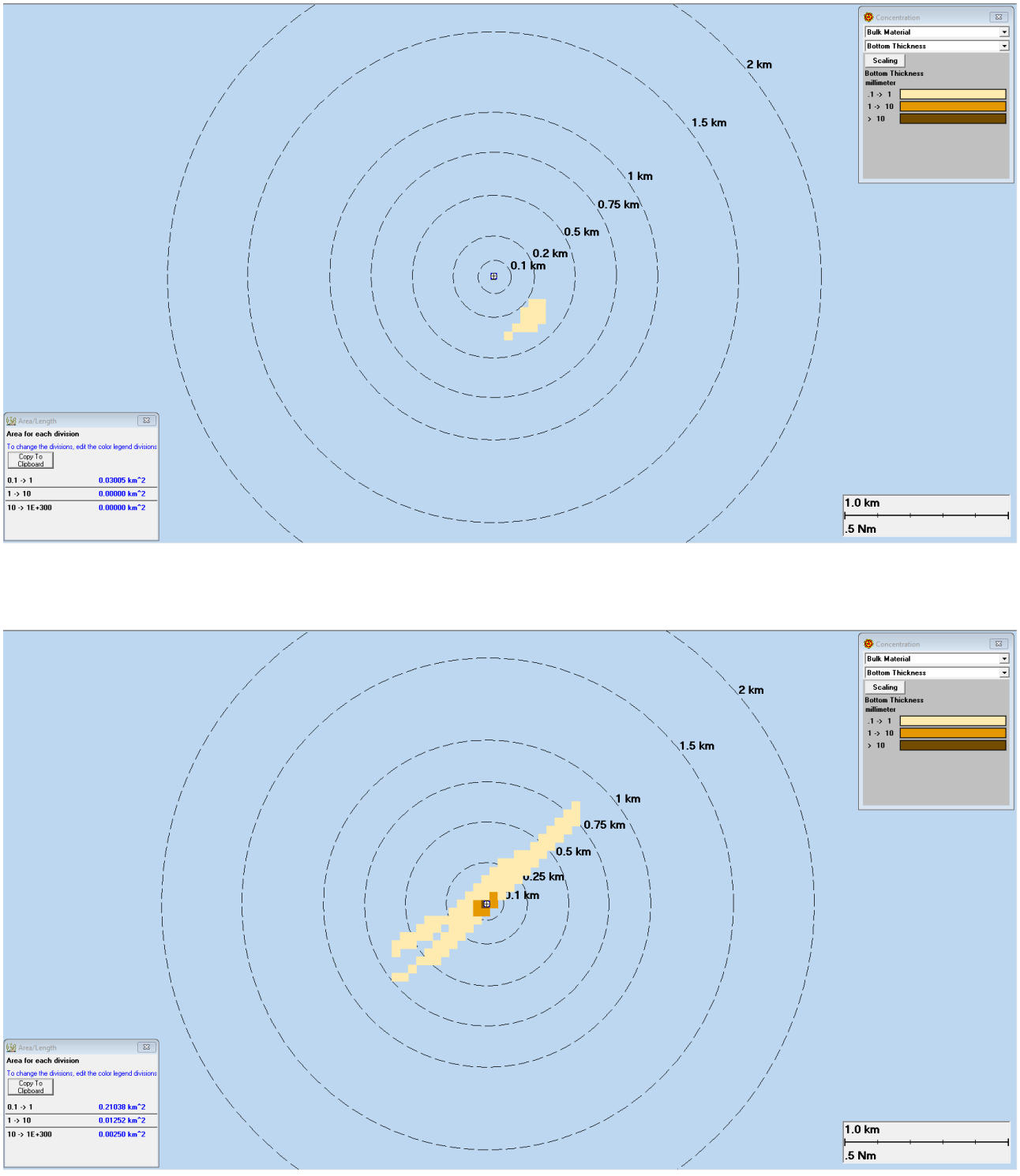



**Figure 6.7 Predicted bottom thicknesses from the surface (top image) and near-seabed (bottom image) discharges of drill cuttings and muds at N1 during July conditions. Results are based on 1 simulation of the 50 modelled as part of the study at N1.**

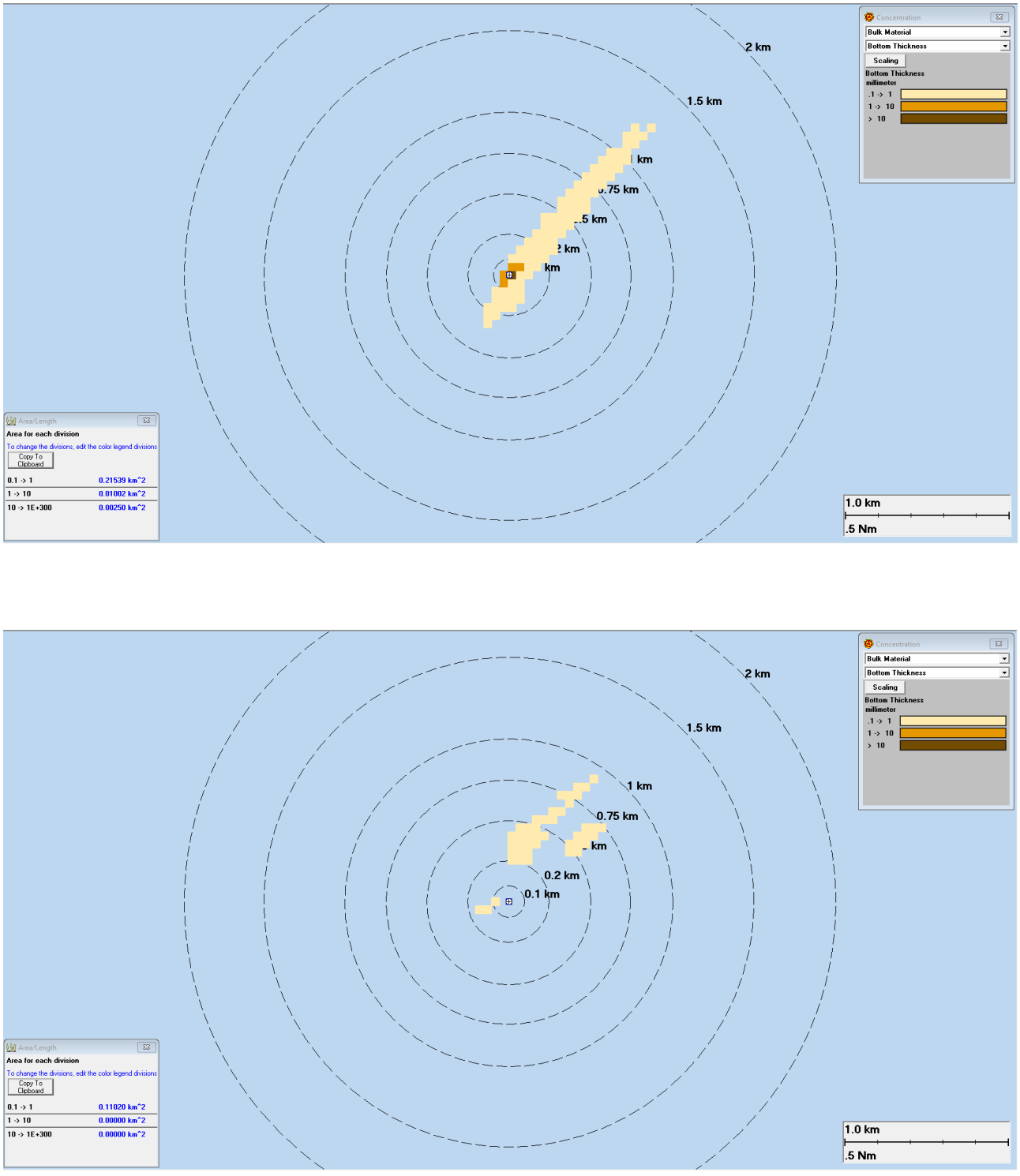



**Figure 6.8** **Predicted bottom thicknesses from the surface (top image) and near-seabed (bottom image) discharges of drill cuttings and muds at W1 during September conditions. Results are based on 1 simulation of the 50 modelled as part of the study at W1.**

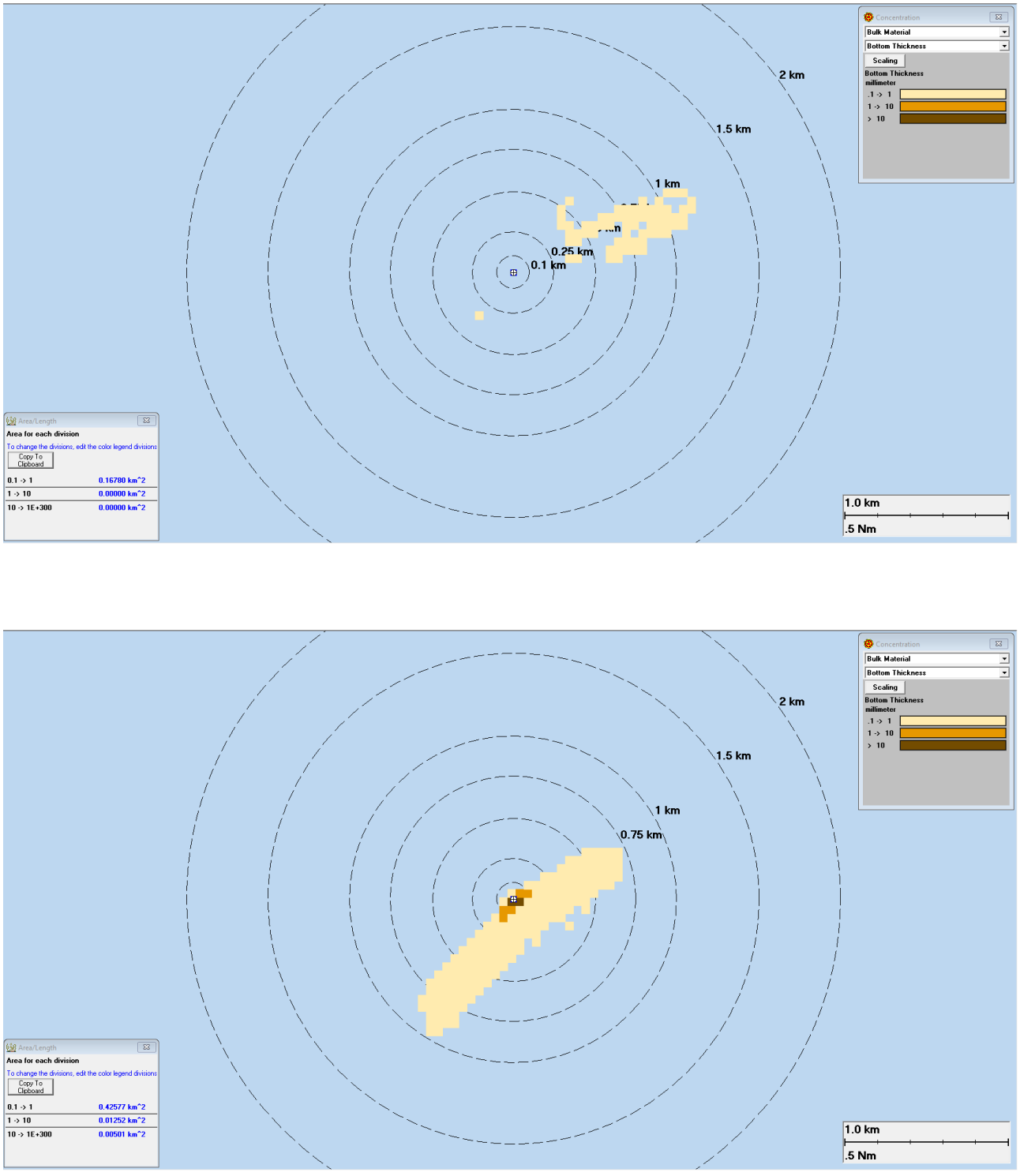



**Figure 6.9** **Predicted bottom thicknesses from the surface (top image) and near-seabed (bottom image) discharges of drill cuttings and muds at W3 during October conditions. Results are based on 1 simulation of the 50 modelled as part of the study at W3.**

## 6.2 Stochastic Modelling Results

### 6.2.1 Sediment Thickness

Figure 6.10 to Figure 6.12 present the maximum thicknesses in each grid cell from all 50 simulations to define the potential exposure from the discharge of cuttings and muds from N1, W1 and W3 for the modelled discharge programs.

Additionally, Figure 6.13 presents the maximum thicknesses in each grid cell based on the combined discharges from all three release locations, N1, W1 and W3.

The near-bottom riserless discharges from the release locations were responsible for the greatest thicknesses of deposited cuttings on the seafloor given the proximity of discharge (2 m) to the seabed. The maximum bottom deposition thicknesses of >2 m for all release locations were predicted to occur within the immediate vicinity of the near-bottom discharges (within 20 m). Note, this predicted maximum thickness is a conservative reported thickness as slumping of the localised deposited material immediately adjacent to the discharge is not accounted for.

Table 6.1 to Table 6.3 summarises the total area of coverage and the maximum distances from the release locations for each thickness threshold from N1, W1 and W3 for the modelled discharge program.

Based on the assessment of 50 simulations per well the maximum distances from the release location to the edge of the minimum reporting threshold (0.1 mm) ranged between 2.1 km (W1) and 2.5 km (N1). The maximum distances to the low (1 mm) and high (10 mm) exposure thresholds were 1.0 km and 0.2 km for N1, 0.8 km and 0.1 km for W1, and 0.9 km and 0.1 km for W3, respectively. The total area of coverage for the minimum reporting threshold ranged between 2.4 $km^2$ (W1) and 3.6 $km^2$ (W3). The total area of coverage for the low and high exposure thresholds were 0.4 $km^2$ and 0.02 $km^2$ for N1, 0.4 $km^2$ and 0.02 $km^2$ for W1, and 0.7 $km^2$ and 0.03 $km^2$ for W3, respectively.

Table 6.4 presents the combined predicted areas of coverage and maximum distances resulting from all three release locations, N1, W1 and W3.

Based on the combined assessment of all 150 simulations the maximum distances, measured from the mid-point between N1, W1 and W3, to the edge of the minimum reporting threshold, and the low and high exposure thresholds were 2.6 km, 1.5 km and 0.2 km, respectively. Additionally, the total area of coverage for the minimum reporting threshold, and the low and high exposure thresholds were 4.1 $km^2$, 1.9 $km^2$ and 0.06 $km^2$, respectively.

**Table 6.1 Predicted areas of coverage and maximum distances from the release location at N1 to each reporting threshold based on the results of all 50 simulations.**

| Reporting threshold | Total area of coverage ($km^2$) | Maximum distance (km) from the release locations |
|---|---|---|
| 0.1 mm thickness | 2.6 | 2.5 |
| 1 mm thickness | 0.4 | 1.0 |
| 10 mm thickness | 0.02 | 0.2 |

**Table 6.2 Predicted areas of coverage and maximum distances from the release location at W1 to each reporting threshold based on the results of all 50 simulations.**

| Reporting threshold | Total area of coverage ($km^2$) | Maximum distance (km) from the release locations |
|---|---|---|
| 0.1 mm thickness | 2.4 | 2.1 |
| 1 mm thickness | 0.4 | 0.9 |
| 10 mm thickness | 0.02 | 0.1 |

**Table 6.3 Predicted areas of coverage and maximum distances from the release location at W3 to each reporting threshold based on the results of all 50 simulations.**

| Reporting threshold | Total area of coverage ($km^2$) | Maximum distance (km) from the release locations |
|---|---|---|
| 0.1 mm thickness | 3.6 | 2.3 |
| 1 mm thickness | 0.7 | 0.9 |
| 10 mm thickness | 0.02 | 0.1 |

**Table 6.4 Combined predicted areas of coverage and maximum distances from all three release locations, N1, W1 and W3, to each reporting threshold based on the results of all 150 simulations.**

| Reporting threshold | Total area of coverage ($km^2$) | Maximum distance (km) from the release locations |
|---|---|---|
| 0.1 mm thickness | 4.1 | 2.6 |
| 1 mm thickness | 1.9 | 1.5 |
| 10 mm thickness | 0.06 | 0.2 |

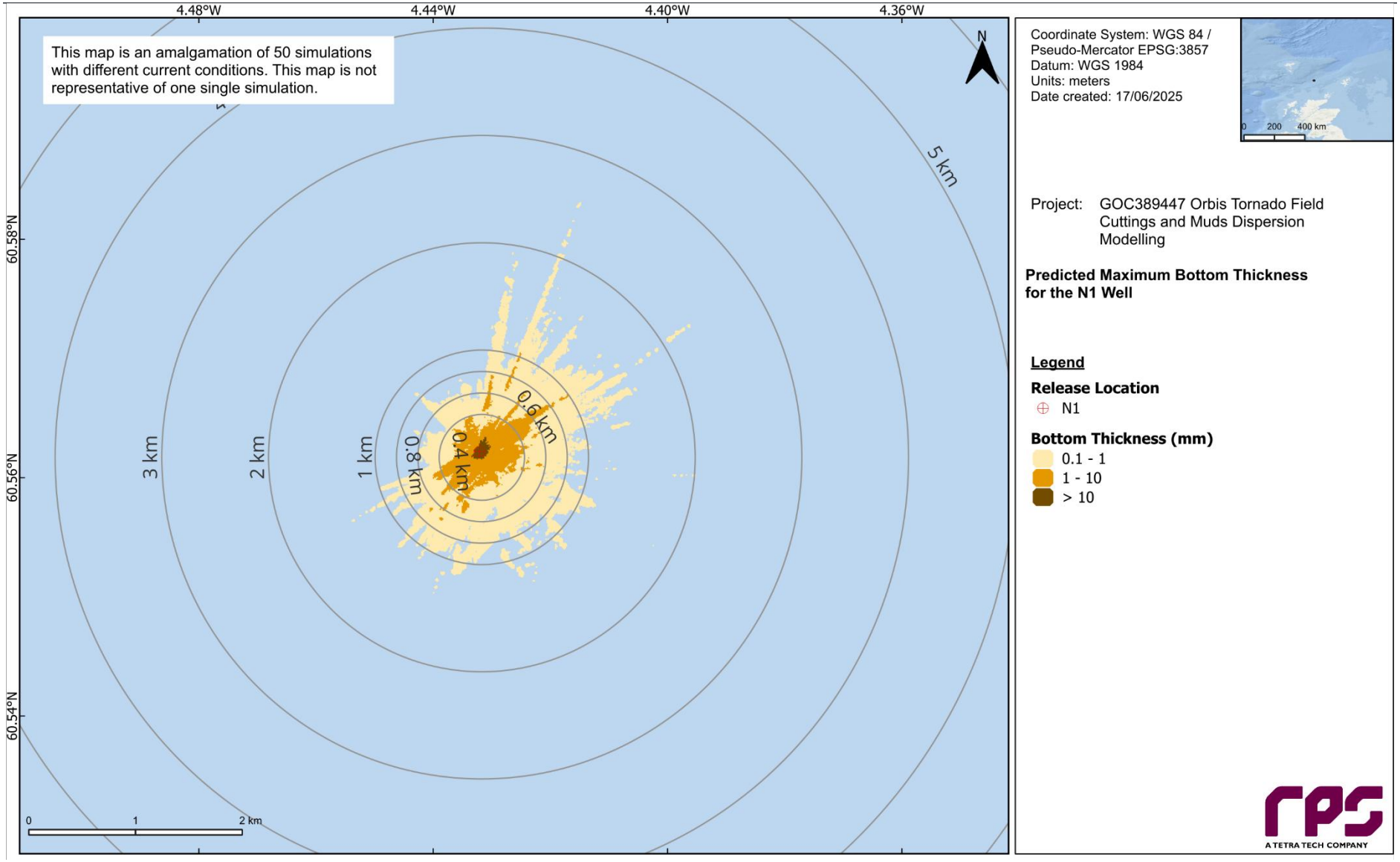



**Figure 6.10 Predicted maximum bottom thicknesses from the discharge of drill cuttings and muds at N1. Results are based on 50 simulations.**

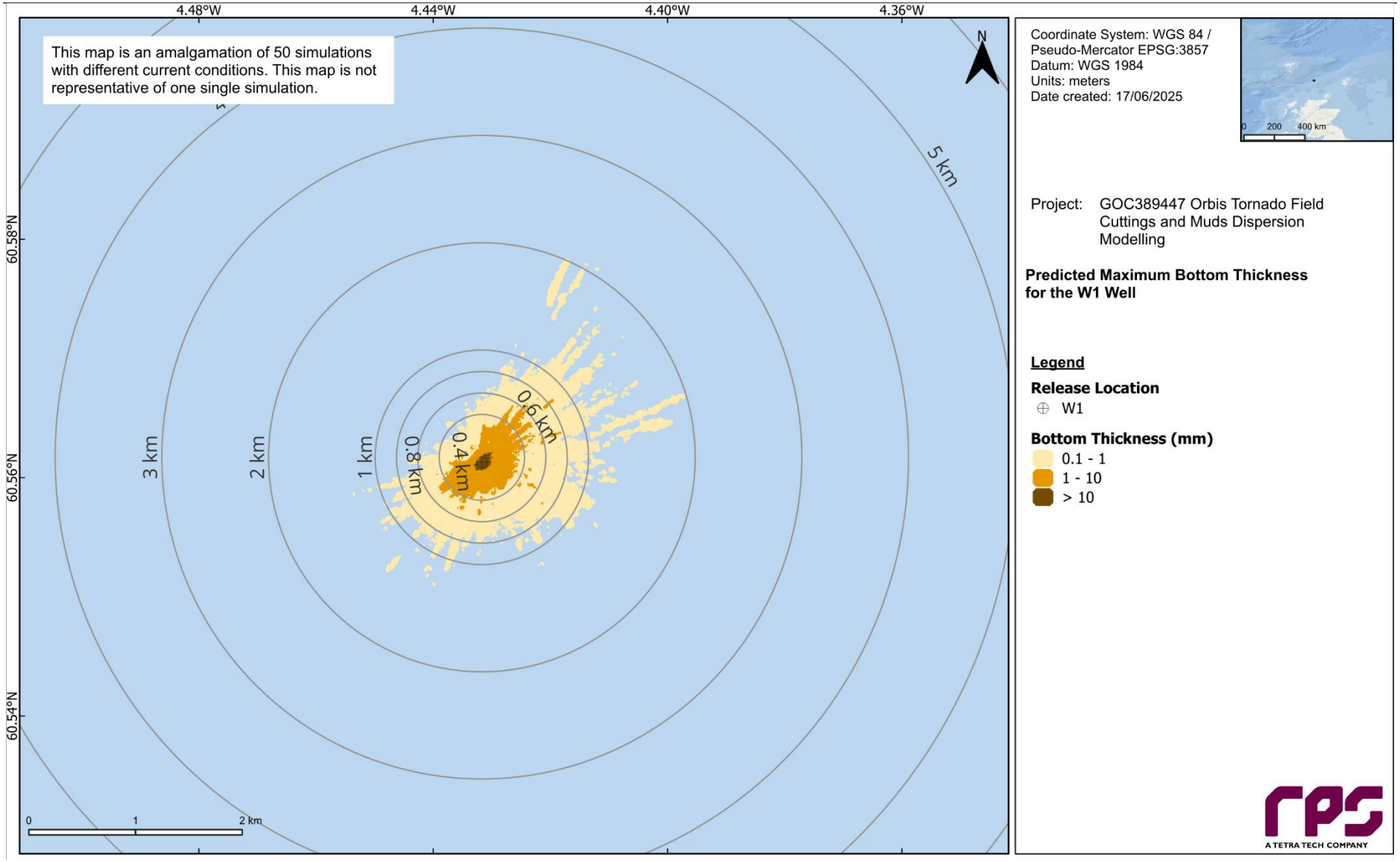



**Figure 6.11 Predicted maximum bottom thicknesses from the discharge of drill cuttings and muds at W1. Results are based on 50 simulations.**

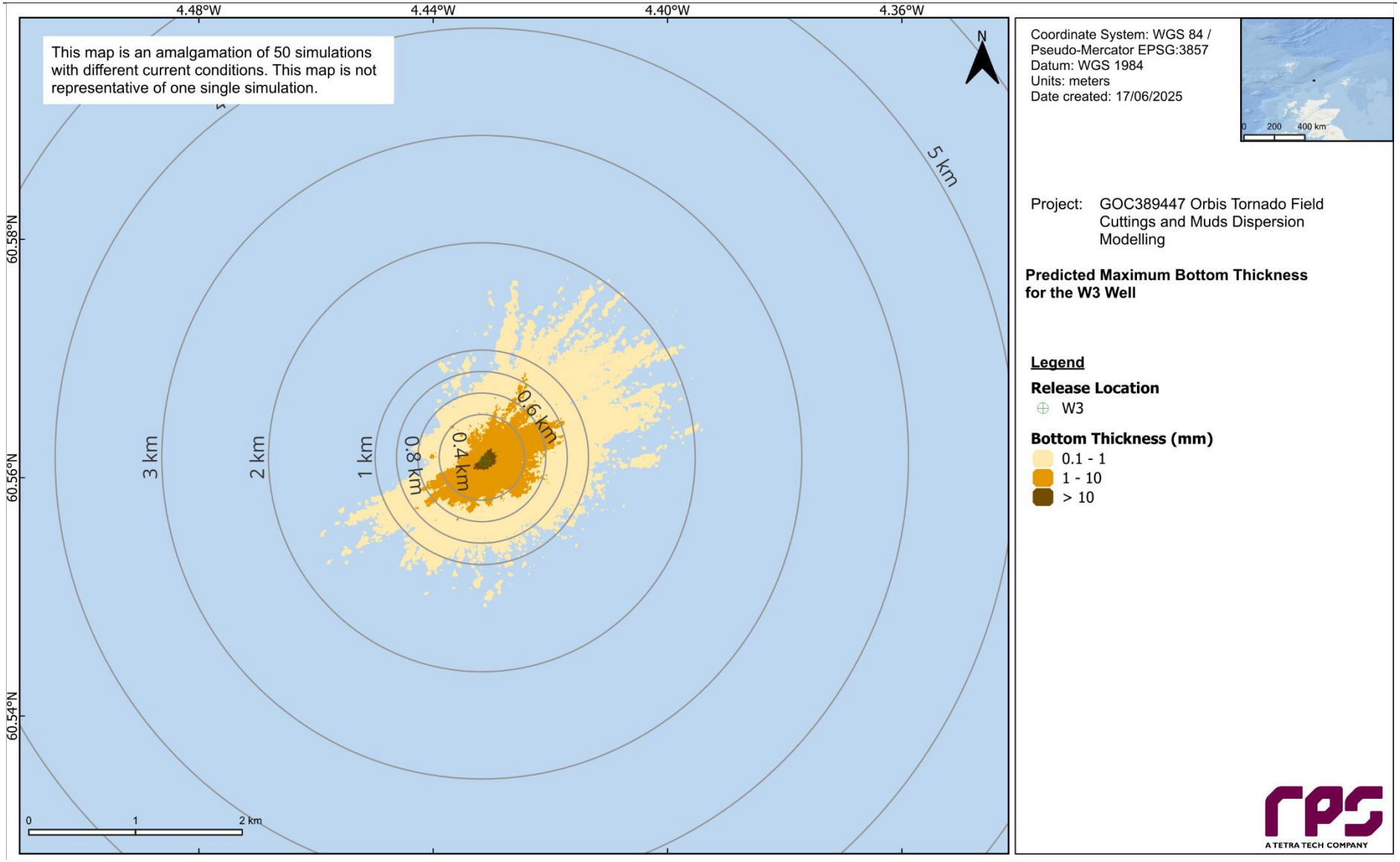



**Figure 6.12 Predicted maximum bottom thicknesses from the discharge of drill cuttings and muds at W3. Results are based on 50 simulations.**

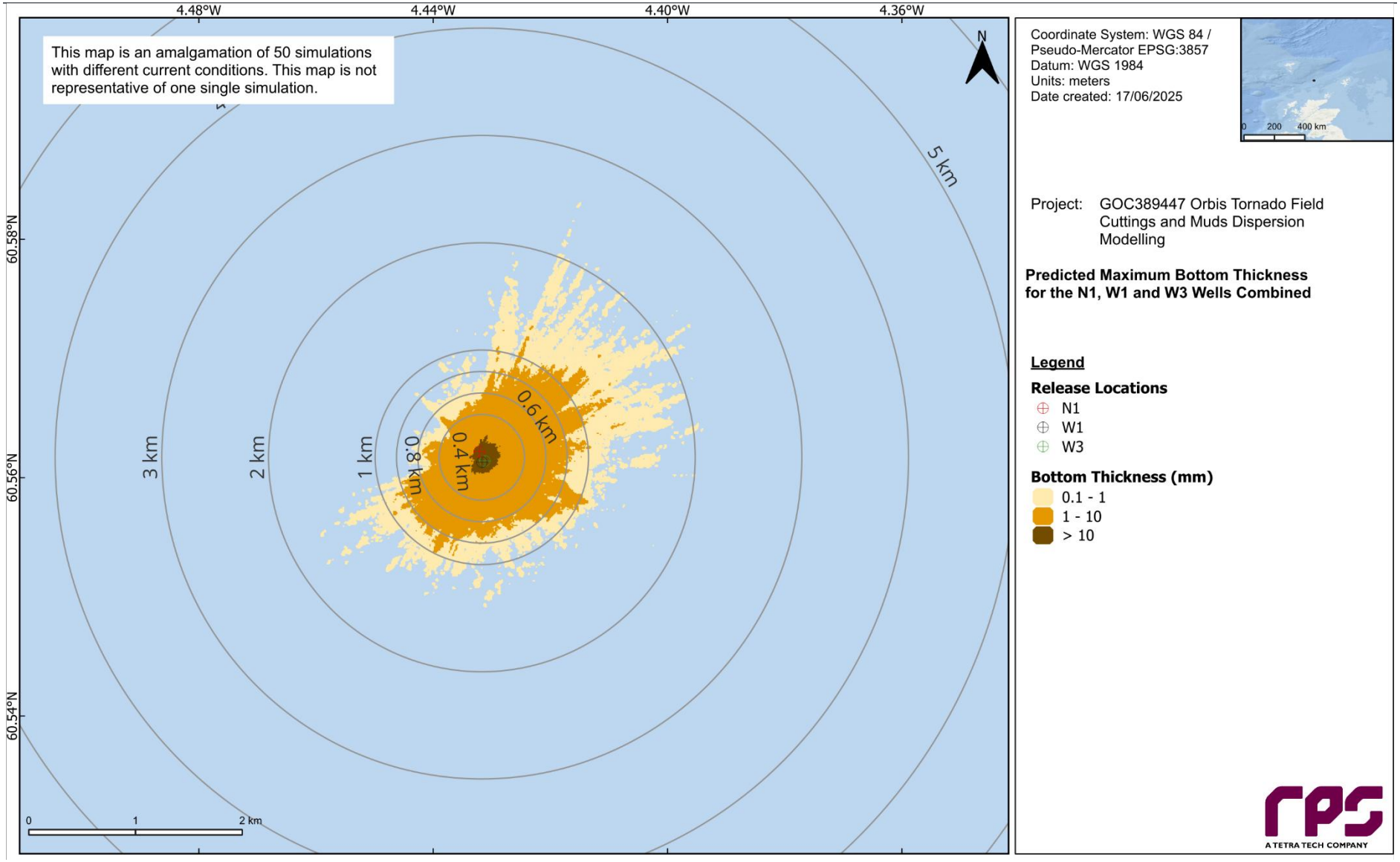



**Figure 6.13 Combined predicted maximum bottom thicknesses from the discharge of drill cuttings and muds at all three release locations, N1, W1 and W3. Results are based on 150 simulations.**

### 6.2.2 Total Suspended Solids

Figure 6.14 to Figure 6.19 illustrate the maximum TSS concentrations in each grid cell from all 50 simulations, based on the predicted 95$^{th}$ and 100$^{th}$ percentile concentrations, to define the potential exposure from the discharge of cuttings and muds from N1, W1 and W3.

Additionally, Figure 6.20 and Figure 6.21 presents the combined the predicted 95$^{th}$ and 100$^{th}$ percentile concentrations, from the discharge of drill cuttings and muds at all three release locations, N1, W1 and W3.

Elevated TSS concentrations were predicted to occur in the immediate vicinity of the release locations (50 m). Predicted maximum 95$^{th}$ and 100$^{th}$ percentile TSS concentrations arising from the discharge of cuttings and muds from the release locations were 311.5 mg/L and 304.0 mg/L (N1), 311.0 mg/L and 298.3 mg/L (W1), and 313.7 mg/L and 303.7 mg/L (W3), respectively.

Table 6.5 to Table 6.7 summarises the total area of coverage and maximum distances from the release location for each TSS concentration threshold based on 95$^{th}$ and 100$^{th}$ percentile analyses of the model output.

Based on the assessment of 50 simulations per well and 95$^{th}$ percentile analysis, maximum distances from the release location to the edge of the minimum reporting threshold (5 mg/L) ranged between 1.5 km (W3) and 3.3 km (W1). The maximum distances to the low exposure thresholds (10 mg/L) were 1.1 km for N1 and W1, and 0.7 km for W3, respectively. The total area of coverage for the minimum reporting threshold (5 mg/L) ranged between 2.3 km$^2$ (W3) and 4.6 km$^2$ (W1). Additionally, the total area of coverage for the low exposure thresholds (10 mg/L) ranged from 0.6 km$^2$ (W3) to 1.2 km$^2$ (N1 and W1).

Table 6.8 presents the combined predicted areas of coverage and maximum distances resulting from all three release locations, N1, W1 and W3 based on the 95$^{th}$ and 100$^{th}$ percentile concentrations.

Based on the combined assessment of all 150 simulations and 95$^{th}$ percentile analysis, the maximum distances, measured from the mid-point between N1, W1 and W3, to the edge of the minimum reporting threshold (5 mg/L) and the low exposure thresholds (10 mg/L) were 3.3 km and 1.1 km, respectively.

The discharge of cuttings and muds will lead to relatively short-lived increased TSS concentrations, which is expected to dilute and reduce with distance from the release locations. Based on the temporary elevated concentrations of TSS concentrations at the low exposure threshold, and the limited occurrence of the very localised high exposure, the impact likelihood is thus considered low.

**Table 6.5 Predicted 95$^{th}$ and 100$^{th}$ (maximum) percentiles of total areas of coverage and maximum distances from the release location N1 to each reporting threshold based on the results of all 50 simulations.**

| Reporting threshold | 95$^{th}$ Percentile Total area of coverage (km$^2$) | 100$^{th}$ Percentile Total area of coverage (km$^2$) | 95$^{th}$ Percentile Maximum distance (km) from the release locations | 100$^{th}$ Percentile Maximum distance (km) from the release locations |
|---|---|---|---|---|
| ≥5 mg/L TSS concentration | 4.5 | 63.4 | 2.0 | 11.6 |
| ≥10 mg/L TSS concentration | 1.2 | 17.8 | 1.1 | 9.3 |
| ≥1,830 mg/L TSS concentration | - | - | - | - |

**Table 6.6** **Predicted 95th percentile total areas of coverage and maximum distances from the release location W1 to each reporting threshold based on the results of all 50 simulations.**

| Reporting threshold | 95th Percentile Total area of coverage (km²) | 100th Percentile Total area of coverage (km²) | 95th Percentile Maximum distance (km) from the release locations | 100th Percentile Maximum distance (km) from the release locations |
|---|---|---|---|---|
| 5 mg/L TSS concentration | 4.6 | 56.4 | 3.3 | 13.0 |
| ≥10 mg/L TSS concentration | 1.2 | 16.3 | 1.1 | 7.0 |
| ≥1,830 mg/L TSS concentration | - | - | - | - |

**Table 6.7** **Predicted 95th and 100th (maximum) percentiles of total areas of coverage and maximum distances from the release location W3 to each reporting threshold based on the results of all 50 simulations.**

| Reporting threshold | 95th Percentile Total area of coverage (km²) | 100th Percentile Total area of coverage (km²) | 95th Percentile Maximum distance (km) from the release locations | 100th Percentile Maximum distance (km) from the release locations |
|---|---|---|---|---|
| ≥5 mg/L TSS concentration | 2.3 | 56.6 | 1.5 | 12.6 |
| ≥10 mg/L TSS concentration | 0.6 | 15.4 | 0.7 | 8.0 |
| ≥1,830 mg/L TSS concentration | - | - | - | - |

**Table 6.8** **Predicted 95th and 100th (maximum) percentiles the combined total areas of coverage and maximum distances from the release location, N1, W1 and W3, to each reporting threshold based on the results of all 150 simulations.**

| Reporting threshold (criteria) | 95th Percentile Total area of coverage (km²) | 100th Percentile Total area of coverage (km²) | 95th Percentile Maximum distance (km) from the release locations | 100th Percentile Maximum distance (km) from the release locations |
|---|---|---|---|---|
| ≥5 mg/L TSS concentration | 5.6 | 86.1 | 3.3 | 13.0 |
| ≥10 mg/L TSS concentration | 1.4 | 24.1 | 1.1 | 9.3 |
| ≥1,830 mg/L TSS concentration | - | - | - | - |

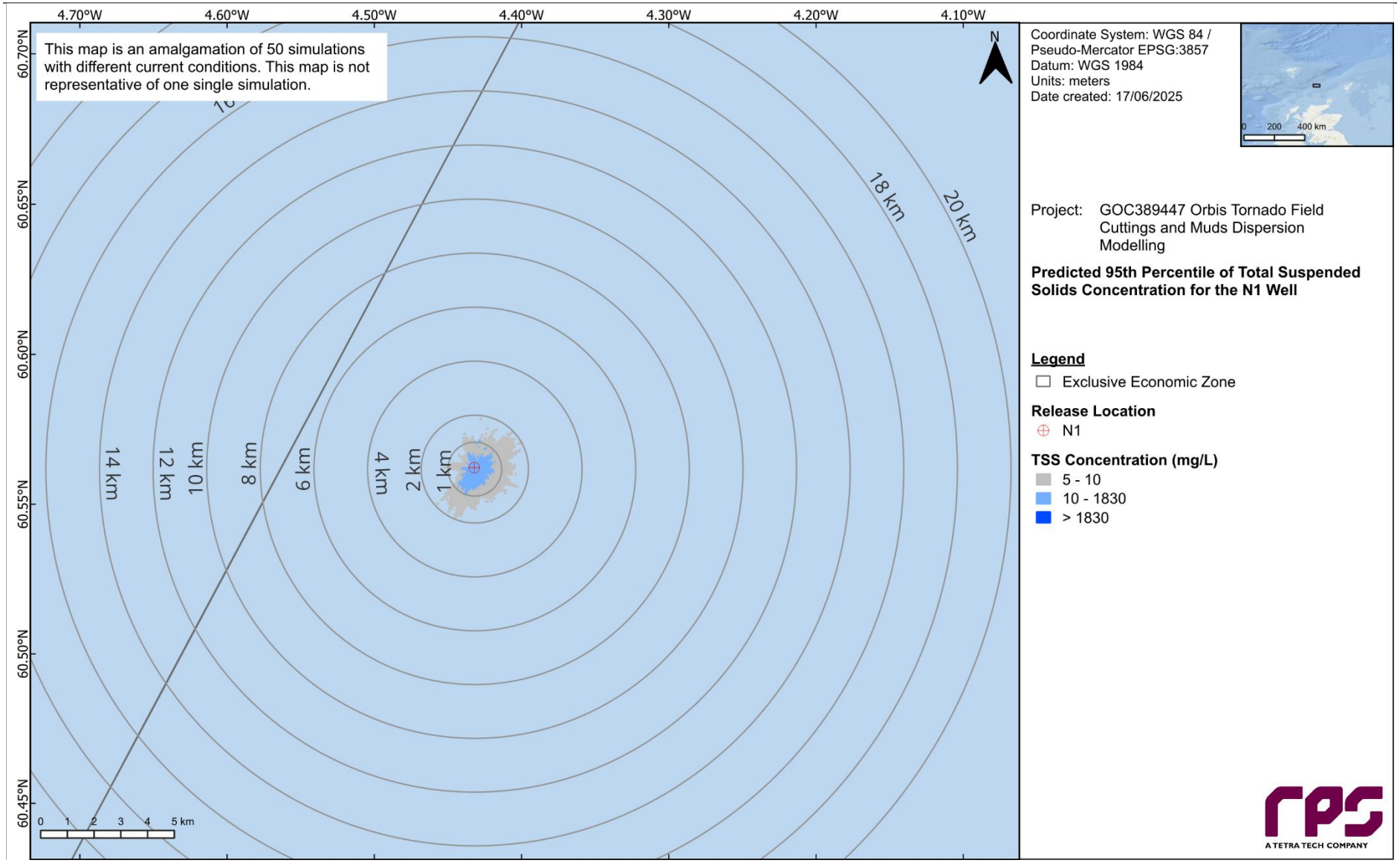



**Figure 6.14 Predicted maximum instantaneous TSS concentrations, based on 95th percentile concentrations from the discharge of drill cuttings and muds at N1. Results are based on 50 simulations.**

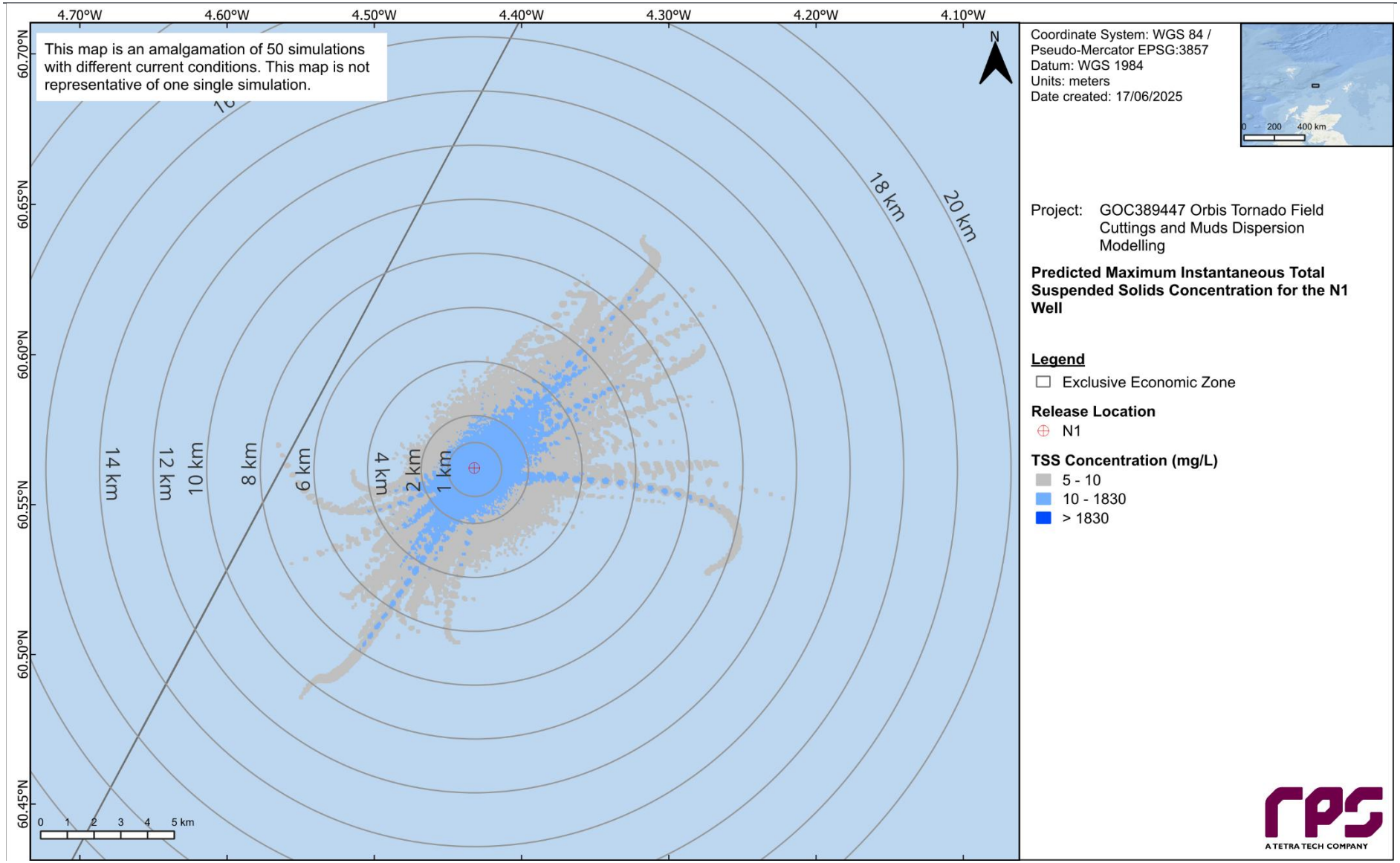



**Figure 6.15 Predicted maximum instantaneous TSS concentrations, based on 100th percentile concentrations from the discharge of drill cuttings and muds at N1. Results are based on 50 simulations.**

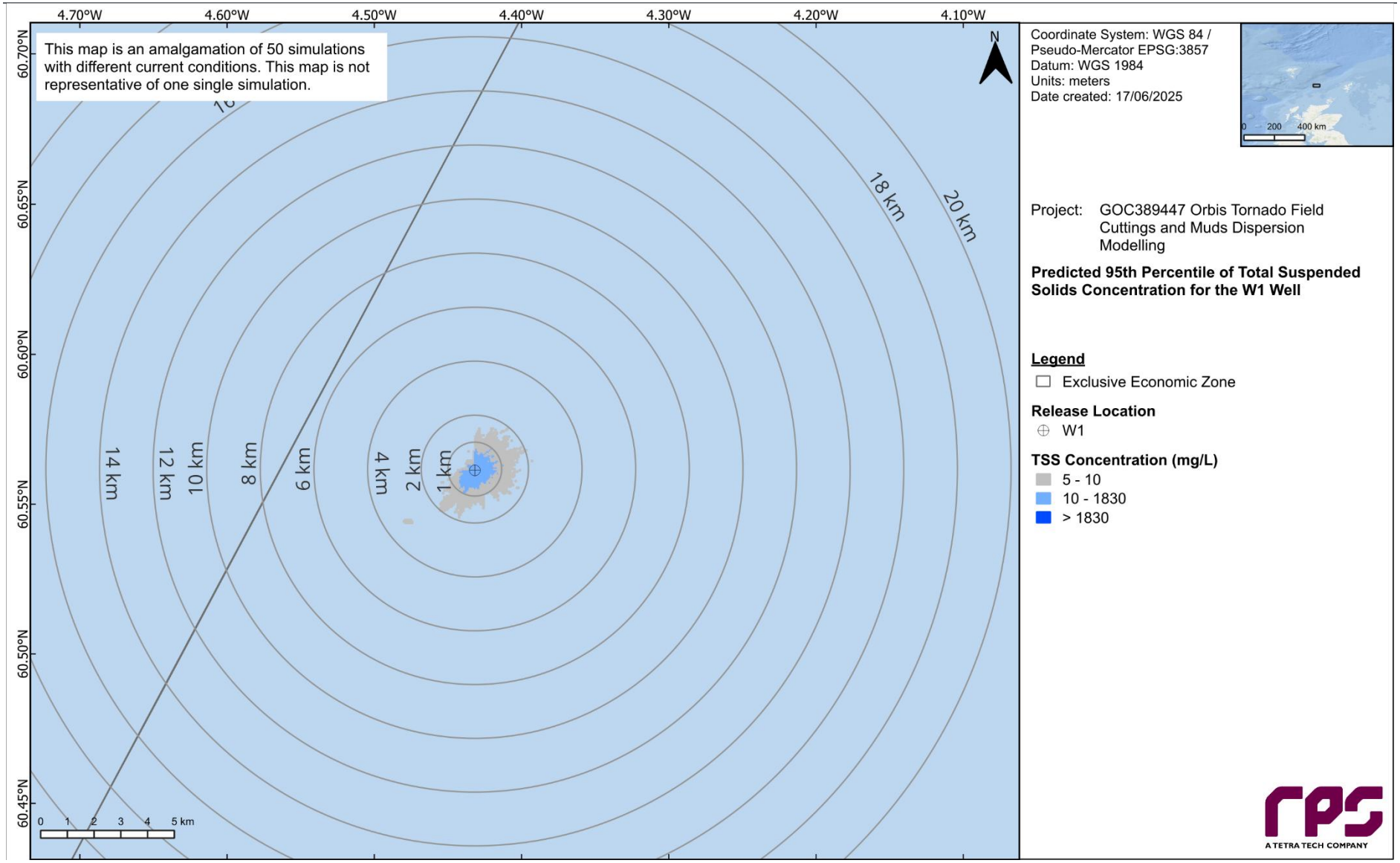



**Figure 6.16 Predicted maximum instantaneous TSS concentrations, based on 95th percentile concentrations from the discharge of drill cuttings and muds at W1. Results are based on 50 simulations.**

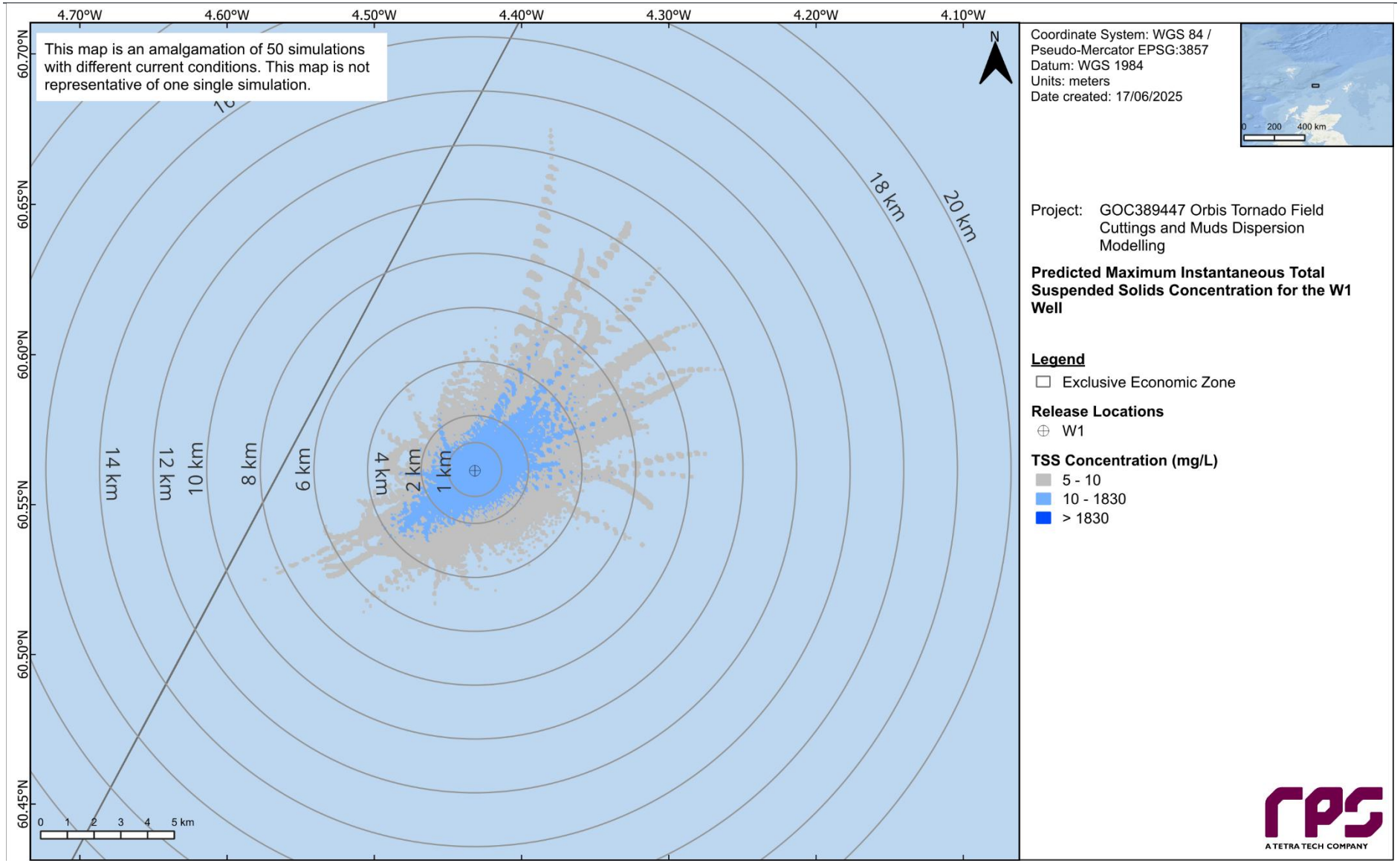



**Figure 6.17 Predicted maximum instantaneous TSS concentrations, based on 100th percentile concentrations from the discharge of drill cuttings and muds at W1. Results are based on 50 simulations.**

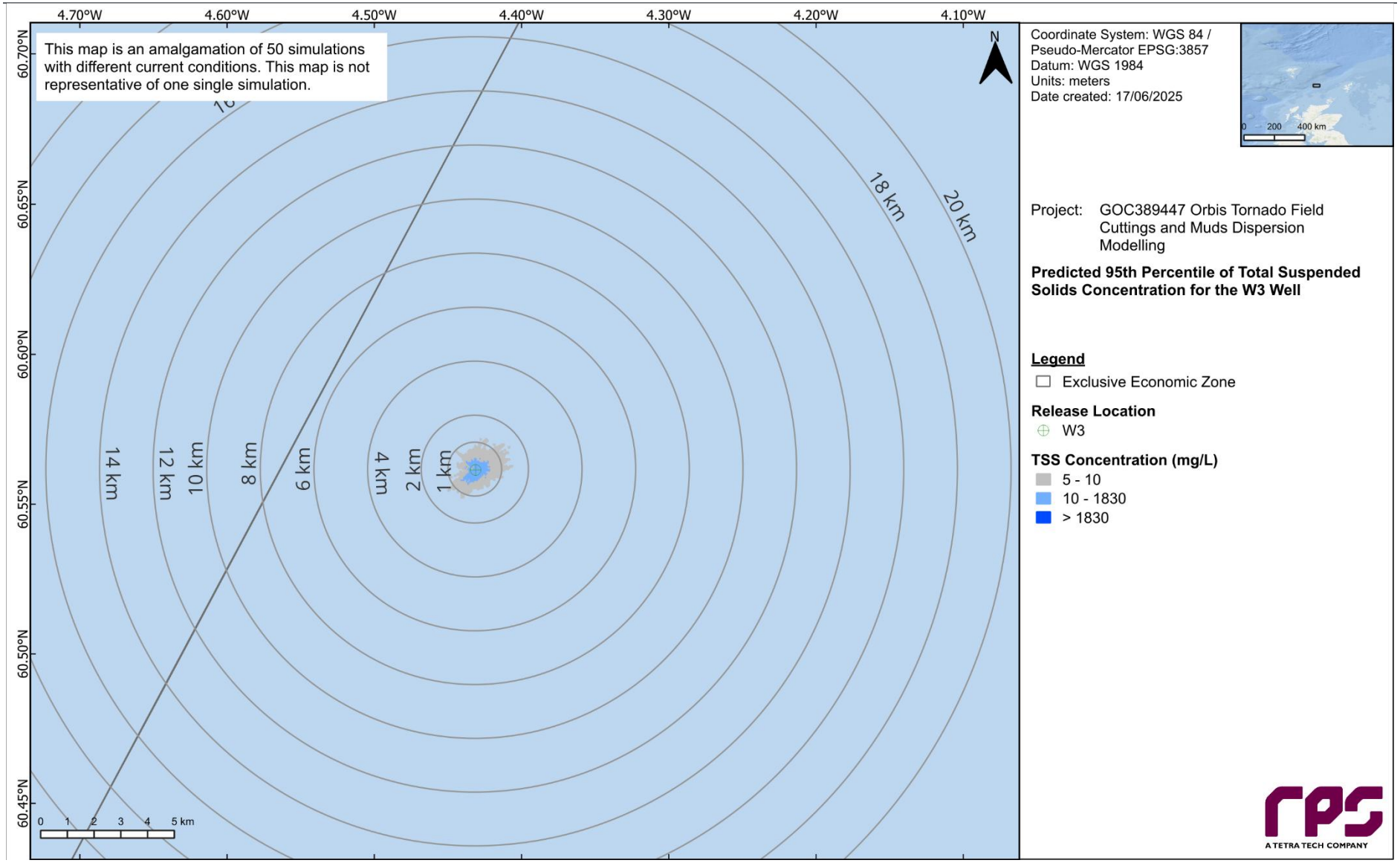



**Figure 6.18 Predicted maximum instantaneous TSS concentrations, based on 95th percentile concentrations from the discharge of drill cuttings and muds at W3. Results are based on 50 simulations.**

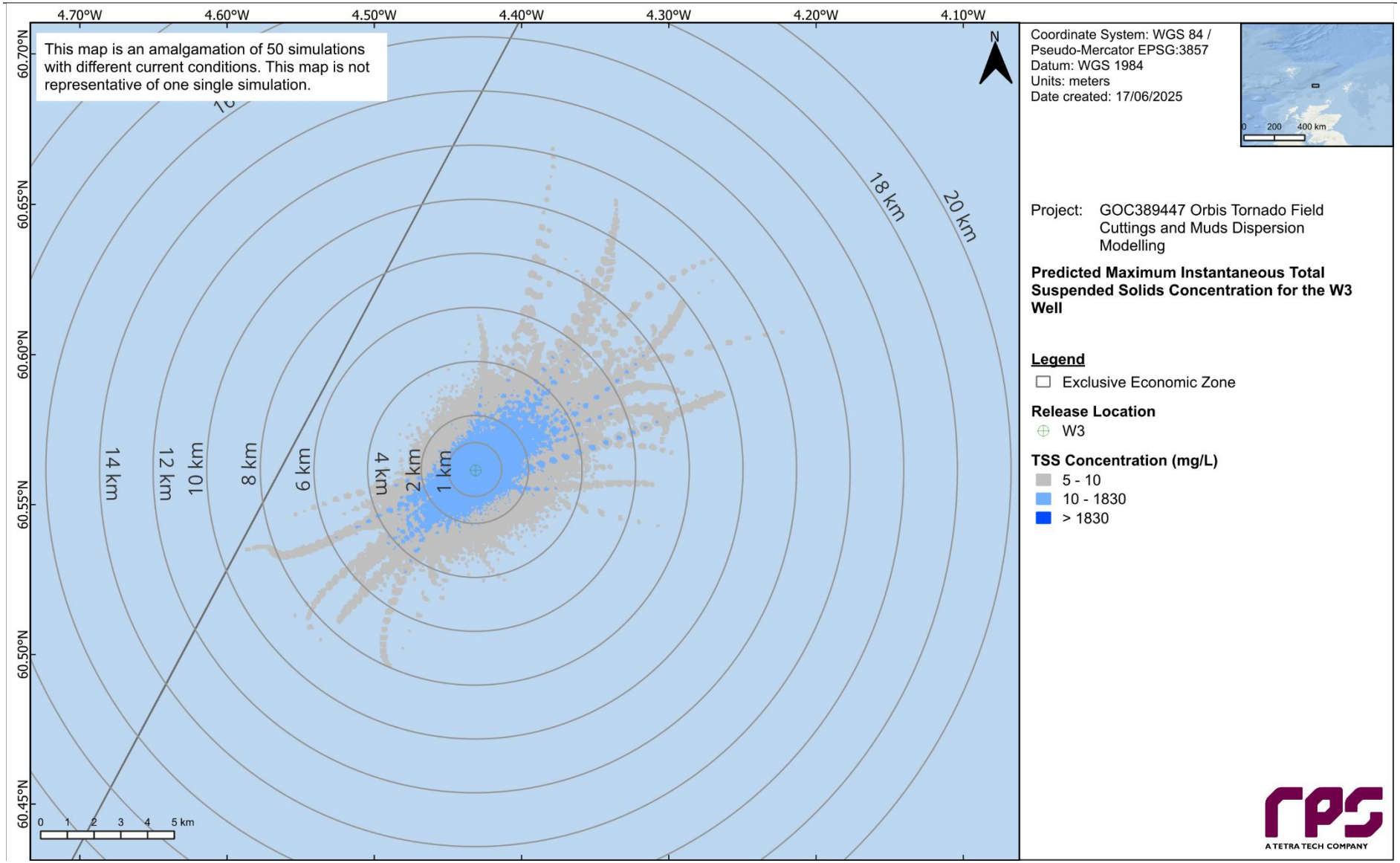



**Figure 6.19 Predicted maximum instantaneous TSS concentrations, based on 100th percentile concentrations from the discharge of drill cuttings and muds at W3. Results are based on 50 simulations.**

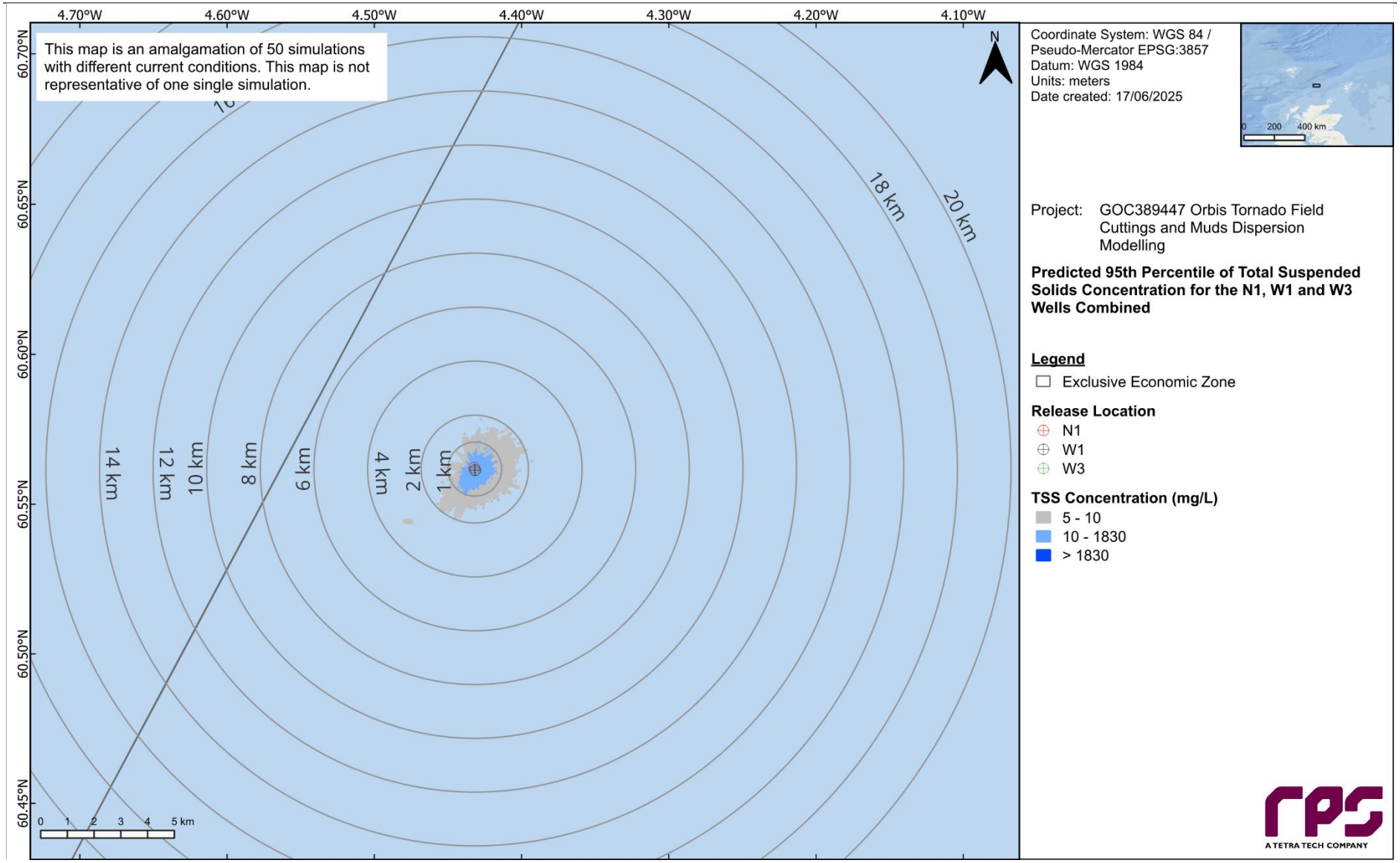



**Figure 6.20 Combined predicted maximum instantaneous TSS concentrations, based on 95th percentile concentrations from the discharge of drill cuttings and muds at all three release locations, N1, W1 and W3. Results are based on 150 simulations.**

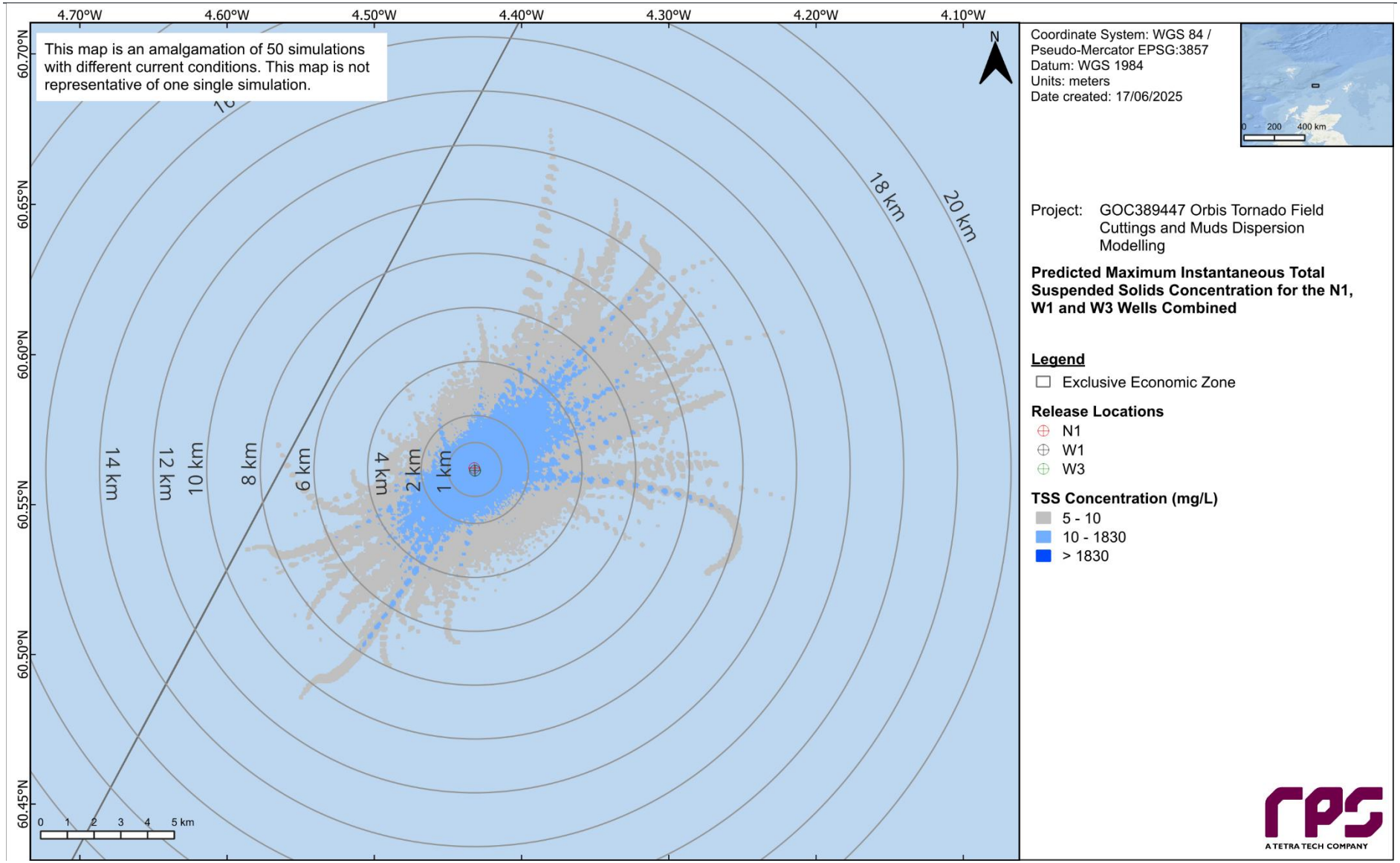



**Figure 6.21 Combined predicted maximum instantaneous TSS concentrations, based on 100th percentile concentrations from the discharge of drill cuttings and muds at all three release locations, N1, W1 and W3. Results are based on 150 simulations.**

# 7 References


Akinbamini, OE, Anifowose, B & Obioma, EC 2022, 'Oil Spill Modeling for the Mariner Oil Field, East of Shetland, United Kingdom, North Sea', *Journal of Environmental Engineering*, vol. 148, no. 8, p.04022037.

Albert, PC & Prosser, CM 2023, 'Modeling demonstrates minimal ecological risks of cuttings discharges associated to oil and gas drilling with deep water wells', *Marine Pollution Bulletin*, vol. 186, pp. 114421.

Amores, A, Jordà, G & Monserrat, S 2019, 'Ocean eddies in the Mediterranean Sea from satellite altimetry: Sensitivity to satellite track location', *Frontiers in Marine Science*, vol. 6, p.703.

Andersen, OB 1995, 'Global ocean tides from ERS 1 and TOPEX/POSEIDON altimetry', *Journal of Geophysical Research: Oceans*, vol. 100, no. C12, pp. 25249–25259.

Bacon, S., 1997: Circulation and Fluxes in the North Atlantic between Greenland and Ireland, Journal of Oceanography, vol. 27, pp. 1420–1435.

Becker, JJ, Sandwell, DT, Smith, WHF, Braud, J, Binder, B, Depner, J, Fabre, D, Factor, J, Ingalls, S, Kim, S-H, Ladner, R, Marks, K, Nelson, S, Pharaoh, A, Trimmer, R, Von Rosenberg, J, Wallace, G & Weatherall, P 2009, 'Global bathymetry and evaluation data at 30 arc seconds resolution: SRTM30_PLUS', *Marine Geodesy*, vol. 32, no. 4, pp. 355–371.

Bischof, B, Mariano, AJ, Ryan, EH 2003, '"The North Atlantic Drift Current" Ocean Surface Currents', viewed 8 April 2025, http://oceancurrents.rsmas.miami.edu/atlantic/north-atlantic-drift.html .

Burns, K, Codi, S, Furnas, M, Heggie, D, Holdway, D, King, B, & McAllister, F 1999, 'Dispersion and Fate of Produced Formation Water Constituents in an Australian Northwest Shelf Shallow Water Ecosystem', *Marine Pollution Bulletin*, vol. 38, no. 7, pp. 593–603.

Chassignet, EP, Hurlburt, HE, Smedstad, OM, Halliwell, GR, Hogan, PJ, Wallcraft, AJ, Baraille, R & Bleck, R 2007, 'The HYCOM (hybrid coordinate ocean model) data assimilative system', *Journal of Marine Systems,* vol. 65, no. 1, pp. 60–83.

Chassignet, E, Hurlburt, H, Metzger, E, Smedstad, O, Cummings, J & Halliwell, G 2009, 'U.S. GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)', *Oceanography*, vol. 22, no. 2, pp. 64–75.

Davies, AM 1977a, 'The numerical solutions of the three-dimensional hydrodynamic equations using a B-spline representation of the vertical current profile', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 1–25.

Davies, AM 1977b, 'Three-dimensional model with depth-varying eddy viscosity', in JC Nihoul (ed), Bottom Turbulence: Proceedings of the 8th Liège Colloquium on Ocean Hydrodynamics, Elsevier Scientific, Amsterdam, pp. 27–48.

Dyer, KR 1986, 'Coastal and Estuarine Sediment Dynamics', John Wiley & Sons Ltd., Chichester.

Eakins, BW & Sharman, GF 2010, 'Volumes of the World's Oceans from ETOPO1', Boulder, CO: NOAA National Geophysical Data Center, viewed 8 April 2025, https://www.ncei.noaa.gov/sites/g/files/anmtlf171/files/2023-01/World%20Ocean%20Volumes.pdfRetrieved 1 October 2016.

Gordon, R 1982, 'Wind driven circulation in Narragansett Bay' PhD thesis, Department of Ocean Engineering, University of Rhode Island.

Huthnance, JM 1991, 'Physical oceanography of the North Sea', *Ocean and Shoreline Management*, vol. 16, no. 3-4, pp. 199-231.

International Association of Oil & Gas Producers (IOGP) 2016, 'Environmental fates and effects of ocean discharge of drill cuttings and associated drilling fluids from offshore oil and gas operations', Technical Report 543, IOGP, London, United Kingdom.

Isaji, T & Spaulding, M 1984, 'A model of the tidally induced residual circulation in the Gulf of Maine and Georges Bank', *Journal of Physical Oceanography*, vol. 14, no. 6, pp. 1119–1126.

Isaji, T, Howlett, E, Dalton C, & Anderson, E 2001, 'Stepwise-continuous-variable-rectangular grid hydrodynamics model', *Proceedings of the 24th Arctic and Marine Oil spill Program (AMOP) Technical Seminar (including 18th TSOCS and 3rd PHYTO)*, Environment Canada, Edmonton, pp. 597–610.

King, B & McAllister, FA 1997, *Modelling the Dispersion of Produced Water Discharge in Australia 1 & 2*. Australian Institute of Marine Science, Townsville.

King, B & McAllister, FA 1998, 'Modelling the dispersion of produced water discharges', *APPEA Journal*, pp.681–691.

King, B, Brushett, B & Lemckert, C 2010, 'A case study of consensus modelling for tracking oil spills', Proceedings of IOP Conference Series: *Earth and Environmental Science*, vol. 11, no. 1, p. 012025, IOP Publishing.

Kjeilen-Eilertsen G, Trannum, H, Jak, RG, Smit, MGD, Neff, J & Durell, G 2004, Literature report on burial: derivation of PNEC as component in the MEMW model tool. Report AM 2004/024. ERMS report 9B.

Koh, HL & Teh, SY 2011, 'Simulation of drill cuttings dispersion and deposition in South China Sea', *Proceedings of the International MultiConference of Engineers and Computer Scientists*, vol. 2.

Kostianoy, AG, Ginzburg, AI, Lebedev, SA, Frankignoulle, M & Delille, B 2003, 'Fronts and mesoscale variability in the southern Indian Ocean as inferred from the TOPEX/POSEIDON and ERS-2 Altimetry data', *Oceanology*, vol. 43, no. 5, pp. 632–642.

Krauss, W 1996, 'The warmwatersphere of the North Atlantic Ocean', Schweizerbart Science Publishers, Stuttgart, Germany, 466p.

Lee, AJ 1980, 'Chapter 14 North Sea: Physical Oceanography', *Elsevier Oceanography Series*, vol. 24, no. Part B, pp. 467–493.

Ludicone, D, Santoleri, R, Marullo, S & Gerosa, P 1998, 'Sea level variability and surface eddy statistics in the Mediterranean Sea from TOPEX/POSEIDON data', *Journal of Geophysical Research I*, vol. 103, no. C2, pp. 2995–3011.

Makarynskyy, O, Langtry, S, Zapata, M & Rayson, M 2010, 'Validations of Hydrodynamic, Wave, and Dredging Simulations in Nearshore Environments', in Estuarine and Coastal Modeling, pp. 547-565, ASCE Library, Reston, USA.

Makarynskyy, O, Makarynska, D, Rayson, M & Langtry, S 2015, 'Combining deterministic modelling with artificial neural networks for suspended sediment estimates', *Applied Soft Computing*, vol. 35, pp. 247-256.

Mathis, M, Elizalde, A, Mikolajewicz, U & Pohlmann, T 2015, 'Variability patterns of the general circulation and sea water temperature in the North Sea', *Progress in Oceanography*, vol. 135, pp 91–112.

Matsumoto, K, Takanezawa, T & Ooe, M 2000, 'Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: A global model and a regional model around Japan', *Journal of Oceanography*, vol. 56, no.5, pp. 567–581.

Melsom, A 2005, 'Mesoscale activity in the North Sea as seen in ensemble simulations', *Ocean Dynamics*, vol. 55, no. 3–4, pp. 338–350.

Neff, J 2005, Composition, environment fates, and biological effect of water based drilling fluids and cuttings discharged to the marine environment: A synthesis and annotated bibliography, Battelle, Duxbury.

Nelson, DS, McManus, J, Richmond, RH, King Jr, DB, Gailani, JZ, Lackey, TC & Bryant, D 2016, 'Predicting dredging-associated effects to coral reefs in Apra Harbor, Guam – Part 2: Potential coral effects', *Journal of Environmental Management*, vol. 168, pp. 111–122.

Owen, A 1980, 'A three-dimensional model of the Bristol Channel', *Journal of Physical Oceanography*, vol. 10, no. 8, pp. 1290–1302.

Qiu, B & Chen, S 2010, 'Eddy-mean flow interaction in the decadally modulating Kuroshio Extension system', *Deep-Sea Research II*, vol. 57, no. 13, pp. 1098–1110.

Reid, JL 1993, 'On the total geostrophic circulation of the North Atlantic Ocean: Flow patterns, tracers, and transports', Progress in Oceanography, vol. 33, pp. 1–92.

Reverdin, G, Niiler, P & Valdimarsson 2003, 'North Atlantic Ocean surface currents', *Journal of Geophysical Research*, vol. 108, no. C1, pp. 3002.

Rossby, T 1996, 'The North Atlantic Current and Surrounding Waters: At the Crossroads, Review of Geophysics', vol. 34, no. 4, pp. 463-481.

Sagnieres, LB, Sharf, I & Deleflie, F 2020, 'Simulation of long-term rotational dynamics of large space debris: A TOPEX/Poseidon case study', *Advances in Space Research*, vol. 65, no. 4, pp. 1182–1195.

Smit, MGD, Holthaus, KIE, Trannum, H, Neff, J, Kjeilen-Eilertsen, G, Jak, RG, Singsaas, I, Huijbregts, MAJ & Hendriks, AJ 2008, 'Species sensitivity distributions for suspended clays, sediment burial, and grain size change in the marine environment', *Environmental Toxicology & Chemistry*, vol. 27, no. 4, pp. 1006–1012.

Spaulding, ML 1994, 'Drilling, production fluids dispersion predicted by model', *Offshore*, vol. 54, no. 4, pp. 78–82.

Talouli, A, Gilbert, T & Monfils Gilbert, R 2009, 'Strategic Environmental Assessment and potential future shoreline impacts of the oil spill from WWII shipwreck Hoyo Maru Chuuk Lagoon-Federated States of Micronesia', Pacific Regional Environment Programme, Apia, Samoa.

Trannum, HC, Nilsson, HC, Schaanning, MT & Øxnevad, S 2009, 'Effects of sedimentation from water-based drill cuttings and natural sediment on benthic macrofaunal community structure and ecosystem processes', *Journal of Experimental Marine Biology and Ecology*, vol. 383, no. 2, pp.111–121.

Veng, T & Andersen, OB 2021, 'Consolidating sea level acceleration estimates from satellite altimetry', *Advances in Space Research*, vol. 68, no. 2, pp. 496–503.

Willmott, CJ 1981, 'On the validation of models', *Physical Geography*, vol. 2, no. 2, pp.184–194.

Willmott, CJ 1982, 'Some comments on the evaluation of model performance', *Bulletin of the American Meteorological Society*, vol. 63, no. 11, pp.1309–1313.

Willmott CJ, Ackleson SG, Davis RE, Feddema JJ, Klink, KM, Legates, DR, O'Donnell, J & Rowe, CM 1985, 'Statistics for the evaluation of model performance', *Journal of Geophysical Research*, vol. I 90, no. C5, pp. 8995–9005.

Willmott, CJ & Matsuura, K 2005, 'Advantages of the mean absolute error (MAE) over the root mean square error (RMSE) in assessing average model performance', *Journal of Climate Research*, vol. 30, no. 1, pp. 79–82.

Winther, NG & Evensen, G 2006, 'A hybrid coordinate ocean model for shelf sea simulation', *Ocean Modelling*, vol. 13, no. 3–4, pp. 221–237.

Winther, NG & Johannessen, JA 2006, 'North Sea circulation: Atlantic inflow and its destination', *Journal of Geophysical Research: Oceans*, vol. 111, no.C12.

Yaremchuk, M & Tangdong, Q 2004, 'Seasonal variability of the large-scale currents near the coast of the Philippines', *Journal of Physical Oceanography*, vol. 34, no., 4, pp. 844–855.

Zeitlhöfler, J, Bloßfeld, M, Rudenko, S, Dettmering, D & Seitz, F 2023, 'Station-dependent satellite laser ranging measurement corrections for TOPEX/Poseidon', *Advances in Space Research*, vol. 71, no. 1, pp. 975–996.

Zigic, S, Zapata, M, Isaji,T, King, B, & Lemckert, C 2003, 'Modelling of Moreton Bay using an ocean/coastal circulation model', *Proceedings of the 16th Australasian Coastal and Ocean Engineering Conference, the 9th Australasian Port and Harbour Conference and the Annual New Zealand Coastal Society Conference*, Institution of Engineers Australia, Auckland, paper 170.

Zigic, S, Makarynskyy, O, Langtry, S & Westbrook, G 2009, 'A numerical modelling study for the proposed increase in Barramundi production, Cone Bay, Western Australia', in Estuarine and Coastal Modeling, pp. 428-446, ASCE Library, Reston, USA.

# APPENDIX D:
# Underwater Noise Modelling

# Vertical Seismic Profiling – UKCS Block 204/13b (West of Shetland): Underwater Noise Modelling Assessment

Issy Morgan

4th April 2025

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# Executive Summary

An assessment of the likely effect on marine mammals and fish of underwater noise from planned Vertical Seismic Profiling (VSP) survey in the North Sea has been undertaken by Subacoustech Environmental Ltd. The assessment covers use of a 3 × 250 cubic inch airgun array, deployed from an offshore rig at a single location. Detailed numerical modelling of the survey was used to generate noise contours, which were then used to predict the likely ranges to the relevant noise exposure criteria for marine mammals and fish.

The results have been interpreted using the guidelines provided in Southall *et al.* (2019) for marine mammals, and Popper *et al.* (2014) for fish. These interpretations are based off worst-case parameters with no implemented mitigation measures.

The largest distance predicted to risk permanent auditory injury in marine mammals is for harbour porpoise during the pipeline survey; the receptors that are within 40 m of the survey may be at risk of permanent auditory injury using the $L_{p,pk}$ criteria. Fish species, such as herring, cod, sprat and shad have the greatest distance predicted for mortality; these animals that remain stationary at a range closer than 50 m of the survey are predicted to be at risk of mortality and/or injury.

Finally, it should be stressed that the modelling and predictions made will produce results that should be considered indicative of the onset of effects on receptors during the works and should not be considered as absolute ranges.

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# Terminology

| | |
|---|---|
| Decibel (dB) | A customary scale commonly used (in various ways) for reporting levels of sound. The dB represents a ratio/comparison of a sound measurement (e.g., sound pressure) over a fixed reference level. The dB symbol is followed by a second symbol identifying the specific reference value (e.g., re 1 µPa). |
| Peak pressure | The highest pressure above or below ambient that is associated with a sound wave. |
| Peak-to-peak pressure | The sum of the highest positive and negative pressures that are associated with a sound wave. |
| Permanent Threshold Shift (PTS) | A permanent total or partial loss of hearing caused by acoustic trauma. PTS results in irreversible damage to the sensory hair cells of the ear, and thus a permanent reduction of hearing acuity. |
| Root Mean Square (RMS) | The square root of the arithmetic average of a set of squared instantaneous values. Used for presentation of an average sound pressure level. |
| Sound Exposure Level (SEL or $L_{E,p}$) | The constant sound level acting for one second, which has the same amount of acoustic energy, as indicated by the square of the sound pressure, as the original sound. It is the time-integrated, sound-pressure-squared level. SEL is typically used to compare transient sound events having different time durations, pressure levels, and temporal characteristics. |
| Sound Exposure Level, cumulative ($SEL_{cum}$) | Single value for the collected, combined total of sound exposure over a specified time or multiple instances of a noise source. |
| Sound Exposure Level, single strike ($SEL_{ss}$) | Calculation of the sound exposure level representative of a single noise impulse, typically a pile strike. |
| Sound Pressure Level (SPL or $L_p$) | The sound pressure level is an expression of sound pressure using the decibel (dB) scale; the standard frequency pressures of which are 1 µPa for water and 20 µPa for air. |
| Sound Pressure Level Peak ($SPL_{peak}$ or $L_{p,pk}$) | The highest (zero-peak) positive or negative sound pressure, in decibels. |
| Temporary Threshold Shift (TTS) | Temporary reduction of hearing acuity because of exposure to sound over time. The mechanisms underlying TTS are not well understood, but there may be some temporary damage to the sensory cells. The duration of TTS varies depending on the nature of the stimulus. |
| Unweighted sound level | Sound levels which are “raw” or have not been adjusted in any way, for example to account for the hearing ability of a species. |
| Weighted sound level | A sound level which has been adjusted with respect to a “weighting envelope” in the frequency domain, typically to make an unweighted level relevant to a particular species. |

# Units

| | |
|---|---|
| cui | Cubic Inch (volume) |
| dB | Decibel (sound pressure) |
| Hz | Hertz (frequency) |
| kHz | Kilohertz (frequency) |
| km | Kilometre (distance) |
| m | Metre (distance) |
| mm/s | Millimetres per second (particle velocity) |
| m/s | Metres per second (speed) |
| Pa | Pascal (pressure) |
| $Pa^2s$ | Pascal squared seconds (acoustic energy) |
| µPa | Micropascal (pressure) |

# Acronyms

| | |
|---|---|
| BGS | British Geological Survey |
| EMODnet | European Marine Observation and Data Network |
| HF | High-Frequency Cetaceans |
| LF | Low-Frequency Cetaceans |
| NPL | National Physical Laboratory |
| PCW | Phocid Carnivores in Water |
| PPV | Peak Particle Velocity |
| PTS | Permanent Threshold Shift |
| RMS | Root Mean Square |
| SNH | Scottish Natural Heritage |
| SE | Sound Exposure |
| SEL ($L_{E,p}$) | Sound Exposure Level |
| $SEL_{cum}$ | Cumulative Sound Exposure Level |
| $SEL_{ss}$ | Single Strike Sound Exposure Level |
| SPL | Sound Pressure Level |
| $SPL_{peak}$ ($L_{p\text{-}pk}$) | Peak Sound Pressure Level |
| $SPL_{peak\text{-}to\text{-}peak}$ ($L_{p,pk\text{-}pk}$) | Peak-to-peak Sound Pressure Level |
| $SPL_{RMS}$ ($L_p$) | Root Mean Square Sound Pressure Level |
| TTS | Temporary Threshold Shift |
| VHF | Very High-Frequency Cetaceans |
| VSP | Vertical Seismic Profiling |

# 1 Introduction

## 1.1 Project Overview

Orbis Energy Ltd have requested underwater noise modelling covering the noise related to a VSP survey, taking place in UKCS Block 204/13b, located to the west of Shetland, in the North Sea, UK. It is expected that the survey will be conducted from a rig, using a 3 × 250 (750) cubic inch airgun array. The potential noise and impacts on relevant marine fauna in the region from these surveys has been assessed using underwater noise modelling.

This report provides the results and findings of the detailed modelling assessment of the VSP survey activity. The modelling has been used to predict the sound pressure levels and sound exposure levels generated during these activities, and to assess the impact of these levels on sensitive marine species in the region, with particular focus on the impact on marine mammals and fish.

## 1.2 Study Area

The VSP survey will be conducted from a stationary rig located in the North Sea, and thus, will take place in one location only. This location is shown in Figure 1-1.

The area considered for modelled covers a 100 km × 100 km area. Within the modelling extent, the bathymetry shows a strip of very deep water running from the northeast corner to the southwest corner of the extent, reaching maximum depths of up to 1,422.8 m. Shallower waters surround the deep water at the northwest corner and the southeast corner of the modelling extent.

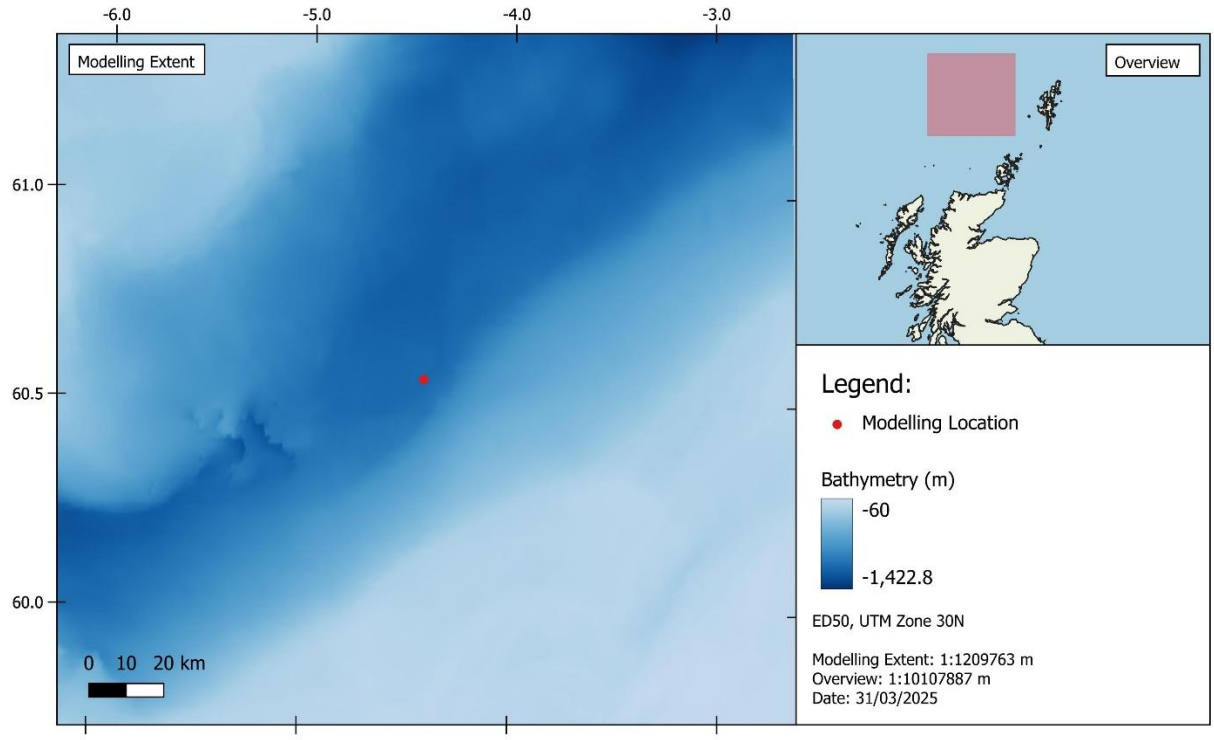



*Figure 1-1: The modelling extent for the VSP survey, including its extent in relation to the UK.*

## 1.3 Noise Sources

The VSP survey has proposed the use a seismic airgun array with the following specification:

- 3 × 250 cubic inch guns (750 cui)

Further details of the modelling of this noise source, including source level calculations, are described in Section 3.1.5

## 1.4 Document Overview

This report presents a detailed assessment of the potential underwater noise from the VSP survey in the North Sea, and covers the following:

- Section 2: Review of background information on measuring and assessing underwater noise.
- Section 3: Discussion of the modelling approach, input parameters and assumptions for the noise modelling undertaken.
- Section 4: Presentation of detailed subsea noise modelling and interpretation of the results using suitable noise metrics and criteria.
- Section 5: Summary and conclusions.

# 2 Underwater Noise Concepts

It is fundamentally important to understand the difference between underwater noise and airborne noise. Sound travels much faster in water (approximately 1,500 $ms^{-1}$) than in air (343 $ms^{-1}$), as water is relatively incompressible, and has a higher density than air. This affects the way in which noise measurements are expressed between the two mediums, which means that noise measured in air is incomparable to noise measured underwater. The following sections relate to concept of underwater noise only.

## 2.1 Units of Measurement

The perception of the relative increase in loudness of a sound are not linear. Equal increments of sound levels do not have an equal increase in the perceived sound, but rather, a double of sound will cause a roughly equal increase in loudness. Therefore, sound measurements are usually expressed using a decibel (dB) scale, which better reflects this perception. The fundamental definition of sound using the dB scale is given by:

$$Sound\ Level = 20 \log_{10}\left(\frac{P}{P_{ref}}\right)$$

where $P$ is pressure, measured in Pascals (Pa), and $P_{ref}$ is the reference pressure, also measured in Pa.

The dB scale represents a ratio, and therefore, when used to define sound, it is used with a reference pressure which expresses the base from which the ratio is expressed. For underwater noise, a reference pressure of 1 µPa ($1 \times 10^{-6}$ Pa) is used, as defined in ISO 18405:2017. It should be noted that any quantity expressed in this dB scale is termed a "level". Sound can be described with several metrics, depending on the nature of the sound, as discussed below.

### *2.1.1 Sound Pressure Level (SPL, $L_p$)*

The Sound Pressure Level (SPL or $L_p$) is normally used to characterise noise and vibration of a continuous nature, such as drilling, boring, continuous wave sonar, or background sea and river noise levels. Unless otherwise defined, all SPL noise levels in this report are referenced to 1 µPa.

#### 2.1.1.1 Peak Sound Pressure Level (peak SPL or $L_{p,pk}$)

The peak SPL, or $L_{p,pk}$, are often used to characterise transient sound from impulsive sources, such as percussive impact piling. $L_{p,pk}$ is calculated using the maximum variation of the pressure from positive to zero within the wave. This represents the maximum change in positive pressure (differential pressure from positive to zero) as the transient pressure wave propagates.

#### 2.1.1.2 Peak-to-peak Sound Pressure Level (peak-to-peak SPL or $L_{pk,pk}$)

A further variation of SPL is the peak-to-peak SPL ($L_{p,pk\text{-}pk}$) where the maximum variation of the pressure from positive to negative is considered. Where the wave is symmetrically distributed in positive and negative pressure, the peak-to-peak pressure will be twice the peak level, or 6 dB higher.

#### 2.1.1.3 RMS Sound Pressure Level ($SPL_{RMS}$ or $L_{p,RMS}$)

The variation in sound pressure is measured over a specific period to determine the level of the time-varying sound. The SPL ($L_{p,RMS}$) can therefore be considered a measure of the average unweighted level of sound over the measurement period. Where SPL is used to characterise transient pressure waves, such as that from impact piling, seismic airgun or underwater blasting, it is critical that the period over which the RMS level is calculated

is quoted (e.g., $L_{p,125ms}$) For instance, in the case of a pile strike lasting a tenth of a second, the mean taken over a tenth of a second will be ten times higher than the mean averaged over one second.

### 2.1.2 Sound Exposure Level (SEL or $L_{E,p}$)

When considering the noise from transient sources, the issue of the duration of the pressure wave is often addressed by measuring the total acoustic energy (energy flux density) of the wave. This form of analysis was used by Bebb and Wright (1953, 1954a, 1954b, 1955), and later by Rawlins (1987), to explain the apparent discrepancies in the biological effect of short and long-range blast waves on human divers. More recently, this form of analysis has been used to develop criteria for assessing injury ranges for fish and marine mammals from various noise sources (Popper *et al.,* 2014; Southall *et al.,* 2019; Southall *et al.,* 2007).

The $L_{E,p}$ sums the acoustic energy over a measurement period, and effectively takes account of both the $L_p$ of the sound and the duration it is present in the acoustic environment. Sound Exposure (SE) is defined by the equation:

$$SE = \int_0^T p^2(t)dt$$

where $p$ is the acoustic pressure in Pascals, $T$ is the total duration of sound in seconds, and $t$ is time in seconds. The SE is a measurement of acoustic energy and has units of Pascal squared seconds ($Pa^2s$).

To express the SE on a logarithmic scale by means of a dB, it must be compared with a reference acoustic energy (${p^2}_{ref}$) and a reference time ($T_{ref}$). The $L_{E,p}$ is then defined by:

$$L_{E,p} = 10 \times \log_{10}\left(\frac{\int_0^T p^2(t)dt}{{p^2}_{ref}T_{ref}}\right)$$

By using a common reference pressure ($p_{ref}$) of 1 µPa for assessments of underwater noise, the $L_E$ and $L_p$ can be compared using the expression:

$$L_{E,p} = L_p + 10 \times \log_{10} T$$

where the $L_p$ is a measure of the average level of broadband noise and the $L_{E,p}$ sums the cumulative broadband noise energy.

This means that, for continuous sounds of less than (i.e., fractions of) one second, the $L_{E,p}$ will be lower than the $L_p$. For periods greater than one second, the $L_{E,p}$ will be numerically greater than the $L_p$ (i.e., for a continuous sound of 10 seconds duration, the $L_{E,p}$ will be 10 dB higher than the $L_p$; for a sound of 100 seconds duration the $L_{E,p}$ will be 20 dB higher than the $L_p$, and so on).

Where a single impulse noise such as the soundwave from a pile strike is considered in isolation, this can be represented by a "single strike" $L_{E,p}$ or $SEL_{ss}$. A cumulative $L_{E,p}$, or $SEL_{cum}$, accounts for the exposure from multiple impulses or pile strikes over time, where the number of impulses replaces the $T$ in the equation above, leading to:

$$Cumulative\ L_{E,p} = L_{E,p} + 10 \times \log_{10} X$$

Where $L_{E,p}$ is the sound exposure level of one impulse and $X$ is the total number of impulses or strikes. Unless otherwise defined, all $L_{E,p}$ noise levels in this report are referenced to 1 $\mu Pa^2s$.

## 2.2 Properties of Sound

### 2.2.1 *Impulsive vs Non-impulsive*

Sound can be categorized loosely into two types: impulsive noise and non-impulsive noise. These can be defined as:

- Non-impulsive noise: a steady-state noise. It does not necessarily have to have a long duration.
    - Examples: vibropiling, drilling
- Impulsive noise: a sound with a high peak sound pressure, short duration, fast rise-time and broad frequency content at the source.
    - Examples: seismic airguns, explosives, impact piling

These differences are important to consider regarding the potential for auditory injury, as impulsive noise is generally more injurious than non-impulsive noise.

Objective categorisation of noise sources as impulsive or non-impulsive can sometimes be challenging. This is particularly this case if a sound is travelling over long distances. For example, if an impulsive sound propagates through an environment, the energy within the sound wave will also dissipate and becomes less impulsive with distance from the noise source. This is important to consider regarding auditory injury and impact range calculations, as impulsive noise will become less injurious if they become less impulsive.

Active research is currently underway to define impulsive and non-impulsive noise (see Martin *et al.* (2020). Although the situation is complex, Hastie *et al.* (2019) concluded that an impulsive sound can be considered effectively non-impulsive 3.5 km from the source. Using these findings, Southall (2021) suggests that noise should be considered non-impulsive when there is no longer energy content above 10 kHz. However, research remains in early stages, and work is ongoing to determine numerical values of other pulse characteristics, such as for kurtosis, that can aid categorisation of a pulse as either impulsive or non-impulsive.

Due to the differences between impulsive and non-impulsive noise sources, different metrics are appropriate for describing these different sound sources. For example:

- Impulsive noises: Use peak SPL ($L_{p,pk}$) and cumulative SEL ($L_{E,p}$)
- Non-impulsive noises: cumulative SEL ($L_{E,p}$)

Here, the noise generated by the VSP survey is categorised as impulsive.

### 2.2.2 *Particle Motion*

The motion of the particles that make up a medium is an important component of sound. Particle motion is present wherever there is sound, and it describes the back-and-forth movement of particles in water, which in the context of underwater noise, are caused by a sound wave passing through the water column. This back-and forth movement means that, unlike sound pressure at a single point, particle motion always contains directional information (Hawkins and Popper, 2017). Regarding quantifying particle motion, it is usually defined in reference to the velocity of the particle (often a peak particle velocity, PPV), but sometimes the related acceleration or displacement of the particle is used.

It has been identified by several researchers that many fish species, (e.g., Popper and Hawkins, 2019; Nedelec *et al*., 2016; Radford *et al.,* 2012), as well as marine invertebrates (see Sole *et al.*, 2023 for review) are sensitive to particle motion. However, sound pressure metrics are still preferred and more widely used than particle motion due to a lack of supporting data (Popper and Hawkins, 2018). There continue to be calls for additional research on the levels of and effects with respect to levels of particle motion.

## 2.3 Analysis of Environmental Effects: Assessment Criteria

Over the last 20 years it has become increasingly evident that noise from human activities in and around underwater environments can have an impact on the marine species in the area. The extent to which intense underwater sound might cause adverse impacts in species is dependent upon the incident sound level, source frequency, duration of exposure, and/or repetition rate of an impulsive sound (see, for example, Hastings and Popper, 2005). As a result, scientific interest in the hearing abilities of aquatic species has increased. Studies are primarily based on evidence from high level sources of underwater noise such as seismic airguns, impact piling and blasting as these sources are likely to have the greatest immediate environmental impact and therefore the clearest observable effects, although interest in chronic noise exposure is increasing.

The impacts of underwater sound on marine species can be broadly summarised as follows:

- Physical traumatic injury and fatality.
- Auditory injury (either permanent or temporary).
- Behavioural responses

The following sections discuss the underwater noise criteria used in this study with respect to species of marine mammals and fish that may be present around the study area in the North Sea.

The main metrics and criteria that have been used in this study to aid assessment of environmental effects come from two key papers covering underwater noise and its effects:

- Southall *et al*. (2019) marine mammal exposure criteria.
- Popper *et al*. (2014) sound exposure guidelines for fishes and sea turtles.

At the time of writing these include the most up-to-date and authoritative criteria for assessing environmental effects for use in impact assessments. Although it is noted that other papers have been published recently with new guidance (e.g., NMFS, 2024), these have not yet been accepted by the Scottish regulators.

### *2.3.1 Marine Mammals*

#### 2.3.1.1 Auditory Injury (PTS and TTS) criteria

The Southall *et al*. (2019) paper is the most used and recognised reference for marine mammal hearing thresholds. It is effectively an update of the previous Southall *et al.* (2007) paper and provides identical thresholds to those from the National Marine Fisheries Service (NMFS) (2018) guidance for marine mammals. It should be noted that, despite the identical thresholds, the marine mammal hearing groups are described slightly differently in the Southall *et al.* (2019) paper to the NMFS (2018) guidance. Therefore, care should be taken when comparing results using the Southall *et al*. (2019) and NMFS (2018) criteria.

The Southall *et al*. (2019) guidance categorises marine mammals into groups of similar species and applies filters to the unweighted noise to approximate the hearing sensitivities of the receptor in question. The hearing groups given by Southall *et al*. (2019) are summarised in Table 2-1 and the relevant auditory weighting functions are shown in Figure 2-1. Further groups for sirenians and other marine carnivores in water are given, but these have not been included in this study as those species are not commonly found in the North Sea.

It should be noted that despite Southall *et al.* (2019) referring to peak SPL as $SPL_{peak}$ and cumulative SEL as $SEL_{cum}$, this notation has since been deprecated (ISO 18405:2017) and will be referred to as $L_{p,pk}$ and $L_{E,p,t}$ respectively in the rest of this report.

*Table 2-1: Marine mammal hearing groups (from Southall et al., 2019).*

| Hearing group | Generalised hearing range | Example species |
|---|---|---|
| **Low-frequency cetaceans (LF)** | 7 Hz to 35 kHz | Baleen whales |
| **High-frequency cetaceans (HF)** | 150 Hz to 160 kHz | Dolphins, toothed whales, beaked whales, bottlenose whales (including bottlenose dolphin) |
| **Very high-frequency cetaceans (VHF)** | 275 Hz to 160 kHz | True porpoises (including harbour porpoise) |
| **Phocid carnivores in water (PCW)** | 50 Hz to 86 kHz | True seals (including harbour seals) |

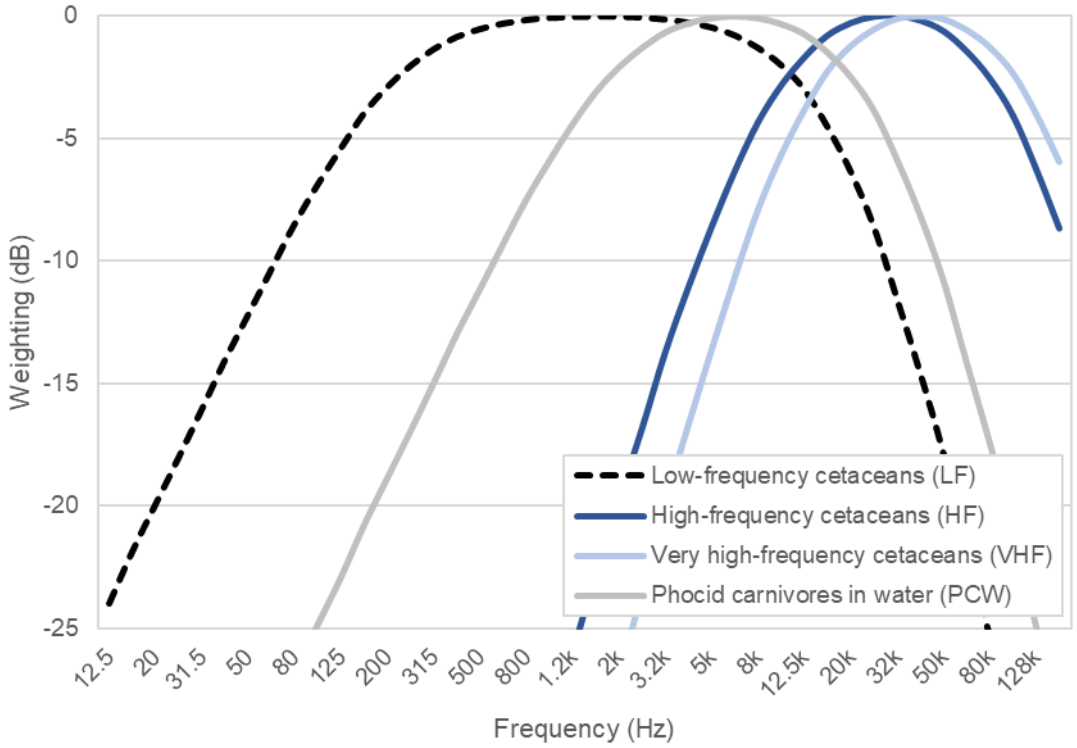



*Figure 2-1: Auditory weighting functions for low-frequency cetaceans (LF), high-frequency cetaceans (HF), very high-frequency cetaceans (VHF), and phocid carnivores in water (PCW) (from Southall et al., 2019)*

Southall *et al.* (2019) presents noise impact thresholds for pre-categorised groups of marine mammals (described above), which are dependent on:

- The nature of the sound (impulsive vs. non-impulsive)
- The type of auditory injury of concern

Southall *et al.* (2019) considers the nature of the sound in the context of whether it is considered as impulsive or non-impulsive noise source (see section 2.2.1 for details).

Although the use of impact ranges derived using the impulsive criteria are recommended for all but clearly non-impulsive sources, it should be recognised that where calculated ranges are beyond 3.5 km (see section 2.2.1), the impact range is therefore likely to be somewhere between the modelled impulsive and non-impulsive impact

range. Therefore, if an impact range of an impulsive noise has been predicted to be greater than 3.5 km, the impact range for a non-impulsive noise source should also be considered. Therefore, unless explicitly clear, both criteria for impulsive and non-impulsive noise have been considered.

Where cumulative SEL thresholds are required for marine mammals, a fleeing animal model has been used. This assumes that a receptor (marine mammal) when exposed to high noise levels, will swim away from the noise source. For this, the following flee speeds have been used for each marine mammal group:

- 2.1 m/s for LF cetaceans (Scottish Natural Heritage; SNH, 2016)
- 1.52 m/s for HF cetaceans (Bailey and Thompson, 2006)
- 1.4 m/s for VHF cetaceans (SNH, 2016)
- 1.8 m/s for PCW pinnipeds (SNH, 2016)

These are considered worst case assumptions, as marine mammals are expected to be able to swim much faster under stress conditions (Kastelein *et al.* 2018), especially at the start of any noisy process when the receptor will be closest.

Within each of the impulsive and non-impulsive noise criterion set out by Southall *et al.* (2019), different impact thresholds are presented depending on the potential of different levels of auditory injury at different noise levels of that sound. Auditory injury has been categorised into two types:

- PTS (permanent threshold shift): the greatest severity, which is unrecoverable (but incremental) reduction in hearing sensitivity.
- TTS (temporary threshold shift): the least severity, which is a short-term reduction in hearing sensitivity.

It should be noted that the greatest calculated impact range is usually associated with TTS. However, the effects from PTS represent the most significant and permanent impairment, and thus, PTS is usually quoted as the most important impact threshold.

In summary, when using Southall *et al.* (2019) as an assessment criterion to calculate impact ranges, three variables are considered:

- The marine mammal receptors within the area
- The nature of the sound (and subsequent appropriate metrics)
- The type of auditory injury of concern

Despite airguns being an impulsive noise source, it is anticipated that the noise generated from them will propagate beyond 3.5 km is an impulsive noise source, for this study, the criteria set out by Southall *et al.* (2019) for PTS and TTS in marine mammals in response to impulsive and non-impulsive noise sources for have been considered, which is summarised in Table 2-2 and Table 2-3 respectively.

*Table 2-2: Peak SPL ($L_{p,pk}$) criteria for PTS and TTS in marine mammals (Southall et al., 2019)*

| Southall *et al.* (2019) | $L_{p,pk}$ (dB re 1 µPa) | |
|---|---|---|
| | Impulsive | |
| | PTS | TTS |
| Low-frequency cetaceans (LF) | 219 | 213 |
| High-frequency cetaceans (HF) | 230 | 224 |
| Very high-frequency cetaceans (VHF) | 202 | 196 |
| Phocid carnivores in water (PCW) | 218 | 212 |

*Table 2-3: Cumulative SEL ($L_{E,24h,wtd}$) criteria for PTS and TTS in marine mammals (Southall et al., 2019)*

| Southall *et al.* (2019) | $L_{E,24h,wtd}$ (dB re 1 µPa$^2$s) | | | |
|---|---|---|---|---|
| | Impulsive | | Non-impulsive | |
| | PTS | TTS | PTS | TTS |
| Low-frequency cetaceans (LF) | 183 | 168 | 199 | 179 |
| High-frequency cetaceans (HF) | 185 | 170 | 198 | 178 |
| Very high-frequency cetaceans (VHF) | 155 | 140 | 173 | 153 |
| Phocid carnivores in water (PCW) | 185 | 170 | 201 | 181 |

### 2.3.2 Fish

#### 2.3.2.1 Mortality, injury and behavioural effects

The Popper *et al.* (2014) guidelines are known as a suitable reference for underwater noise impacts on marine fauna (aside from marine mammals) in UK waters. While previous studies have applied a broad criterion based on limited studies of fish that are not present in UK waters, or measurement data not intended to be used as criteria, Popper *et al.* (2014) provides a summary of the latest research and guidelines for fish (and other marine fauna) exposure to sound and uses categories for fish that are representative of the species present in the UK.

The Popper *et al.* (2014) guidelines present criteria dependent on the sound source, the species of marine fauna (and their hearing capabilities), and the impact type. Separate criteria are provided for each sound source, including:

- Explosions
- Pile driving.
- Seismic Airguns
- Low frequency Naval Sonar
- Mid frequency Naval Sonar
- Shipping and other continuous noise

If a sound source is not listed, it is common practice to use the criteria which is the best fit to the sound source required in the assessment.

For each sound source, the marine fauna is categorised into groups of sea turtles, eggs and larvae, and fish. Due to their diversity and quantity, fish are categorised further into three groups depending on their hearing capabilities, which can be indicated by whether they possess a swim bladder or not, and whether the swim bladder is involved in hearing. These three categories are:

- Fish: no swim bladder
- Fish: swim bladder not involved in hearing
- Fish: Swim bladder involved in hearing.

Popper *et al.* (2014) provides separate criteria, depending on the species and the noise source, for various impacts associated with noise exposure. These include:

- Mortality and potential mortal injury
- Impairment
    - Recoverable injury
    - Temporary Threshold Shift (TTS)
    - Masking
- Behavioural effects.

Where insufficient data is available, Popper *et al.* (2014) also gives a qualitative criterion. This criterion summarises the effect of the noise as having either a high, moderate or low relative risk of an effect on an individual in either the near-field (tens of meters), intermediate-field (hundreds of meters) or far-field (thousands of meters).

Where cumulative thresholds are required for fish, both a stationary and fleeing animal model has been used. This is due to the diversity of species considered under this criterion, and as a result, both models encompass the diversity of responses to noise.

Most species described by Popper *et al.* (2014) are likely to move away from a sound that is loud enough to cause harm (Dahl *et al*., 2015; Popper *et al*., 2014). For those species that flee, a speed of 1.5 m/s (based on Hirata, 1999) is considered a conservative speed at which to base a fleeing animal model. However, considering the diversity of species described by Popper *et al*. (2014), whether an animal flees or remains stationary in response to a loud noise will differ between species. It is recognised that there is limited evidence for fish fleeing from high level noise sources in the wild. Those species that are likely to remain stationary are thought more likely to be benthic species or species without a swim bladder, due to their reduced hearing capabilities making these species the least sensitive to noise (e.g., Goertner *et al*., 1994, 1978; Stephenson *et al*., 2010; Halvorsen *et al*., 2012). Despite this, including only a stationary animal model as a worst-case scenario is likely to greatly overestimate the potential risk to fish species. Therefore, a combined approach should be considered, which considers impact ranges from both fleeing and stationary receptors. Impact ranges from stationary and fleeing receptors is therefore included in this report.

Depending on the noise source, quantitative criteria are given in appropriate metrics ($SPL_{peak}$, $SPL_{RMS}$, $SEL_{cum}$, etc.), which can then be used as thresholds for onsets of listed impact. It should be noted the notation used by Popper *et al.* (2014) has since been deprecated (ISO 18405:2017) and will be referred to as $L_{p,pk}$, $L_{p,RMS}$ and $L_{E,p}$ in the rest of this report.

For this study, the criteria set out by Popper *et al.* (2014) for seismic airguns have been considered, which is summarised in Table 2-4.

*Table 2-4: Recommended guidelines for seismic airguns according to Popper et al. (2014) for speices of fish, sea turtles and eggs and larvae (N = Near-field; I = Intermediate-field; F = Far-field).*

| Popper *et al.* (2014) criteria for Seismic Airguns | | | | | |
|---|---|---|---|---|---|
| **Type of fish** | **Mortality and potential mortal injury** | **Impairment** | | | **Behaviour** |
| | | **Recoverable injury** | **TTS** | **Masking** | |
| **Fish: no swim bladder** | **>219 $L_{E,p}$**<br>**>213 $L_{p,pk}$** | **>216 $L_{E,p}$**<br>**>213 $L_{p,pk}$** | **>>186 $L_{E,p}$** | (N) Low<br>(I) Low<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low |
| **Fish: swim bladder not involved in hearing** | **210 $L_{E,p}$**<br>**>207 $L_{p,pk}$** | **203 $L_{E,p}$**<br>**>207 $L_{p,pk}$** | **>186 $L_{E,p}$** | (N) Low<br>(I) Low<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low |
| **Fish: swim bladder involved in hearing** | **207 $L_{E,p}$**<br>**>207 $L_{p,pk}$** | **203 $L_{E,p}$**<br>**>207 $L_{p,pk}$** | **186 $L_{E,p}$** | (N) Low<br>(I) Low<br>(F) Moderate | (N) High<br>(I) High<br>(F) Moderate |
| **Sea Turtles** | **210 $L_{E,p}$**<br>**>207 $L_{p,pk}$** | (N) High<br>(I) Low<br>(F) Low | (N) High<br>(I) Low<br>(F) Low | (N) Low<br>(I) Low<br>(F) Low | (N) High<br>(I) Moderate<br>(F) Low |
| **Eggs and Larvae** | **>210 dB $SEL_{cum}$**<br>**>207 $L_{p,pk}$** | (N) Moderate<br>(I) Low<br>(F) Low | (N) Moderate<br>(I) Low<br>(F) Low | (N) Low<br>(I) Low<br>(F) Low | (N) Moderate<br>(I) Low<br>(F) Low |

It is important to note that despite the emerging evidence that fish are sensitive to particle motion (see section 2.2.2), the Popper *et al.* (2014) criteria define noise impacts in terms of sound pressure or sound pressure-associated functions (i.e. SEL).

It has been suggested that the criteria set out by Popper *et al.* (2014) could have been derived from unmeasured particle motion, as well as sound pressure. Whilst this may be true, sound pressure remains the preferred metric in the criteria due to a lack of data surrounding particle motion (Popper and Hawkins, 2018), particularly in regarding the ability to predict the consequences of the particle motion of a noise source, and the sensitivity of fish to a specific particle motion value. Therefore, as stated by Popper and Hawkins (2019): "since there is an immediate need for updated criteria and guidelines on potential effects of anthropogenic sound on fishes, we recommend, as do our colleagues in Sweden (Andersson *et al*., 2017), that the criteria proposed by Popper *et al*. (2014) should be used."

# 3 Underwater Noise Modelling: Methodology

Modelling of underwater noise is complex and can be approached in several different ways. Measurements are only possible at limited locations, so modelling has been undertaken to provide a more comprehensive set of results. To estimate the noise levels generated by the VSP survey, Subacoustech have chosen to utilise the dBSea noise modelling software, which uses various numerical solvers to calculate underwater noise. This assessment uses two different solvers:

- A parabolic equation (PE) method for lower frequencies (12.5 Hz to 250 Hz)
    - Widely used within the underwater acoustics community but has computational limitations at high frequencies.
- A ray tracing method for higher frequencies (315 Hz to 100 kHz).
    - More computationally efficient at higher frequencies but is not suited to low frequencies (Etter, 1991).

These solvers account for a wide array of environmental input parameters within the study area, including bathymetry, sediment data and sound speed, as well as the characteristics of the noise source, such as source frequency content, to ensure as detailed results as possible. The input parameters used in this study are described in the following sections.

## 3.1 Input Parameters

### *3.1.1 Modelling Location*

A single representative modelling location was selected at the offshore rig where VSP survey is proposed to take place. Since the equipment will be suspended from the rig below sea level, the noise source was assumed to be deployed to a depth of 5 m from the sea surface. Details of the noise source location used are presented in Table 3-1.

*Table 3-1: Details of the modelling locations. Eastings/Northings are in ED50, UTM Zone 30N.*

| Modelling location | Northing (m) | Easting (m) | Source depth below surface (m) | Depth at source location (m) |
|---|---|---|---|---|
| **Field Survey Area** | 6,715,029 | 421,638 | 5 | 1,057 |

### *3.1.2 Bathymetry*

The bathymetry data used in the modelling was obtained from The European Marine Observation and Data Network (EMODnet, 2018). This data has a resolution of 1/16$^{th}$ arcminutes (approximately 115 × 115 m). The bathymetry used for modelling covers an area of 100 km × 100 km surrounding the survey area.

### *3.1.3 Seabed Properties*

Characteristics of the seabed were based on local data supplied by the Marine Scotland NMPi tool. The seabed in the area is assumed to be comprised of a 50 m sediment layer of gravelly sand, which is above a bedrock layer of sandstone. Geo-acoustic properties for the seabed were based on available data from Jensen et al. (1994, 2011), which are provided in Table 3-2.

*Table 3-2: Seabed geo-acoustic properties of the survey area.*

| Material | Compressive sound speed profile in substrate (m/s) | Density profile in substrate (kg/m³) | Attenuation profile in substrate (dB/wavelength) |
|---|---|---|---|
| **Gravelly Sand** | 1,725 | 1,950 | 0.7 |
| **Sandstone** | 3,000 | 2,500 | 0.1 |

### 3.1.4 Sound Speed Profile

The speed of sound in the water has been calculated for the average annual temperature and salinity using the Mackenzie (1981) equation, with data from the Marine Scotland for the modelling location. The resulting profile is shown in Figure 3-1.

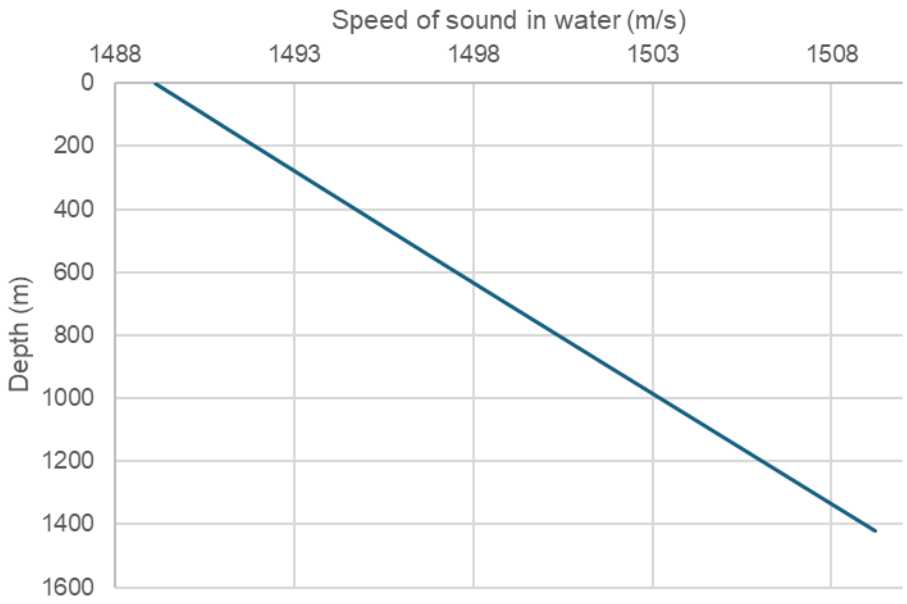



*Figure 3-1: Sound speed profile used for detailed modelling of the area.*

### 3.1.5 Noise Source

It is understood that the VSP survey is proposed to use 3 × 250 cubic inch airguns (750 cubic inch total). At present, no further information was provided for these airguns, so the noise source characteristics were based off data used in previous modelling for a similar noise source, as detailed in Barham and Mason (2022). The source characteristics were then scaled based on the specifications of each airgun, which subsequently provided estimate source levels. The $L_{E,p,ss}$ source level was based on the crest factor between the $L_{p,pk}$ and $L_{E,p,ss}$ for a single airgun source, which was then extrapolated to three air guns. The source levels used in modelling for the airgun array are presented in Table 3-3.

*Table 3-3: Summary of the combined calculated $L_{p,pk}$ and $L_{E,p,ss}$ source levels for the airguns.*

| Equipment | Estimated source level @ 1 m | |
|---|---|---|
| | $L_{p,pk}$ (dB re 1 µPa) | $L_{E,p,ss}$ (dB re 1 µPa²s) |
| 3 × 250 cubic inch airguns | 232 | 215 |

A source spectrum used in the modelling for the airguns were based on previous data for an airgun array with similar specifications. From this measured data, the 1/3rd octave levels were then adjusted to achieve the required source levels and peak frequencies for the airgun (values stated in Table 3-3). The 1/3rd octave source spectrum for the airgun shown in Figure 3-2.

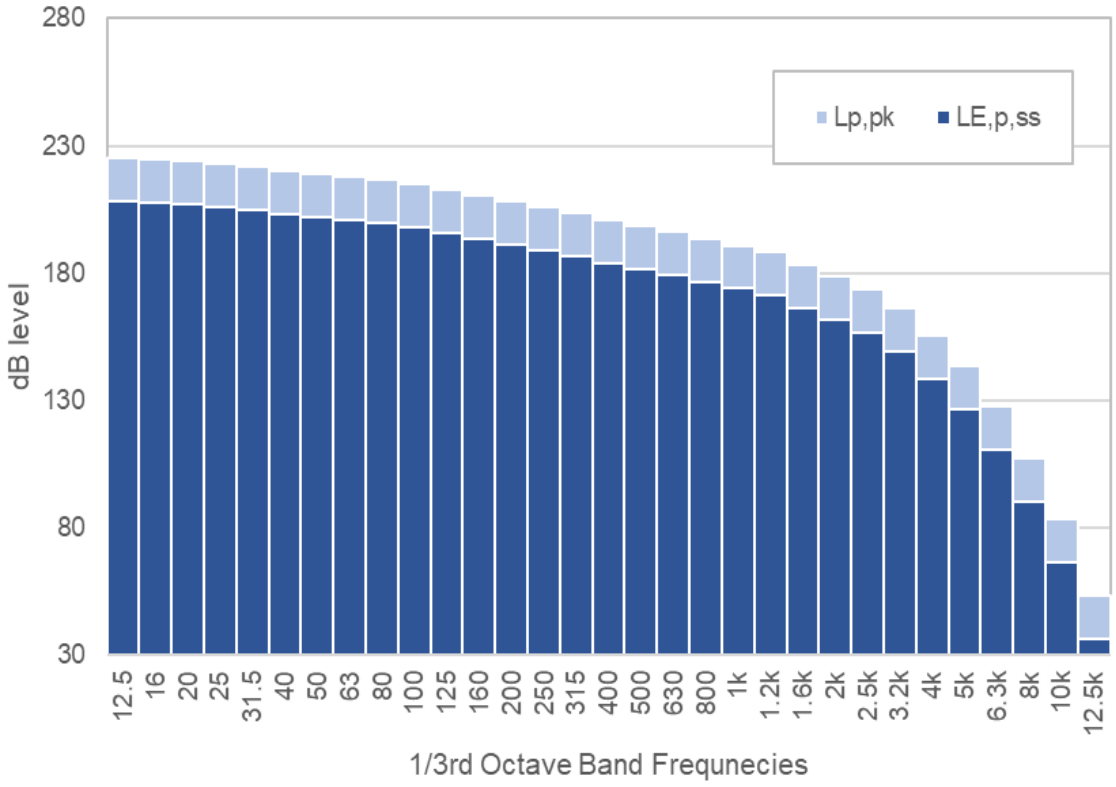



*Figure 3-2: The source spectrum containing 1/3rd octave band levels used to model the airguns.*

For $L_{E,p,ss}$, a shot interval of 20 seconds was assumed, with operations taking place over a period of 24-hours per day, as a worst case scenario.

# 4 Underwater Noise Modelling: Results

## 4.1 Predicted Noise Levels

The distribution of noise from the airgun array is presented as noise contour plots in Figure 4-1 and Figure 4-2 according to different metrics. These plots show the maximum predicted noise level in the water column.

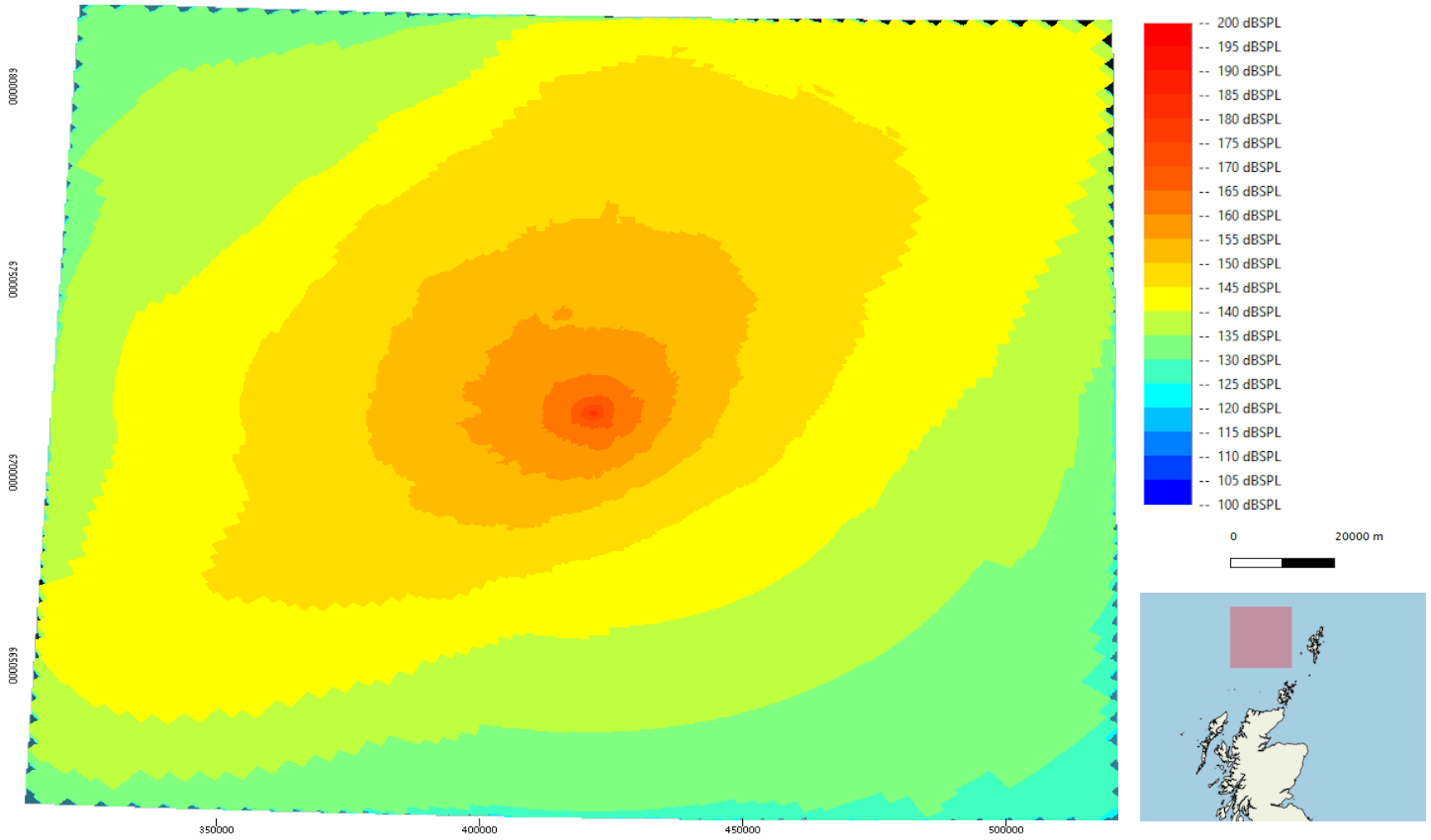



*Figure 4-1: $L_{p,pk}$ noise level contours of the predicted for the VSP survey.*

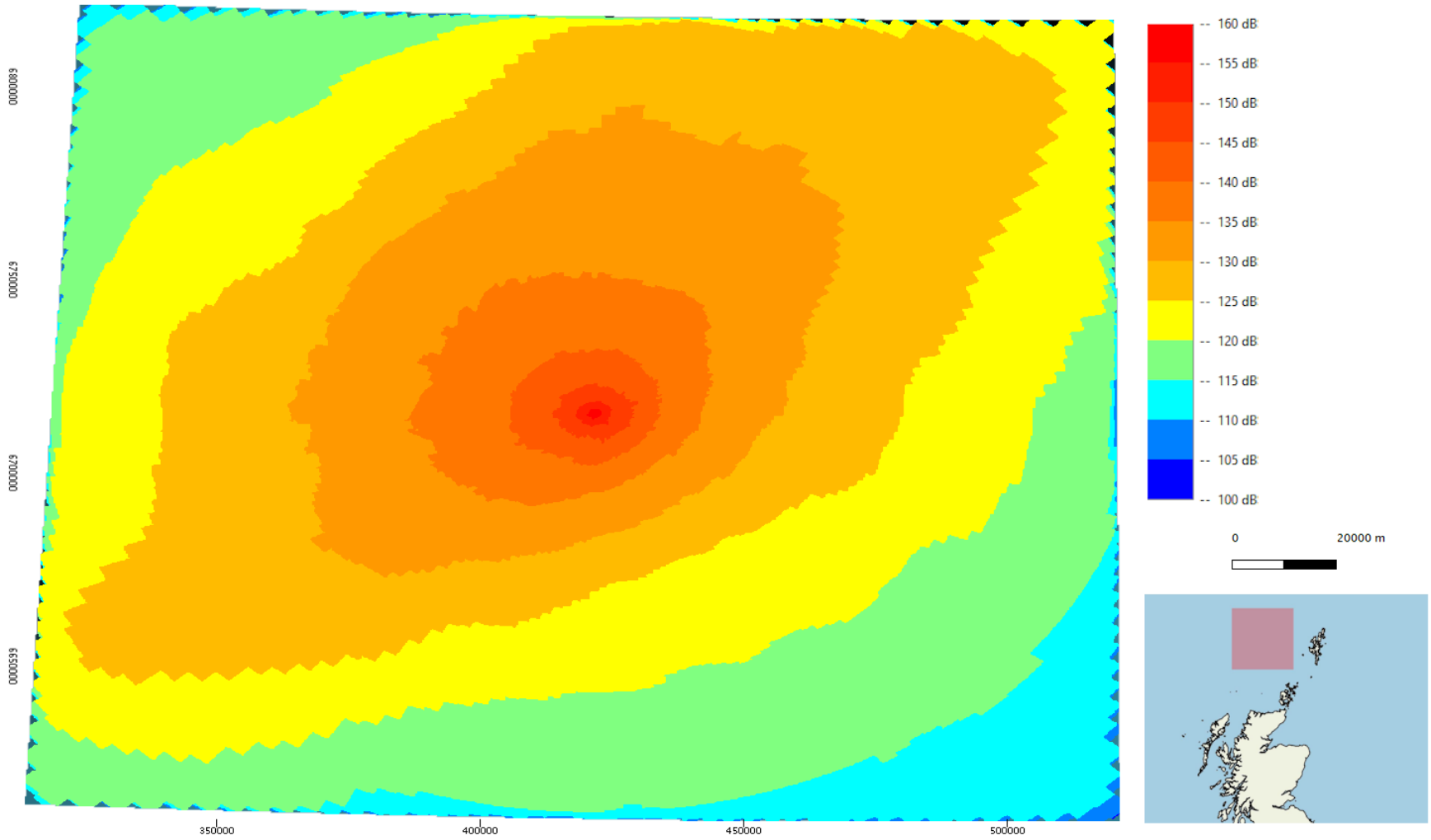



*Figure 4-2: $L_{E,p}$ noise level contours of the predicted for the VSP survey.*

## 4.2 Interpretation

Due to the complexity in noise conditions at close range to the source, estimated impact ranges are limited to a resolution of 10 m from the source, as such, ranges smaller than this have been presented as "< 10 m".

### 4.2.1 Assessment: Marine Mammals

The noise level results from Section 4.1 were assessed against the Southall *et al.* (2019) guidelines and weightings to predict the likely range at which the thresholds for impulsive and non-impulsive sounds would be exceeded by marine mammals.

Using the $L_{p,pk}$ criteria applied to the predicted noise contours, the VHF cetacean group are predicted to have the largest PTS impact ranges. Animals within 40 m of the survey are likely to exceed the PTS threshold for VHF cetaceans. These details, along with PTS impact ranges predicted for other species groups, and TTS impact ranges predicted across all groups, are presented in Table 4-1.

*Table 4-1: Estimated impact ranges for the VSP equipment using the Southall et al. (2019) $L_{p,pk}$ marine mammal criteria for impulsive noise sources.*

| Southall *et al.* (2019) criteria $L_{p,pk}$ (Impulsive) | | Estimated impact range (m) | | |
|---|---|---|---|---|
| | | Maximum | Mean | Minimum |
| LF Cetaceans | PTS | < 10 | < 10 | < 10 |
| | TTS | < 10 | < 10 | < 10 |
| HF Cetaceans | PTS | < 10 | < 10 | < 10 |
| | TTS | < 10 | < 10 | < 10 |
| VHF Cetaceans | PTS | 40 | 40 | 40 |
| | TTS | 70 | 70 | 70 |
| PCW Pinnipeds | PTS | < 10 | < 10 | < 10 |
| | TTS | 10 | 10 | 10 |

When the $L_{E,p,24h,wtd}$ criteria for both impulsive and non-impulsive noise is applied to the predicted noise contours, the LF cetacean group are predicted to have the largest PTS impact ranges. Animals within 10 m of the survey at the start of the survey are predicted exceed the PTS threshold for VHF cetaceans, under the impulsive criteria. This assumes that the survey equipment is continuously operational for 24 hours, and that the animals flee away from the noise source at a constant speed. These details, along with PTS impact ranges predicted for other species groups, and TTS impact ranges predicted across all groups, are presented in Table 4-2 for the impulsive criteria and Table 4-3 for the non-impulsive criteria.

*Table 4-2: Estimated impact ranges for the VSP survey using the Southall et al. (2019) $L_{E,p,wtd}$ marine mammal criteria for impulsive noise sources assuming a fleeing animal.*

| Southall *et al.* (2019) criteria $L_{E,p,wtd}$ (Impulsive) | | Estimated impact range (m) | | |
|---|---|---|---|---|
| | | Maximum | Mean | Minimum |
| LF Cetaceans | PTS | 10 | 10 | 10 |
| | TTS | 270 | 250 | 220 |
| HF Cetaceans | PTS | < 10 | < 10 | < 10 |
| | TTS | < 10 | < 10 | < 10 |
| VHF Cetaceans | PTS | < 10 | < 10 | < 10 |
| | TTS | 10 | 10 | 10 |
| PCW Pinnipeds | PTS | < 10 | < 10 | < 10 |
| | TTS | 10 | 10 | 10 |

*Table 4-3: Estimated impact ranges for the VSP survey using the Southall et al. (2019) $L_{E,p,wtd}$ marine mammal criteria for non-impulsive noise sources assuming a fleeing animal.*

| Southall *et al.* (2019) criteria $L_{E,p,wtd}$ (Non-impulsive) | | Estimated impact range (m) | | |
|---|---|---|---|---|
| | | Maximum | Mean | Minimum |
| LF Cetaceans | PTS | 10 | 10 | 10 |
| | TTS | 20 | 20 | 20 |
| HF Cetaceans | PTS | < 10 | < 10 | < 10 |
| | TTS | < 10 | < 10 | < 10 |
| VHF Cetaceans | PTS | < 10 | < 10 | < 10 |
| | TTS | < 10 | < 10 | < 10 |
| PCW Pinnipeds | PTS | < 10 | < 10 | < 10 |
| | TTS | 10 | 10 | 10 |

### 4.2.2 Assessment: Fish

The noise level results from Section 4.1 were assessed against the Popper *et al.* (2014) guidelines to predict the likely range at which the thresholds for seismic airguns would be exceeded by fish. According to the $L_{p,pk}$ metric , the maximum predicted range for the threshold of mortality is predicted for fish with a swim bladder (involved and not involved in hearing) at 20 m from the survey equipment. These details, along with other fish species, and impact ranges for other effects, are provided in Table 4-4.

*Table 4-4: Estimated impact ranges for the VSP survey equipment using the Popper et al. (2014) $L_{p,pk}$ fish criteria for seismic airguns.*

| Popper *et al.* (2014) criteria $L_{p,pk}$ (Seismic airguns) | | Estimated impact range (m) | | |
|---|---|---|---|---|
| | | Maximum | Mean | Minimum |
| Fish: no swim bladder | Mortal and potential mortal injury | < 10 | < 10 | < 10 |
| | Recoverable injury | < 10 | < 10 | < 10 |
| Fish: swim bladder not involved in hearing | Mortal and potential mortal injury | 20 | 20 | 20 |
| | Recoverable injury | 20 | 20 | 20 |
| Fish: swim bladder involved in hearing | Mortal and potential mortal injury | 20 | 20 | 20 |
| | Recoverable injury | 20 | 20 | 20 |

Using the $L_{E,p}$ metric , the largest predicted range for the threshold for mortality is predicted for fish with a swim bladder (involved and not involved in hearing) at 10 m from the survey equipment if they are assumed to flee from the source. If they are assumed to remain stationary, the highest predicted range for mortality is for fish with a swim bladder involved in hearing is 170 m. These details, along with other fish species, and impact ranges for other effects, are provided in Table 4-5 for fleeing fish, and Table 4-6 for stationary fish.

*Table 4-5: Estimated impact ranges for the VSP survey equipment using the Popper et al (2014) $L_{E,p,24h}$ fish criteria for seismic airguns assuming a fleeing animal.*

| Popper *et al.* (2014) criteria $L_{E,p,24h}$ (Seismic airguns) | | Estimated impact range, fleeing (m) | | |
|---|---|---|---|---|
| | | Maximum | Mean | Minimum |
| Fish: no swim bladder | Mortal and potential mortal injury | < 10 | < 10 | < 10 |
| | Recoverable injury | < 10 | < 10 | < 10 |
| | TTS | 50 | 50 | 50 |
| Fish: swim bladder not involved in hearing | Mortal and potential mortal injury | 10 | 10 | 10 |
| | Recoverable injury | 10 | 10 | 10 |
| | TTS | 50 | 50 | 50 |
| Fish: swim bladder involved in hearing | Mortal and potential mortal injury | 10 | 10 | 10 |
| | Recoverable injury | 10 | 10 | 10 |
| | TTS | 50 | 50 | 50 |

*Table 4-6: Estimated impact ranges for the VSP survey equipment using the Popper et al (2014) $L_{E,p,24h}$ fish criteria for seismic airguns assuming a stationary animal.*

| Popper *et al.* (2014) criteria $L_{E,p,24h}$ (Seismic airguns) | | Estimated impact range, stationary (m) | | |
|---|---|---|---|---|
| | | Maximum | Mean | Minimum |
| Fish: no swim bladder | Mortal and potential mortal injury | 50 | 50 | 50 |
| | Recoverable injury | 60 | 60 | 60 |
| | TTS | 5100 | 4600 | 3900 |
| Fish: swim bladder not involved in hearing | Mortal and potential mortal injury | 120 | 120 | 120 |
| | Recoverable injury | 270 | 270 | 270 |
| | TTS | 5100 | 4600 | 3900 |
| Fish: swim bladder involved in hearing | Mortal and potential mortal injury | 170 | 170 | 170 |
| | Recoverable injury | 270 | 270 | 270 |
| | TTS | 5100 | 4600 | 3900 |

# 5 Summary and Conclusions

Subacoustech Environmental, on behalf of Orbis Energy Ltd, has undertaken an underwater noise modelling study in anticipation of a VSP survey taking place in UKCS Block 204/13b, located to the west of Shetland, in the North Sea, UK. The survey is proposed to take place from a rig using 3 × 250 (750) cubic inch airgun array.

The level of underwater noise generated by the survey was estimated using a combined parabolic equation and ray tracing modelling approach. The modelling considers a wide array of input parameters including the equipment source level, sound frequency content, seabed properties and the sound speed profile in the water column. Full account is also taken of the bathymetry in the areas surrounding the survey site. The modelled noise levels were then interpreted in accordance with the guidelines outlined in Southall *et al.* (2019) for marine mammals in relation to impulsive and non-impulsive noise sources, and Popper *et al.* (2014) for fish in relation to seismic airguns.

Using the Southall *et al.* (2019) guidance for marine mammals, the VHF cetacean group is predicted to have the largest PTS impact range. Animals within 40 m of the survey at the start would exceed the $L_{p,pk}$ VHF PTS threshold. When the total noise output is considered, the LF cetacean group is considered to have the largest PTS impact range. As a worst-case, animals within 10 m of the survey at the start that continuously flee away from the source would surpass the LF cetacean $L_{E,p,t}$ PTS threshold.

For fish, using the Popper *et al.* (2014) guidance, the largest mortality impact ranges are predicted are predicted for fish with a swim bladder (both involved and not involved in hearing). Animals that are within 20 m of the survey are expected to exceed this threshold. When the total noise output is considered, the largest mortality impact ranges is predicted for fish with a swim bladder involved in hearing. As a worst-case, animals within 50 m of the survey equipment are likely to exceed this threshold, if they remain stationary.

Finally, it should be stressed that, by its nature, mathematical modelling will produce results that indicate a precise range at which a criterion will be reached, but this does not reflect the inherent uncertainty in the physical processes, including many that change constantly under real world conditions. While the results present specific ranges at which each impact threshold is met based on the modelling results, the ranges should be taken as indicative in determining where environmental effects may occur in receptors during the proposed operations.

# References

Andersson M H, Andersson S, Ahlsén J, Andersson B L, Hammar J, Persson L K G, Pihl J, Sigray P, Wilkström A (2017). *A framework for regulating underwater noise during pile driving*. A technical Vindval report, ISBN 978-91-620-6775-5, Swedish Environmental Protection Agency, Stockholm, Sweden.

Bailey H, Thompson P (2006). *Quantitative analysis of bottlenose dolphin movement patterns and their relationship with foraging.* Journal of Animal Ecology 75: 456-465.

Barham R, Mason T (2022). *Underwater noise propagation modelling of seismic airgun array noise at the North Eigg field*. Subacoustech Report Ref P311R0101.

Bebb A H, Wright H C (1953). Injury to animals from underwater explosions. Medical Research Council, Royal Navy Physiological Report 53/732, Underwater Blast Report 31, January 1953.

Bebb A H, Wright H C (1954a). Lethal conditions from underwater explosion blast. RNP Report 51/654, RNPL 3/51, National Archies Reference ADM 298/109, March 1954.

Bebb A H, Wright H C (1954b). Protection from underwater explosion blast: III. Animal experiments and physical measurements. RNP Report 57/792, RNPL 2/54m March 1954.

Bebb A H, Wright H C (1955). Underwater explosion blast data from the Royal Navy Physiological Labs 1950/1955. Medical Research Council, April 1955.

Dahl P H, de Jong C A, Popper A N (2015). *The underwater sound field from impact pile driving and its potential effects on marine life.* Acoustics Today, Spring 2015, Volume 11, Issue 2.

Etter P C (1991). *Underwater acoustic modelling: Principles, techniques and applications.* Elsevier Science Publishers Ltd, Essex. ISBN 1-85166-528-5.

Goertner J F (1978). *Dynamical model for explosion injury to fish.* Naval Surface Weapons Center, White Oak Lab, Silver Spring, MD. Report No. NSWC/WOL.TR-76-155.

Goertner J F, Wiley M L, Young G A, McDonald W W (1994). *Effects of underwater explosions on fish without swim bladders.* Naval Surface Warfare Center. Report No. NSWC/TR-76-155.

Halvorsen M B, Casper B C, Matthew D, Carlson T J, Popper A N (2012). *Effects of exposure to pile driving sounds on the lake sturgeon, Nila tilapia, and hogchoker.* Proc. Roy. Soc. B 279: 4705-4714.

Hastings M C, Popper A N (2005). *Effects of sound on fish.* Report to the California Department of Transport, under Contract No. 43A01392005, January 2005.

Hawkins A D, Popper A N (2017). A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. ICES J. Mar. Sci. 74 (3), 635–651. doi: 10.1093/icesjms/fsw205

Jensen F B, Kuperman W A, Porter M B, Schmidt H (1994). *Computational Ocean Acoustics.* Woodbury NW, AIP Press.

Jensen F B, Kuperman W A, Porter M B, Schmidt H (2011). *Computational Ocean Acoustics.* Modern Acoustics and Signal Processing. Springer-Verlag, NY. ISBN: 978-1-4419-8678-8.

Kastelein R A, van de Voorde S, Jennings N (2018). *Swimming speed of a harbor porpoise (Phocoena phocoena) during playbacks of offshore pile driving sounds.* Aquatic Mammals. 2018, 44(1), 92-99, DOI 10.1578/AM.44.1.2018.92.

Mackenzie K V (1981). *Nine-term equation for the sound speed in the oceans*. J. Acoust. Soc. Am. 70(3), pp 807-812.

National Marine Fisheries Service (NMFS) (2018). *2018 Revisions to: Technical guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts.* U.S. Dept. of Commer., NOAA. NOAA Technical Memorandu, NMFS-OPR-59.

National Marine Fisheries Service (NMFS) (2024). *2024 update to: Technical guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 3.0): Underwater and In-Air Criteria for Onset of Auditory Injury and Temporary Threshold Shifts.* U.S. Dept. of Commer., NOAA. NOAA Technical Memorandu, NMFS-OPR-71.

Popper A N, Hawkins A D, Fay R R, Mann D A, Bartol S, Carlson T J, Coombs S, Ellison W T, Gentry R L, Halvorsen M B, Løkkeborg S, Rogers P H, Southall B L, Zeddies D G, Tavolga W N (2014). *Sound exposure guidelines for Fishes and Sea Turtles.* Springer Briefs in Oceanography DOI 10. 1007/978-3-319-06659-2.

Popper A N, Hawkins A D (2018). *The importance of particle motion to fishes and invertebrates.* J. Acoust. Soc. Am. 143, 470 – 486.

Popper A N, Hawkins A D (2019). *An overview in fish bioacoustics and the impacts of anthropogenic sounds on fishes.* Journal of Fish Biology, 1-22. DOI: 10.111/jfp.13948.

Radford C A, Montgomery J C, Caiger P, Higgs D M (2012). *Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts.* Journal of Experimental Biology, 215, 3429 – 3435.

Rawlins J S P (1987). *Problems in predicting safe ranges from underwater explosions.* Journal of Naval Science, Volume 14, No. 4 pp. 235-246.

Scottish Natural Heritage (SNH) (2016). *Assessing collision risk between underwater turbines and marine wildlife.* SNH guidance note.

Solé M, Kaifu K, Mooney T A, Nedelec S L, Olivier F, Radford A N, Vazzana M, Wale M A, Semmens J M, Simpson S D, Buscaino G, Hawkins A, Aguilar de Soto N, Akamatsu T, Chauvaud L, Day R D, Fitzgibbon Q, McCauley R D, André M (2023). 'Marine invertebrates and noise', Frontiers in Marine Science, 10.

Southall B L, Finneran J J, Reichmuth C, Nachtigall P E, Ketten D R, Bowles A E, Ellison W T, Nowacek D P, Tyack P L (2019). *Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects.* Aquatic Mammals 2019, 45(2), 125-232, DOI 10.1578/AM.45.2.2019.125.

Southall B L, Bowles A E, Ellison W T, Finneran J J, Gentry R L, Green Jr. C R, Kastak D, Ketten D R, Miller J H, Nachtigall P E, Richardson W J, Thomas J A, Tyack P L (2007). *Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations.* Aquatic Mammals, 33 (4), pp. 411-509.

Stephenson J R, Gingerich A J, Brown R S, Pflugrath B D, Deng Z, Carlson T J, Langeslay M J, Ahmann M L, Johnson R L, Seaburg A G (2010). *Assessing barotrauma in neutrally and negatively buoyant juvenile salmonids exposed to simulated hydro-turbine passage using a mobile aquatic barotrauma laboratory.* Fisheries Research Volume 106, Issue 3, pp 271-278, December 2010.

# APPENDIX E:
# Pipeline Dewatering Modelling

# TORNADO FIELD

## Hydrotest Discharge Dispersion Modelling



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# EXECUTIVE SUMMARY

## Project Background

Ithaca SP E&P Limited (Ithaca) are operators of the Tornado Field, West of Shetland. The Tornado Field includes UK Continental Shelf (UKCS) Block 204/13b, within which Ithaca is proposing to drill up to three development wells and install associated pipeline infrastructure. The Tornado Field is located 160 km west of the Shetland Islands in a water depth of approximately 1,060 m.

As part of the pipeline installation process, once installed the pipeline will be hydrotested to verify system integrity, which will include the discharge of a pipeline hydrotest chemical. It is anticipated that a hydrotest cocktail such as Roemex RX-5255 will be used. Roemex RX-5255 is a 4 in 1 liquid hydrotest cocktail comprising corrosion inhibitor, biocide, oxygen scavenger and leak detection dye.

To support the environmental impact assessment for the proposed pipeline installation within the Tornado Field, Ithaca commissioned RPS to undertake a detailed hydrotest dispersion modelling study for the following scenario:

- An 8,897.20 $m^3$ discharge over a period of 0.65 days (570.3 $m^3/h$), 1.5 m above the seafloor containing a 550 mg/L initial concentration of the hydrotest treatment.

The purpose of the modelling is to provide an understanding of the potential area of exposure from the hydrotest chemicals within the receiving environment.

## Methodology

The physical mixing and dilution of the discharged hydrotest within the receiving environment is divided into two distinct zones: the near-field and the far-field. The near-field zone involves the initial mixing of the hydrotest discharge, which is influenced primarily by the plume's initial momentum and buoyancy as it enters the receiving environment. Thereafter, once the near-field mixing is complete the far-field mixing phase commences. During the far-field phase, the plume is transported and mixed by the ambient currents.

To effectively model these processes, the study was conducted in several stages. Initially, a near-field model (CORMIX) was used to simulate the hydrotest plume as it discharged from the pipeline. This allowed for the assessment of plume dynamics and achieved dilutions across various current speeds.

In the second phase, current data, discharge information and plume characteristics from the near-field results were input into the three-dimensional discharge and plume behaviour model (MUDMAP). This model simulated 100 individual 2-day long simulations. The 100 simulations were modelled under a wide range of local current conditions by stochastic modelling (i.e. repeated simulations with each simulation using a unique time-sequence of current flow, chosen at random from the 10-year time series of current data). The results for each scenario were combined to create an annual assessment based on the predicted minimum and 95$^{th}$ percentile dilutions.

## Key Results: Near-Field Modelling

- Under the weak current speed, the near-field mixing region ends 36.2 m from the release location with a plume centreline dilution of 1:14.3, whilst under the moderate conditions the near-field mixing region ends 25.2 m from the release location with a plume diameter of 3 m and a plume centreline dilution of 1:12.7. In comparison, the strong current conditions influenced the discharge plume with the near-field extending 68.9 m from the release location where the plume diameter and centreline dilutions were 3 m and 1:23.7, respectively.

# Key Results: Far-Field Modelling

- Dilutions of 1:981, which represents the required dilution to not exceed the worst case toxicity of the single most toxic component of the liquid hydrotest cocktail were achieved within 87 m and 157 m from the release location based on the 95$^{th}$ percentile and minimum dilutions, respectively. The maximum distances from the release location to the 1:1,000 dilutions were 98 m (95$^{th}$ percentile) and 194 m (minimum dilution) and 1:2,000 dilutions were 211 m (95$^{th}$ percentile) and 976 m (minimum dilution). With increasing dilutions, the maximum distances to achieve 1:5,000 and 1:10,000 were 730 m (95$^{th}$ percentile) and 4,438 m (minimum dilution), and 4,170 m (95$^{th}$ percentile) and 7,548 m (minimum dilution), respectively. Additionally, the maximum distances from the release location to the 1:42,300 dilution based on the predicted 95$^{th}$ percentile and minimum dilutions of the hydrotest discharge from Tornado DC2.1 were 11,900 m and 23,300 m, respectively.

# 1 INTRODUCTION

## 1.1 Background

Ithaca are operators of the Tornado Field, West of Shetland. The Tornado Field includes UK Continental Shelf (UKCS) Block 204/13b, within which Ithaca is proposing to drill up to three development wells and install associated pipeline infrastructure. The Tornado Field is located 160 km west of the Shetland Islands in a water depth of approximately 1,060 m.

As part of the pipeline installation process, once installed the pipeline will be hydrotested to verify system integrity, which will include the discharge of a pipeline hydrotest treatment. It is anticipated that a hydrotest cocktail such as Roemex RX-5255 will be used. Roemex RX-5255 is a 4 in 1 liquid hydrotest cocktail comprising corrosion inhibitor, biocide, oxygen scavenger and leak detection dye.

To support the environmental impact assessment for the proposed pipeline installation within the Tornado Field, Ithaca commissioned RPS to undertake a detailed hydrotest dispersion modelling study for the following scenario:

- An 8,897.20 $m^3$ discharge over a period of 0.65 days (570.3 $m^3$/h), 1.5 m above the seafloor containing a 550 mg/L initial concentration of the hydrotest treatment.

The coordinates for the discharge release location are presented in Table 1.1 and Figure 1.1.

The purpose of the modelling is to provide an understanding of the potential area of exposure from the hydrotest chemicals within the receiving environment.

**Table 1.1 Coordinates for the hydrotest discharge dispersion modelling release location.**

| Release location | Latitude* | Longitude* | Water depth (m) |
|---|---|---|---|
| Tornado DC2.1 | 60° 33' 41.571'' N | 4° 25' 51.940'' W | 1,061.5 |

*Datum: WGS 1984

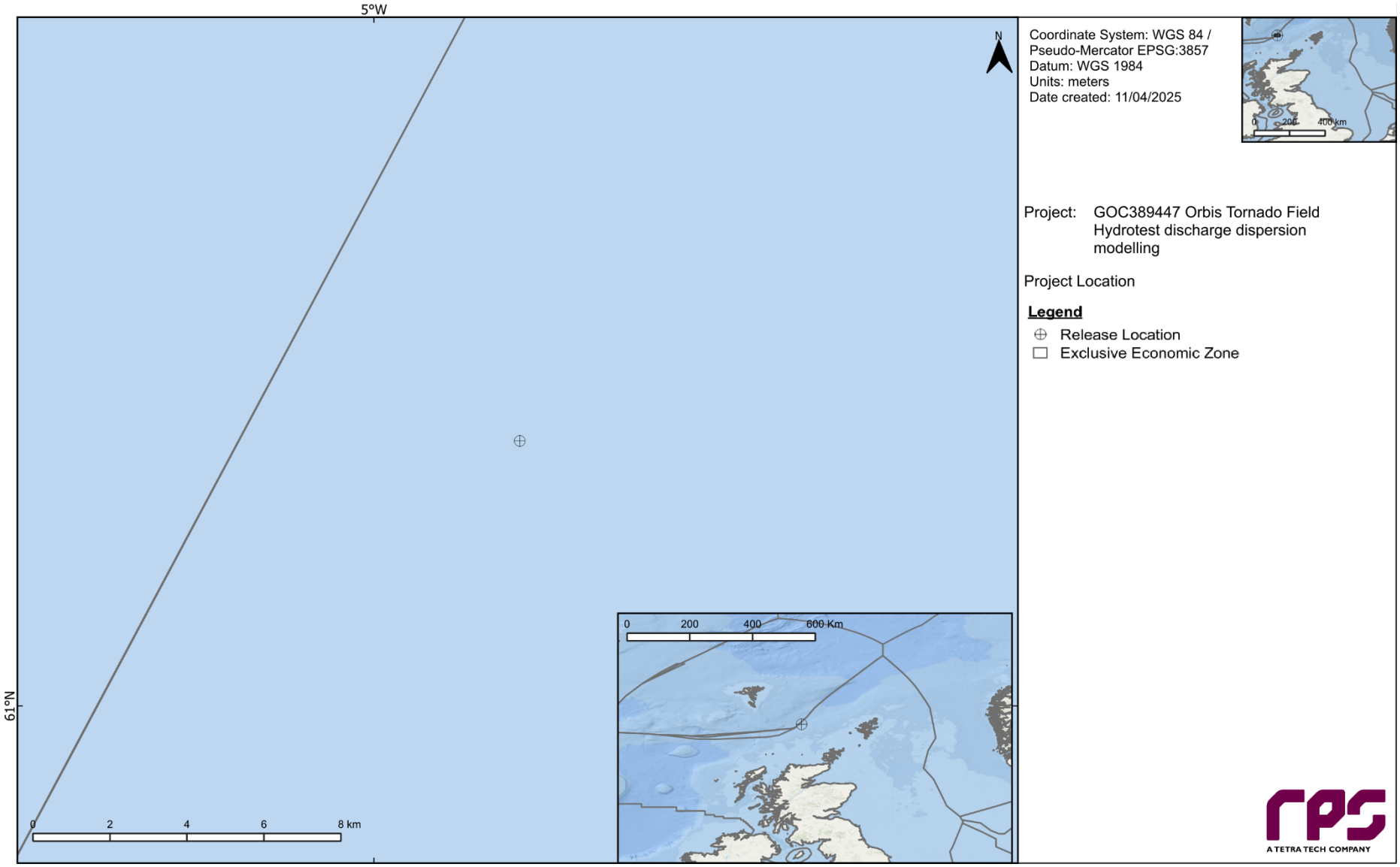



**Figure 1.1 Tornado Field hydrotest discharge modelling release location.**

# 2 SCOPE OF WORK

The physical mixing and dilution of the discharged hydrotest within the receiving environment is divided into two distinct zones: the near-field and the far-field. The near-field zone involves the initial mixing of the hydrotest discharge, which is influenced primarily by the plume's initial momentum and buoyancy as it enters the receiving environment. Thereafter, once the near-field mixing is complete the far-field mixing phase commences. During the far-field phase, the plume is transported and mixed by the ambient currents.

The following scope of work was completed to assess dilution of the hydrotest discharge through near-field and far-field dilution phases:

- Ten years (2010 to 2019 (inclusive)) of current data were generated, which included the combined influence of ocean and tidal currents. The current data is suitably long enough to be indicative of interannual variability in ocean currents;
- Derivation of statistical distributions for the current speed and directions for use in the near-field modelling. Analyses included percentile distributions and development of current roses. This analysis was important to ensure that current data samples applied in the dispersion model were statistically representative;
- Collation of vertical water density profiles at the release location for use as input to the dispersion models;
- Conduct near-field modelling to assess the initial mixing of the discharge due to turbulence and subsequent entrainment of ambient water. This modelling was conducted at high spatial and temporal resolution (scales of metres and seconds, respectively) with outcomes from the near-field modelling included estimates of the width, shape and orientation of the plumes, and resulting chemical concentrations and dilutions, for a range of incident current speeds;
- Establish far-field dispersion modelling inputs to calculate dispersive mixing and dilution under current and turbulence influences;
- Simulate the transport and dispersive mixing of the plume (beyond the near-field zone) under a wide range of local current conditions by stochastic modelling (i.e. 100 repeated simulations with each simulation using a unique time-sequence of current flow, chosen at random from the 10-year time series of current data); and
- Analysis and mapping of the receiving environment that might be exposed to different levels of dilution.

# 3 REGIONAL CURRENTS

The release location is located within the northeastern region of the North Atlantic Ocean. The North Atlantic Ocean is a large ocean bounded by the Arctic Ocean to the north, the equator to the south, and the continents of North and South America to the west, and Europe and Africa to the east. The ocean has an average depth of 3,646 m (Eakins and Sharman, 2010) and is known for its powerful ocean currents, such as the Gulf Stream and the North Atlantic Current.

Specifically, the study region is located within the area of influence of the North Atlantic Drift Current (NADC), an extension of the North Atlantic Current. The NADC is a slow-moving body of water located between approximately 50°-64°N and 10°-30°W, recognised as a shallow, widespread and variable wind-driven surface movement of warm water that covers a large part of the eastern subpolar North Atlantic and slowly spills into the Nordic Seas (Bischof et al., 2003).

The northward flow of surface waters of the NADC which replace the sinking waters in the North Atlantic polar seas (Bischof et al., 2003) has a volumetric rate of transport calculated to range between 2 – 16 Sv (Krauss, 1996; Bacon, 1997).

Readers are referred to Reid (1994), Rossby (1996) and Reverdin at al. (2003) for details reviews of the physical oceanography of the North Atlantic Ocean.

To accurately describe the variability in currents both horizontally and vertically, data based on the combination of ocean currents and tides were included as part of this study. Below is a summary of the combined datasets.

## 3.1 Tidal Currents – HYDROMAP

The effects of tides were generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world for over 35 years (Isaji and Spaulding, 1984; Isaji et al., 2001; Zigic et al., 2003; Makarynskyy et al., 2010), whilst being used for a wide variety of disciplines within marine environments (e.g. Zigic et al., 2003; 2009; Talouli et al., 2009; King et al., 2010; Makarynskyy et al., 2010, 2015). In fact, HYDROMAP tidal current data have been used as input for the OILMAP hydrocarbon spill modelling system, which forms part of the Incident Management System (IMS) operated by Maritime New Zealand (MNZ), Australian Maritime Safety Authority (AMSA) and the United Kingdom Maritime and Coastguard Agency, as well as several major oil and gas companies.

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji and Spaulding (1984) and Isaji et al. (2001).

### 3.1.1 Grid Setup

RPS has a seamless global tidal model. The tidal domains are sub-gridded to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grid cells are allocated in a step-wise fashion to more accurately resolve flows along the coastline, around islands and over regions with more complex bathymetry. Figure 3.1 shows a zoomed in image of the North Atlantic Ocean and North Sea model regions.

A combination of datasets was used to describe the shape of the seabed within the high-resolution grid. Depths for the region were extracted from nautical charts and the SRTM30_PLUS dataset (see Becker et al., 2009), which provides a 30-arc second, or approximately 1 km, resolution.

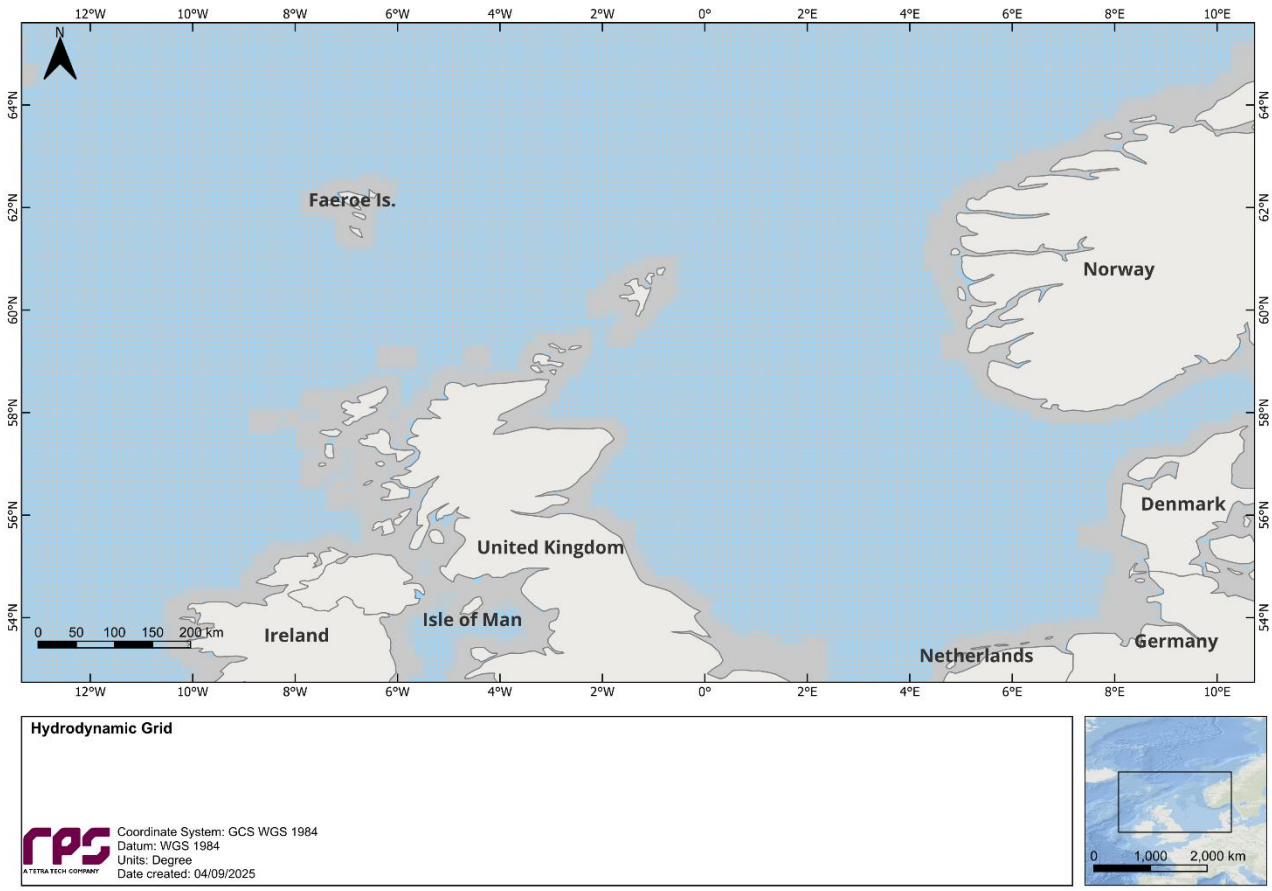



**Figure 3.1 Map showing the regions of sub-gridding for the study area and example nearshore resolution.**

### 3.1.2 Tidal Conditions

The ocean boundary data for the regional model were obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were $K_2$, $S_2$, $M_2$, $N_2$, $K_1$, $P_1$, $O_1$ and $Q_1$. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The Topex-Poseidon satellite data are produced, and quality controlled by National Aeronautics and Space Administration (NASA). The satellites, equipped with two highly accurate altimeters, capable of taking sea level measurements accurate to less than ± 5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total these satellites carried out 62,000 orbits of the planet. The Topex-Poseidon tidal data have been widely used amongst the oceanographic community, being the subject of more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010; Amores et al., 2019; Sagnieres et al., 2020; Veng et al., 2021; Zeitlhöfler et al., 2023). As such the Topex/Poseidon tidal data are considered suitably accurate for this study.

### 3.1.3 Surface Elevation Validation

To ensure that tidal predictions were accurate, predicted surface elevations were compared to data observed at twelve (12) locations situated across the study region (Figure 3.2).

Figure 3.3 to Figure 3.6 illustrate a comparison of the predicted and observed surface elevations for each location for January 2014. As shown on the graph, the model accurately reproduced the phase and amplitudes throughout the spring and neap tidal cycles well.

To provide a statistical measure of the model's performance, the Index of Agreement (IOA – Willmott, 1981) and the Mean Absolute Error (MAE – Willmott, 1982; Willmott and Matsuura, 2005) were used.

The MAE is the average of the absolute values of the difference between the model-predicted (P) and observed (O) variables. It is a more natural measure of the average error and more readily understood (Willmott and Matsuura, 2005).

$$MAE = N^{-1}\sum_{i=1}^{N}|P_i - O_i|$$

The Index of Agreement (IOA) is determined by:

$$IOA = 1 - \frac{\sum|X_{model} - X_{obs}|^2}{\sum(|X_{model} - \overline{X_{obs}}| + |X_{obs} - \overline{X_{obs}}|)^2}$$

Where: *X* represents the variable being compared and the time mean of that variable. A perfect agreement exists between the model and field observations if the index gives an agreement value of 1 and complete disagreement will produce an index measure of 0 (Wilmott, 1981). Willmott et al., (1985) also suggests that values meaningfully larger than 0.5 represent good model performance. Clearly, a greater IOA and lower MAE represent a better model performance.

Table 3.1 shows the IOA and MAE values for the selected locations.




**Figure 3.2 Location of the tide stations around used to demonstrate the accuracy of the tidal model.**

**Table 3.1 Statistical comparison between the observed and HYDROMAP predicted surface elevations data from the 1st to 31st January 2014.**

| Tide Station | IOA | MAE (m) |
|---|---|---|
| Aberdeen | 0.99 | 0.13 |
| Arendal | 0.92 | 0.03 |
| Belfast | 0.99 | 0.15 |
| Concarneau | 1.00 | 0.09 |
| Dover | 0.95 | 0.50 |
| Galway | 0.99 | 0.14 |
| Hvalba | 0.99 | 0.32 |
| Immingham | 0.91 | 0.66 |
| Kristiansund | 0.96 | 0.91 |
| Lerwick, Shetland Islands | 0.99 | 0.06 |
| Milford Haven | 0.98 | 0.32 |
| Wierumergronden | 0.92 | 0.28 |
| **Average** | **0.97** | **0.30** |

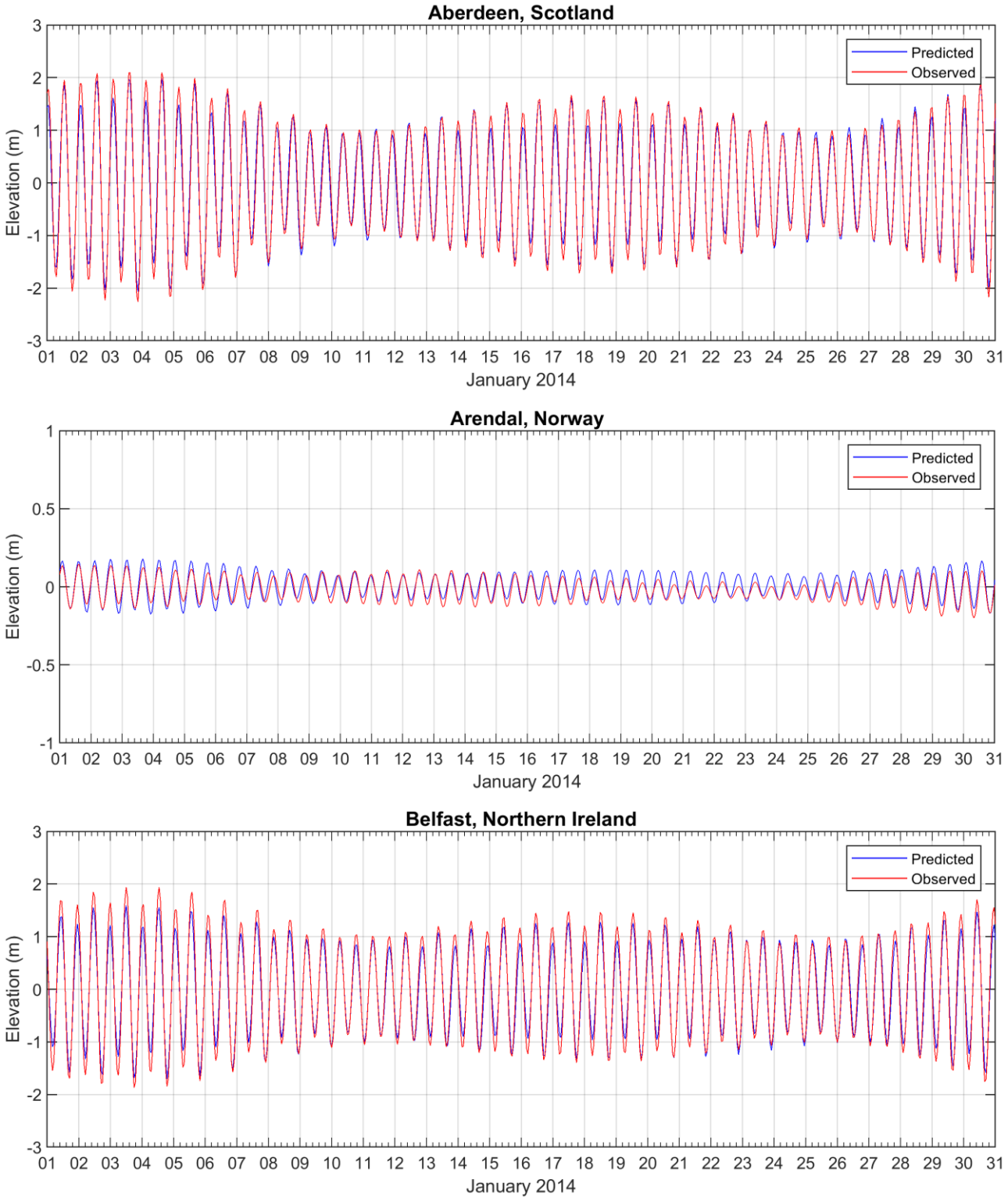



**Figure 3.3 Comparison between predicted (blue line) and observed (red line) surface elevation variation at Aberdeen (top), Arendal (middle) and Belfast (bottom), between the 1st and the 31st of July 2014.**

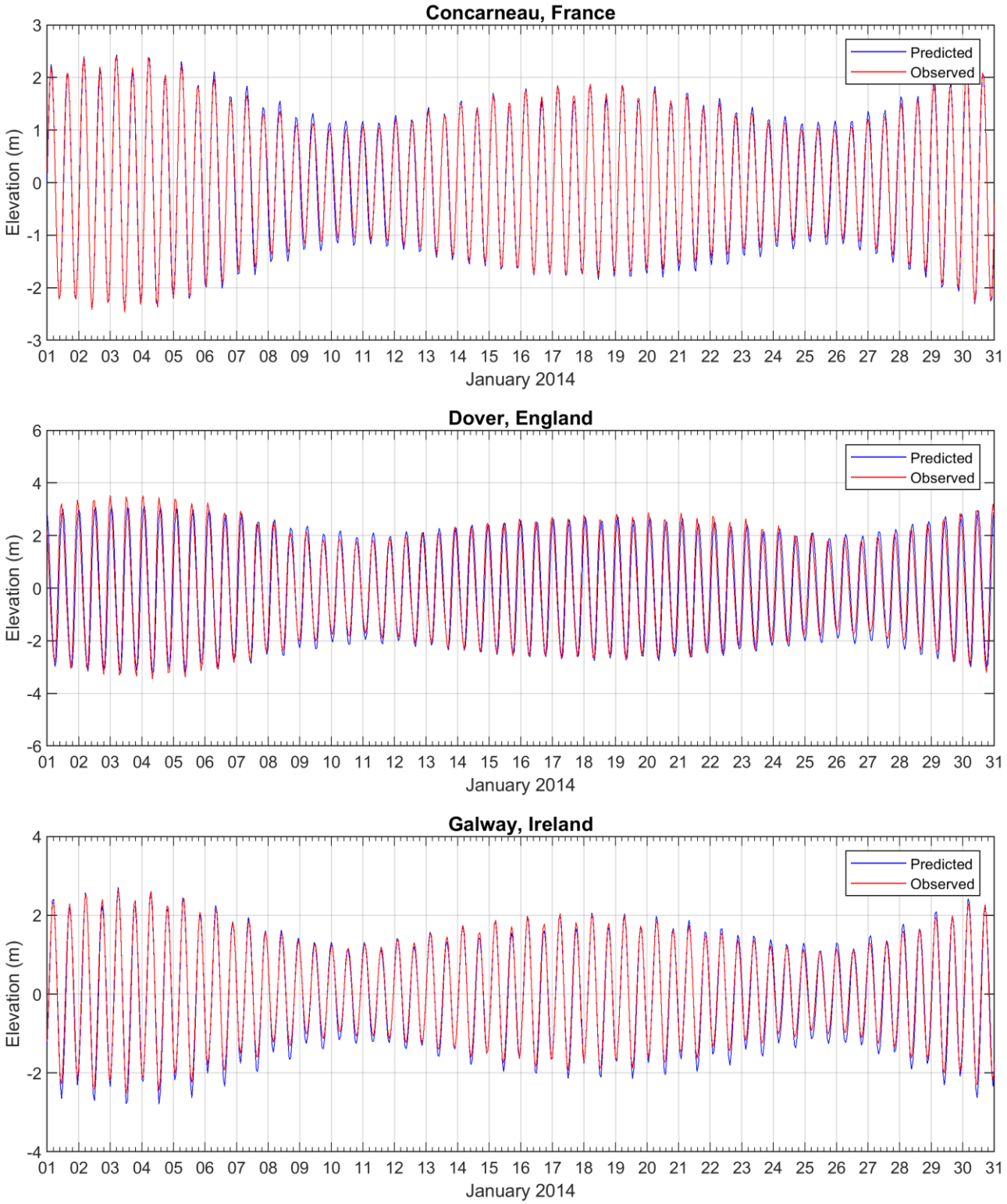



**Figure 3.4 Comparison between predicted (blue line) and observed (red line) surface elevation variation at Concarneau (top), Dover (middle) and Galway (bottom), between the 1st and the 31st of July 2014.**

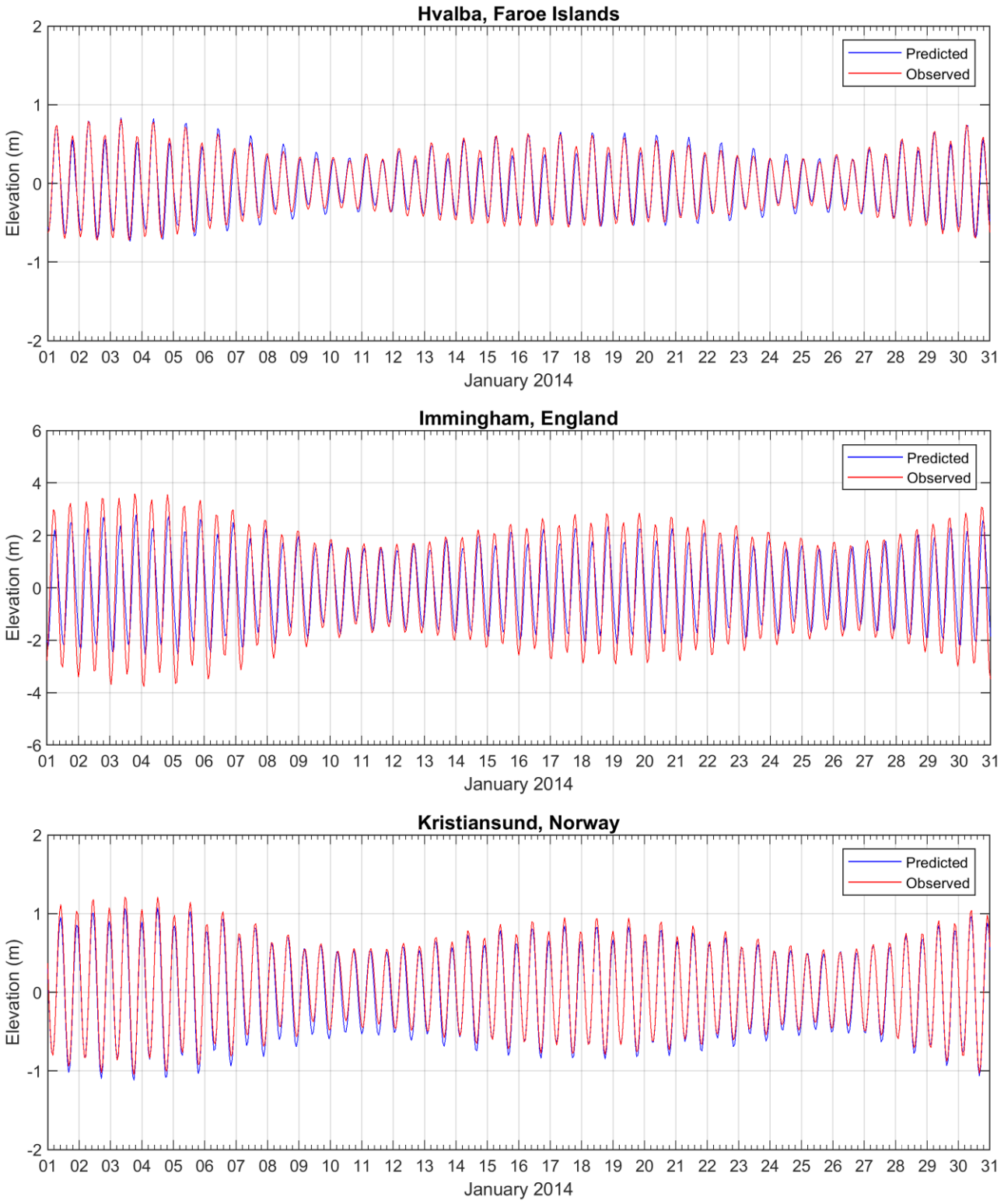



**Figure 3.5 Comparison between predicted (blue line) and observed (red line) surface elevation variation at Hvalba (top), Immingham (middle) and Kristiansund (bottom), between the 1st and the 31st of July 2014.**

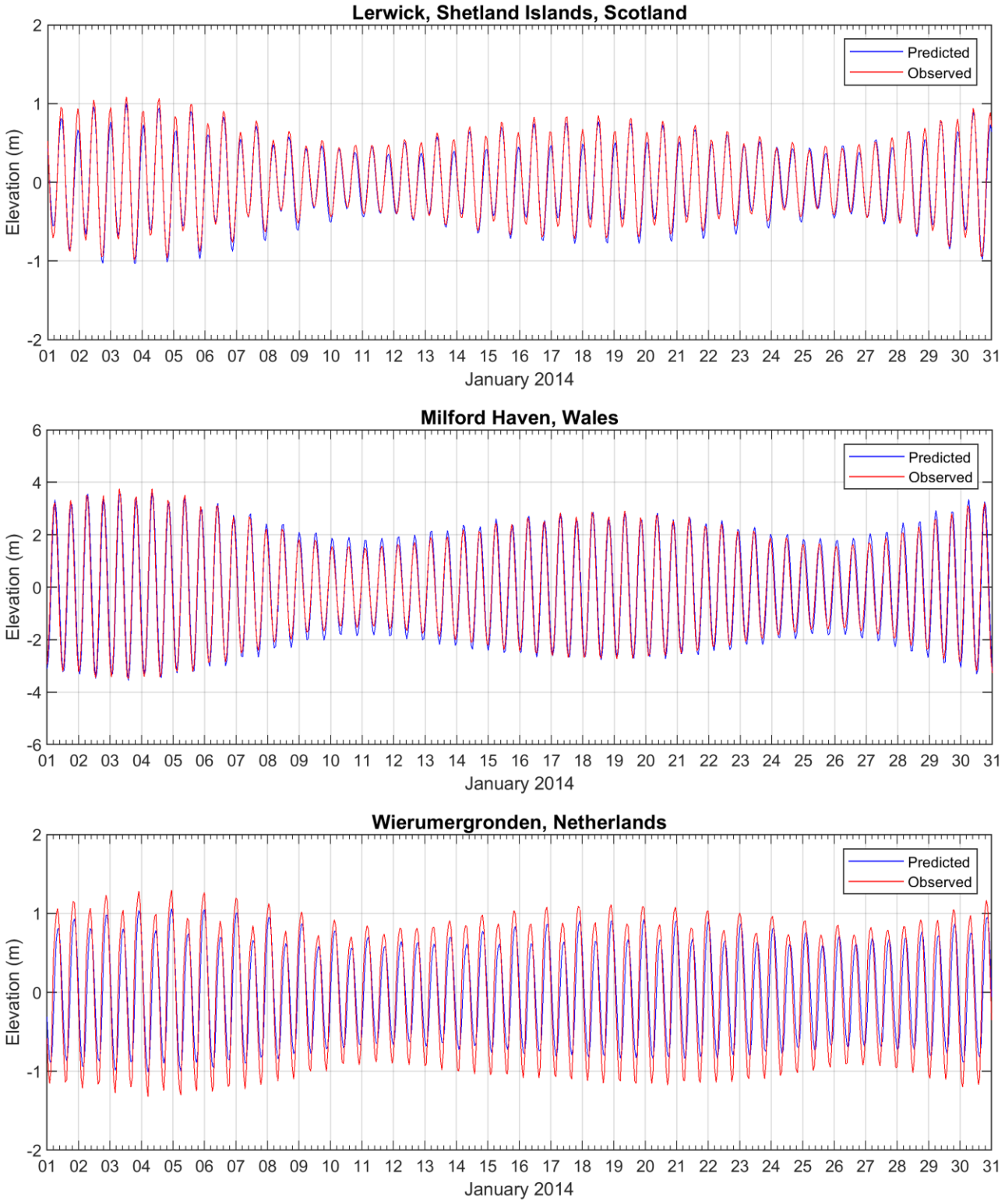



**Figure 3.6 Comparison between predicted (blue line) and observed (red line) surface elevation variation at Lerwick (top), Milford Haven (middle) and Wierumergronden (bottom), between the 1st and the 31st of July 2014.**

## 3.2 Three-Dimensional Ocean Currents – HYCOM

The three-dimensional ocean current data from 2010 to 2019 (inclusive) were obtained from the Hybrid Coordinate Ocean Model (HYCOM; see Chassignet et al., 2007), which is operated by the HYCOM Consortium, and sponsored by the Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a three-dimensional ocean model and is self-validating, meaning that it automatically integrates actual observations of sea surface heights, sea surface and in-situ temperatures and salinity measurements (Chassignet et al., 2009). Hence, the automatic integration of available measurements makes the predictions more reliable. The ocean current data are at a horizontal spatial resolution of approximately 8.25 km (1/12$^{th}$ of a degree) over the region, at a frequency of 3 hourly.

HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas.

The HYCOM model has been extensively documented through many publications which are available online[1]. The HYCOM data have also been used within the region for various applications (e.g. Melsom, 2005; Winther and Johannessen, 2006; Winther and Evensen, 2006; Akinbamini et al., 2022).

For this study, the HYCOM hindcast currents were obtained for the year 2010-2019. Figure 3.7 provides an example of the modelled surface ocean currents (HYCOM) for the region.

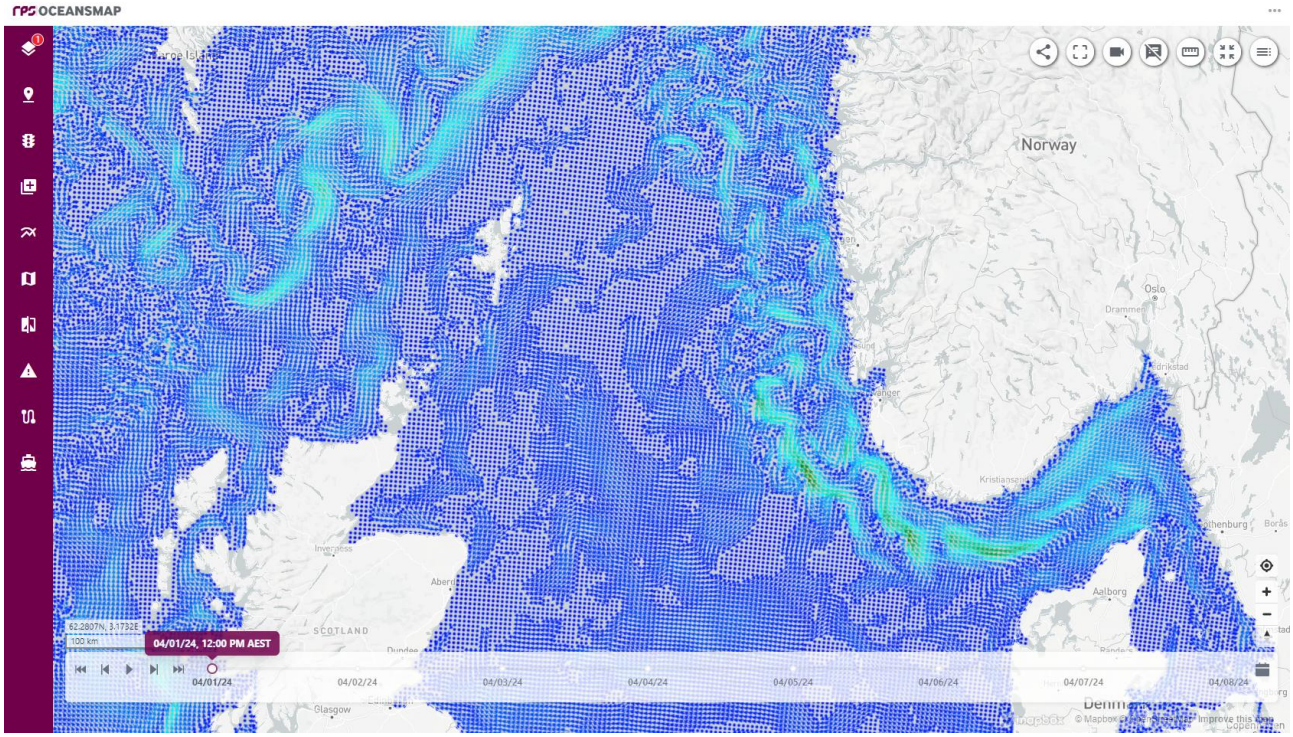



**Figure 3.7 Snapshot example of the predicted HYCOM ocean surface currents in the region. Colour and size of individual arrows indicate current speed (m/s).**

[1] https://hycom.org/publications

## 3.3 Near-Bottom Currents Nearby the Release Location

Figure 3.8 present the monthly surface and near-bottom current roses nearby the release locations, respectively. Note the convention for defining current direction is the direction the current flows towards, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.05 m/s are predominantly used in these current roses. The length of each coloured segment is relative to the proportion of currents flowing within the corresponding speed and direction.

Table 3.2 presents the near-bottom monthly current speeds and directions nearby the release location.

The monthly average near-bottom current speeds were relatively consistent ranging from 0.15 m/s (October and December) to 0.17 m/s (September), whilst near-bottom monthly maximum current speeds ranged between 0.42 m/s (June) and 0.58 m/s (April; Table 3.2). Additionally, the near-bottom current direction predominantly occurred towards the southwest (Figure 3.8).

**Table 3.2 Monthly average and maximum near-bottom current speeds nearby the release location. The data was derived by combining the HYCOM ocean data and HYDROMAP tidal data for 2010-2019.**

| Month | Average current speed (m/s) | Maximum current speed (m/s) | General direction |
|---|---|---|---|
| January | 0.16 | 0.49 | Southwest |
| February | 0.16 | 0.52 | |
| March | 0.16 | 0.51 | |
| April | 0.16 | 0.58 | |
| May | 0.16 | 0.55 | |
| June | 0.16 | 0.42 | |
| July | 0.16 | 0.50 | |
| August | 0.16 | 0.45 | |
| September | 0.17 | 0.51 | |
| October | 0.15 | 0.50 | |
| November | 0.16 | 0.50 | |
| December | 0.15 | 0.53 | |
| **Minimum** | **0.15** | **0.42** | - |
| **Maximum** | **0.17** | **0.58** | |

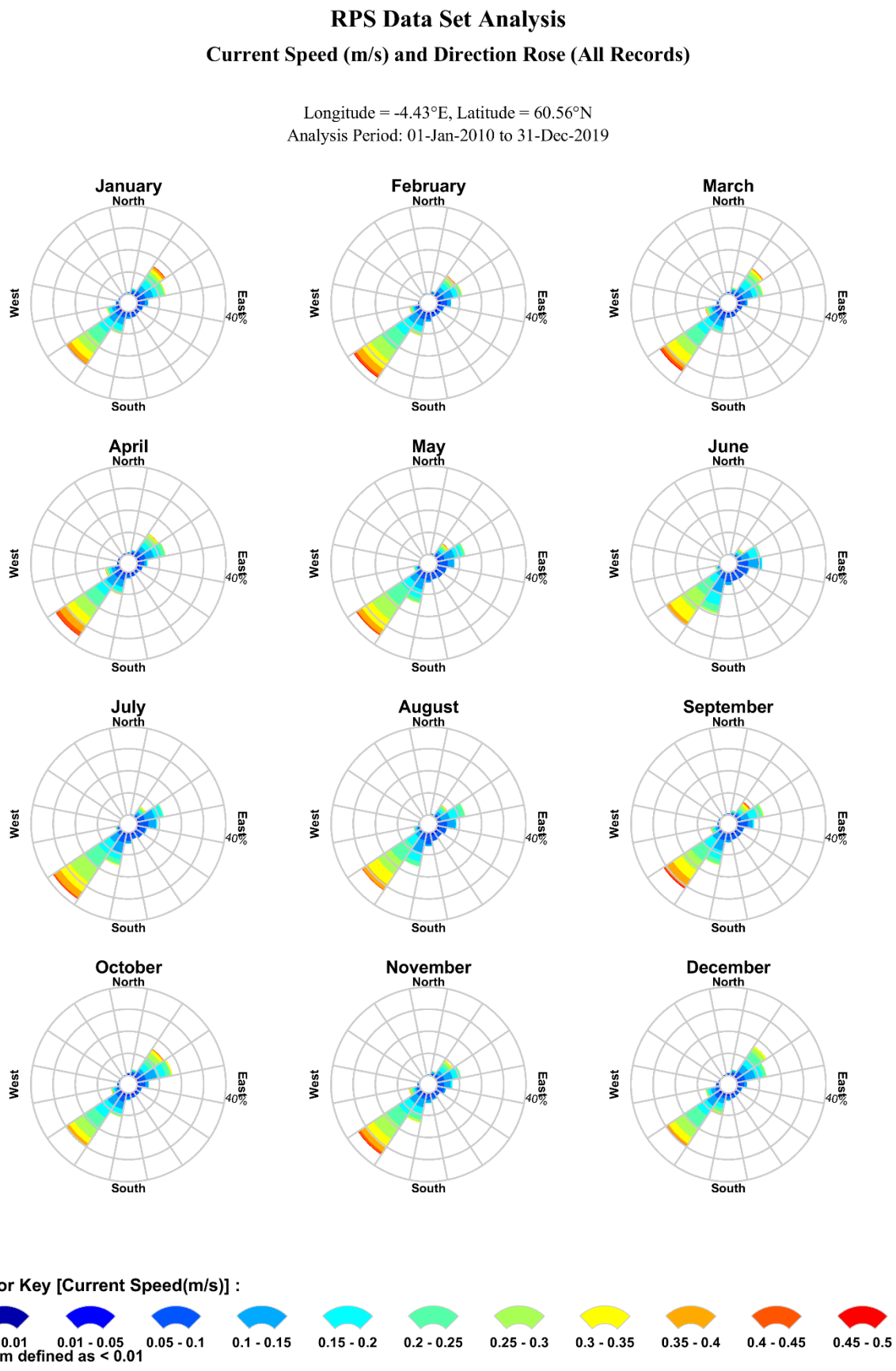



**Figure 3.8 Monthly near-bottom current rose distributions nearby the release location, derived from the 2010 to 2019 modelled dataset.**

# 4 WATER TEMPERATURE AND SALINITY

The monthly depth-varying water temperature and salinity profiles nearest to the release locations were obtained from the HYCOM dataset (see Section 3.2).

The three-dimensional salinity and temperature datasets are used in the model domain to inform water density through the water column layers.

Table 4.1 presents the monthly average sea temperature and salinity of the near-bottom layers nearby the release location. Monthly average near-bottom water temperature ranged from -1.0ºC (May) to -0.8ºC (January to April, August to October). Salinity remained consistent through the year at 34.9 practical salinity units (psu).

Figure 4.1 presents depth profiles of water temperature and salinity nearby the release locations.

**Table 4.1 Monthly average near-seabed temperature and salinity nearby the release locations.**

| Month | Temperature (ºC) | Salinity (psu) |
|---|---|---|
| | Near-bottom | Near-bottom |
| January | -0.8 | 34.9 |
| February | -0.8 | 34.9 |
| March | -0.8 | 34.9 |
| April | -0.8 | 34.9 |
| May | -1.0 | 34.9 |
| June | -0.9 | 34.9 |
| July | -0.9 | 34.9 |
| August | -0.8 | 34.9 |
| September | -0.8 | 34.9 |
| October | -0.8 | 34.9 |
| November | -0.9 | 34.9 |
| December | -0.9 | 34.9 |
| **Minimum** | **-1.0** | 34.9 |
| **Maximum** | **-0.8** | 34.9 |

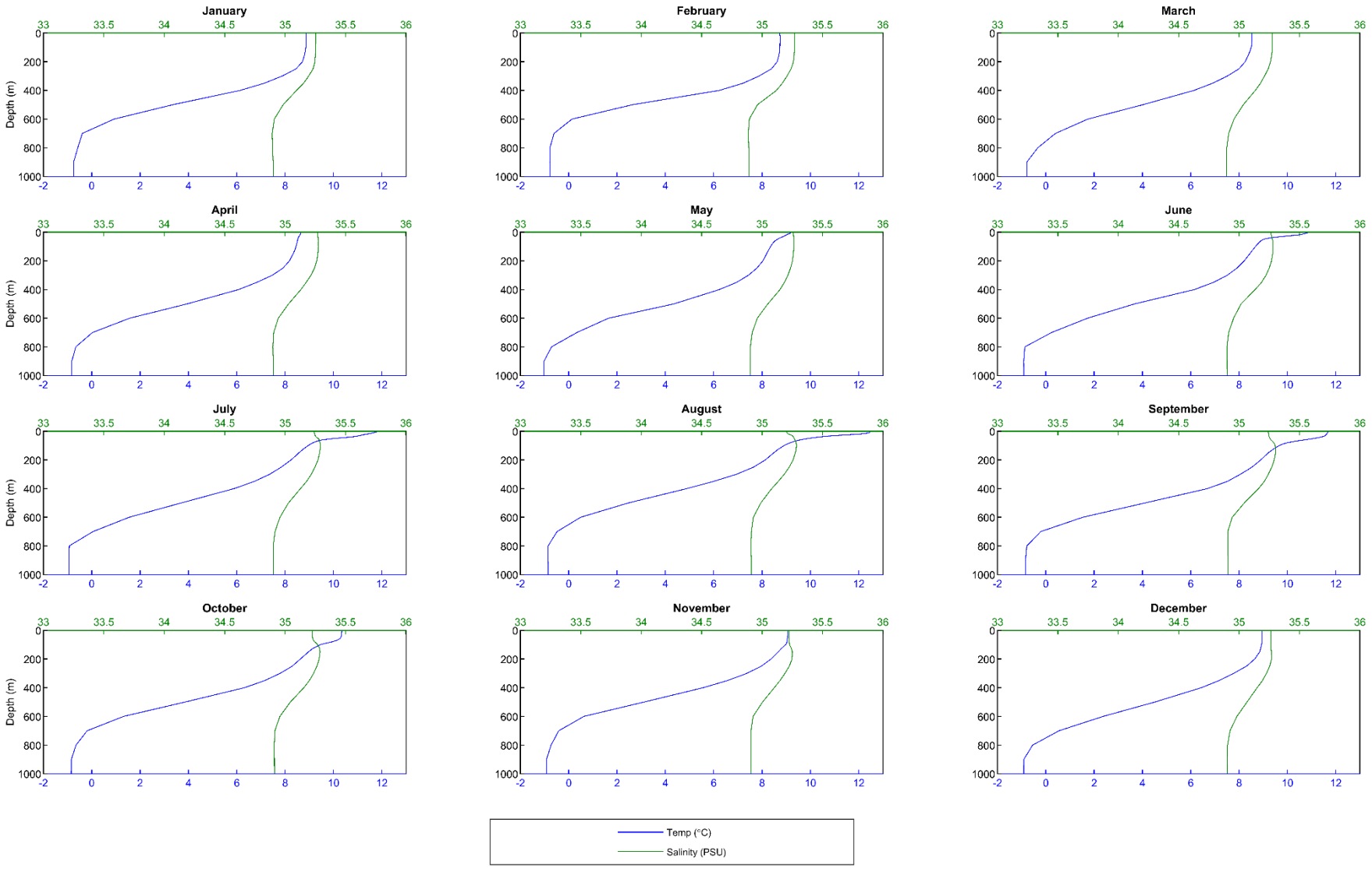



**Figure 4.1 Monthly average depth profiles of water temperature and salinity nearby the release location.**

# 5 MODELLING METHODOLOGY

## 5.1 Near-Field Modelling

### 5.1.1 Overview

Numerical modelling was applied to quantify the area of influence of the hydrotest discharge, in terms of the distribution of the maximum contaminant concentrations that might occur with distance from the source given defined discharge configurations, source concentrations, and the range of metocean conditions that affect the discharge location.

The dispersion of the hydrotest discharge will depend, initially, on the geometry and hydrodynamics of the discharge itself, where the induced momentum and buoyancy effects dominate over background processes. This region is generally referred to as the near-field zone and is characterised by variations over short time and space scales. As the discharges mix with the ambient waters, the momentum and buoyancy signatures are eroded, and the background – or ambient – processes become dominant.

The shape and orientation of the discharged water plumes, and hence the distribution and dilution rate of the plume, will vary significantly with natural variation in prevailing water currents. Therefore, to best calculate the likely outcomes of the discharges, it is necessary to simulate discharge under a range of current speeds statistically representative of the release location (Tornado DC2.1).

### 5.1.2 Description of Near-Field Model: CORMIX

The near-field mixing and plume dispersion was simulated using the three-dimensional flow model, CORMIX. CORMIX is a mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones. CORMIX contains a series of elements for the analysis and design of single or multi-port discharges. Discharges may be submerged or above surface, buoyant or denser than receiving water and the receiving water may be stratified or unstratified. The emphasis of the model is the influence of the geometry and dilution characteristics on the initial mixing zone (Doneker and Jirka, 1990; Jirka et al., 1991). CORMIX is widely applied worldwide and has been validated in many independent studies (http://www.cormix.info/validations.php).

CORMIX is a collection of analytic solutions to simplified forms of the mathematical equations describing transport and dispersion of water borne constituents. The simplifications come about through a range of assumptions about the source configuration, source characteristics (discharge and buoyancy) and the ambient environment. These assumptions effectively limit the domain within which the analytic solutions apply. For a typical source flow, two main zones can be defined as described in Table 5.1.

Although CORMIX does calculate far-field dispersion, the assumptions of the algorithms limit application to homogeneous environments with no eddies in the ambient flow and little recirculation. For this reason, the CORMIX component of the calculations for this study were limited to the near-field zone.

**Table 5.1 CORMIX mixing zones.**

| Zone | Description |
|---|---|
| Near-field | Jet characteristics, momentum flux, buoyancy flux and outfall geometry influence the plume's trajectory and mixing. |
| Far-field | Ambient conditions control the plume's trajectory and dilution due to density current buoyant spreading and ambient turbulence. |

CORMIX specifies the average dilution or bulk dilution (flux averaged) as 1.7 times the centreline dilution. The centreline is defined by the points of maximum concentration (maximum temperature, minimum dilution etc) at each vertical section along the longitudinal axis. Accordingly, centreline depth is defined as the depth of the maximum concentration point (maximum temperature, minimum dilution) along the longitudinal axis.

## 5.1.3 Setup of Near-Field Model

### 5.1.3.1 Discharge Characteristics

The hydrotest discharge characteristics for the discharge case are summarised in Table 5.2. The discharge is assumed to occur from Tornado DC2.1 at a discharge rate of 570.3 $m^3$/h. The hydrotest is discharged from a 0.365 m internal diameter pipe orientated horizontal and positioned 1.5 m above the seafloor. The discharge was assumed to have an average temperature and salinity of -0.6°C and 34.8 psu, respectively.

**Table 5.2 Summary of the hydrotest discharge characteristics.**

| Parameter | Value/description |
|---|---|
| Flow rate ($m^3$/h) | 570.3 |
| Location | Tornado DC2.1 |
| Duration (min) | Continuous |
| Outlet pipe internal diameter (m) | 0.365 |
| Number of Ports | 1 |
| Outlet pipe orientation | Horizontal |
| Discharge Depth (m) | 1,060 (below MSL) |
| Discharge temperature (°C) | -0.6 (average) |
| Discharge salinity (ppt) | 34.8 |

### 5.1.3.2 Ambient Environmental Conditions

Inputs of ambient environmental conditions to the CORMIX model included vertical profiles of temperature and salinity (see Section 4) with constant current speeds and general direction (per simulation). The temperature and salinity profiles are required to accurately account for the relative buoyancy of the diluting plume, while the current speeds control the intensity of initial mixing and the deflection of the hydrotest plume. Near-field ambient current inputs are described in the section below.

#### 5.1.3.2.1 Ambient Current

Ocean current data was sourced from a ten-year hindcast data set of combined tidal currents and large-scale ocean (HYCOM). The data was statistically analysed to determine the 5$^{th}$, 50$^{th}$ and 95$^{th}$ percentile current speeds (see Section 3.3). These statistical current speeds can be considered representative of annual conditions at the location as current speeds did not reveal to be substantially sensitive to seasonality.

Table 5.3 presents the annual steady-state, unidirectional, current speeds at varying depths used as input to the near-field model as forcing for each discharge case:

- 5$^{th}$ percentile current speed: weak currents, low dilution and slow advection.
- 50$^{th}$ percentile (median) current speed: medium currents, moderate dilution and advection.
- 95$^{th}$ percentile current speed: strong currents, high dilution and rapid advection to nearby areas.

The 5$^{th}$, 50$^{th}$ and 95$^{th}$ percentile values are referenced as weak, medium and strong current speeds, respectively.

**Table 5.3 Adopted ambient current conditions adjacent to the release location.**

| Season | 5th Percentile (Weak) Current Speed (m/s) | 50th Percentile (Medium) Current Speed (m/s) | 95th Percentile (Strong) Current Speed (m/s) |
|---|---|---|---|
| Annual | 0.04 | 0.14 | 0.34 |

## 5.2 Far-Field Modelling

### 5.2.1 Overview

The far-field modelling expands on the near-field work by allowing the time-varying nature of currents to be included, with the potential for localised build-up when current speeds are low (e.g. at the turning of the tide) and recirculation of the plume back to the discharge location might occur. In this case, concentrations near the discharge point can be increased due to the discharge plume mixing with the remnant plume from an earlier time. This may be a potential source of episodic increases in pollutant concentrations in the receiving waters.

### 5.2.2 Description of Far-Field Model: MUDMAP

The mixing and dispersion of the produced formation water discharges beyond the near-field zone was predicted using the three-dimensional discharge and plume behaviour model, MUDMAP (Koh and Chang, 1973; Khondaker, 2000). MUDMAP predicts the transport and passive dispersion of the discharged material due to the local currents and dispersive forces in the water column. Dispersion of the discharged material will be enhanced with increased current speeds, greater variation in current direction over time and increased wave energy.

The passive dispersion stage employs a particle-based, random walk, procedure. Constituents within the discharge stream are represented by a sample of Lagrangian particles. These particles are moved in three dimensions over each subsequent time step according to the prevailing local current data as well as horizontal and vertical mixing coefficients. Seabed deposition patterns are calculated for particulate sinking material, with sinking rates varying by particle size.

MUDMAP treats the Lagrangian particles as conservative tracers (i.e. they are not removed over time to account for chemical interactions, decay or precipitation). Predicted concentrations will therefore be conservative overestimates where these processes do occur. Each particle represents a proportion of the discharge, by mass, and particles are released at a given rate to represent the rate of the discharge (mass per unit time). Concentrations of constituents are predicted over time by counting the number of particles that occur within a given depth level and grid square and converting this value to mass per unit volume.

The system has been extensively validated and applied for discharge operations in Australian waters for other operational discharges (e.g. Burns et al., 1999; King and McAllister, 1997, 1998).

### 5.2.3 Stochastic Modelling

A stochastic modelling procedure was applied in the far-field modelling to sample a representative set of conditions that could affect the distribution of constituents. This approach involved 100 simulations of the scenario discharge, with each simulation representing discharge for 0.65 days under a different, randomly selected, conditions of current speed and direction data. These conditions were selected at random from the 10-year database of current data for the site. The initial dilution and shape of the discharge was set by the results of the near-field results described in Section 5.1. This methodology ensures that the calculated movement and fate of each discharge is representative of the passive dispersive forces for the range of prevailing currents that occur at the discharge location. Assumed hydrotest discharge characteristics are summarised in Table 5.4.

Once the stochastic modelling was complete, all simulations were statistically analysed to map distributions of possible outcomes. The stochastic simulations were jointly processed annually (100 replicate simulations).

The analysis calculated the frequency of occurrence of a given dilution level, by depth and horizontal location, at surrounding locations. Results were summarised for the minimum (100$^{th}$ percentile) and 95$^{th}$ percentile dilutions over time.

## 5.2.4 Setup of Far-Field Model

### 5.2.4.1 Discharge Characteristics

The MUDMAP model simulated the discharge into a time-varying current field with the initial dilution and shape of the discharge set by the near-field results described in Section 5.1. The hydrotest discharge scenario was modelled as a continuous discharge under time-varying current assuming the initial dilution and density change imposed by the near-field mixing.

Table 5.4 presents a summary of the far-field model inputs used to calculate the transport and mixing of the hydrotest treatment by the ambient currents. As previously mentioned, 100 simulations were run as a representation of annual conditions and each simulation had a different start time, which ensured a range of current conditions were sampled.

The simulated discharge period, 0.65 days, was modelled based on the length of the pipeline (85,000 m) and anticipated travel speed of the pipeline inspection gauge (1.5 m/s). Each simulation had a total model duration of 2 days.

**Table 5.4 Summary of hydrotest discharge modelling assumed for far-field modelling.**

| Parameter | Discharge Case |
|---|---|
| Hindcast modelling period | 2010-2019 |
| Seasons | Annual |
| Flow rate ($m^3$/h) | 570.3 |
| Initial concentration of hydrotest solution, Roemex RX-5255 (mg/L) | 550 |
| Depth of discharge (m) | 1,060 |
| Number of simulations | 100 |
| Simulated discharge type | Continuous |
| Simulated discharge period (days) | 0.65 |
| Model duration (days) | 2 |

### 5.2.4.2 Mixing Parameters

Horizontal and vertical dispersion coefficients in dispersion modelling represent turbulence-driven mixing and diffusion, which occur at sub-grid scales relative to the model's hydrodynamics. These coefficients, expressed in m²/s, govern the rate of area change per second. Increasing the horizontal dispersion coefficient enhances lateral plume spread, reducing centreline concentrations, while increasing the vertical coefficient accelerates downward mixing into the water column.

Horizontal turbulent diffusion depends on metocean conditions (wind, waves and currents) and the plume's scale relative to oceanic dispersion processes. For plumes 10–100 m wide, small-scale swirling motions and vertical mixing dominate, with horizontal dispersion rates near 0.1 m²/s. As the plume's width expands to 1–10 km, mesoscale eddies drive dispersion rates of a few to tens of m²/s. At scales exceeding mesoscale eddies, eddy mixing dominates with dispersion rates of 100–1,000 m²/s.

A spatially uniform and conservative dispersion coefficients of 1.0 m²/s (horizontal) and 0.001 m²/s (vertical) was applied to control hydrotest plume spreading. These values were selected through extensive sensitivity testing, ensuring conservative concentration estimates, as in-situ mixing under average and high-energy conditions is expected to be at least an order of magnitude greater (King and McAllister, 1997, 1998).

### 5.2.4.3 Grid Configuration

MUDMAP uses a three-dimensional grid to represent the geographic region under study (water depth and bathymetric profiles). The model was setup, and analysed and mapped on two grid scales, representing the aqueous and particulates components, respectively. Due to the rapid mixing and small-scale effect of the hydrotest discharge, it was necessary to use a fine grid with a resolution of 50 m x 50 m to track the movement and fate of the aqueous discharge plume. The extent of the grid region measured approximately 50 km (longitude or x-axis) by 50 km (latitude or y-axis), which was subdivided horizontally into approximately 1,000 x 1,000 cells. The vertical resolution was set to 20 m.

# 6 MODELLING RESULTS

## 6.1 Near-field Modelling

### 6.1.1 Overview

Figure 6.1 to Figure 6.3 present the change in minimum dilution of the plume under constant weak, medium and strong current speeds, respectively. The figures illustrate the predicted horizontal distance travelled by the plume before the end of the near-field phase (i.e. before the plume becomes neutrally buoyant).

Please note the differing x-axis and y-axis aspect ratios between the currents speed cases to best highlight details for each case.

The plots show the general shape expected for the plume given the discharge characteristics and different current speeds immediately adjacent to the seafloor.

Under the weak current speed, the near-field mixing region ends 36.2 m from the release location with a plume centreline dilution of 1:14.3, whilst under the medium conditions the near-field mixing region ends 25.2 m from the release location with a plume diameter of 3 m and a plume centreline dilution of 1:12.7. In comparison, the strong current conditions influenced the discharge plume with the near-field extending 68.9 m from the release location where the plume diameter and centreline dilutions were 3 m and 1:23.7, respectively.

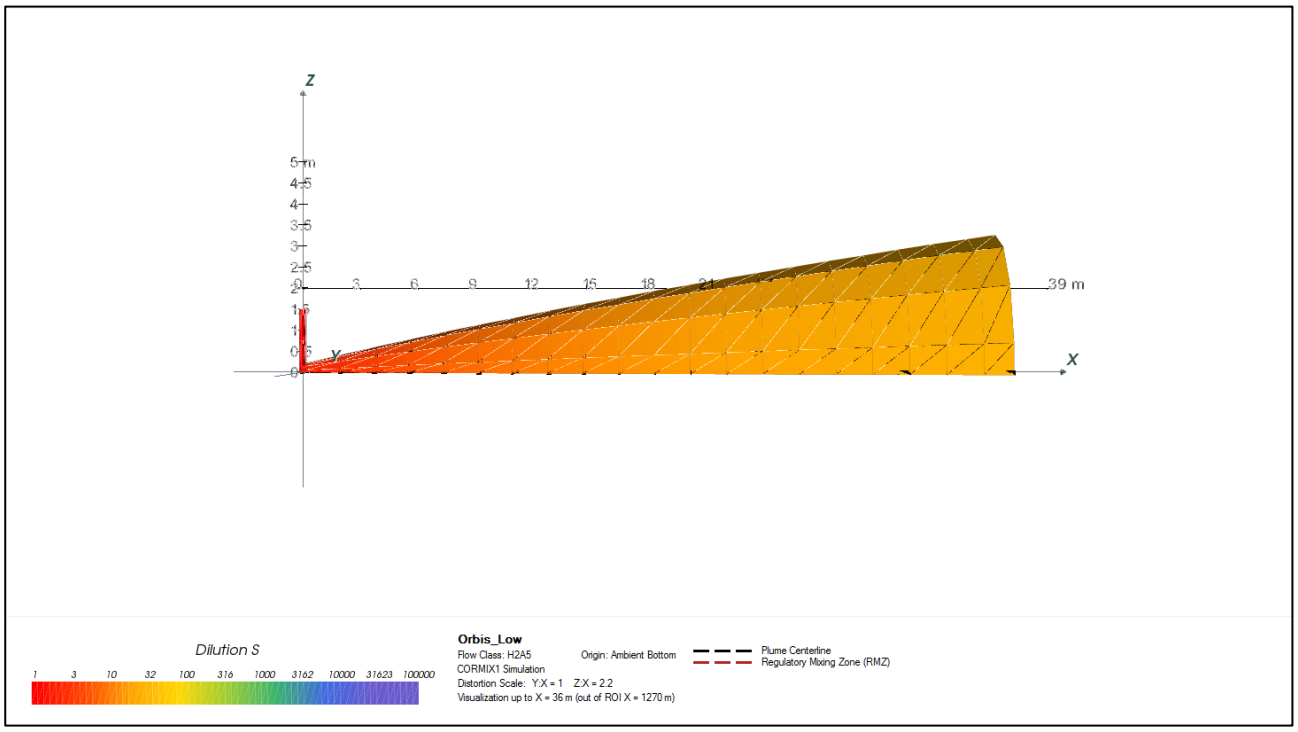



**Figure 6.1 Near-field dilution results for constant weak current speed (0.04 m/s) with a discharge flow rate of 570.3 m³/h at a discharge depth of 1,060 m below the sea surface.**

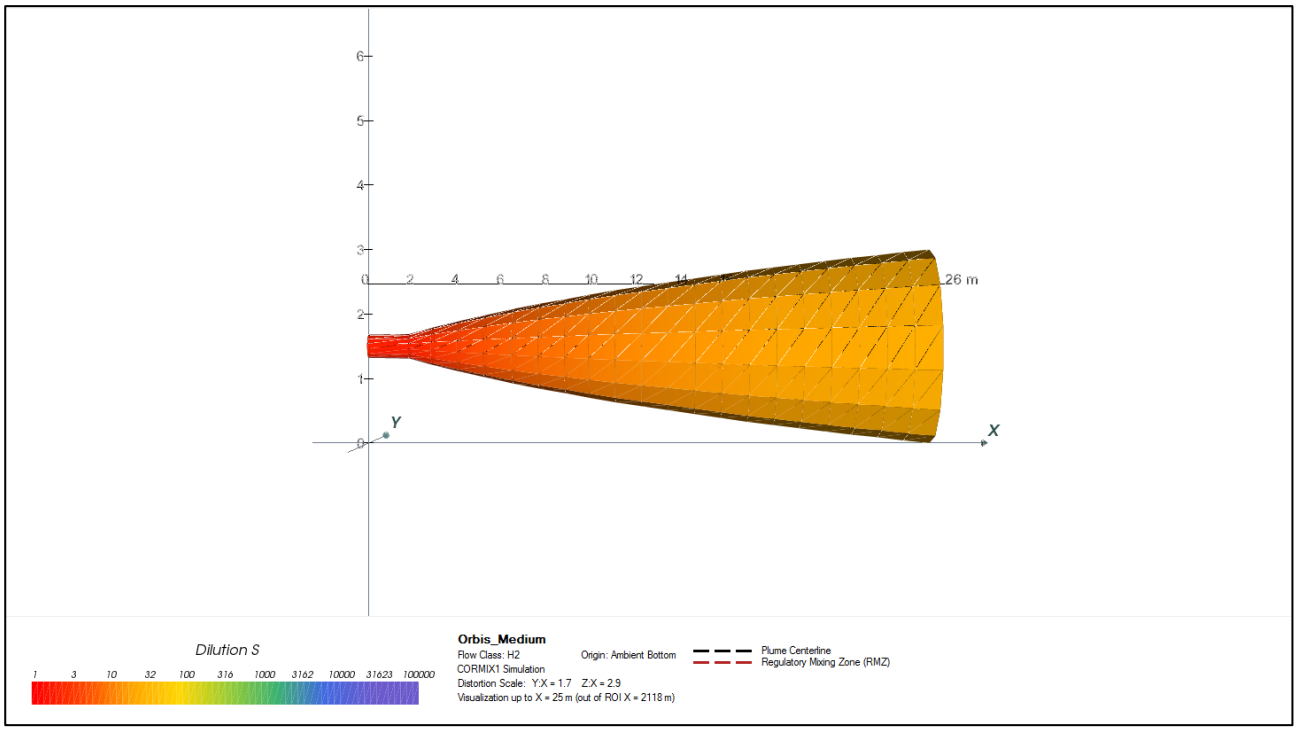



**Figure 6.2 Near-field dilution results for constant medium current speed (0.14 m/s) with a discharge flow rate of 570.3 m$^3$/h at a discharge depth of 1,060 m below the sea surface.**

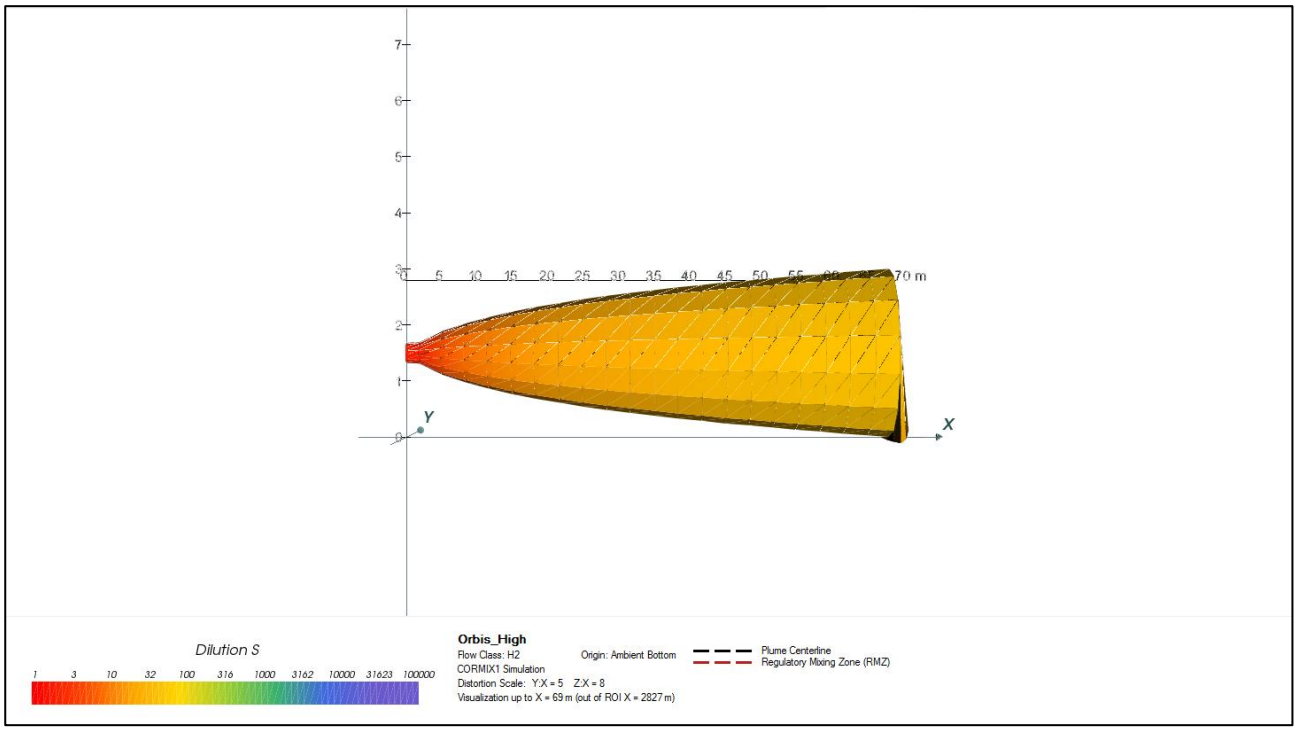



**Figure 6.3 Near-field dilution results for constant strong current speed (0.34 m/s) with a discharge flow rate of 570.3 m$^3$/h at a discharge depth of 1,060 m below the sea surface.**

## 6.2 Far-Field Modelling

### 6.2.1 Overview

Near-field and far-field modelling describe different processes at different scales, as such the respective results may not always align where the two overlap near the discharge location. Far-field modelling accounts for time-varying currents (speed and direction), which can sometimes lead to plume pooling at the release site under weak currents. When this pooled plume is later carried away, it can result in instances of lower dilutions (higher concentrations) migrating farther from the discharge point.

### 6.2.2 Interpretation of Percentile Dilutions

Simulation results were aggregated, and statistical analysis was conducted to derive the 95$^{th}$ percentile dilution.

It is important to note that the (minimum dilution) and 95$^{th}$ percentile dilution figures provided do not represent the spatial extent of the plume at any single moment in time. Instead, providing a statistical and spatial summary of how often specific dilution values occur across all simulations. For example, if the model predicts a 95$^{th}$ percentile minimum dilution of 100 at a given location, this indicates that dilution levels are greater than 100 for 95% of the time and fall below this threshold for only 5% of the time. Given the 2-day simulation period used in the model, a 5% exceedance translates to approximately 2.4 hours.

Dilution contours were derived by calculating the ratio of contaminant concentrations in the receiving waters to the initial discharge concentration (550 mg/L). However, the hydrotest (chemical) cocktail comprising corrosion inhibitor, biocide, oxygen scavenger and leak detection dye within the pipeline will undergo reactions and break down in the pipeline in order to bring about their primary functions. The discharge concentration of these chemicals will therefore be very much lower than the concentrations initially added, thus the assumed equivalent concentrations in the receiving environment for a given dilution, based on the initial 550 mg/L dose concentration into the pipeline, is likely to be significantly lower.

Additionally, the analysis also assumes that the background concentration of the discharged constituent is negligible, and that no significant biodegradation occurs over the timescale of the dispersion processes within the receiving environment. Under these assumptions, dilution values provide a direct means of estimating concentration changes, given an initial discharge concentration.

The far-field modelling results are presented according to a large and conservative range of dilutions with a maximum dilution of 1:42,300 being presented. Given an initial discharge concentration of 550 mg/L this dilution represents concentrations of <0.013 mg/L, equal to the PNEC value provided by the client for this chemical (Table 6.1).

Importantly, the reported dilutions also include a dilution contour of 1:981, which represents the required dilution to not exceed the worst-case toxicity of the single most toxic component of the liquid hydrotest cocktail (i.e., corrosion inhibitor, biocide, oxygen scavenger or leak detection dye). This dilution was calculated by assuming a 2.3% contribution (CEFAS, 2023) to the overall 550 mg/L hydrotest cocktail concentration and a PNEC of 0.013 mg/L. Note the PNEC value of 0.013 was calculated from the worst case toxicity data of the single most toxic component of the liquid hydrotest cocktail (i.e., 0.13 mg/L, CEFAS, 2023) utilising the methodology used in the preparation of UK offshore chemical permits (i.e., CHARM assessment factor of 10 (CIN, 2017)) given the low number of aquatic toxicity tests (3) (CEFAS, 2023).

**Table 6.1 Reporting concentration change given dilution based on an initial discharge concentration of 550 mg/L.**

| Initial concentrations and dilutions | Concentration (mg/L) |
|---|---|
| Initial concentration in discharge | 550 |
| Initial concentration in receiving waters | 0 |
| Concentration at 1:100 dilution | 5.500 |
| Concentration at 1:200 dilution | 2.750 |
| Concentration at 1:300 dilution | 1.833 |
| Concentration at 1:400 dilution | 1.375 |
| Concentration at 1:500 dilution | 1.100 |
| Concentration at 1:750 dilution | 0.733 |
| Concentration at 1:981 dilution | 0.561 |
| Concentration at 1:1,000 dilution | 0.550 |
| Concentration at 1:2,000 dilution | 0.277 |
| Concentration at 1:5,000 dilution | 0.110 |
| Concentration at 1:7,500 dilution | 0.073 |
| Concentration at 1:10,000 dilution | 0.055 |
| Concentration at 1:12,500 dilution | 0.044 |
| Concentration at 1:15,000 dilution | 0.036 |
| Concentration at 1:17,500 dilution | 0.031 |
| Concentration at 1:20,000 dilution | 0.027 |
| Concentration at 1:42,300 dilution | 0.013 |

### 6.2.3 Annual Analysis

The 100 individual simulation model results from the ten-year hindcast period (2010-2019) were combined and analysed on an annual basis.

Table 6.2 summarises the maximum distances from the discharge location to achieve various dilution levels, ranging between 100 and 20,000 dilutions, for the predicted minimum and 95$^{th}$ percentile dilutions.

Dilutions of 1:981 were achieved within 87 m and 157 m from the release location based on the 95$^{th}$ percentile and minimum dilutions, respectively. The maximum distances from the release location to the 1:1,000 dilutions were 98 m (95$^{th}$ percentile) and 194 m (minimum dilution) and 1:2,000 dilutions were 211 m (95$^{th}$ percentile) and 976 m (minimum dilution). With increasing dilutions, the maximum distances to achieve 1:5,000 and 1:10,000 were 730 m (95$^{th}$ percentile) and 4,438 m (minimum dilution), and 4,170 m (95$^{th}$ percentile) and 7,548 m (minimum dilution), respectively. Additionally, the maximum distances from the release location to the 1:42,300 dilution based on the predicted 95$^{th}$ percentile and minimum dilutions of the hydrotest discharge from Tornado DC2.1 were 11,900 m and 23,300 m, respectively.

Figure 6.4 and Figure 6.5 present the predicted 95$^{th}$ percentile and minimum dilutions of the hydrotest discharge from Tornado DC2.1. Figures present contours representing a large and conservative range of dilutions with a maximum dilution of 1:42,300 being presented.

Additionally, time-series snapshots of the predicted minimum dilutions of the hydrotest discharge (570.3 m$^3$/h) at Tornado DC2.1 based on a single example simulation during October conditions are presented in Figure 6.6 to Figure 6.8. These figures present the movement of the plume 4, 8, 12, 16, 20 and 24 hours after the commencement of the discharge. Lastly Figure 6.9 presents the minimum predicted dilutions for the entire example simulation.

**Table 6.2 Summary of the maximum distance from the hydrotest discharge release location to achieve given dilutions.**

| Dilution | Maximum distance (m) from discharge location to achieve given dilution | |
|---|---|---|
| | 95th percentile dilutions | Minimum dilutions |
| 1:100 | - | - |
| 1:200 | - | - |
| 1:300 | - | - |
| 1:400 | - | - |
| 1:500 | - | - |
| 1:750 | 61 | 100 |
| 1:981 | 87 | 157 |
| 1:1,000 | 98 | 194 |
| 1:2,000 | 211 | 976 |
| 1:5,000 | 730 | 4,438 |
| 1:7,500 | 1,890 | 6,732 |
| 1:10,000 | 4,170 | 7,548 |
| 1:12,500 | 7,457 | 9,824 |
| 1:15,000 | 7,557 | 11,418 |
| 1:17,500 | 7,688 | 12,619 |
| 1:20,000 | 9,970 | 13,364 |
| 1:30,000 | 10,200 | 17,804 |
| 1:42,300 | 11,900 | 23,300 |

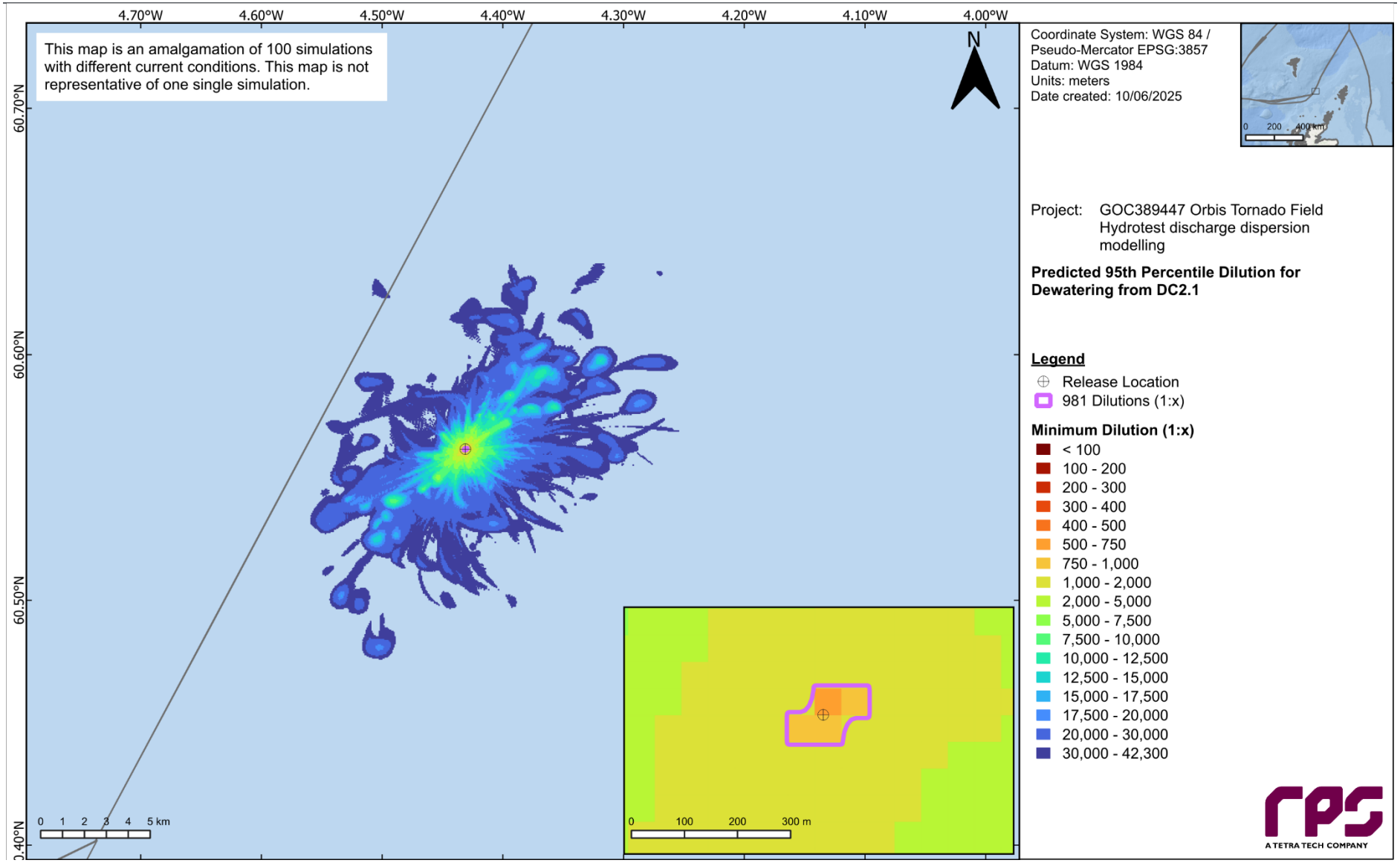



**Figure 6.4 Predicted 95th percentile dilutions of the hydrotest discharge (570.3 m³/h) at Tornado DC2.1. Results are based on 100 simulations. Note, inset presents zoomed-in view surrounding release location and the 1:981 dilution contour.**

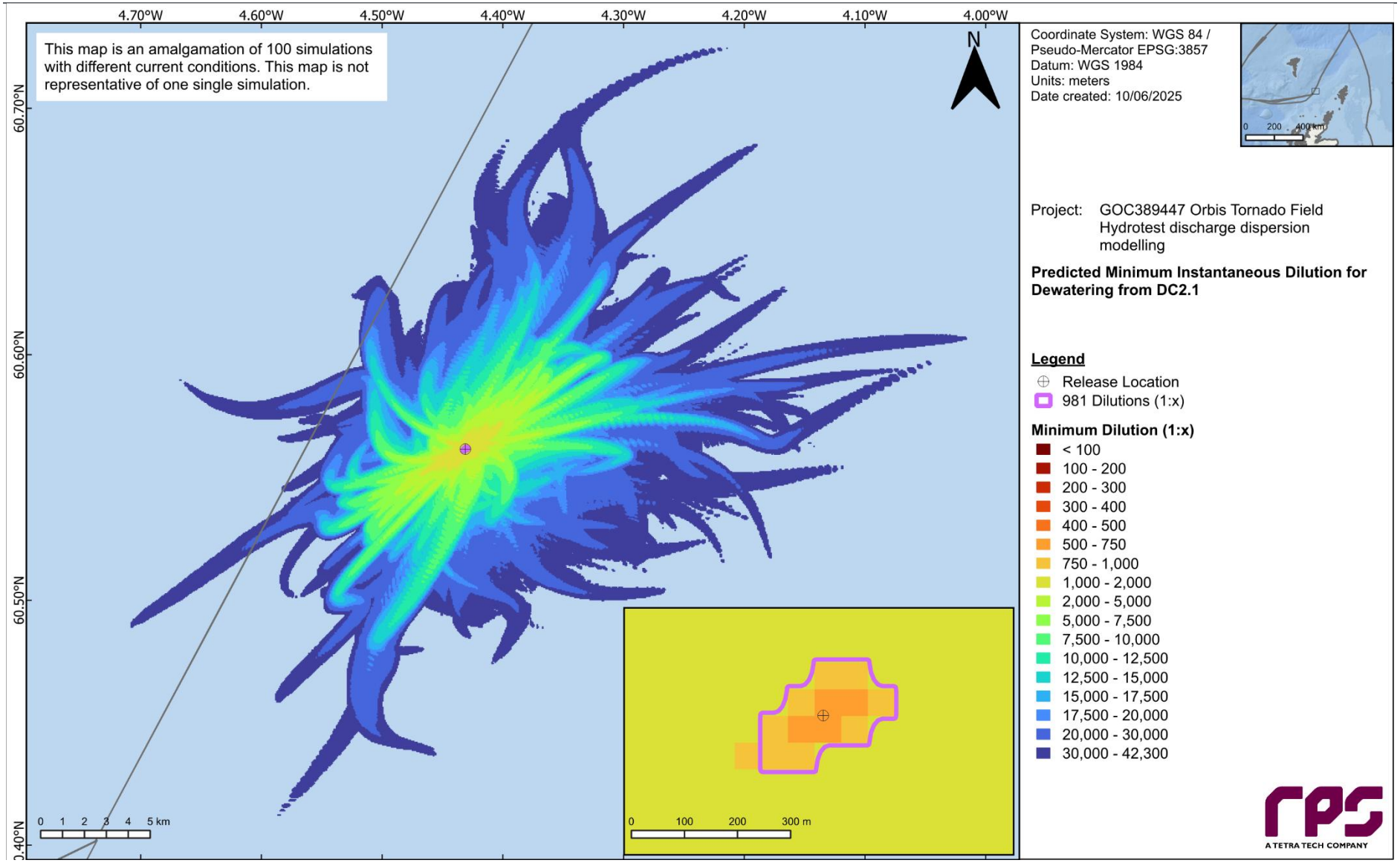



**Figure 6.5 Predicted minimum dilutions of the hydrotest discharge (570.3 m³/h) at Tornado DC2.1. Results are based on 100 simulations. Note, inset presents zoomed-in view surrounding release location and the 1:981 dilution contour.**

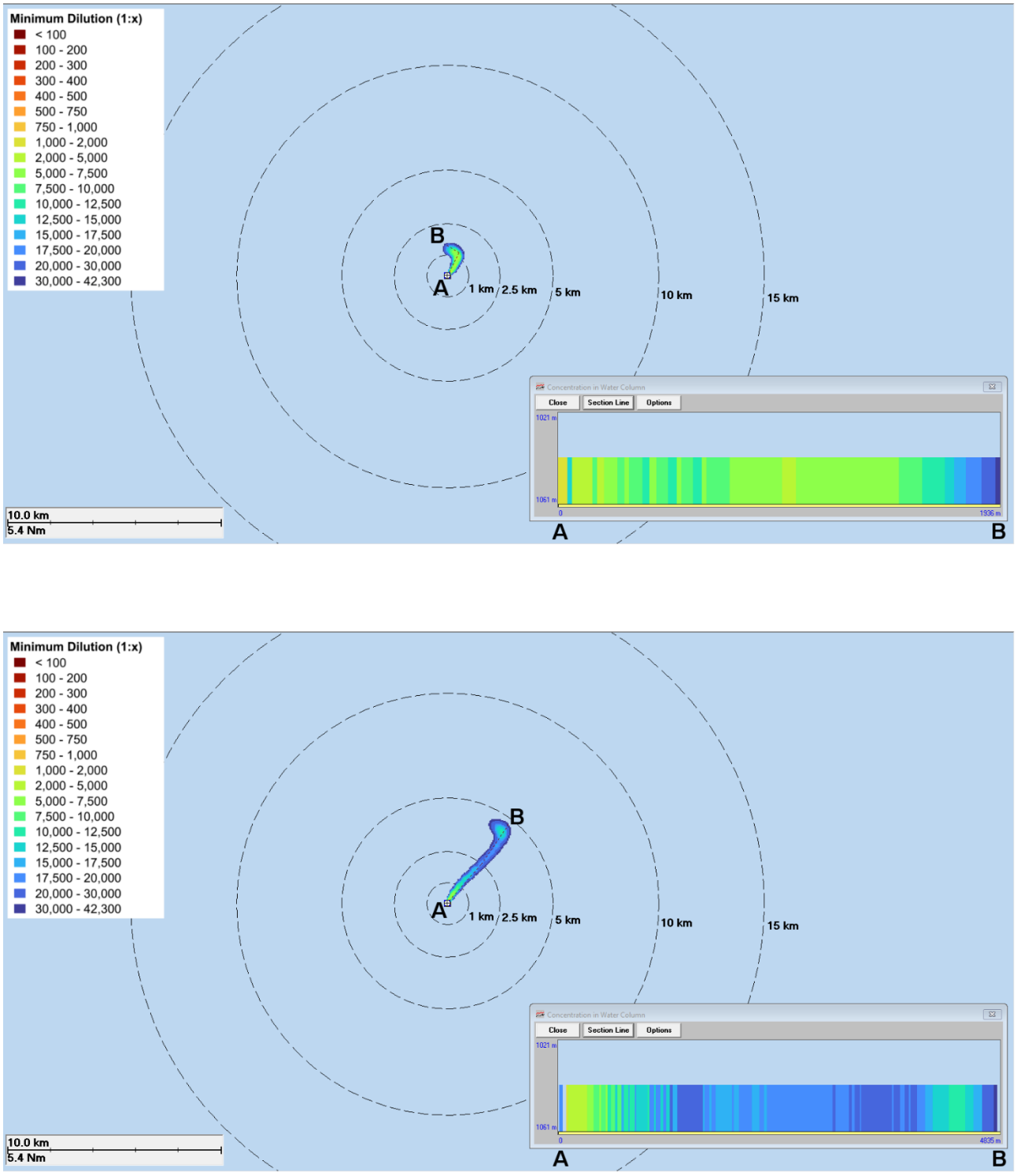



**Figure 6.6 Example plan-view and water column (cross section) screenshots of the predicted minimum dilutions of the hydrotest discharge (570.3 $m^3$/h) 4 hours (top image) and 8 hours (bottom image) into the discharge at Tornado DC2 during October conditions. Screenshot results are based on 1 simulation of the 100 modelled as part of the study.**

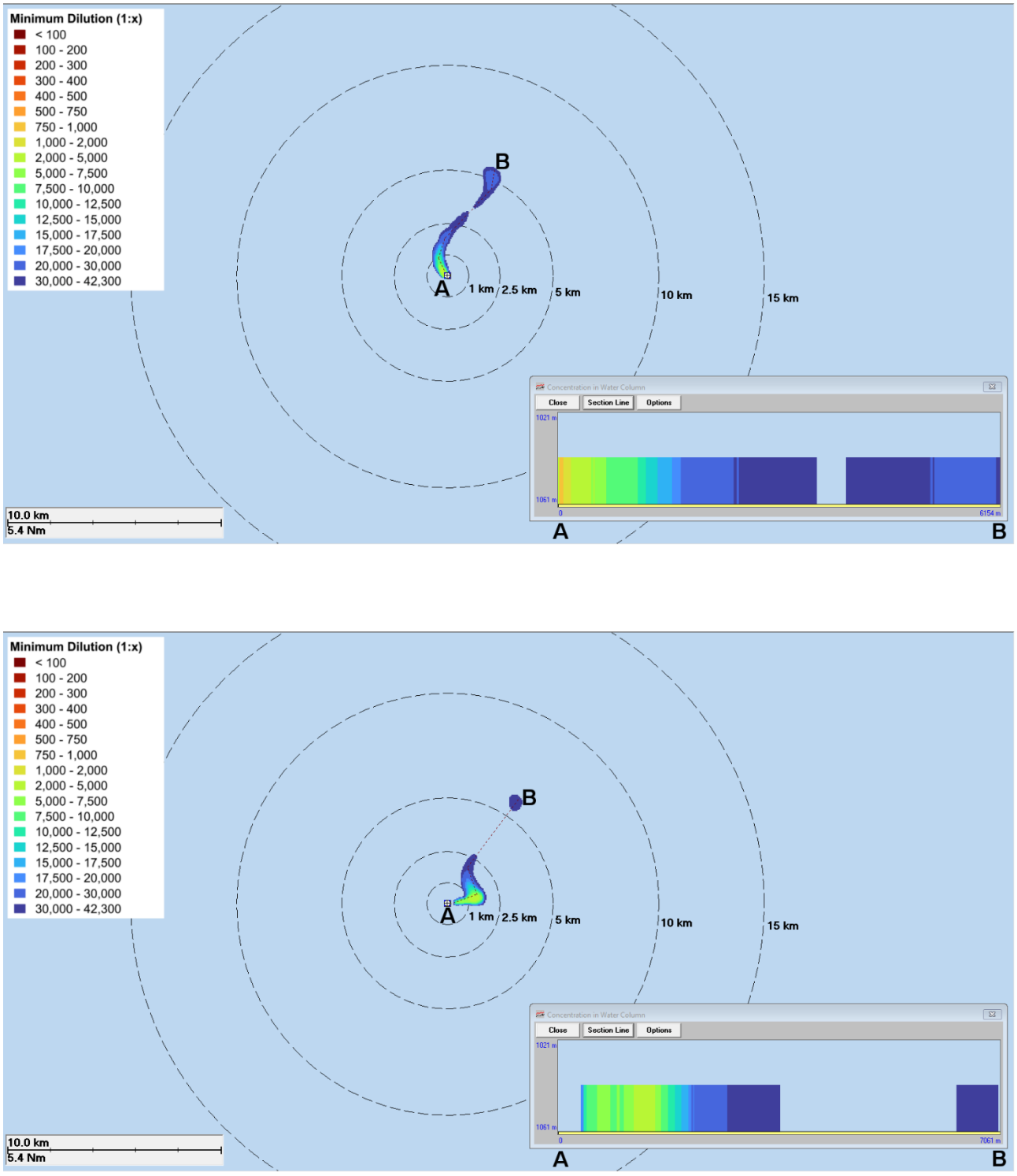



**Figure 6.7 Example plan-view and water column (cross section) screenshots of the predicted minimum dilutions of the hydrotest discharge (570.3 $m^3$/h) 12 hours (top image) and 16 hours (bottom image) into the discharge at Tornado DC2 during October conditions. Screenshot results are based on 1 simulation of the 100 modelled as part of the study.**

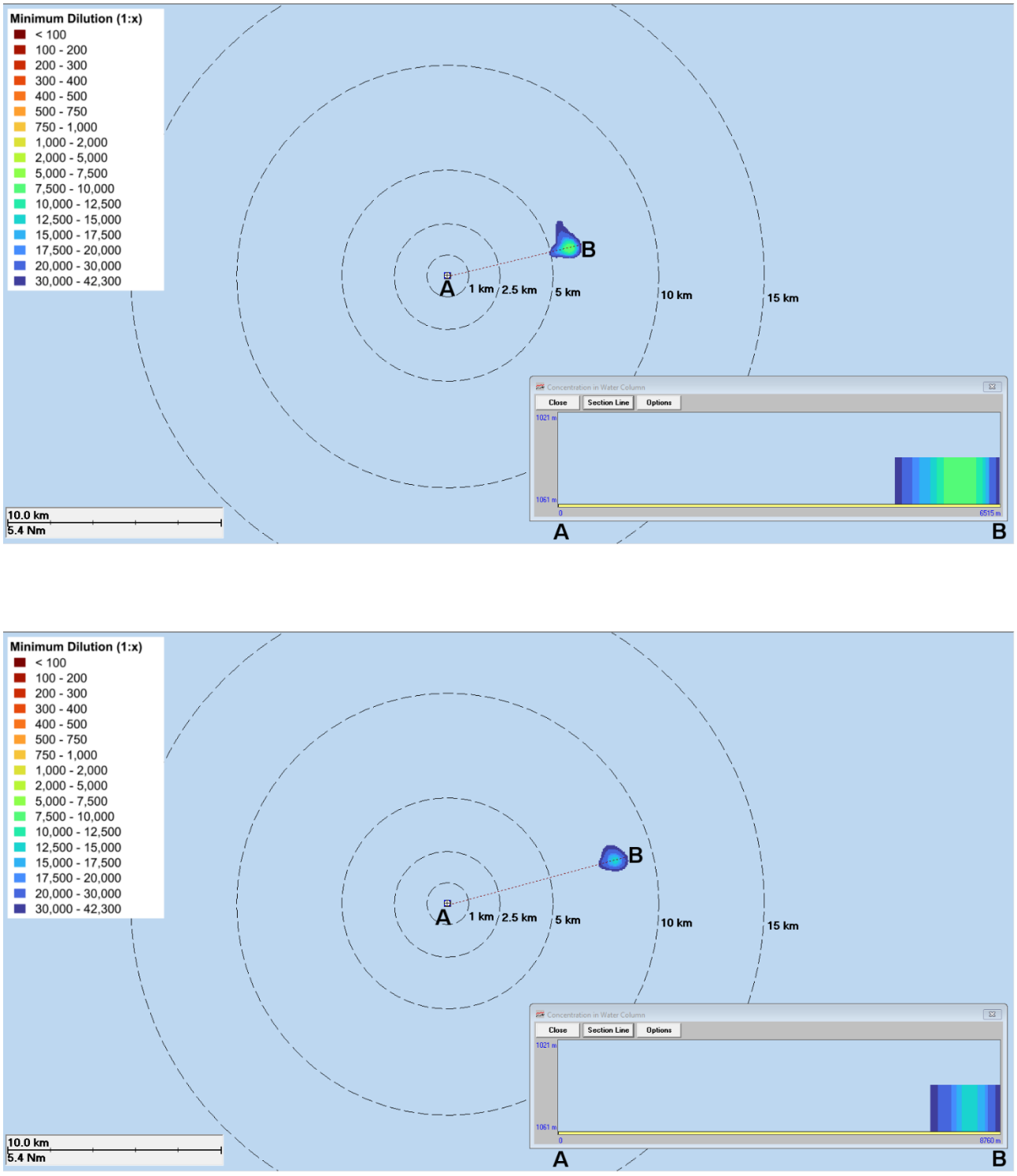



**Figure 6.8 Example plan-view and water column (cross section) screenshots of the predicted minimum dilutions of the hydrotest discharge (570.3 $m^3$/h) 20 hours (top image) and 24 hours (bottom image) into the discharge at Tornado DC2 during October conditions. Screenshot results are based on 1 simulation of the 100 modelled as part of the study.**

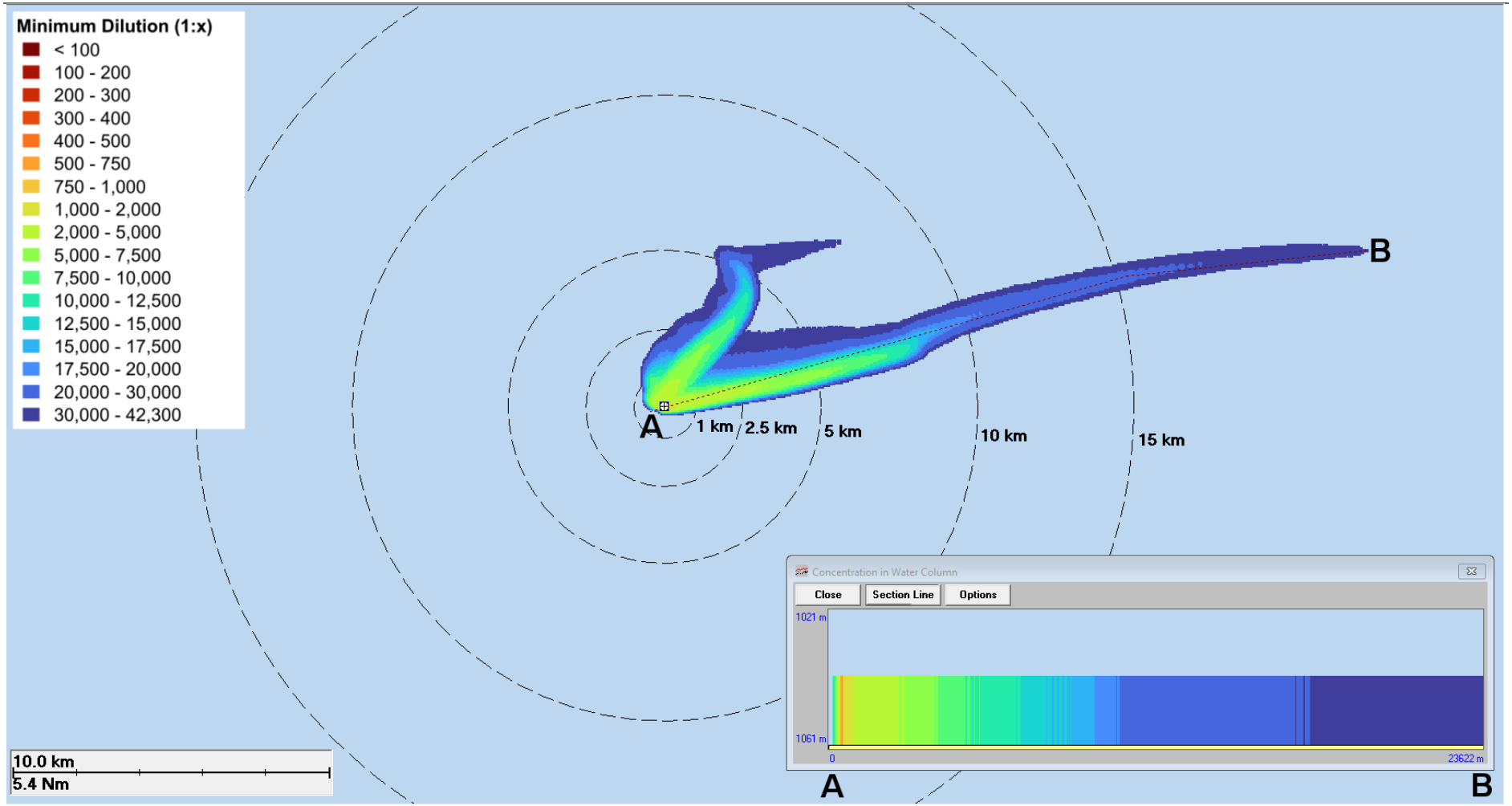



**Figure 6.9 Predicted minimum dilutions of the hydrotest discharge (570.3 $m^3$/h) at Tornado DC2.1. Results are based on 1 simulation of the 100 modelled as part of the study.**

# 7 REFERENCES


Akinbamini, OE, Anifowose, B & Obioma, EC 2022, 'Oil Spill Modeling for the Mariner Oil Field, East of Shetland, United Kingdom, North Sea', *Journal of Environmental Engineering*, vol. 148, no. 8, p.04022037.

Amores, A, Jordà, G & Monserrat, S 2019, 'Ocean eddies in the Mediterranean Sea from satellite altimetry: Sensitivity to satellite track location', *Frontiers in Marine Science*, vol. 6, p.703.

Andersen, OB 1995, 'Global ocean tides from ERS 1 and TOPEX/POSEIDON altimetry', *Journal of Geophysical Research: Oceans*, vol. 100, no. C12, pp. 25249-25259.

Bacon, S., 1997: Circulation and Fluxes in the North Atlantic between Greenland and Ireland, *Journal of Oceanography*, vol. 27, pp. 1420–1435.

Becker, JJ, Sandwell, DT, Smith, WHF, Braud, J, Binder, B, Depner, J, Fabre, D, Factor, J, Ingalls, S, Kim, S-H, Ladner, R, Marks, K, Nelson, S, Pharaoh, A, Trimmer, R, Von Rosenberg, J, Wallace, G & Weatherall, P 2009, 'Global bathymetry and evaluation data at 30 arc seconds resolution: SRTM30_PLUS', *Marine Geodesy*, vol. 32, no. 4, pp. 355–371.

Bischof, B, Mariano, AJ, Ryan, EH 2003, '"The North Atlantic Drift Current." Ocean Surface Currents', viewed 8 April 2025, http://oceancurrents.rsmas.miami.edu/atlantic/north-atlantic-drift.html.

Burns, K, Codi, S, Furnas, M, Heggie, D, Holdway, D, King, B & McAllister, F 1999, 'Dispersion and fate of produced formation water constituents in an Australian Northwest Shelf shallow water ecosystem', *Marine Pollution Bulletin*, vol. 38, pp. 593-603.

Centre for Environment Fisheries and Aquaculture Science (CEFAS) 2023, 'RX-5255 template and safety data sheet', Department for Business, Energy and Industrial Strategy, London, United Kingdom.

Charm Implementation Network (CIN) 2017, 'Chemical hazard assessment and risk management: For the use and discharge of chemicals used offshore - User guide version 1.5'

Chassignet, EP, Hurlburt, HE, Smedstad, OM, Halliwell, GR, Hogan, PJ, Wallcraft, AJ, Baraille, R & Bleck, R 2007, 'The HYCOM (HYbrid Coordinate Ocean Model) data assimilative system', *Journal of Marine Systems*, vol. 65, no. 1, pp. 60-83.

Chassignet, EP, Hurlburt, HE, Metzger, E, Smedstad, OM, Cummings, J & Halliwell, GR 2009, 'U.S. GODAE: Global ocean prediction with the HYbrid Coordinate Ocean Model (HYCOM)', *Oceanography*, vol. 22, no. 2, pp. 64-75.

Davies, AM 1977a, 'The numerical solutions of the three-dimensional hydrodynamic equations using a B-spline representation of the vertical current profile', in Bottom Turbulence: Proceedings of the 8th Liege Colloquium on Ocean Hydrodynamics, ed. Nihoul, JCJ, Elsevier.

Davies, AM 1977b, 'Three-dimensional model with depth-varying eddy viscosity', in Bottom Turbulence: Proceedings of the 8th Liege Colloquium on Ocean Hydrodynamics, ed. Nihoul, JCJ, Elsevier.

Doneker, R & Jirka, G 1990, 'Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Submerged Single Port Discharges (CORMIX1)', EPA/600/3-90/012, U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, Georgia.

Eakins, BW & Sharman, GF 2010, 'Volumes of the World's Oceans from ETOPO1', NOAA National Geophysical Data Center, Boulder, Colorado USA.

Gordon, R 1982, Wind driven circulation in Narragansett Bay, PhD thesis, University of Rhode Island, Kingston, RI, USA.

Isaji, T & Spaulding, ML 1984, 'A model of the tidally induced residual circulation in the Gulf of Maine and Georges Bank', *Journal of Physical Oceanography*, vol. 14, no. 6, pp. 1119-1126.

Isaji, T, Howlett, E, Dalton, C & Anderson, E 2001, 'Stepwise-continuous-variable-rectangular grid hydrodynamics model', in Proceedings of the 24th Arctic and Marine Oilspill Program (AMOP) Technical Seminar, Edmonton, AB, Canada, pp. 597-610.

Jirka, GH, Doneker, RL, & Barnwell, TO, 1991, 'CORMIX: an expert system for mixing zone analysis', *Water Science and Technology*, vol. 24, no. 6, pp. 267–274.

Khondaker, AN 2000, 'Modeling the fate of drilling waste in marine environment – an overview', *Journal of Computers and Geosciences*, vol. 26, pp. 531-540.

King, B & McAllister, FA 1997, 'The application of MUDMAP to investigate the dilution and mixing of the above water discharge at the Harriet A petroleum platform on the Northwest Shelf', in Modelling the Dispersion of Produced Water Discharge in Australia, Australian Institute of Marine Science, Canberra, ACT, Australia.

King, B & McAllister, FA 1998, 'Modelling the dispersion of produced water discharges', *APPEA Journal*, pp. 681-691.

King, B, Brushett, B & Lemckert, C 2010, 'A case study of consensus modelling for tracking oil spills', Proceedings of IOP Conference Series: *Earth and Environmental Science*, vol. 11, no. 1, p. 012025, IOP Publishing.

Koh, RCY & Chang, YC 1973, Mathematical model for barged ocean disposal of waste, Environmental Protection Technology Series, EPA 660/2-73-029, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, USA.

Kostianoy, AG, Ginzburg, AI, Lebedev, SA, Frankignoulle, M & Delille, B 2003, 'Fronts and mesoscale variability in the southern Indian Ocean as inferred from the TOPEX/POSEIDON and ERS-2 Altimetry data', *Oceanology*, vol. 43, no. 5, pp. 632-642.

Krauss, W 1996, 'The warmwatersphere of the North Atlantic Ocean', Schweizerbart Science Publishers , Stuttgart, Germany, 466p.

Ludicone, D, Santoleri, R, Marullo, S & Gerosa, P 1998, 'Sea level variability and surface eddy statistics in the Mediterranean Sea from TOPEX/POSEIDON data', *Journal of Geophysical Research I*, vol. 103, no. C2, pp. 2995-3011.

Makarynskyy, O, Langtry, S, Zapata, M & Rayson, M 2010, 'Validations of Hydrodynamic, Wave, and Dredging Simulations in Nearshore Environments', in *Estuarine and Coastal Modeling*, pp. 547-565, ASCE Library, Reston, USA.

Makarynskyy, O, Makarynska, D, Rayson, M & Langtry, S 2015, 'Combining deterministic modelling with artificial neural networks for suspended sediment estimates', *Applied Soft Computing*, vol. 35, pp. 247-256.

Matsumoto, K, Takanezawa, T & Ooe, M 2000, 'Ocean tide models developed by assimilating TOPEX/POSEIDON altimeter data into hydrodynamical model: A global model and a regional model around Japan', *Journal of Oceanography*, vol. 56, no. 5, pp. 567-581.

Melsom, A 2005, 'Mesoscale activity in the North Sea as seen in ensemble simulations', *Ocean Dynamics*, vol. 55, no. 3–4, pp. 338–350.

Owen, A 1980, 'A three-dimensional model of the Bristol Channel', *Journal of Physical Oceanography*, vol. 10, no. 8, pp. 1290-1302.

Qiu, B & Chen, S 2010, 'Eddy-mean flow interaction in the decadally modulating Kuroshio Extension system', *Deep-Sea Research II*, vol. 57, no. 13, pp. 1098-1110.

Reid, JL 1993, 'On the total geostrophic circulation of the North Atlantic Ocean: Flow patterns, tracers, and transports', *Progress in Oceanography*, vol. 33, pp. 1–92.

Reverdin, G, Niiler, P & Valdimarsson 2003, 'North Atlantic Ocean surface currents', *Journal of Geophysical Research*, vol. 108, no. C1, pp. 3002.

Rossby, T 1996, 'The North Atlantic Current and Surrounding Waters: At the Crossroads', *Review of Geophysics*, vol. 34, no. 4, pp. 463-481.

Sagnieres, LB, Sharf, I & Deleflie, F 2020, 'Simulation of long-term rotational dynamics of large space debris: A TOPEX/Poseidon case study', *Advances in Space Research*, vol. 65, no. 4, pp. 1182–1195.

Talouli, A, Gilbert, T & Monfils Gilbert, R 2009, 'Strategic Environmental Assessment and potential future shoreline impacts of the oil spill from WWII shipwreck Hoyo Maru Chuuk Lagoon-Federated States of Micronesia', Pacific Regional Environment Programme, Apia, Samoa.

Veng, T & Andersen, OB 2021, 'Consolidating sea level acceleration estimates from satellite altimetry', *Advances in Space Research*, vol. 68, no. 2, pp. 496–503.

Willmott, CJ 1981, 'On the validation of models', *Physical Geography*, vol. 2, no. 2, pp.184–194.

Willmott, CJ 1982, 'Some comments on the evaluation of model performance', *Bulletin of the American Meteorological Society*, vol. 63, no. 11, pp.1309–1313.

Willmott CJ, Ackleson SG, Davis RE, Feddema JJ, Klink, KM, Legates, DR, O'Donnell, J & Rowe, CM 1985, 'Statistics for the evaluation of model performance', *Journal of Geophysical Research*, vol. I 90, no. C5, pp. 8995–9005.

Willmott, CJ & Matsuura, K 2005, 'Advantages of the mean absolute error (MAE) over the root mean square error (RMSE) in assessing average model performance', *Journal of Climate Research*, vol. 30, no. 1, pp. 79–82.

Winther, NG & Evensen, G 2006, 'A hybrid coordinate ocean model for shelf sea simulation', *Ocean Modelling*, vol. 13, no. 3–4, pp. 221–237.

Winther, NG & Johannessen, JA 2006, 'North Sea circulation: Atlantic inflow and its destination', *Journal of Geophysical Research: Oceans*, vol. 111, no.C12.

Yaremchuk, M & Tangdong, Q 2004, 'Seasonal variability of the large-scale currents near the coast of the Philippines', *Journal of Physical Oceanography*, vol. 34, no. 4, pp. 844-855.

Zeitlhöfler, J, Bloßfeld, M, Rudenko, S, Dettmering, D & Seitz, F 2023, 'Station-dependent satellite laser ranging measurement corrections for TOPEX/Poseidon', *Advances in Space Research*, vol. 71, no. 1, pp. 975–996.

Zigic, S, Zapata, M, Isaji, T, King, B & Lemckert, C 2003, 'Modelling of Moreton Bay using an ocean/coastal circulation model', in Proceedings of the Coasts & Ports 2003 Australasian Conference, Auckland, New Zealand, paper no. 170.

Zigic, S, Makarynskyy, O, Langtry, S & Westbrook, G 2009, 'A numerical modelling study for the proposed increase in Barramundi production, Cone Bay, Western Australia', in Estuarine and Coastal Modeling, pp. 428-446, ASCE Library, Reston, USA.

# Appendix F: Oil Spill Modelling Study

This appendix presents the results of the oil spill modelling study undertaken to support the Tornado Field Development ES in order to gain an understanding of the behaviour of a potential worst case oil spill scenario in the marine environment originating from a subsea well blowout. The modelling has been completed in line with the OPRED Guidance Notes for Preparing Oil Pollution Emergency Plans for Offshore Oil & Gas Installations and Relevant Oil Handling Facilities (Revision 7: June 2022).

## F.1 OILMAP Spill Modelling Package

This oil spill modelling study has been carried out in RPS ASA's OILMAP (Version 7.7.218.1528) modelling system, which predicts the surface trajectory of spilled oil and includes algorithms for oil spreading, evaporation, emulsification, entrainment, and oil shoreline interaction. The distribution and mass balance of oil with respect to time are predicted for the specific oil spilled. Additional modules are utilised in OILMAP to execute more in-depth modelling processes such as simulating subsurface oil releases and computing probability.

The following modules have been utilised in OILMAP for the Tornado oil spill modelling study:

- **OILMAP Deep:** This module is a near-field model used to simulate subsurface releases of oil and gas. OILMAP Deep predicts the near-field plume characteristics and oil droplet size distributions for a specified release.
- **Trajectory and Fates Model:** The trajectory and fates module is a far-field model, for surface and subsurface releases, that predicts the 3D trajectory and fate of oil for instantaneous or continuous release spills.
- **Stochastic Model (RunStoch):** The stochastic module is used for risk assessment and contingency planning. It helps determine the most likely spill paths and the minimum time for oil to reach specific points on monthly, seasonal, or annual basis.

### F.1.1 OILMAP Deep

The OILMAP Deep module was developed as an enhanced version of the OILMAP modelling system and is based on published work on plume formation and behaviour as well as droplet formation. The OILMAP Deep model contains two major sub-models, the droplet size distribution model and the plume model.

The droplet size distribution model employs a character diameter calculation ($d_{95}$ hereby referred to as maximum droplet size) and the Rosin Rammler distribution (Yapa et al., 2001) based on the oil properties (primarily the interfacial tension between oil and seawater) and the energy of the release through calculation of the dimensionless Weber number associated with the release. The Weber number is based on the volumetric release rate, the pipe diameter and receiving water density in the numerator, and the oil interfacial tension (IFT) in the denominator. The maximum droplet diameter for a release is related to the Weber number, i.e. a larger Weber number results in larger droplet size. Therefore, lowering the IFT or increasing exit velocity results in a distribution of relatively smaller droplets.

The plume model solves equations for the conservation of water mass, momentum, buoyancy, and gas mass using integral plume theory, following work outlined in McDougall (1978), Spaulding (1982), and Fanneløp and Sjøen (1980). A simplified integral jet theory is employed for the vertical and horizontal motions of the gas-oil plume. The necessary model parameters defining the rates of entrainment and spreading of the jet are obtained from laboratory studies. The plume model calculates the evolution of the blowout plume as it rises and entrains water until it eventually either surfaces or comes into equilibrium with the receiving water. The receiving water is characterized by a site-specific, depth-variable temperature and density profile. These water column properties influence the plume properties since the state of gas is a function of the temperature and pressure. Similarly, temperature and pressure are used to adjust plume bulk density, based on the volume of entrained seawater, to determine the depth at which the plume bulk density approaches the receiving water density. At the point the plume bulk density is equal to that of the receiving water, plume ascension ceases, and the

plume becomes trapped at what is referred to as the termination (plume trap) height. The plume dynamics account for oil and gas buoyancy, gas compression and expansion as a function of depth, hydrate formation, dynamic gas bubble size distribution formulation, gas dissolution, and seawater entrainment and plume spreading processes.

### F.1.2 Trajectory and Fates Model

Following OILMAP Deep, the Trajectory and Fates model simulates the droplet rise phase and surfaced oil. The model predicts the transport and weathering of oil from instantaneous or continuous spills. Predictions show the location and concentration of the surface and subsurface oil versus time. The model estimates the temporal variation of the oil's areal coverage, oil thickness, and oil viscosity.

The model 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, emulsification and an oil-shoreline interaction:

- **Spreading** is represented using the thick slick portion of Mackay *et al*. (1980, 1982) thick-thin approach.
- **Evaporation** is based on Mackay's analytic formulation parameterized in terms of evaporative exposure (Mackay *et al*., 1980, 1982).
- **Entrainment or Natural Dispersion** is modelled using Delvigne and Sweeney's (1988) formulation which explicitly represents oil injection rates into the water column by droplet size. The entrainment coefficient, as a function of oil viscosity, is based on Delvigne and Hulsen (1994).
- **Emulsification** of the oil, as function of evaporative losses and changes in water content, is based on Mackay et al. (1980, 1982).
- **Oil-Shoreline Interaction** is modelled based on a simplified version of Reed *et al*. (1989) which formulates the problem in terms of a shore type dependent holding capacity and exponential removal rate.

### F.1.3 Stochastic Model (RunStoch)

The stochastic model is useful as a contingency planning tool. It is used to determine the range of distances and directions oil spills from a particular site are likely to travel, given the historical wind speed and direction data for the area. The stochastic model performs a large number of single simulations (typically 100 individual trajectory runs) for a given spill site, varying the wind and tidal conditions for each scenario. These trajectories are used to predict probabilities and minimum time that water surface and shoreline areas will be oiled by a release from the given site.

Figure F.1 shows how a simple probability map is created. The example uses four trajectory runs to create a final probability map. Following the same example, Figure F.2 demonstrates how to interpret probability and features of interest (e.g. marine protected areas).

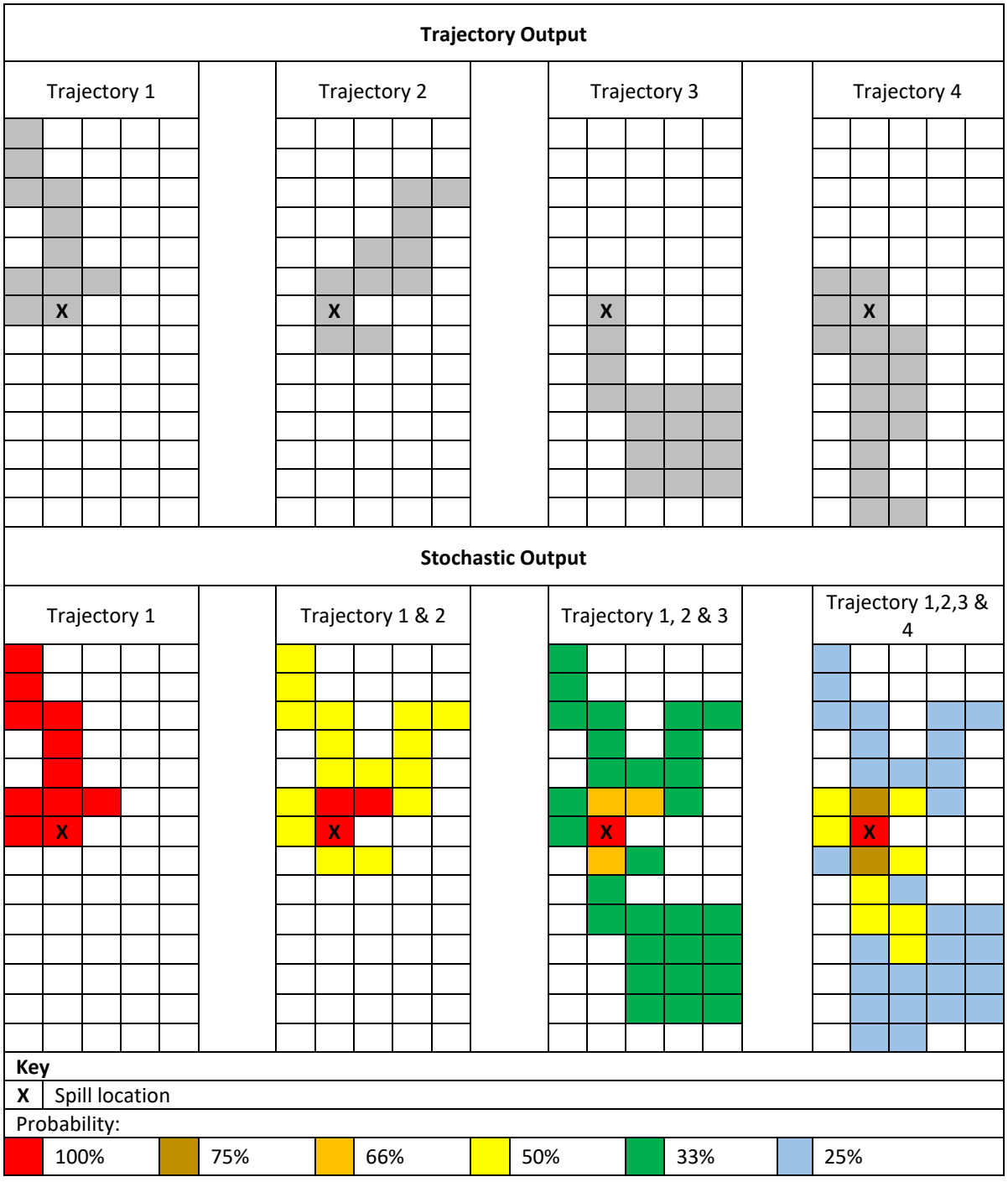



**Figure F.1: Diagram to show how stochastic probability maps are made**

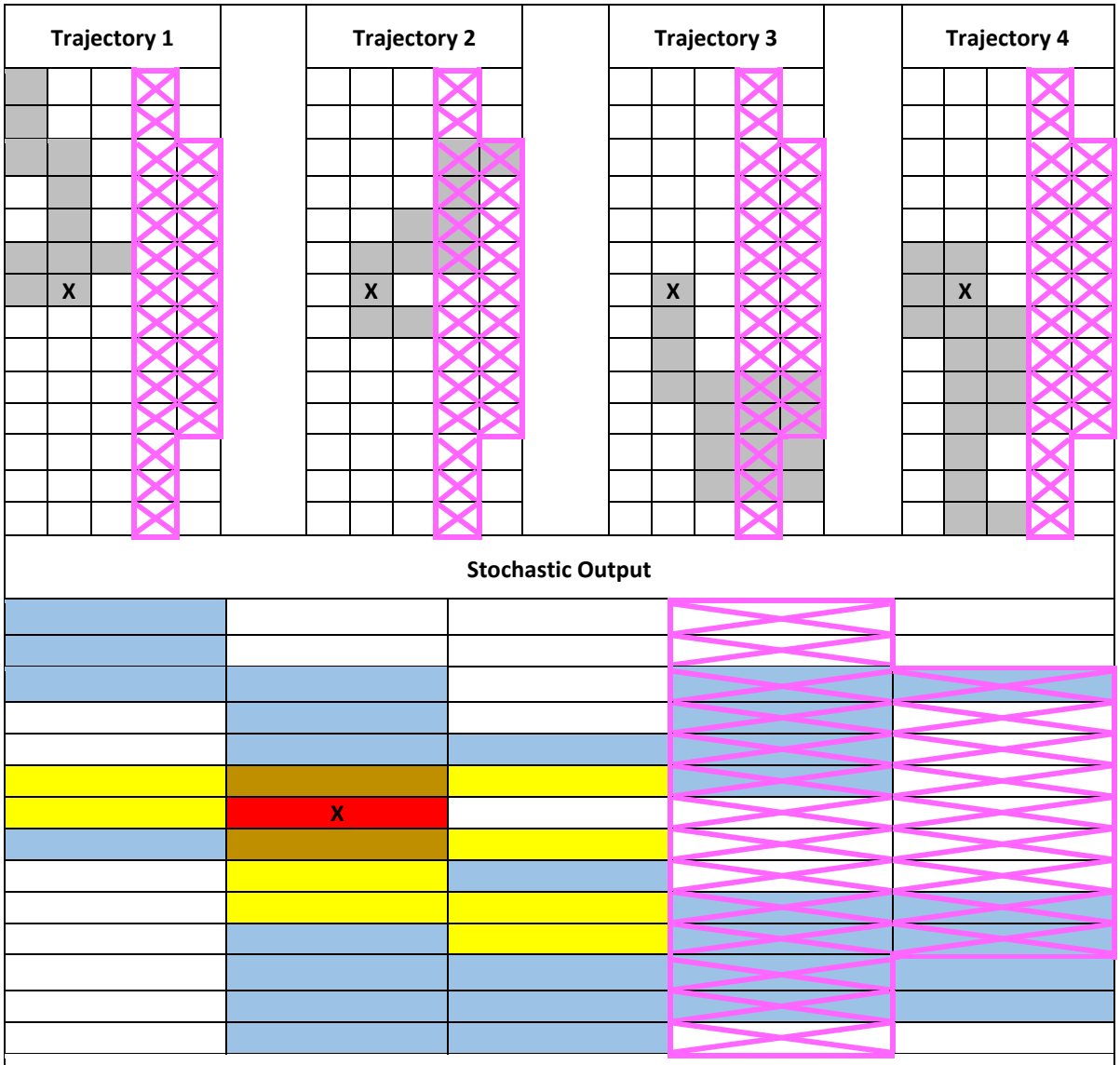



**Figure F.2: Interpretation of Probability Mapping (Probability Grid vs Context Driven)**

# F.2 Modelled Scenario

## F.2.1 Worst Case Spill Scenario

The following worst case spill scenario has been modelled for the Tornado field development:

- Subsurface blowout release from the Tornado W3 development well with a cumulative release of 1,265,922.7 barrels (bbl) (201,266 cubic metre ($m^3$)) of 47.6°API condensate, released over a period of 180 days.

## F.2.2 Summary of Model Input Parameters

The model input parameters for the Tornado W3 blowout scenario are detailed in Table F.1.

**Table F.1: Model Input Parameters for a Subsurface Blowout in the Tornado Field**

| **Scenario 1: Well Loss Parameters** | | | |
|---|---|---|---|
| **Loss from Well / FPSO / Rig (please specify)** | Tornado W3 Well Blowout | **Instantaneous Loss?** | No |
| **Worst case volume** | 1,265,922.7 bbl (201,266 $m^3$) | **Will the well self-kill? If yes, when** | No, it is assumed a relief well would be required. |
| **Flow rate** | Declining flow rate - starting at 10,967 bbl (1,744 $m^3$) / day on day 1, declining to 5,175 bbl (823 $m^3$) / day on day 180 (refer to Section F.6.4) | | |
| **Justification for predicted worst case volume** | This represents the anticipated worst case blowout scenario for the Tornado Development in terms of both the volume of condensate which would be released and the duration of the spill (i.e. it assumes the flow can only be stemmed by drilling a relief well which would take a total of 180 days to drill). | | |

| **Location** | | | |
|---|---|---|---|
| **Spill Source point Latitude (N/S)** | 60° 33’ 41.1’’ N | **Spill source point Longitude (E/W)** | 04° 25’ 52.1’’ W |
| **Installation / Facility Name** | Proposed Tornado W3 Development Well | **Quad / Block** | 204/13 |

| **Hydrocarbon Properties** | | | |
|---|---|---|---|
| **Hydrocarbon name** | Condensate | | |
| **Assay available** | No | **Was an analogue used for spill modelling?** | Yes – the Wonnich assay was amended to match the expected Tornado Condensate properties. |

| | **Name** | **ITOPF Category** | **Density** | **API** | **Viscosity at temp** | **Pour Point (°C)** | **Wax Content (%)** | **Asphaltene Content (%)** |
|---|---|---|---|---|---|---|---|---|
| **Analogue** | Amended Wonnich Analogue (refer to Section F.6.3) | Group 1 | 0.7902 | 47.6° | 0.78 cP @ 13°C; 0.62 cP @ 20°C | -24 | 1 | 0.2 |

| Metocean Parameters | | | | |
|---|---|---|---|---|
| **Sea surface temperature** | Winter (Dec – Feb) | 8°C | Summer (June – Aug) | 12°C |
| | Spring (Mar – May) | 9°C | Autumn (Sep – Nov) | 9°C |
| **Wind data** | Data period | 2019 – 2023 | | |
| | Data reference | European Centre for Medium-Range Weather Forecasts (ECMWF) - Reanalysis v5 (ERA5) | | |
| **Current data** | Data period | 2019 – 2023 | | |
| | Data reference | HYCOM (HYbrid Coordinate Ocean Model) general ocean circulation model and HYDROMAP hydrodynamic model | | |

| Modelled Release Parameters | | | |
|---|---|---|---|
| **Surface or Subsurface** | Subsurface | **Depth** | 1,069 m |
| **Release duration** | 180 Days | **Instantaneous?** | No |
| **Persistence duration** | 10 Days | **Release rate** | Declining flow rate - starting at 10,967 bbl (1,744 $m^3$) / day on day 1, declining to 5,175 bbl (823 $m^3$) / day on day 180 (refer to Section F.6.4) |
| **Total simulation time** | 190 Days | **Total cumulative release** | 1,265,922.7 bbl (201,266 $m^3$) |

| | | |
|---|---|---|
| **Subsea Release Parameters (OILMAP Deep Blowout Model)** | Gas to Oil Ratio (GOR) | 9,894.08 $m^3/m^3$ |
| | Salinity and Temperature Profile | Refer to Section F.6.1. |
| | Gas Viscosity | 0.0190 Centipoise (cP) |
| | Gas Diffusivity | 0.0000000011 $m^2/s$ |
| | Diameter of Release Hole | 12 inches |
| | Oil Temperature | 56.7 °C |
| | Particle Size / Velocity Distribution Method | Model calculated with 6 droplet size bins |
| **No. of Runs** | 100 simulation runs per season | |

| Stochastic Parameters | | |
|---|---|---|
| **Probability grid (Grid Cell Size)** | Fixed Cell Size:<br>Cell Size (X and Y axis) = 2,000 metres (m)<br>Cell Size (Z axis) = 1,200 m | |
| **Distribution of Mass On Grid Cells** | Fixed Mass (mass of spillet is placed only in the grid cell that intersects with the centre of the spillet, without any spreading). Mass is not distributed to any other grid cells. | |
| **Minimum Thresholds** | Surface Thickness: | 0.0003 millimetres (mm) |
| | Shoreline Thickness: | 0.001 mm |
| | Water Column Concentration: | 1.0 parts per billion (ppb) |

| Oil Spill Modelling Software | | | |
|---|---|---|---|
| **Name of software** | OILMAP | **Version** | 7.7.218.1528 |

## F.2.3 Reporting Thresholds

### Probability and Minimum Time

Table F.2 outlines the minimum oiling thresholds used for this study to determine the probability and minimum time for oiling.

**Table F.2: Minimum Oiling Thresholds used for Probability and Minimum Time Reporting**

| Category | Threshold | Justification |
|---|---|---|
| Surface | Minimum Thickness of 0.3 micrometres (µm) | The OPRED Guidance Notes for Preparing OPEPs for Offshore Oil & Gas Installations and Relevant Oil Handling Facilities (Revision 7: June 2022) states that model results must be displayed to an oil thickness of 0.3 µm. |
| Water Column | Minimum Concentration of 1.0 ppb (total oil) | Screening threshold for potential effects on sensitive organisms & socio-economic activity (e.g. seafood production) (Trudel, 1989; French-McCay, 2002; French-McCay, 2004; French-McCay, *et al*. 2012). |
| Shoreline | Minimum Thickness of 1.0 µm | This threshold has been selected for potential effects on socio-economic resource uses, as this amount of oil may conservatively trigger the need for shoreline clean-up on amenity beaches. And impact shoreline recreation and tourism (French-McCay, *et al*. 2011 and French-McCay, *et al*. 2012).<br>Shoreline oiling at this threshold may appear as a coat, patches or scattered tar. |

### Surface Oiling Severity

The surface oil thickness key in Table F.3 is derived from the Bonn Oil Appearance Code (BOAC). Mapping surface oil thickness by the BOAC will help determine surface oiling severity in the spatial context.

**Table F.3: The Bonn Agreement Oil Appearance Code**

| Code | Description - Appearance | Layer Thickness Interval (µm) | Litres per km$^2$ | Colour |
|---|---|---|---|---|
| 1 | Sheen (silvery/grey) | 0.04 to 0.30 | 40 – 300 | |
| 2 | Rainbow | 0.30 to 5.0 | 300 – 5000 | |
| 3 | Metallic | 5.0 to 50 | 5000 – 50,000 | |
| 4 | Discontinuous True Oil Colour | 50 to 200 | 50,000 – 200,000 | |
| 5 | Continuous True Oil Colour | More than 200 | More than 200,000 | |

### Water Column Oiling Severity

Table F.4 details four different thresholds for water column oiling concentrations and the effect on marine fauna. The different thresholds are derived from various research papers and will help determine sub surface oiling severity in the spatial context.

**Table F.4: Water Column Oil Concentration Thresholds**

| Threshold for Water Column Oil Concentration (ppb) | Justification | Colour |
|---|---|---|
| 1 | Screening threshold for potential effects on sensitive organisms & socio-economic activity (e.g. seafood production) (Trudel, 1989; French-McCay, 2002; French-McCay, 2004; French-McCay, et al. 2012). | |
| 58 | Nilsen *et al*. (2006) developed species sensitivity dose-response curves to assess the impact to organisms from different water column hydrocarbon concentrations. A 5$^{th}$ percentile $LC_{50}$[1] for Total Hydrocarbon Concentrations (THC) was reported at 58 ppb. The 58 ppb concentration is a conservative lethal exposure value for marine fauna as it is below the $LC_{50}$ for 95 % of species. At this concentration mortality is highly unlikely. However, toxicological effects may be both short and long term. | |
| 70.5 | Smit *et al*. (2009) calculated an $EC_5$ for growth, reproduction and survival of marine organisms of 70.5 ppb THC based on laboratory experiments performed at IRIS (Norway). The dataset included organisms representing five different phyla (fish, crustaceans, polychaetes, echinoderms and molluscs). The 70.5 ppb figure is the OSPAR recommended predicted no-effect concentration (OSPAR, 2014). | |
| 100 | Vikebø *et al*. (2013) used 1 ppb total Polycyclic Aromatic Hydrocarbons (PAHs) as the lethal effect level (and 0.1 ppb PAHs as the sub lethal effect level) to simulate the impact on cod larvae from a major oil spill originating from various locations outside the Norwegian coast, and coinciding with the spawning season of Barents Sea cod (*Gadus morhua*). Soluble PAHs are approximately 1 % of the THC mass (1 ppb PAH = 100 ppb THC). | |

## Shoreline Oiling Severity

Table F.5 details three different thresholds for shoreline oiling concentrations that represent light oiling, moderate oiling and heavy oiling. The shoreline oiling classifications are derived from the International Tanker Owners Pollution Federation Limited (ITOPF) Technical Information Paper No.6 'Recognition of oil on shorelines (ITOPF, 2014a). The shoreline oiling classifications will help determine shoreline oiling severity in the spatial context.

**Table F.5: Shoreline Oil Thickness Thresholds**

| Shoreline Oiling Classification (ITOPF, 2014a) | Thickness Threshold (mm) | Concentration | Colour |
|---|---|---|---|
| Light Oiling | 0.001 - <1 | 0.001 – 1 litres / $m^2$ | |
| Moderate Oiling | 1 – 10 | 1 – 10 litres / $m^2$ | |
| Heavy Oiling | >10 | >10 litres / $m^2$ | |

# F.3 Stochastic Modelling Results

## F.3.1 Summary of Results

Table F.6 summarises the stochastic results for a worst case subsea well blowout in the Tornado field across all seasons. The results in Table F.6 report the minimum arrival time and probability of oil to reach land and the territorial waters of nearby countries.

**Table F.6: Summary of Stochastic Modelling Results**

| **Scenario 1: Subsea Well Blowout in the Tornado Field** | | | | | |
|---|---|---|---|---|---|
| **Spill Scenario / Descriptor:** 1,265,922.7 bbl (201,266 $m^3$) of Condensate (47.6 °API) released over 180 days | | | | | |
| **Season** | | Winter (December – February) | Spring (March – May) | Summer (June – August) | Autumn (September – November) |
| **Median Crossing** [Note 1] | | | | | |
| **Identified Median Line** | **Surface Oil: Probability and Shortest Time to Reach (Minimum Thickness of 0.3 µm)** | | | | |
| Norway | *Maximum Probability* | 3 % | 1 % | 1 % | 2 % |
| | *Shortest Arrival Time* | 271 hrs | 296 hrs | 492 hrs | 288 hrs |
| Faroe Islands | *Maximum Probability* | 100 % | 100 % | 100 % | 100 % |
| | *Shortest Arrival Time* | 16 hrs | 19 hrs | 18 hrs | 24 hrs |
| **Identified Median Line** | **Subsurface Oil: Probability and Shortest Time to Reach (Minimum Water Column Concentration 1.0 ppb)** | | | | |
| Sweden | *Maximum Probability* | 10 % | N/A | 6 % | 25 % |
| | *Shortest Arrival Time* | 1,102 hrs | N/A | 4,050 hrs | 1,754 hrs |
| Denmark | *Maximum Probability* | 32 % | 12 % | 9 % | 25% |
| | *Shortest Arrival Time* | 957 hrs | 1,929 hrs | 3,347 hrs | 1,615 hrs |
| Norway | *Maximum Probability* | 100 % | 100 % | 100 % | 100 % |
| | *Shortest Arrival Time* | 162 hrs | 219 hrs | 305 hrs | 177 hrs |

| | | | | | |
|---|---|---|---|---|---|
| Iceland | *Maximum Probability* | 3 % | 5 % | 22 % | 9 % |
| | *Shortest Arrival Time* | 2,748 hrs | 1,282 hrs | 2,309 hrs | 1,237 hrs |
| Faroe Islands | *Maximum Probability* | 100 % | 100 % | 100 % | 100 % |
| | *Shortest Arrival Time* | 17 hrs | 16 hrs | 21 hrs | 18 hrs |
| Jan Mayen (Norway) | *Maximum Probability* | 29 % | 42 % | 54 % | 30 % |
| | *Shortest Arrival Time* | 1,256 hrs | 1,559 hrs | 1,377 hrs | 1,043 hrs |
| **Landfall** [Note 1] | | | | | |
| **Predicted Locations** | **Shoreline Oil: Probability and Shortest Time to Reach (Minimum Thickness of 1.0 µm)** | | | | |
| United Kingdom | *Maximum Probability* | 3 % | 1 % | 1 % | 2 % |
| | *Shortest Arrival Time* | 189 hrs | 388 hrs | 4,069 | 1,783 hrs |
| **Worst Case Trajectory Simulations Identified from Stochastic Results** | | | | | |
| **Greatest Volume of Oil Beached (in any one location)** | *Trajectory Run No. (out of 100)* | 26 | 74 | 30 | 5 |
| | $m^3$ | 29.55 | 7.42 | 4.07 | 21.93 |
| | *bbl* | 185.85 | 46.67 | 25.60 | 137.92 |
| | *Tonnes* | 23.35 | 5.86 | 3.22 | 17.33 |
| | *Sim Start Date* | 15/12/2021 | 22/03/2021 | 24/08/2021 | 24/11/2021 |
| | *Sim Start Time* | 00:00 | 08:00 | 12:00 | 12:00 |

Note 1: 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.

## F.3.2 Stochastic Maps

The stochastic results for a worst case subsea well blowout in the Tornado field were calculated from a total of 400 trajectory runs (100 simulations per season). The well blowout scenario involves the release of 1,265,922.7 bbl (201,266 $m^3$) of condensate (47.6 °API) over a 180-day period. The model is simulated for an additional 10 days following cessation of the blowout.

The stochastic model analysis used a 2 kilometres (km) x 2 km grid cell size. Therefore, the mapped stochastic output is shown at a 4 square kilometres ($km^2$) resolution. The following maps are presented using the WGS84 coordinate system:

### Sea Surface

- **Figure F.3** - Probability of oil reaching surface cells.
- **Figure F.4** - Minimum arrival time of oil to surface cells.
- **Figure F.5** - Maximum surface oil thickness.

### Water Column

- **Figure F.6 (a & b)** - Probability that a water column cell could be impacted.
- **Figure F.7 (a & b)** - Minimum arrival time of oil to water column cells.
- **Figure F.8 (a & b)** - Maximum total water column oil concentration.

### Shoreline

- **Figure F.9** - Probability that a shoreline cell could be impacted.
- **Figure F.10** - Minimum arrival time of oil to shoreline cells.
- **Figure F.11** - Maximum shoreline oil thickness.

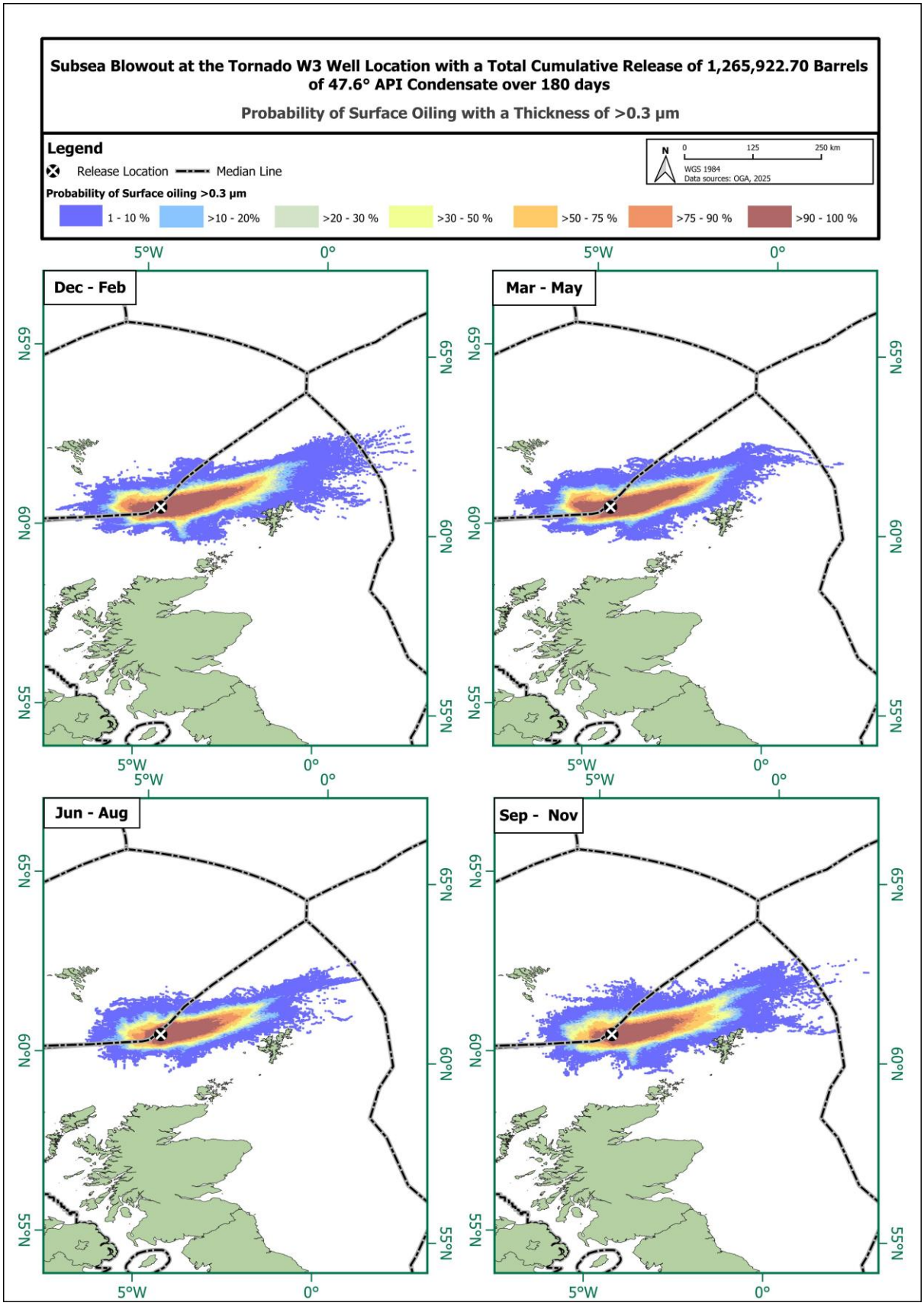



**Figure F.3: Probability of Oil Reaching Surface Cells**

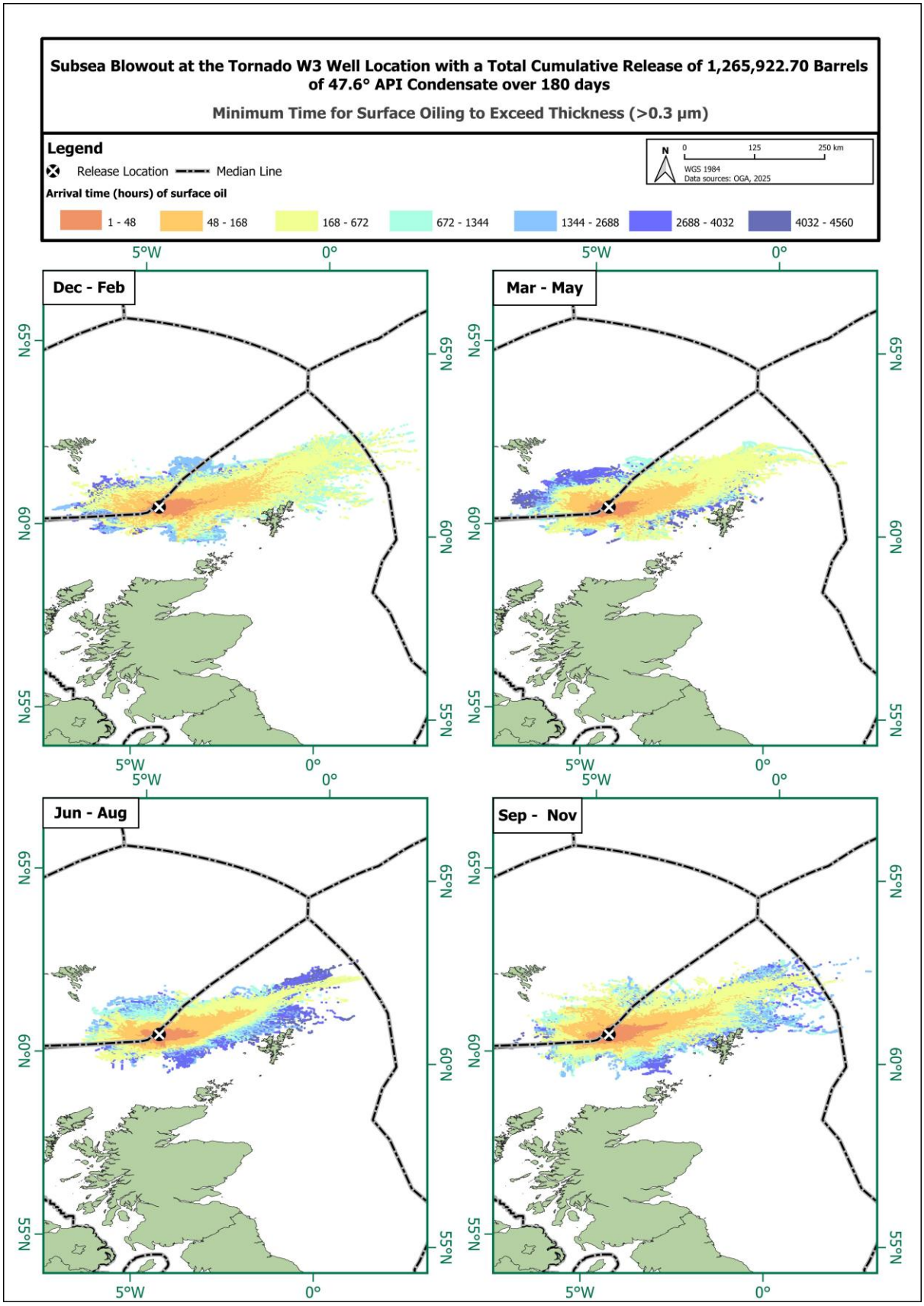



**Figure F.4: Minimum Arrival Time of Oil to Surface Cells**

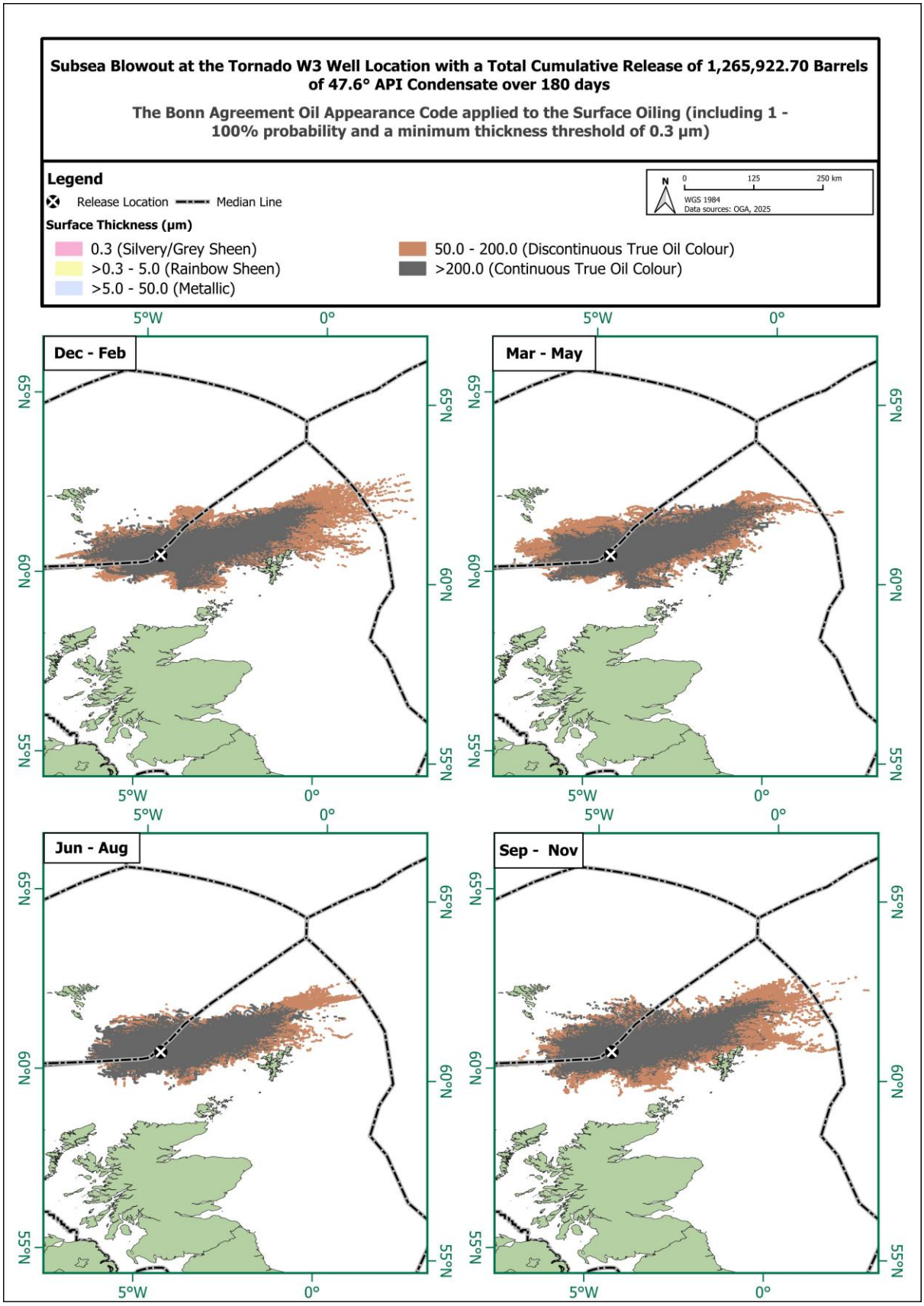



**Figure F.5: Maximum Surface Oil Thickness (Bonn Code)**

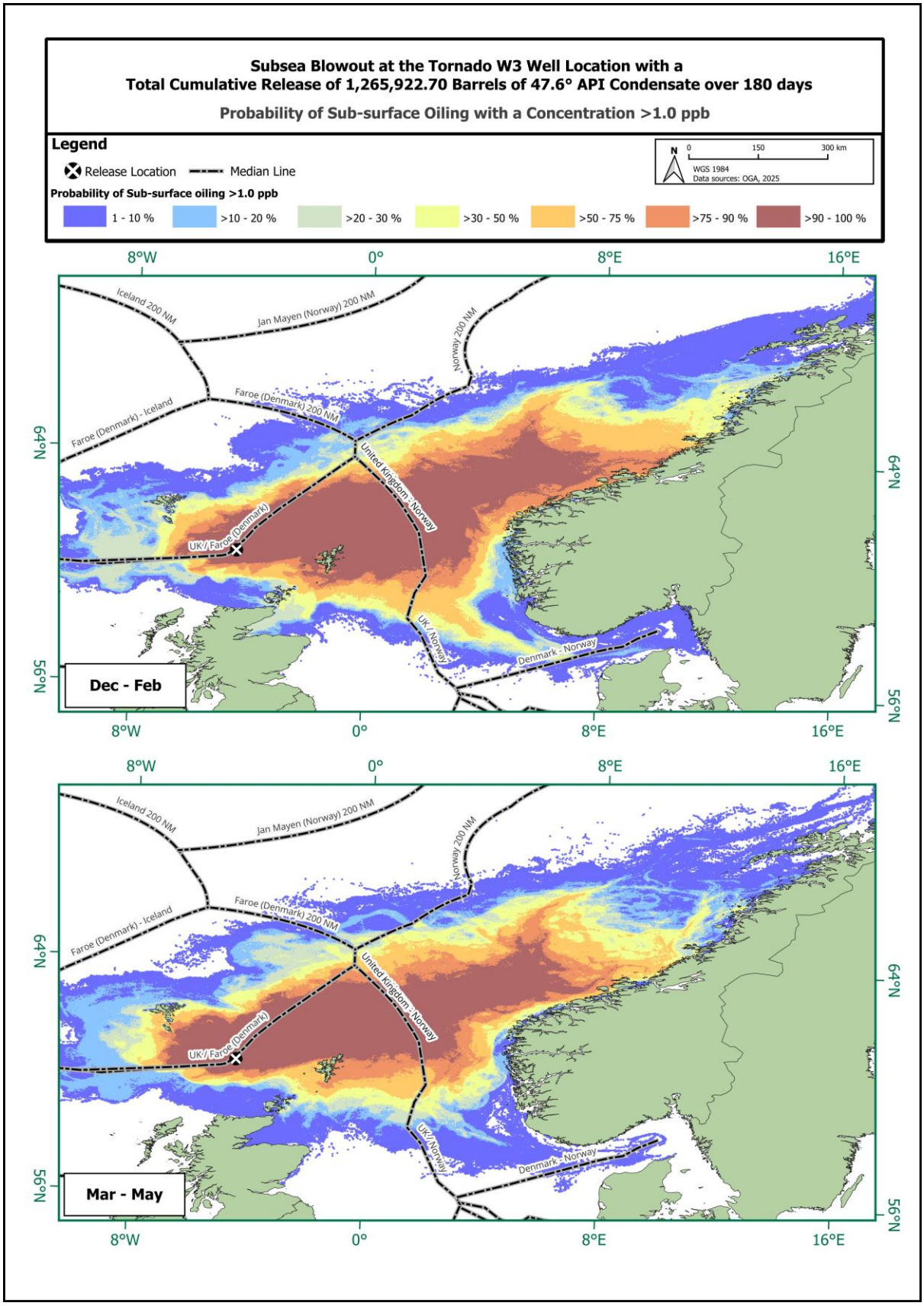



**Figure F.6a: Probability of Water Column Cells Impacted (Map 1 of 2)**

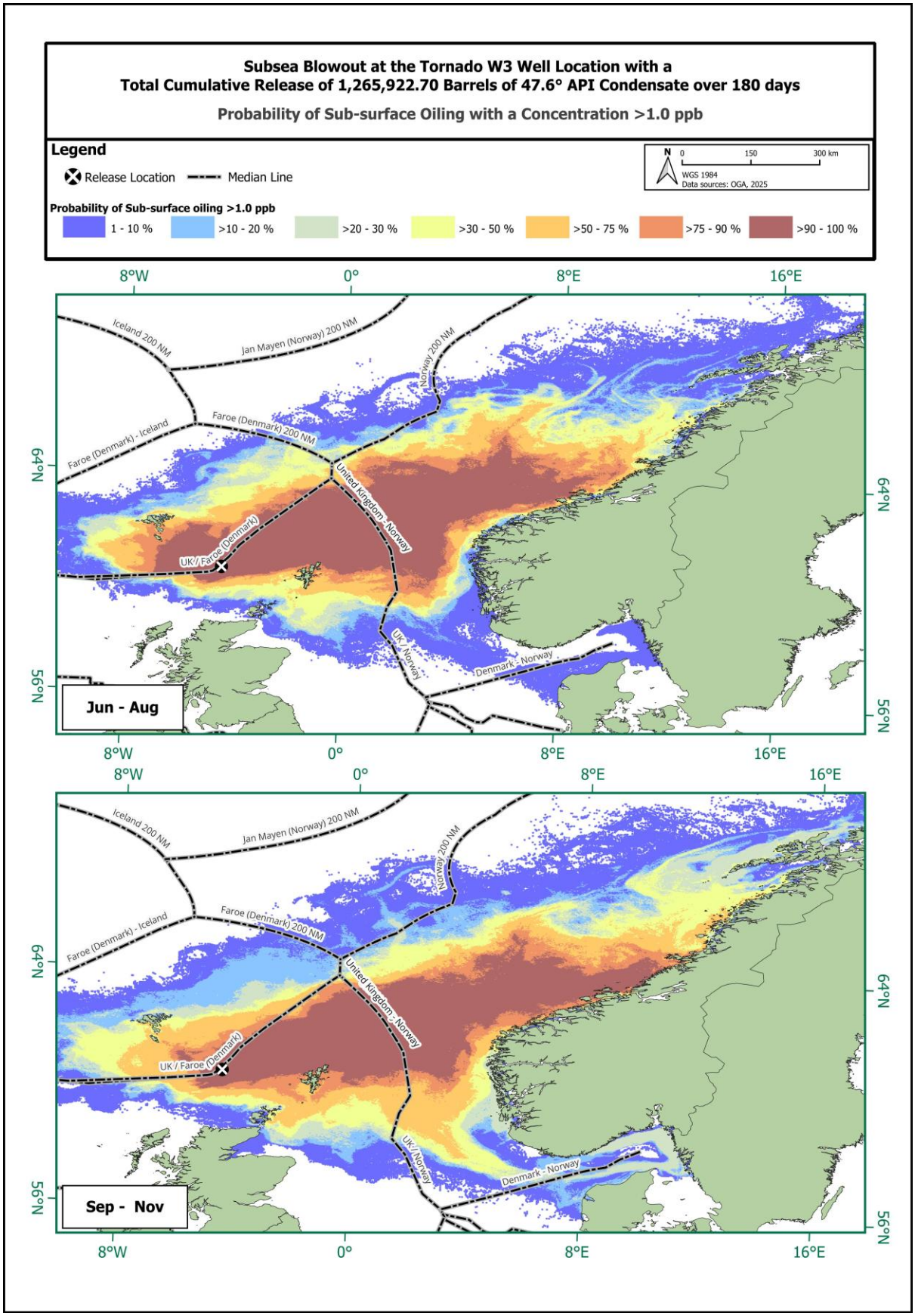



**Figure F.6b: Probability of Water Column Cells Impacted (Map 2 of 2)**

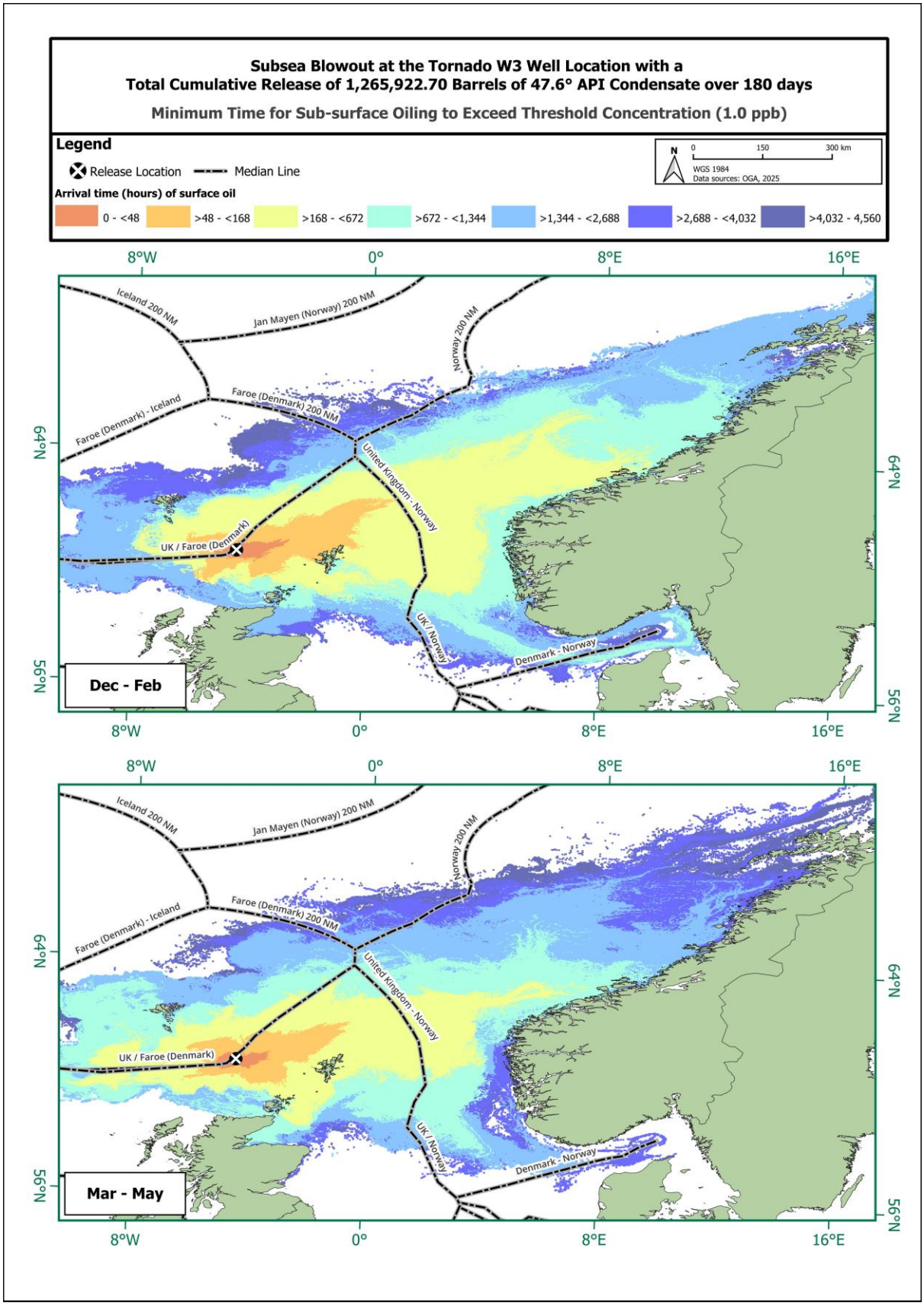



**Figure F.7a: Minimum Arrival Time of Oil to Water Column Cells (Map 1 of 2)**

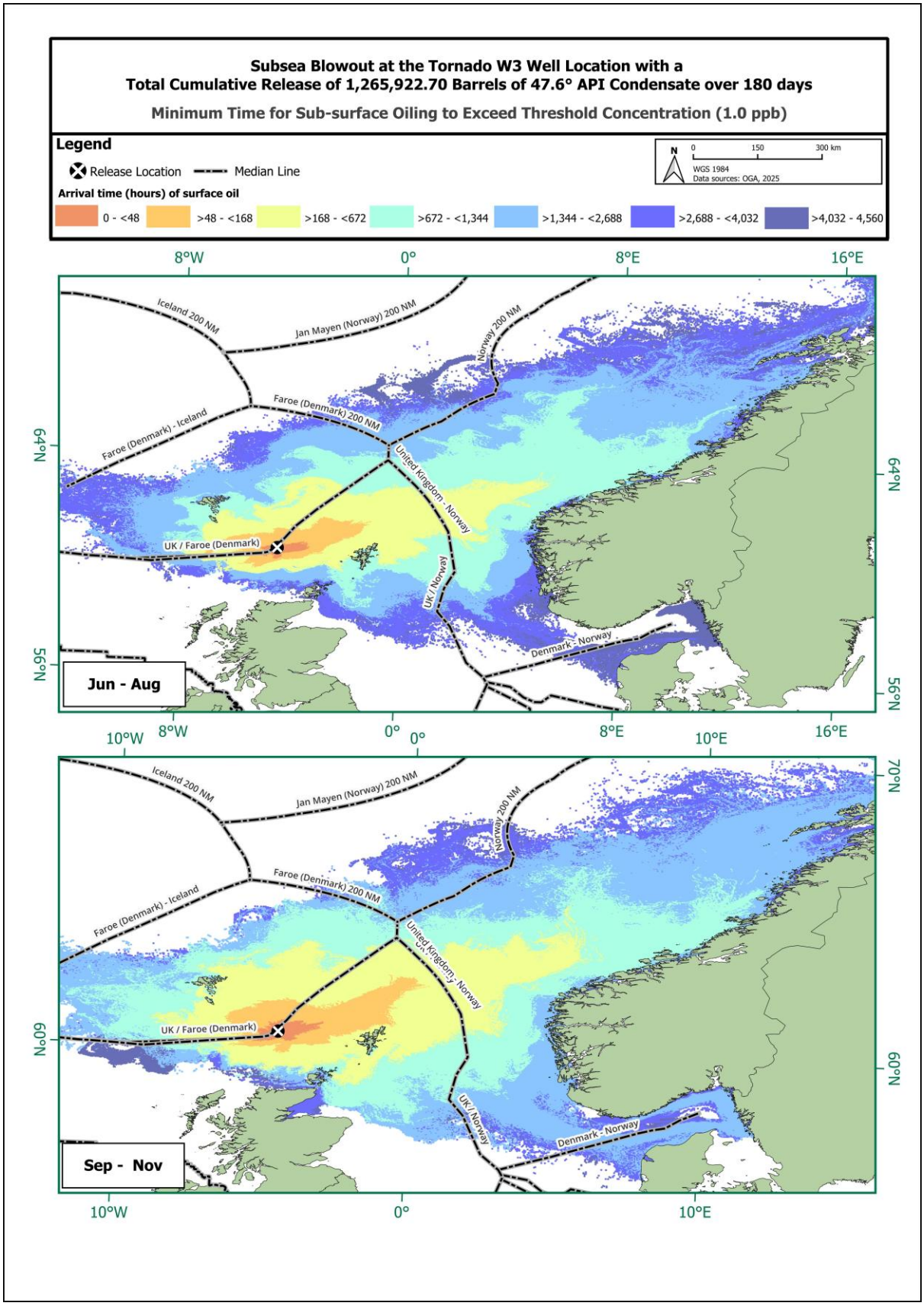



**Figure F.7b: Minimum Arrival Time of Oil to Water Column Cells (Map 2 of 2)**

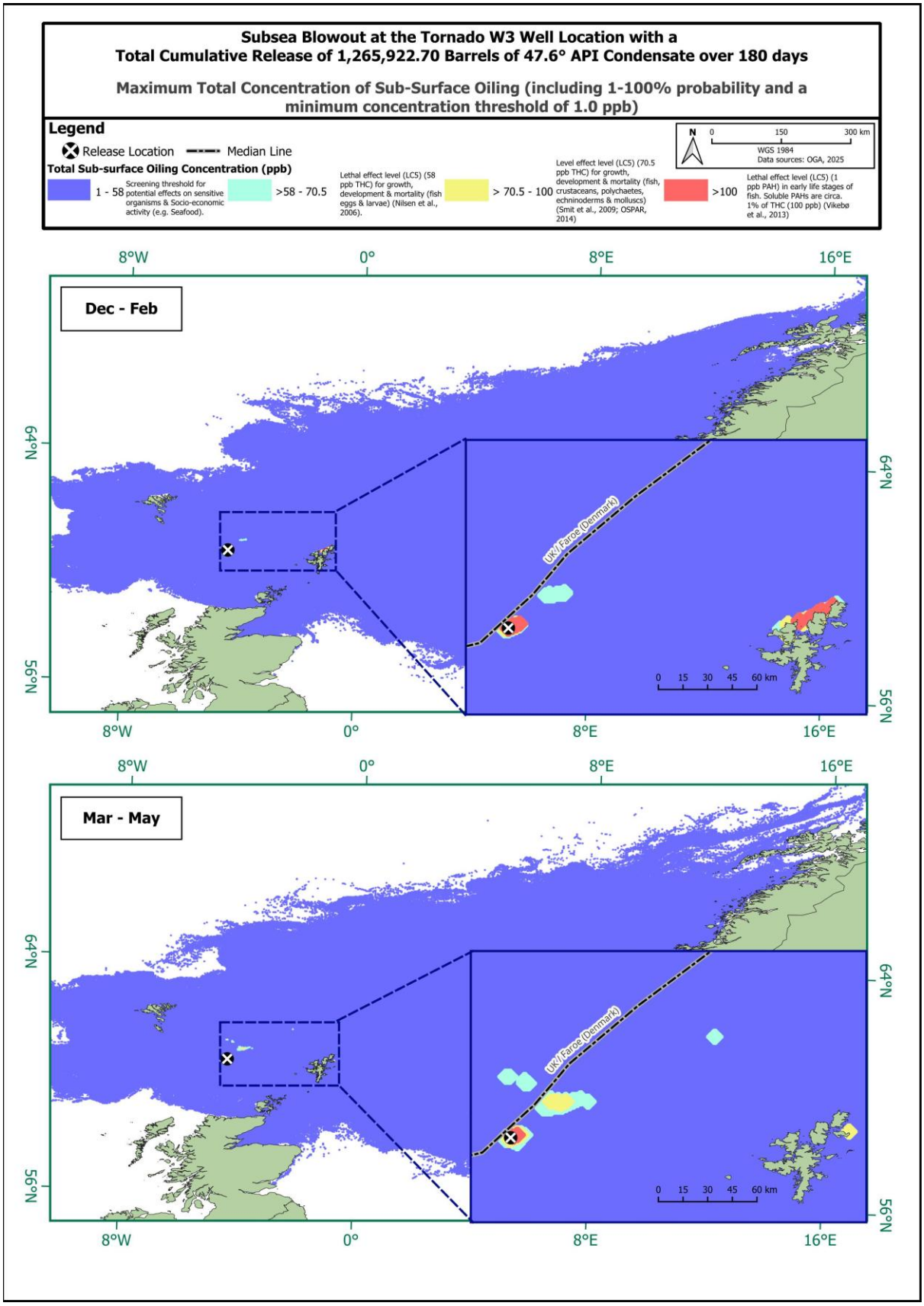



**Figure F.8a: Maximum Total Water Column Oil Concentrations (Map 1 of 2)**

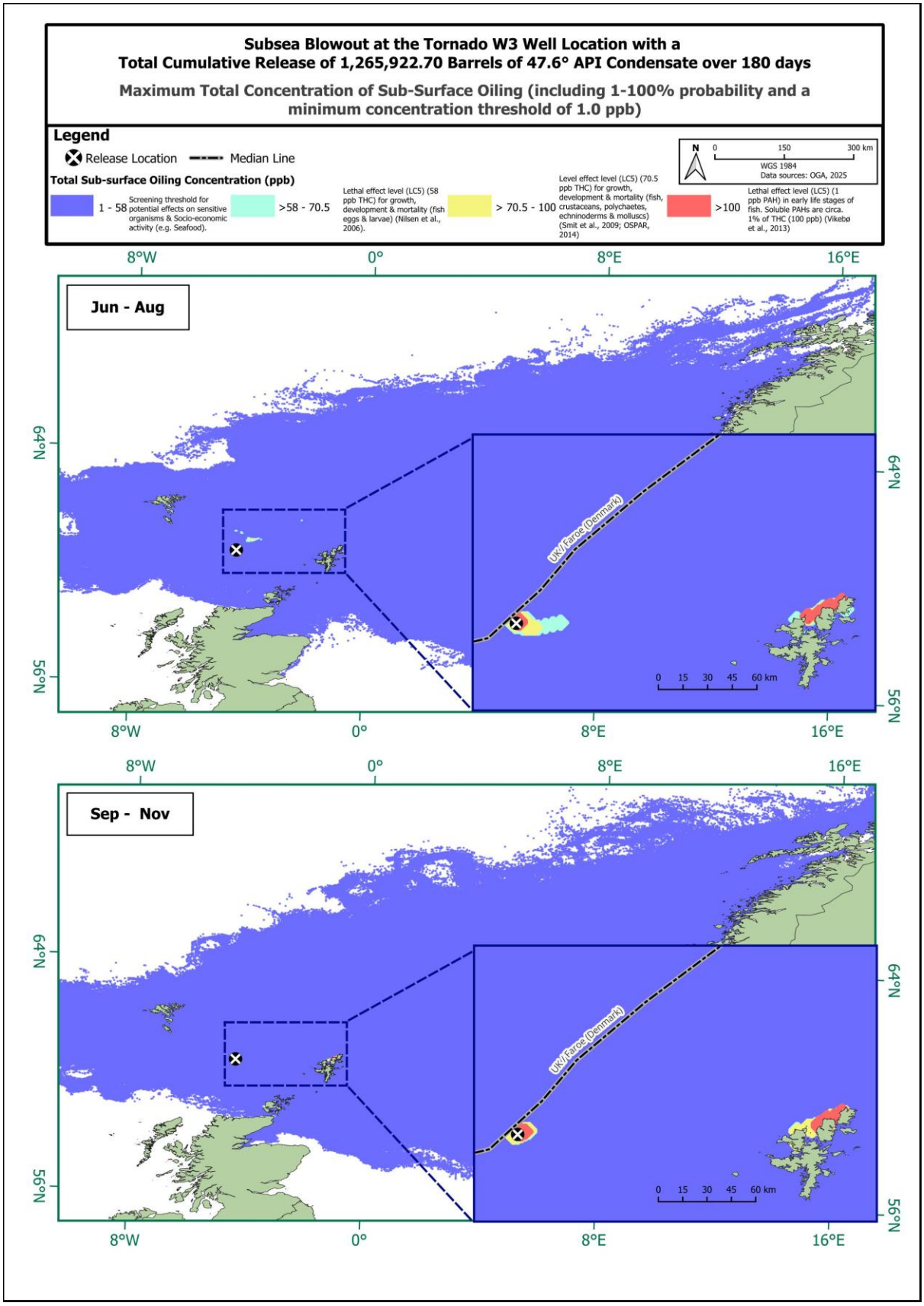



**Figure F.8b: Maximum Total Water Column Oil Concentrations (Map 2 of 2)**

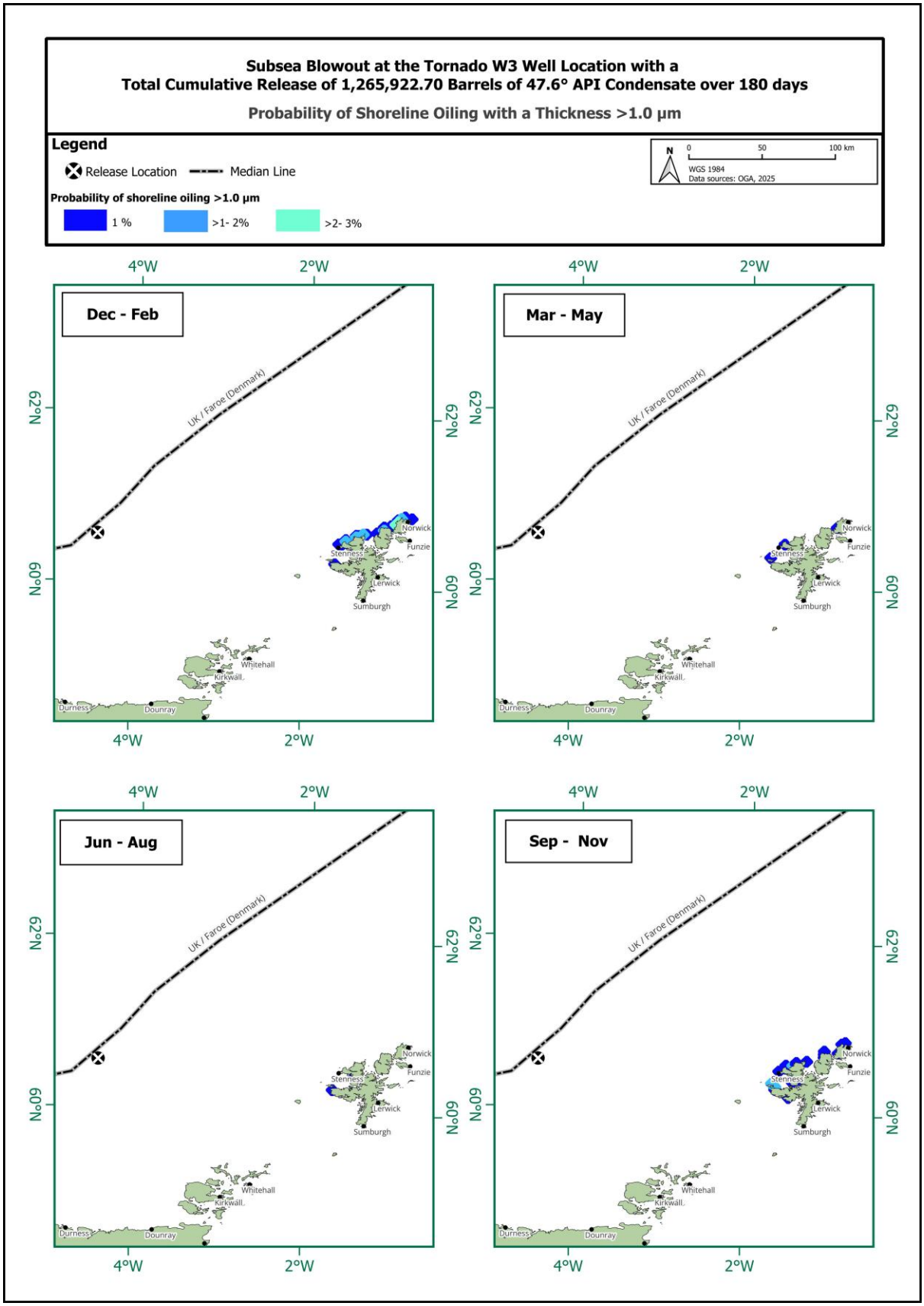



**Figure F.9: Probability of Shoreline Oiling**

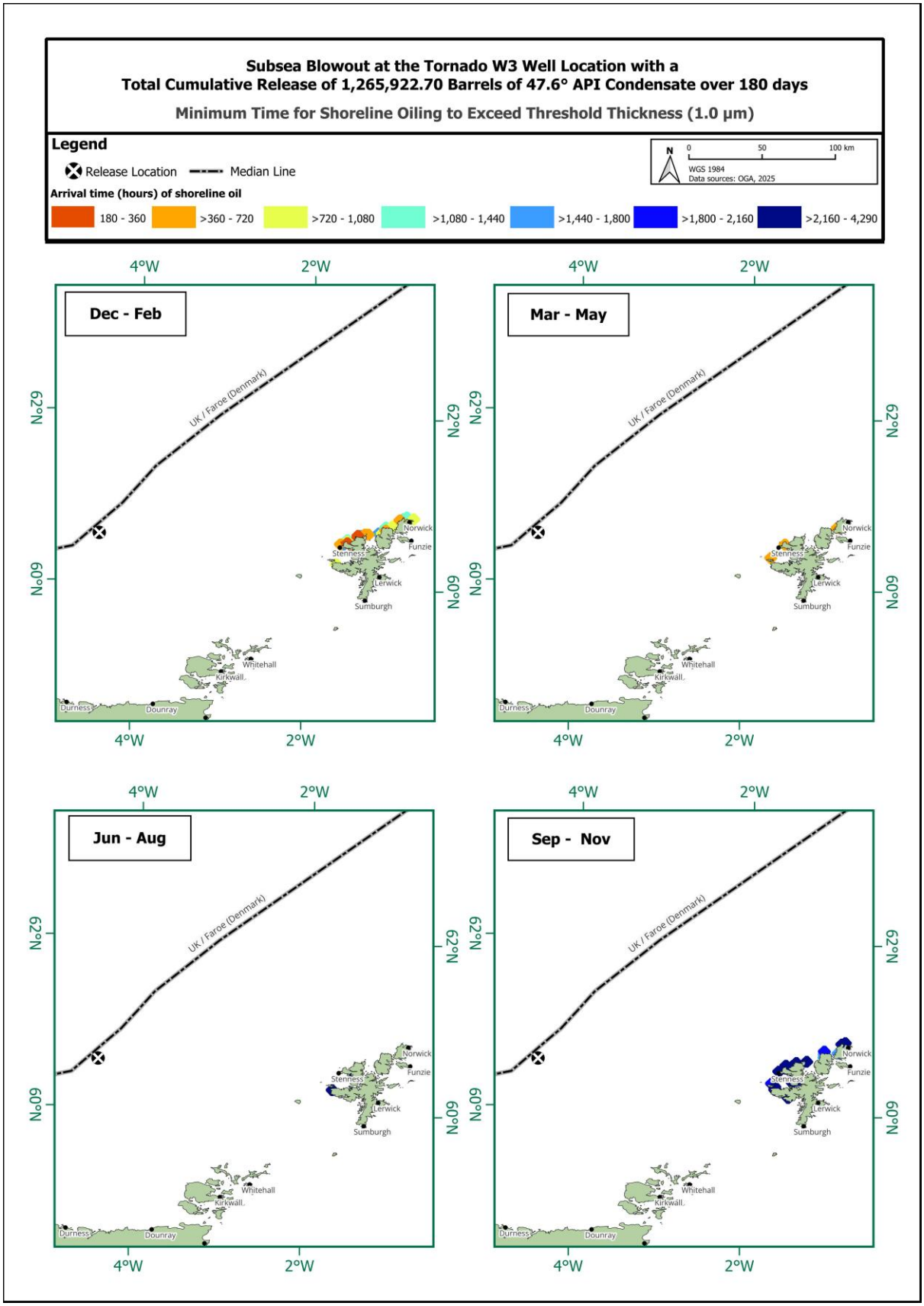



**Figure F.10: Minimum Arrival Time of Oil to Shoreline Cells**

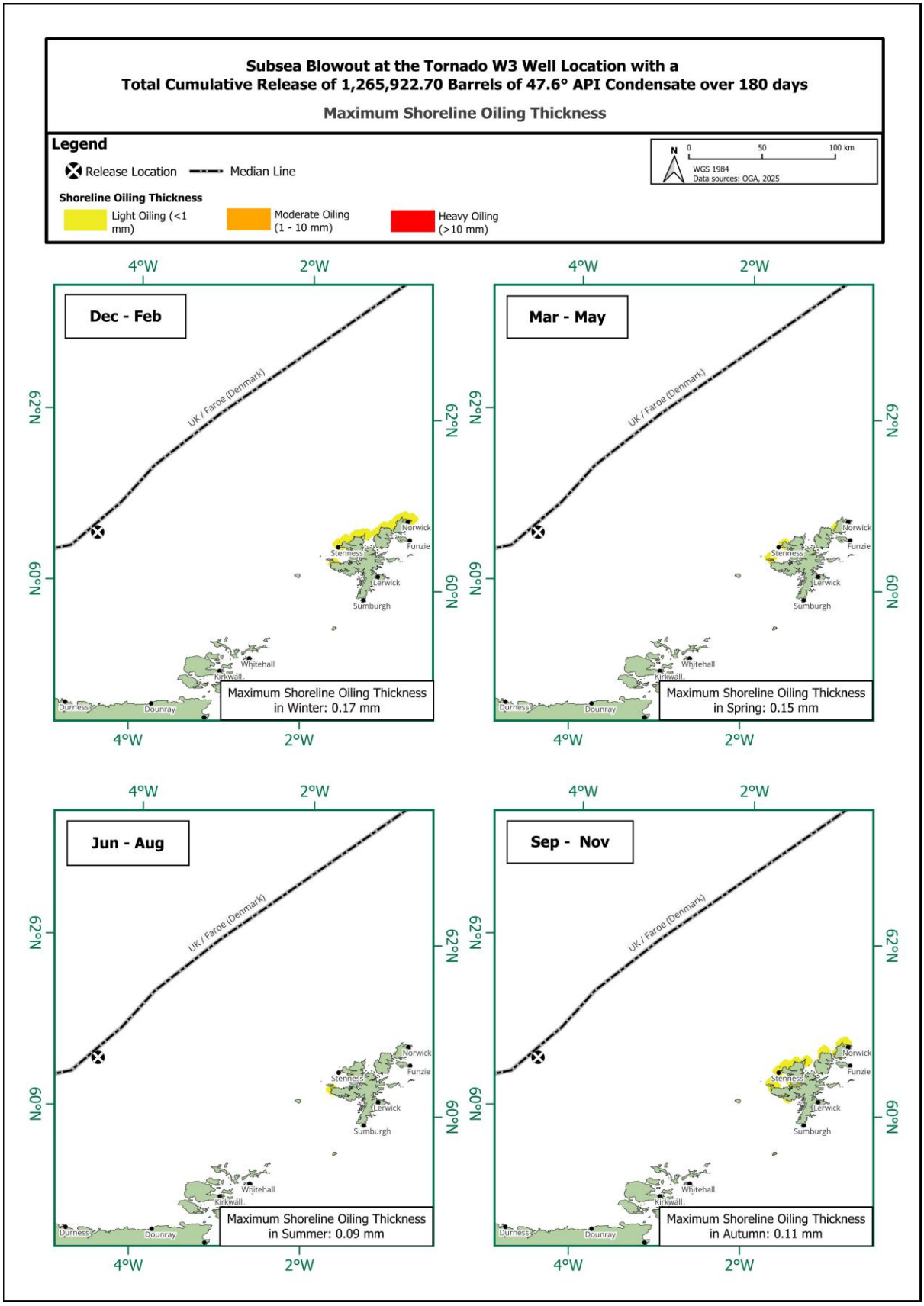



**Figure F.11: Maximum Shoreline Oiling Thickness**

## F.3.3 Protected Areas at Risk

### Stochastic Analysis for Protected Areas at Risk

Table F.7 lists the protected areas at risk from oiling. The worst case probability, minimum time and severity of oiling is reported for surface, shoreline and subsurface oil across all seasons.

**Table F.7: Protected Areas at Risk from Surface, Shoreline and Subsurface Oiling** [Note 1]

| Protected Area | Surface Oil (Minimum Thickness of 0.3 µm) | | | Shoreline Oil (Minimum Thickness of 1.0 µm) | | | Subsurface Oil (Minimum Water Column Concentration 1.0 ppb) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Maximum Probability | Shortest Arrival Time | Maximum Severity of Surface Oiling (refer to Table F.3) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Shoreline Oiling (refer to Table F.5) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Water Column Oiling (refer to Table F.4) |
| **Special Protected Areas (SPA) with Marine Components** | | | | | | | | | |
| Outer Firth of Forth and St Andrews Bay Complex SPA | N/A | N/A | N/A | N/A | N/A | N/A | 6 % | 3,866 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Ythan Estuary, Sands of Forvie and Meikle Loch SPA | N/A | N/A | N/A | N/A | N/A | N/A | 3 % | 3,330 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Buchan Ness to Collieston Coast SPA | N/A | N/A | N/A | N/A | N/A | N/A | 3 % | 3,598 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Troup, Pennan and Lion's Head SPA | N/A | N/A | N/A | N/A | N/A | N/A | 3 % | 3,834 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| East Caithness Cliffs SPA | N/A | N/A | N/A | N/A | N/A | N/A | 23 % | 819 hrs | Below $LC_5$ for marine fauna (<58 ppb) |

| Protected Area | Surface Oil (Minimum Thickness of 0.3 µm) | | | Shoreline Oil (Minimum Thickness of 1.0 µm) | | | Subsurface Oil (Minimum Water Column Concentration 1.0 ppb) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Maximum Probability | Shortest Arrival Time | Maximum Severity of Surface Oiling (refer to Table F.3) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Shoreline Oiling (refer to Table F.5) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Water Column Oiling (refer to Table F.4) |
| Moray Firth SPA | N/A | N/A | N/A | N/A | N/A | N/A | 22 % | 858 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| North Caithness Cliffs SPA | N/A | N/A | N/A | N/A | N/A | N/A | 38 % | 683 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Hoy SPA | N/A | N/A | N/A | N/A | N/A | N/A | 26 % | 705 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Scapa Flow SPA | N/A | N/A | N/A | N/A | N/A | N/A | 63 % | 653 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Copinsay SPA | N/A | N/A | N/A | N/A | N/A | N/A | 61 % | 303 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| North Orkney SPA | N/A | N/A | N/A | N/A | N/A | N/A | 53 % | 668 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Rousay SPA | N/A | N/A | N/A | N/A | N/A | N/A | 13 % | 1,072 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| West Westray SPA | N/A | N/A | N/A | N/A | N/A | N/A | 34 % | 294 hrs | Below $LC_5$ for marine fauna (<58 ppb) |

| Protected Area | Surface Oil (Minimum Thickness of 0.3 µm) | | | Shoreline Oil (Minimum Thickness of 1.0 µm) | | | Subsurface Oil (Minimum Water Column Concentration 1.0 ppb) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Maximum Probability | Shortest Arrival Time | Maximum Severity of Surface Oiling (refer to Table F.3) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Shoreline Oiling (refer to Table F.5) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Water Column Oiling (refer to Table F.4) |
| East Sanday Coast SPA | N/A | N/A | N/A | N/A | N/A | N/A | 49 % | 265 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Calf of Eday SPA | N/A | N/A | N/A | N/A | N/A | N/A | 52 % | 239 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Seas Off Foula SPA | 37 % | 102 hrs | Bonn Code: 5 (Continuous True Oil Colour) | N/A | N/A | N/A | 100 % | 65 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Fair Isle SPA | N/A | N/A | N/A | N/A | N/A | N/A | 89 % | 274 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Sumburgh Head SPA | N/A | N/A | N/A | N/A | N/A | N/A | 96 % | 385 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Noss SPA | N/A | N/A | N/A | N/A | N/A | N/A | 100 % | 301 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| East Mainland Coast, Shetland SPA | N/A | N/A | N/A | N/A | N/A | N/A | 100 % | 279 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Bluemull and Colgrave Sounds SPA | 1 % | 374 hrs | Bonn Code: 5 (Continuous True Oil Colour) | 1 % | 578 hrs | Light Oiling (0.001 – 1 litres / $m^2$) | 100 % | 177 hrs | Below $LC_5$ for marine fauna (<58 ppb) |

| Protected Area | Surface Oil (Minimum Thickness of 0.3 µm) | | | Shoreline Oil (Minimum Thickness of 1.0 µm) | | | Subsurface Oil (Minimum Water Column Concentration 1.0 ppb) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Maximum Probability | Shortest Arrival Time | Maximum Severity of Surface Oiling (refer to Table F.3) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Shoreline Oiling (refer to Table F.5) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Water Column Oiling (refer to Table F.4) |
| Fetlar SPA | N/A | N/A | N/A | N/A | N/A | N/A | 100 % | 201 hrs | Above OSPAR recommended PNEC (>70.5 ppb) |
| Hermaness, Saxa Vord and Valla Field SPA | 3 % | 260 hrs | Bonn Code: 5 (Continuous True Oil Colour) | 2 % | 371 hrs | Light Oiling (0.001 – 1 litres / $m^2$) | 100 % | 131 hrs | Above the lethal effect level (>100 ppb) |
| Marwick Head SPA | N/A | N/A | N/A | N/A | N/A | N/A | 2 % | 1,545 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Ronas Hill – North Roe and Tingon SPA | N/A | N/A | N/A | 2 % | 197 hrs | Light Oiling (0.001 – 1 litres / $m^2$) | N/A | N/A | N/A |
| Papa Stour SPA | N/A | N/A | N/A | 2 % | 573 hrs | Light Oiling (0.001 – 1 litres / $m^2$) | N/A | N/A | N/A |
| North Rona and Sula Sgeir SPA | N/A | N/A | N/A | N/A | N/A | N/A | 8 % | 1,203 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Sule Skerry and Sule Stack SPA | N/A | N/A | N/A | N/A | N/A | N/A | 11 % | 548 hrs | Below LC5 for marine fauna (<58 ppb) |

| Protected Area | Surface Oil (Minimum Thickness of 0.3 µm) | | | Shoreline Oil (Minimum Thickness of 1.0 µm) | | | Subsurface Oil (Minimum Water Column Concentration 1.0 ppb) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Maximum Probability | Shortest Arrival Time | Maximum Severity of Surface Oiling (refer to Table F.3) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Shoreline Oiling (refer to Table F.5) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Water Column Oiling (refer to Table F.4) |
| **Special Area of Conservation (SAC) with Marine Components** | | | | | | | | | |
| Braemar Pockmarks SAC | N/A | N/A | N/A | N/A | N/A | N/A | 68 % | 826 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Darwin Mounds SAC | N/A | N/A | N/A | N/A | N/A | N/A | 35 % | 382 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Faray and Holm of Faray SAC | N/A | N/A | N/A | N/A | N/A | N/A | 30 % | 310 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Firth of Tay and Eden Estuary SAC | N/A | N/A | N/A | N/A | N/A | N/A | 1 % | 3,960 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Moray Firth SAC | N/A | N/A | N/A | N/A | N/A | N/A | 22 % | 873 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Mousa SAC | N/A | N/A | N/A | N/A | N/A | N/A | 99 % | 479 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| North Rona SAC | N/A | N/A | N/A | N/A | N/A | N/A | 8 % | 1,332 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Papa Stour SAC | 1 % | 1470 hrs | Bonn Code: 4 (Discontinuous True Oil Colour) | 2 % | 573 hrs | Light Oiling (0.001 – 1 litres / $m^2$) | 100 % | 142 hrs | Below $LC_5$ for marine fauna (<58 ppb) |

| Protected Area | Surface Oil (Minimum Thickness of 0.3 µm) | | | Shoreline Oil (Minimum Thickness of 1.0 µm) | | | Subsurface Oil (Minimum Water Column Concentration 1.0 ppb) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Maximum Probability | Shortest Arrival Time | Maximum Severity of Surface Oiling (refer to Table F.3) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Shoreline Oiling (refer to Table F.5) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Water Column Oiling (refer to Table F.4) |
| Pobie Bank Reef SAC | 2 % | 215 hrs | Bonn Code: 5 (Continuous True Oil Colour) | N/A | N/A | N/A | 100 % | 169 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Sanday SAC | N/A | N/A | N/A | N/A | N/A | N/A | 54 % | 238 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Scanner Pockmark SAC | N/A | N/A | N/A | N/A | N/A | N/A | 16 % | 1,636 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Solan Bank Reef SAC | N/A | N/A | N/A | N/A | N/A | N/A | 12 % | 943 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Sullom Voe SAC | N/A | N/A | N/A | N/A | N/A | N/A | 97 % | 321 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Wyville Thomson Ridge SAC | 5 % | 217 hrs | Bonn Code: 4 (Discontinuous True Oil Colour) | N/A | N/A | N/A | 86 % | 140 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Yell Sound Coast SAC | N/A | N/A | N/A | N/A | N/A | N/A | 100 % | 335 hrs | Below $LC_5$ for marine fauna (<58 ppb) |

| Protected Area | Surface Oil (Minimum Thickness of 0.3 µm) | | | Shoreline Oil (Minimum Thickness of 1.0 µm) | | | Subsurface Oil (Minimum Water Column Concentration 1.0 ppb) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Maximum Probability | Shortest Arrival Time | Maximum Severity of Surface Oiling (refer to Table F.3) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Shoreline Oiling (refer to Table F.5) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Water Column Oiling (refer to Table F.4) |
| **RAMSAR** | | | | | | | | | |
| Firth of Tay and Eden Estuary RAMSAR | N/A | N/A | N/A | N/A | N/A | N/A | 1 % | 3,960 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Moray and Nairn Coast RAMSAR | N/A | N/A | N/A | N/A | N/A | N/A | 22 % | 1,412 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Cromarty Firth RAMSAR | N/A | N/A | N/A | N/A | N/A | N/A | 22 % | 1,234 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Dornoch Firth and Loch Fleet RAMSAR | N/A | N/A | N/A | N/A | N/A | N/A | 22 % | 1,034 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| East Sanday Coast RAMSAR | N/A | N/A | N/A | N/A | N/A | N/A | 49 % | 251 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Ronas Hill – North Roe and Tingon RAMSAR | 2 % | 192 hrs | Bonn Code: 5 (Continuous True Oil Colour) | 2 % | 197 hrs | Light Oiling (0.001 – 1 litres / $m^2$) | 97 % | 138 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| **Nature Conservation Marine Protected Areas (NC MPA)** | | | | | | | | | |
| Turbot Bank MPA | N/A | N/A | N/A | N/A | N/A | N/A | 3 % | 1,395 hrs | Below $LC_5$ for marine fauna (<58 ppb) |

| Protected Area | Surface Oil (Minimum Thickness of 0.3 µm) | | | Shoreline Oil (Minimum Thickness of 1.0 µm) | | | Subsurface Oil (Minimum Water Column Concentration 1.0 ppb) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Maximum Probability | Shortest Arrival Time | Maximum Severity of Surface Oiling (refer to Table F.3) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Shoreline Oiling (refer to Table F.5) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Water Column Oiling (refer to Table F.4) |
| Southern Trench MPA | N/A | N/A | N/A | N/A | N/A | N/A | 20 % | 1,746 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| East Caithness Cliffs MPA | N/A | N/A | N/A | N/A | N/A | N/A | 23 % | 1,656 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Noss Head MPA | N/A | N/A | N/A | N/A | N/A | N/A | 30 % | 1,655 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| West Shetland Shelf MPA | 7 % | 345 hrs | Bonn Code: 5 (Continuous True Oil Colour) | N/A | N/A | N/A | 75 % | 93 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| North West Orkney MPA | 10 % | 514 hrs | Bonn Code: 5 (Continuous True Oil Colour) | N/A | N/A | N/A | 83 % | 134 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Papa Westray MPA | N/A | N/A | N/A | N/A | N/A | N/A | 31 % | 844 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Wyre and Rousay Sounds MPA | N/A | N/A | N/A | N/A | N/A | N/A | 2 % | 1,754 hrs | Below $LC_5$ for marine fauna (<58 ppb) |

| Protected Area | Surface Oil (Minimum Thickness of 0.3 µm) | | | Shoreline Oil (Minimum Thickness of 1.0 µm) | | | Subsurface Oil (Minimum Water Column Concentration 1.0 ppb) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Maximum Probability | Shortest Arrival Time | Maximum Severity of Surface Oiling (refer to Table F.3) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Shoreline Oiling (refer to Table F.5) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Water Column Oiling (refer to Table F.4) |
| Faroe Shetland Sponge Belt MPA | 100 % | 11 hrs | Bonn Code: 5 (Continuous True Oil Colour) | N/A | N/A | N/A | 100 % | 10 hrs | Above OSPAR recommended PNEC (>70.5 ppb) |
| Mousa to Boddam MPA | N/A | N/A | N/A | N/A | N/A | N/A | 99 % | 359 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| Fetlar to Haroldswick MPA | N/A | N/A | N/A | N/A | N/A | N/A | 100 % | 193 hrs | Above OSPAR recommended PNEC (>70.5 ppb) |
| Central Fladen MPA | N/A | N/A | N/A | N/A | N/A | N/A | 62 % | 462 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| North East Faroe-Shetland Channel MPA | 53 % | 129 hrs | Bonn Code: 5 (Continuous True Oil Colour) | N/A | N/A | N/A | 100 % | 81 hrs | Above $LC_5$ for marine fauna (>58 ppb) |
| Norwegian Boundary Sediment Plain MPA | N/A | N/A | N/A | N/A | N/A | N/A | 14 % | 1,449 hrs | Below $LC_5$ for marine fauna (<58 ppb) |
| East of Gannet and Montrose Fields MPA | N/A | N/A | N/A | N/A | N/A | N/A | 6 % | 1,510 hrs | Below $LC_5$ for marine fauna (<58 ppb) |

| Protected Area | Surface Oil (Minimum Thickness of 0.3 µm) | | | Shoreline Oil (Minimum Thickness of 1.0 µm) | | | Subsurface Oil (Minimum Water Column Concentration 1.0 ppb) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Maximum Probability | Shortest Arrival Time | Maximum Severity of Surface Oiling (refer to Table F.3) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Shoreline Oiling (refer to Table F.5) | Maximum Probability | Shortest Arrival Time | Maximum Severity of Water Column Oiling (refer to Table F.4) |
| West of Scotland MPA | N/A | N/A | N/A | N/A | N/A | N/A | 23 % | 682 hrs | Below $LC_5$ for marine fauna (<58 ppb) |

Note 1: 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.

## F.4 Trajectory Modelling Results

The stochastic modelling results detailed above in Section F.3 were composed of 100 individual trajectory simulations per season. The worst case trajectory simulation for each season has been extracted to produce a fates analysis for the duration of the spill plus 10 days (total 190 days model duration).

The worst case trajectory simulations have been identified by the 'greatest mass of beached condensate at any one location'. The following trajectory simulations have been extracted and analysed:

- **Winter (Dec-Feb):** Run No. 26 (Start Date: 15/12/2021; Start Time: 00:00), 23.35 tonnes (185.85 bbl or 29.55 $m^3$) of condensate beached.
- **Spring (Mar-May):** Run No. 74 (Start Date: 22/03/2021; Start Time: 08:00), 5.86 tonnes (46.67 bbl or 7.42 $m^3$) of condensate beached.
- **Summer (Jun-Aug):** Run No. 30 (Start Date: 24/08/2021; Start Time: 12:00), 3.22 tonnes (25.60 bbl or 4.07 $m^3$) of condensate beached.
- **Autumn (Sep-Nov):** Run No. 5 (Start Date: 24/11/2021; Start Time: 12:00), 17.33 tonnes (137.92 bbl or 21.93 $m^3$) of condensate beached.

Figure F.12 displays the trajectory simulations spatially, with total swept area of surface and shoreline oiling at 24-hour time steps after 190 days. Table F.8 provides summary statistics for the trajectory simulations. The fate of the released condensate is consistent between seasons with the majority evaporated and degraded after 190 days. The winter and autumn simulations produce the greatest impact on the shoreline.

**Table F.8: Fate Analysis Summary for Trajectory Simulations**

| Season | Trajectory Run No. | Minimum Time for Surface Oiling | Maximum Surface Slick Area | Minimum Time for Shoreline Oiling | Impacted Length of Coastline after 190 days | Fate of Released Condensate after 190 days (% of total release) Note 1 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ashore | Surface | Water Column | Evaporated | Degraded | Sediment |
| Winter | 26 | 11 hrs | 1,911.35 $km^2$ | 1,301 hrs | 3.56 km | 0.00 | 0.00 | 28.10 | 21.91 | 49.98 | 0.00 |
| Spring | 74 | 11 hrs | 2,017.61 $km^2$ | 388 hrs | 1 km | 0.00 | 0.00 | 28.14 | 22.22 | 49.64 | 0.00 |
| Summer | 30 | 10 hrs | 1,305.42 $km^2$ | 4,069 hrs | 0.51 km | 0.00 | 0.00 | 28.02 | 22.57 | 49.41 | 0.00 |
| Autumn | 5 | 11 hrs | 1,627.09 $km^2$ | 1,783 hrs | 3.54 km | 0.00 | 0.00 | 28.11 | 22.09 | 49.80 | 0.00 |

Note 1: Refer to fates analysis graphs (**Winter**: Figure F.13; **Spring**: Figure F.14; **Summer**: Figure F.15; **Autumn**: Figure F.16) showing spill progression in 10-day (240 hour) intervals, total simulation = 190 days (4,560 hours).

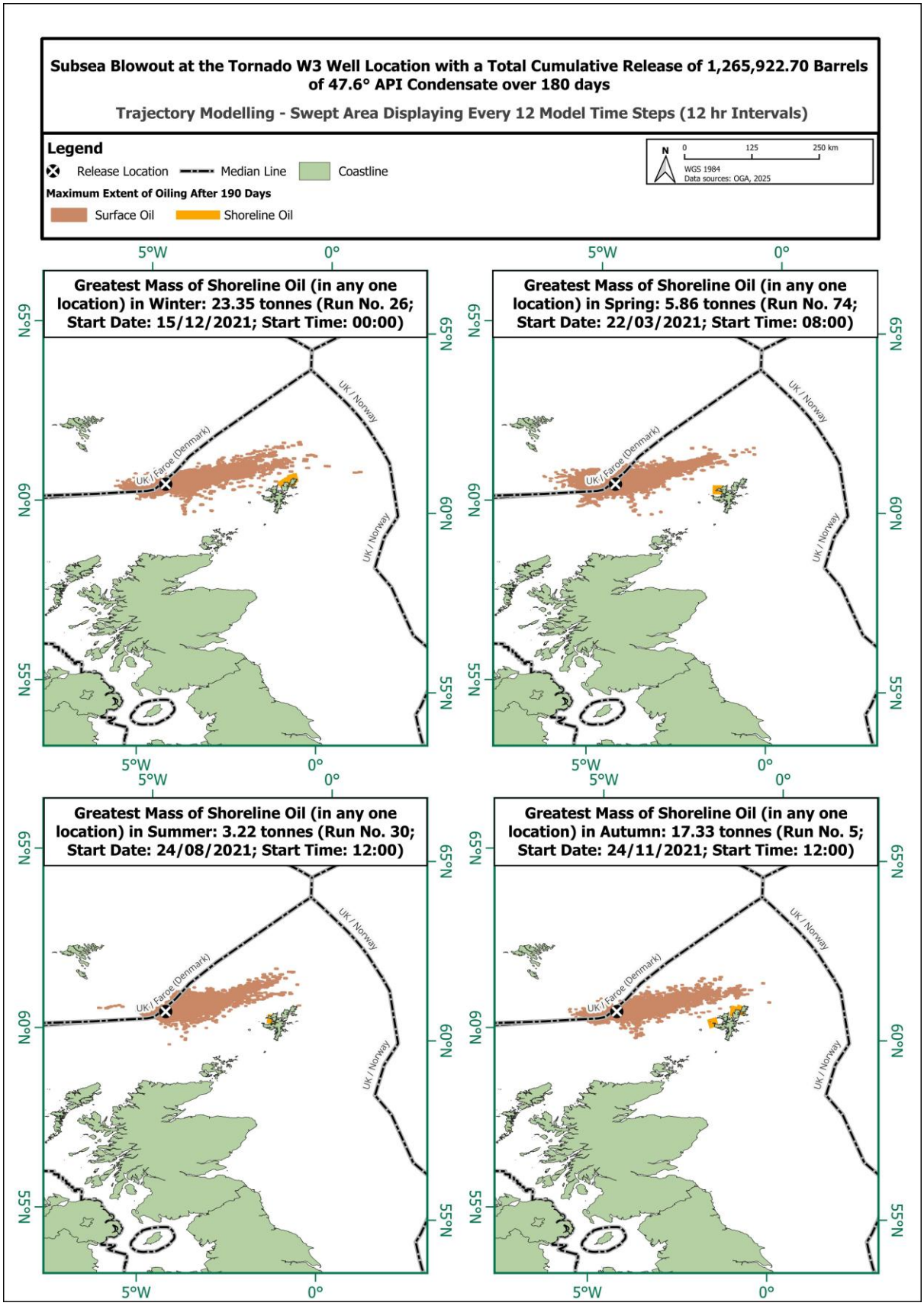



**Figure F.12: Worst Case Trajectory Simulations Showing Swept Area for Surface and Shoreline Oiling at 12-hour intervals**

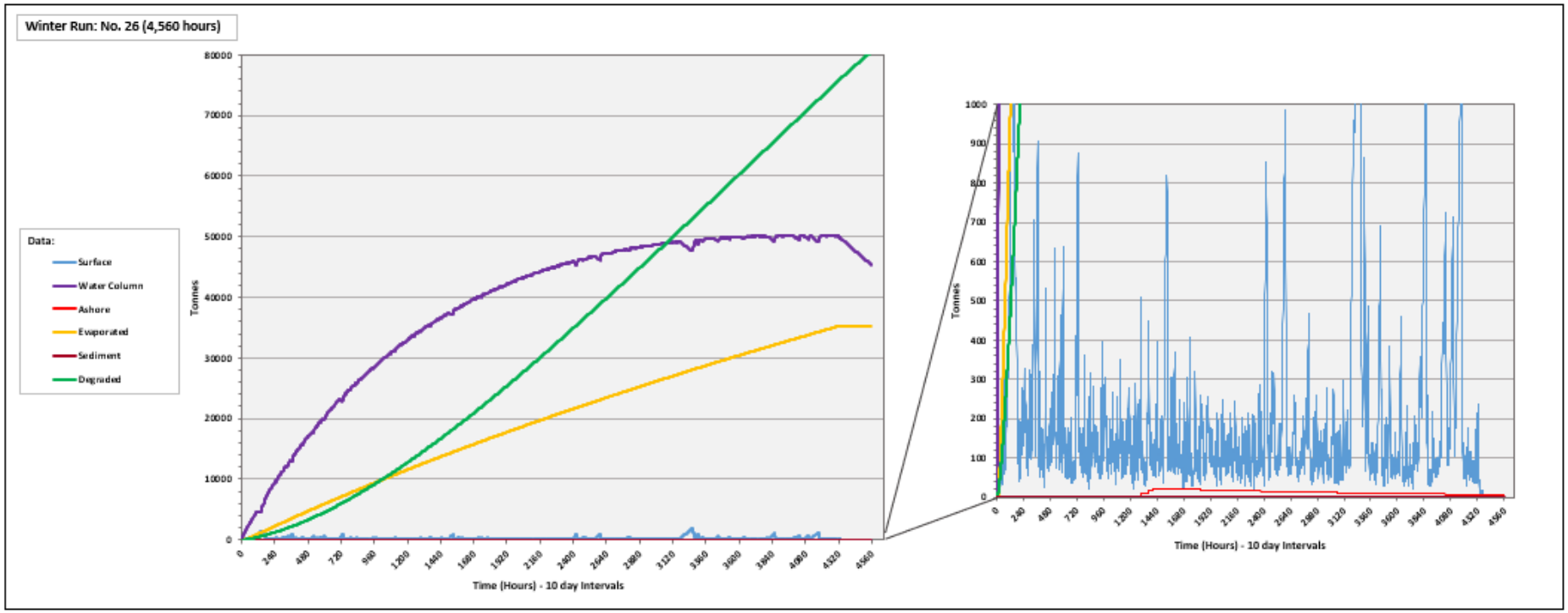



**Figure F.13: Fate of the condensate released from Winter Run No. 26 (showing model duration 190 days)**

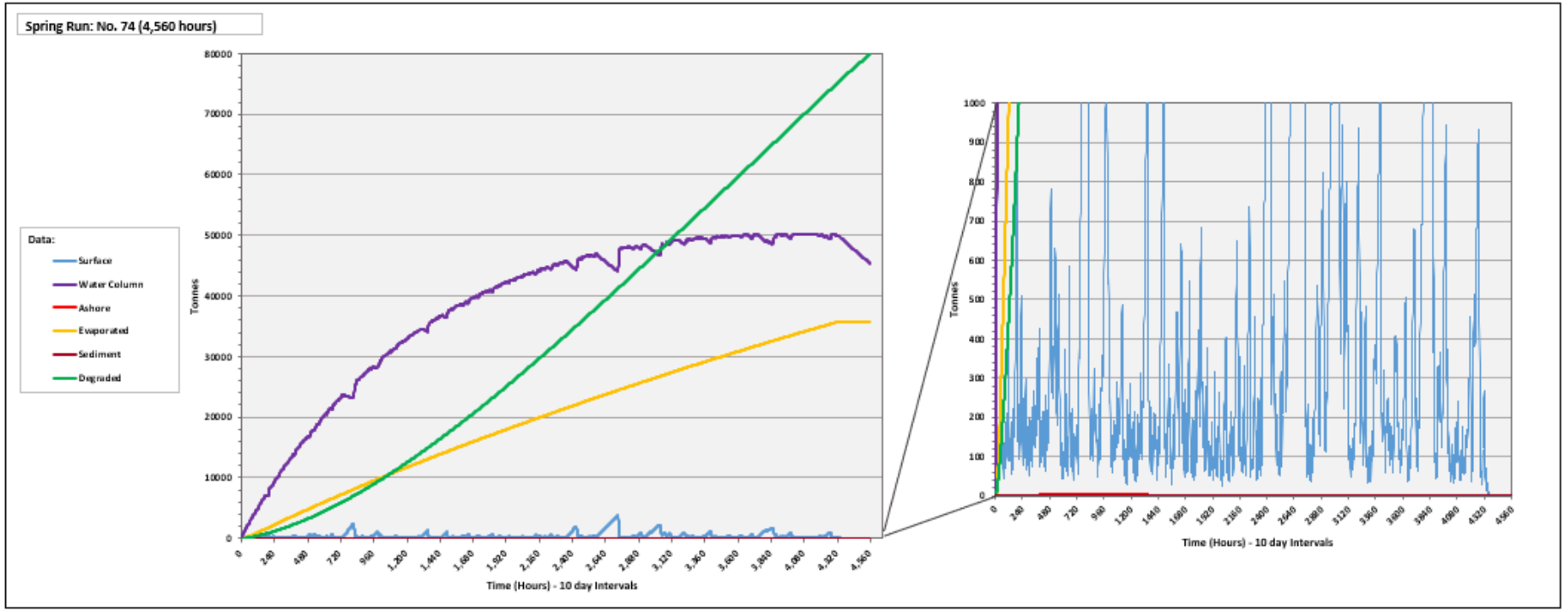



**Figure F.14: Fate of the condensate released from Spring Run No. 74 (showing model duration 190 days)**

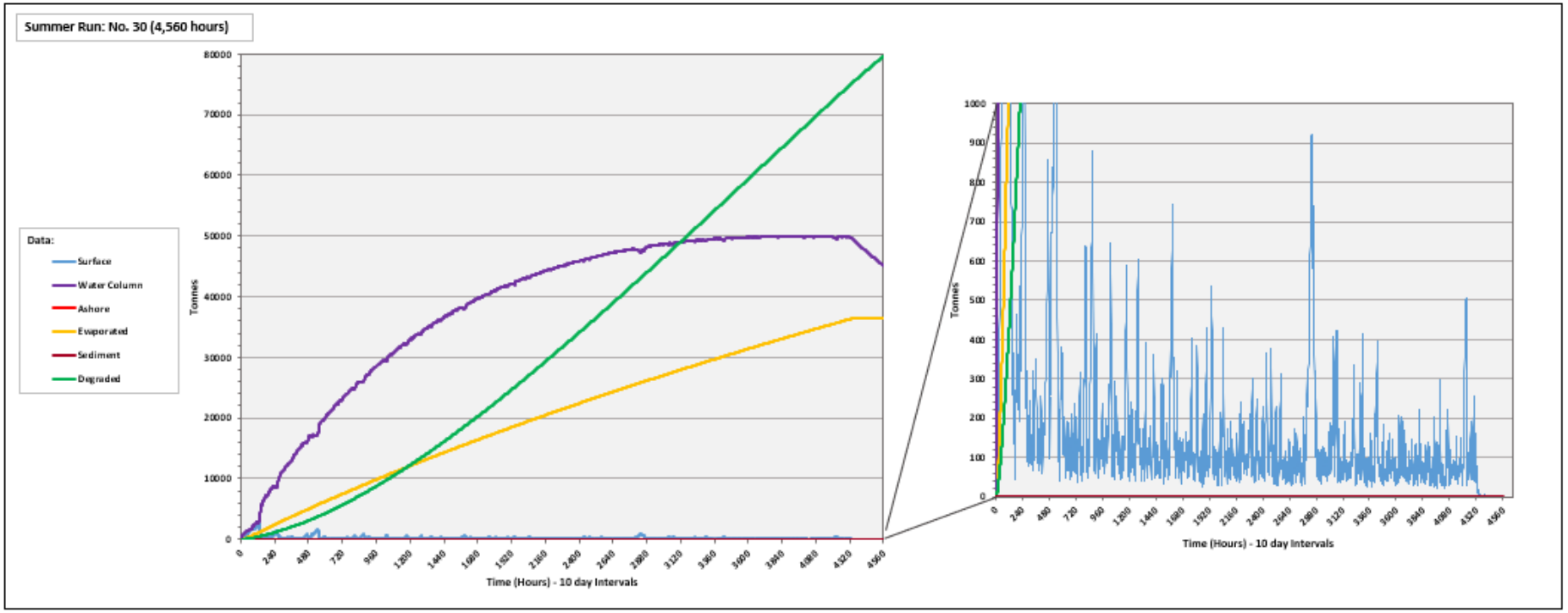



**Figure F.15: Fate of the condensate released from Summer Run No. 30 (showing model duration 190 days)**

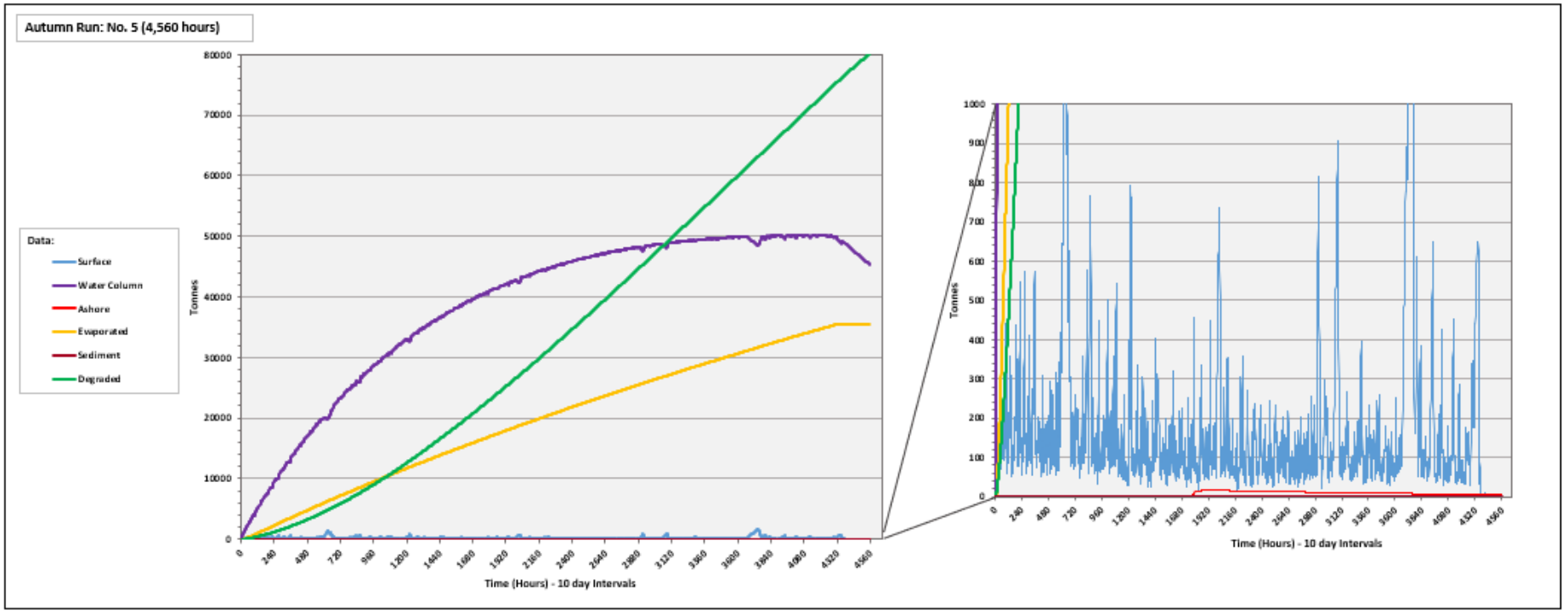



**Figure F.16: Fate of the condensate released from Autumn Run No. 5 (showing model duration 190 days)**

# F.5 Vertical Profile Modelling

## F.5.1 Background

The OILMAP Deep plume model evaluates the jet and buoyant plume of the oil and gas release near the wellhead release point. Figure F.17 presents a schematic of the various stages of a subsurface release in the water column. The OILMAP Deep blowout model estimates the radius and location of a buoyant oil and gas plume in response to the release parameters and environmental characteristics, tracking the development of the plume until the point where the integrated density of the plume matches the ambient density, through entrainment of surrounding seawater in the stratified ocean. At this depth, the plume buoyancy has decreased to an extent that the oil and gas mixture no longer rises. At this stage the blowout model outputs the locations, volumes, and droplet sizes of the released oil droplets, which then become input to the oil trajectory and fate model.

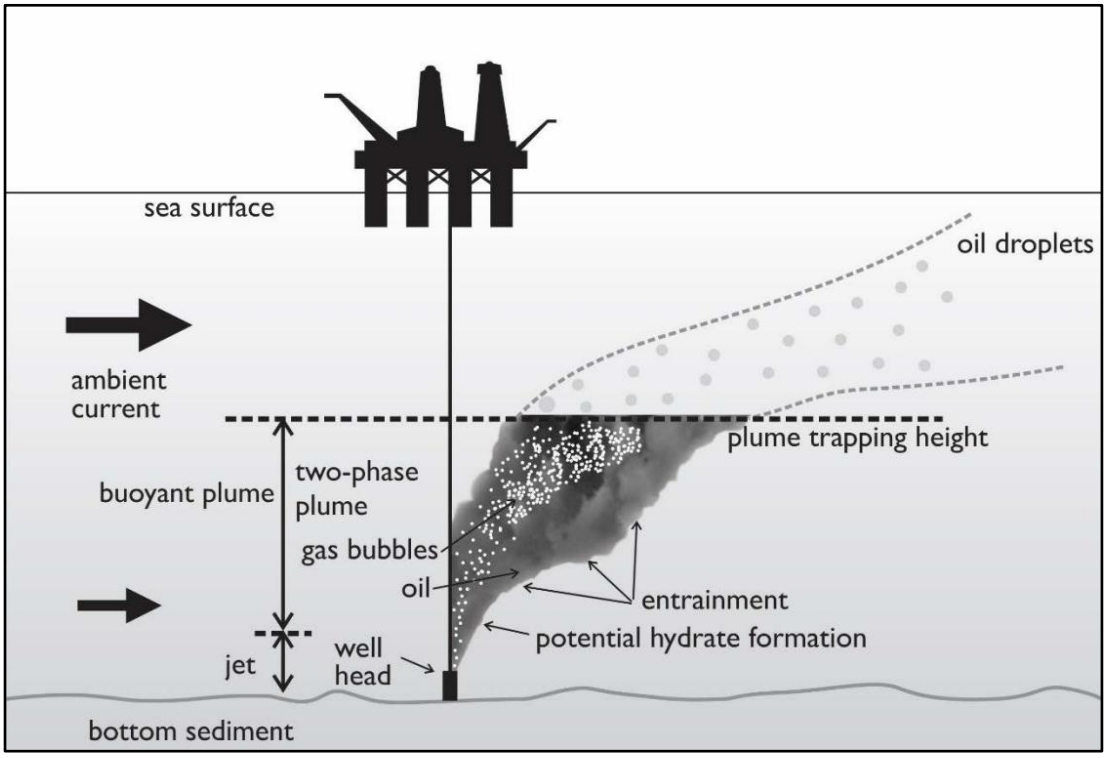



**Figure F.17: Stages of a deep-water blowout plume**

### Blowout Description

In a subsurface well blowout, discharged materials consisting of a mixture of gaseous and liquid hydrocarbons go through three phases, namely (1) momentum jet, (2) buoyant plume, and (3) oil droplets free-rise and advection-diffusion (Zheng et al., 2003), (as illustrated schematically in Figure F.17):

- **Phase 1 momentum jet:** The difference between the pressure immediately inside the well and that of the ambient water drives the discharge in a momentum jet exiting the blowout orifice. The momentum of the jet dissipates relatively quickly as it entrains surrounding water, and hence the jet zone is always confined to the immediate vicinity of the wellhead, or blowout site (typically on the order of metres, depending on the release hole size). At the blowout opening, the oil in the release is exposed to significant turbulent energy, resulting in the break-up of oil into small droplets. These droplets (typically micrometres to millimetres in diameter) are transported upward with the rising plume.
- **Phase 2 buoyant density plume:** As the discharge moves upward, the density difference between the gas bubbles (and to a lesser extent, oil droplets) in the plume and the ambient waters results in a buoyant force which drives the plume. As the plume rises, it continues to

entrain sea water, increasing the plume's density and radius, and reducing the velocity and buoyancy. The plume gas is in the form of bubbles which are subject to dissolution based on Zheng and Yapa (2002) which serves to reduce the buoyancy. If the ambient currents are strong enough the plume may bend as shown in Figure F.17. Gas bubbles may also separate from the plume if their rise speeds exceed the plume's rise rate. The oil droplets continue to be transported upwards with the plume, but their individual rise velocities contribute little to their upward motion.

- **Phase 3: oil droplets free-rise and advection-diffusion:** When the plume reaches the sea surface or its termination or trap height (all plume buoyancy is lost), it can be deflected in a radial pattern, within a horizontal flow zone, without appreciable loss of momentum. This radial flow carries the oil particles rapidly away from the centre of the plume, while the velocity and oil concentrations in this flow zone decrease with distance from the plume centreline of the release. Subsequently, oil particles ascend to the surface solely driven by their own buoyancy. Rise velocities of oil droplets are much slower than the velocity of a buoyant gas-liquid plume, resulting in particle transport that may take considerably longer to reach the surface and moving further (horizontally) from the release site because of ambient currents.

Of the three phases described above, the OILMAP Deep plume model simulates only Phase 2, the buoyancy driven portion. The assumption is that Phase 1, the momentum jet, is very limited in distance from the release (a few times the diameter of the discharge hole) and hence relatively insignificant in the prediction of the overall plume development and the trap height. Phase 3, the passive oil droplet transport and fate, is simulated using the OILMAP Trajectory and Fates model (far-field oil particle transport and fates).

In deeper water (>200 m) the basic dynamics of the oil-gas jet-plume become more complicated, principally due to the increase in hydrostatic pressure at the seabed which leads to the possibility of rapid gas dissolution and formation of gas hydrate solids. The behaviour of gas is altered significantly in the higher pressures associated with deep water. In addition, the solubility of the gas in water is also affected by the ambient pressure, temperature, and salinity. In the deeper waters, the gas dissolution rate may exceed the expansion rate of the gas bubbles, in which case there is a potential for a significant portion of the gas to dissolve as the plume rises, decreasing the buoyancy forces driving the plume upwards.

## F.5.2 Blowout Plume

The key inputs for the OILMAP Deep near-field model include the well release rate, GOR, diameter of release hole, and a vertical profile of water temperature and density. For the Tornado W3 blowout scenario, the GOR was 9,894.08 $m^3/m^3$ and the diameter of release hole was 12-inches.

The near-field modelling results provide a description of the plume characteristics, including the plume location (namely plume trap height), plume geometry (plume radius), and the release droplet size distribution. The results of the near-field model are then used to provide the initial conditions for the stochastic and deterministic far-field modelling in OILMAP Trajectory and Fates model, including:

- Termination height (trap height) of the plume;
- Diameter of the plume; and
- Oil droplet size distribution.

Table F.9 presents a summary of the OILMAP Deep plume modelling results the Tornado W3 well blowout scenario by season. There is very little variation in plume formation and behaviour as well as oil droplet formation between seasons.

**Table F.9: Predicted blowout plume characteristics for the Tornado W3 well blowout scenario by season**

| Season | Plume Trap Height Day 1 (height above the wellhead) | Plume Trap Height Day 180 (height above the wellhead) | Time to reach Plume Trap Height | Maximum Plume Radius at Trap Height | Maximum Oil Plume Concentration Note 2 | Maximum Dissolved Methane Concentration Note 3 | Oil Droplet Size (µm) Note 1 (free-rise and advection-diffusion) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Minimum | Maximum | Median |
| Winter | 598.64 m | 539.84 m | 607 seconds | 101.32 m | 3.729 ppm | 710.790 mol/m$^3$ | 82.22 | 1,115.65 | 438.87 |
| Spring | 609.33 m | 550.53 m | 652 seconds | 153.36 m | 3.727 ppm | 712.026 mol/m$^3$ | 82.17 | 1,114.93 | 438.59 |
| Summer | 630.71 m | 561.22 m | 661 seconds | 111.33 m | 3.727 ppm | 712.156 mol/m$^3$ | 82.16 | 1,114.86 | 438.56 |
| Autumn | 609.33 m | 550.53 m | 625 seconds | 101.80 m | 3.727 ppm | 712.061 mol/m$^3$ | 82.17 | 1,114.90 | 438.57 |

Note 1: The oil droplet size distribution is in a histogram in Figure F.18.
Note 2: ppm = parts per million
Note 3: mol = moles

Figure F.18 shows the plume radius after 180 days plotted as a function of the height above the sea floor (wellhead), and plume velocity along the centreline of the blowout as a function of the height above the seafloor. The plume centreline velocity defines the vertical movement of the mixture of gas, oil, and water along the centre of the plume. The model indicates that the velocity of the plume decreases quickly at heights further from the discharge point as it entrains heavier ambient seawater. As the plume continues to rise and entrain more ambient seawater, the centreline velocity gradually decreases and approaches zero at 539.84 m (winter); 550.53 m (spring); 561.22 m (summer); 609.33 m (autumn) above the wellhead (at depths between 507.78 m – 529.16 m below the water surface). From this termination (trap) height, gas and oil droplets will ascend to the water surface under free rise velocities determined by Stokes' law. The plume is expected to reach a maximum radius of 153.36 m during spring (refer to Table F.9 and Figure F.18).

The near-field modelling results also provide a characterisation of the oil droplet size distribution generated by the blowout. This distribution has a profound effect on how oil is transported after the initial plume, as the droplet size dictates how long the oil droplet will remain suspended in the water column.

shows the model-estimated droplet size distribution. The minimum, maximum and median oil droplet sizes are presented in Table F.9. Oil droplet sizes >1,000 µm account for 1.8 % of the Tornado W3 spill volume, these droplet sizes are associated with low energy and will rise fastest to the sea surface. Oil droplet sizes >200 µm and ≤1,000 µm account for 85.1% of the Tornado W3 spill volume, these droplet sizes are associated with an intermediate turbulent energy and rise slowly in deep waters. Oil droplet sizes ≤200 µm account for 13.1% of the Tornado W3 spill volume, these droplet sizes are associated with high turbulence and rise very slowly to the sea surface. Oil droplets <70 µm do not rise to the surface and remain within the water column (Delvigne and Sweeny, 1988).

The median oil droplet size across all seasons modelled was circa. 439 µm; a droplet this size was found to surface within 10 – 11 hours.

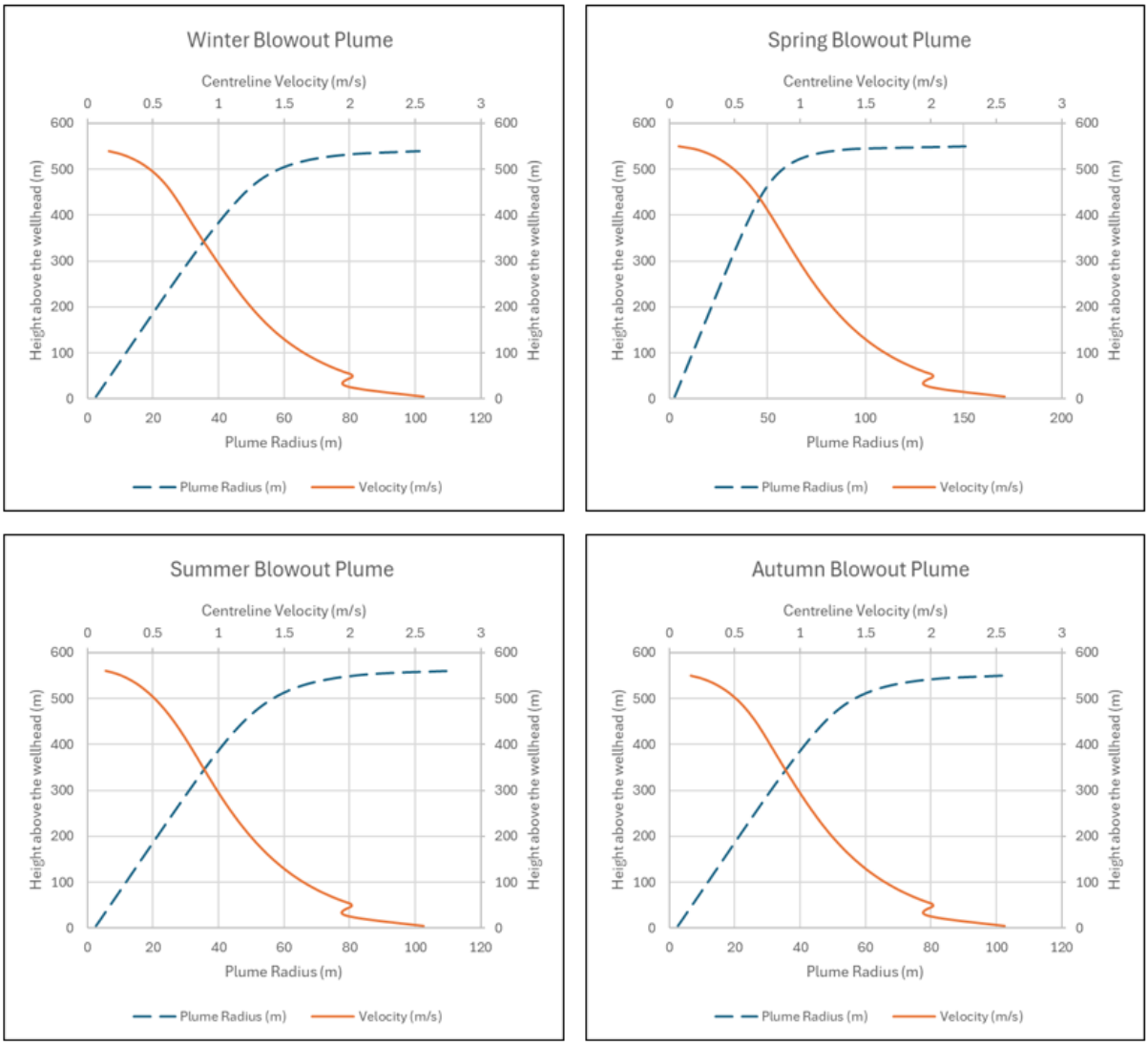



**Figure F.18: Predicted blowout plume centreline velocity and plume radius after 180 days versus elevation above the release point for the Tornado W3 well blowout scenario by season**

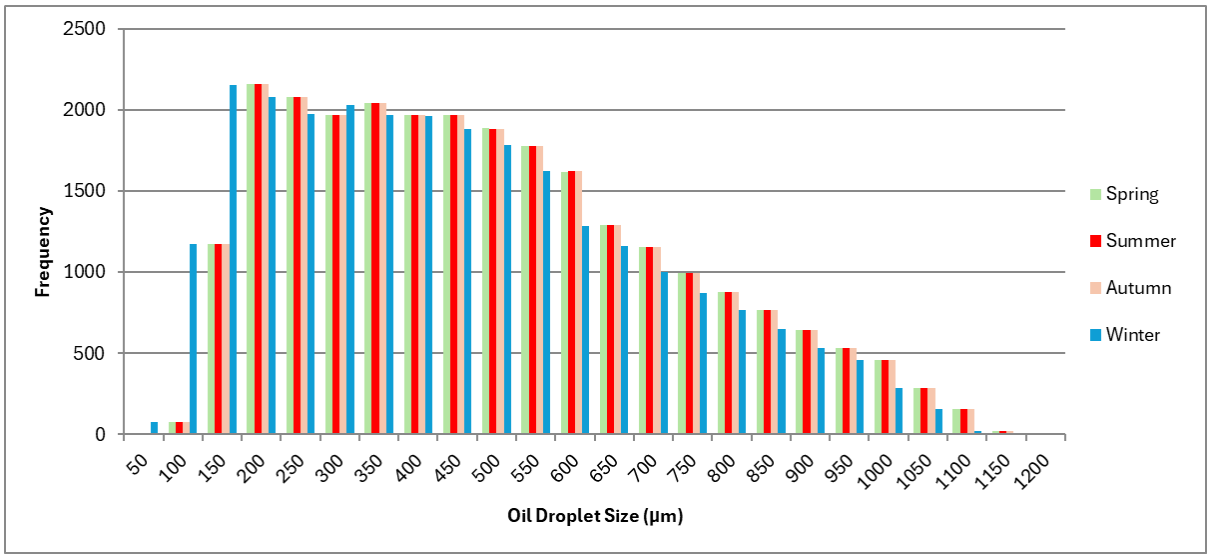



**Figure F.19: Oil Droplet Size Distribution**

### F.5.3 Oil Droplets in the Water Column

Of the trajectory modelling detailed in Section F.4, the Summer Trajectory Run No. 30 was identified as having the minimum time for surface oiling to occur (after 10 hrs, refer to Table F.8). Therefore, the Summer Trajectory Run No. 30 has been selected to show the far-field oil particle transport and fates in the vertical water column, refer to Figure F.20 and Figure F.21.

The vertical profile in Figure F.20 shows the oil droplets leaving a plume trap (630.71 m above the release location) after the first 10 hours of spill duration.

The vertical profile in Figure F.21 shows the swept area of oil droplets after a model duration of 4,560 hours. Figure F.21 demonstrates the extent of the horizontal flow zone which has been driven by the ambient currents of the upper Faroe-Shetland slope current that generally flows towards the north-east (towards Norway) all year round.

The oil droplets released from the plume trap height rise towards the sea surface with no droplets sinking or recorded in the sediment after 4,560 hours model duration.

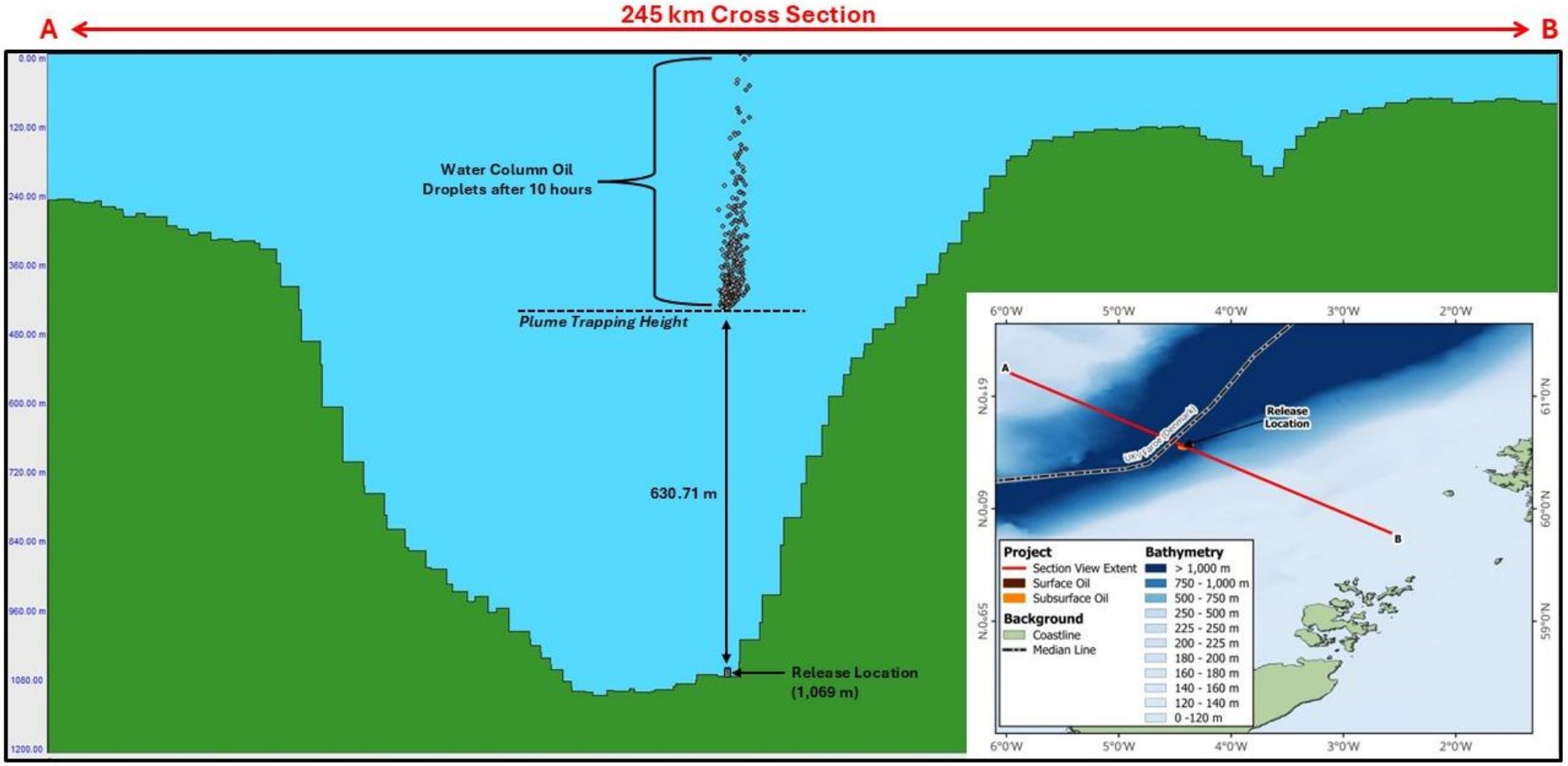



**Figure F.20: Section View of 'oil droplet free-rise & advection-diffusion' for Summer Trajectory Run No. 30 after 10 hrs Spill Duration**

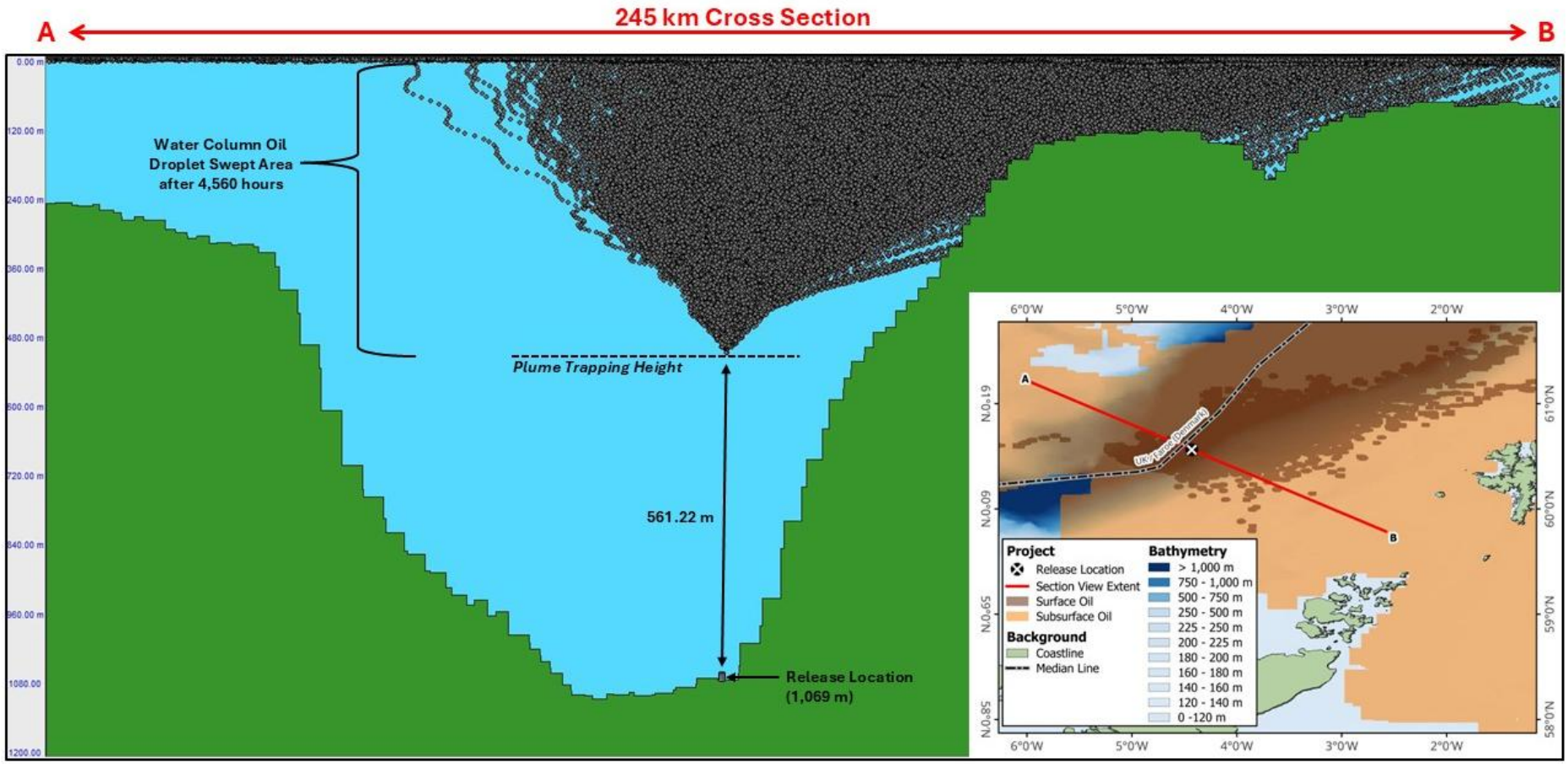



**Figure F.21: Section View of 'oil droplet free-rise & advection-diffusion' Swept Area for Summer Trajectory Run No. 30 after 4,560 hrs Model Duration**

# F.6 Model Input Data

## F.6.1 Metocean Data

### Current and Tidal Data

To capture the complex nature of the regional and coastal circulation for the areas near to the UK, two different current datasets are provided which can be combined to simulate an oil spill (refer to Table F.10):

- A regional dataset (HYDROMAP) that captures the general mesoscale circulation (HYCOM);
- A higher resolution dataset developed by RPS to capture the tidal circulation important in the coastal areas.

**Table F.10: Current dataset details used for the modelling**

| Parameter | Global | Regional tidal |
|---|---|---|
| Name of Dataset | HYCOM (GLBy0.08/expt_93.0) | HYDROMAP |
| Owner/Provider | Naval Research Laboratory (USA) | RPS |
| Bathymetry | GEBCO | GEBCO |
| Wind Forcing | NAVGEM (USA) | No |
| Tides | No | Yes |
| Horizontal Grid Size | 0.08° x 0.04° | ~300m to 9km |
| Hindcast Period | 2019 - 2023 | Periodic tidal constituents' phase and amplitude |
| Output Frequency | Daily | 30-minute processing |

Global Current dataset – HYCOM analysis

Current data was obtained from the HYCOM + Navy Coupled Ocean Data Assimilation (NCODA) Global 1/12° analysis (Table F.10) which captures the oceanic large-scale tidal residual circulation. Details of the data assimilation procedure are described in Cummings and Smedstad (2013) and Cummings (2005). Forcing data for the model comes from the NAVy Global Environmental Model (NAVGEM). The analysis is composed of 3-D temperature, salinity, sea surface height, zonal velocity and meridional velocity fields. Ocean dynamics including geostrophic, and wind driven currents are reproduced by the model. The most recent version of the model is 'GLBu0.08/expt_19.1' which includes data from January 2019 to December 2023. However, as this version of HYCOM does not include tidal information, a separate model (HYDROMAP Tidal Model) was used to supplement HYCOM and generate tidal currents.

Tidal Currents – HYDROMAP Tidal Model

HYDROMAP, a hydrodynamic model (Table F.10) developed by RPS, was used to reproduce the local circulation due to tides around UK. It is a globally re-locatable hydrodynamic model (Isaji, et al., 2001a, 2001b) capable of simulating complex circulation patterns due to tidal forcing, wind stress, and freshwater flows. The framework used by HYDROMAP, employs a novel step-wise-continuous-variable-rectangular gridding strategy with up to six levels of resolution. The term "step-wise continuous" implies that the boundaries between successively smaller and larger grids are managed in a consistent integer step. This model has been applied in numerous sediment dispersion and transport studies in the U.S. and worldwide.

HYDROMAP can be used to make constant cyclical current fields for each component of the circulation separately. These cyclical current fields in the form of tidal ellipses are saved in CIR file. Once generated,

the CIR file can be combined with the HYCOM circulation to present a complete hydrodynamic dataset for the oil spill simulation.

### Wind Data

Wind model output were obtained from the ECMWF Reanalysis Product for a 5-year period (2019 to 2023), as described in Table F.11. The ECMWF provides the ERA5 reanalysis product that includes wind hindcast data on a global scale. The data are generated using an atmospheric model with data assimilation and distributed on a grid with 0.25° horizontal resolution. ERA5 covers the period of January 1st, 1979, to present time. Gridded data products include a large variety of surface parameters, describing atmospheric as well as ocean-wave and land-surface conditions (Dee et al., 2011).

**Table F.11: Wind dataset details used for the modelling**

| Name of Dataset | ERA5 |
|---|---|
| Coverage | -20°E to 30°E and 40°N to 72°N |
| Owner/Provider | ECMWF |
| Horizontal Grid Size | 0.25°x0.25° |
| Hindcast Period | 2019 - 2023 |
| Time Step | 6-hour |

### Temperature and Salinity Data

Figure F.22 presents a salinity and temperature plot against depth for the modelled location per season.

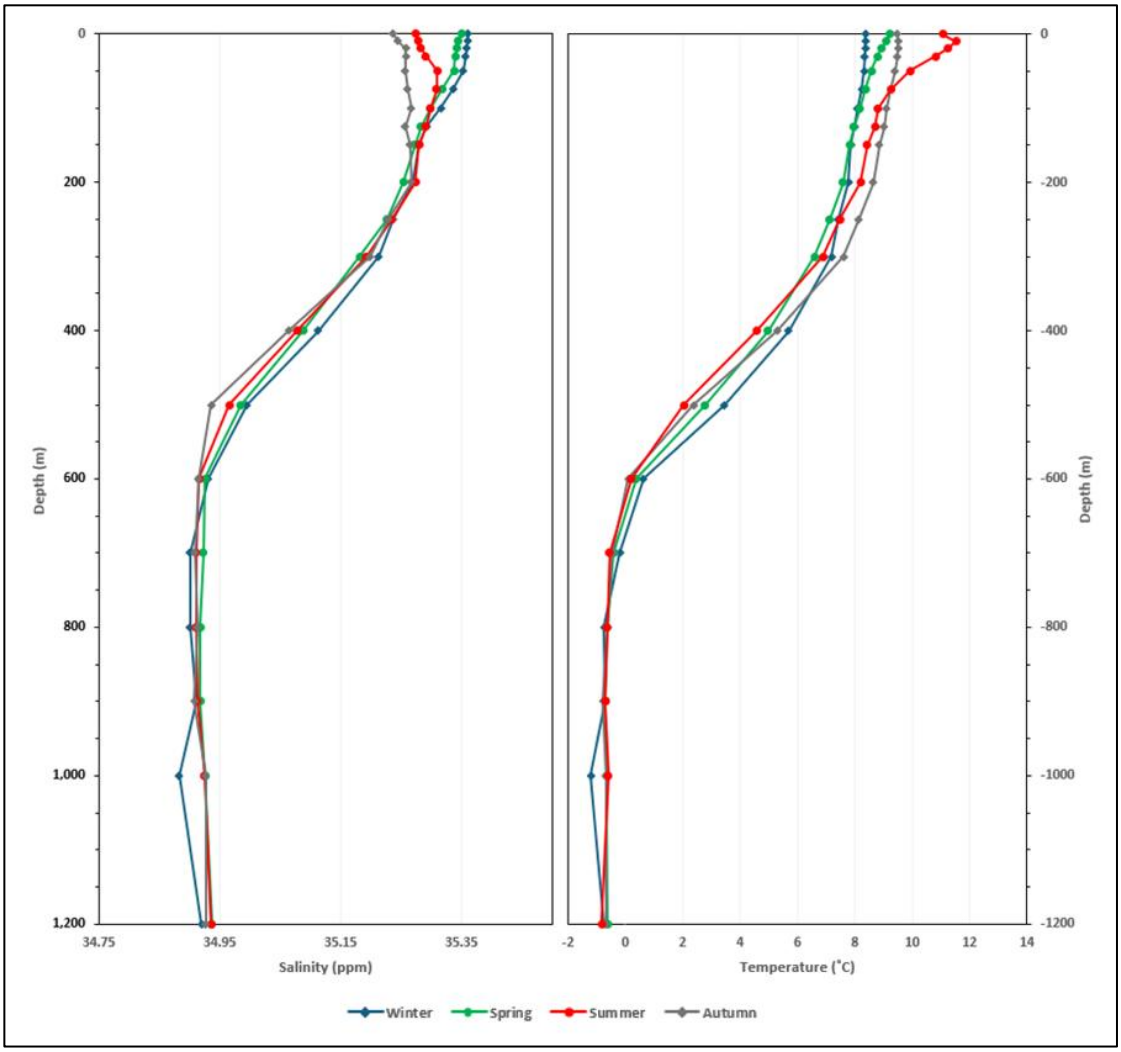



**Figure F.22: Salinity and Temperature plot against depth for each modelled season at the Tornado W3 release location**

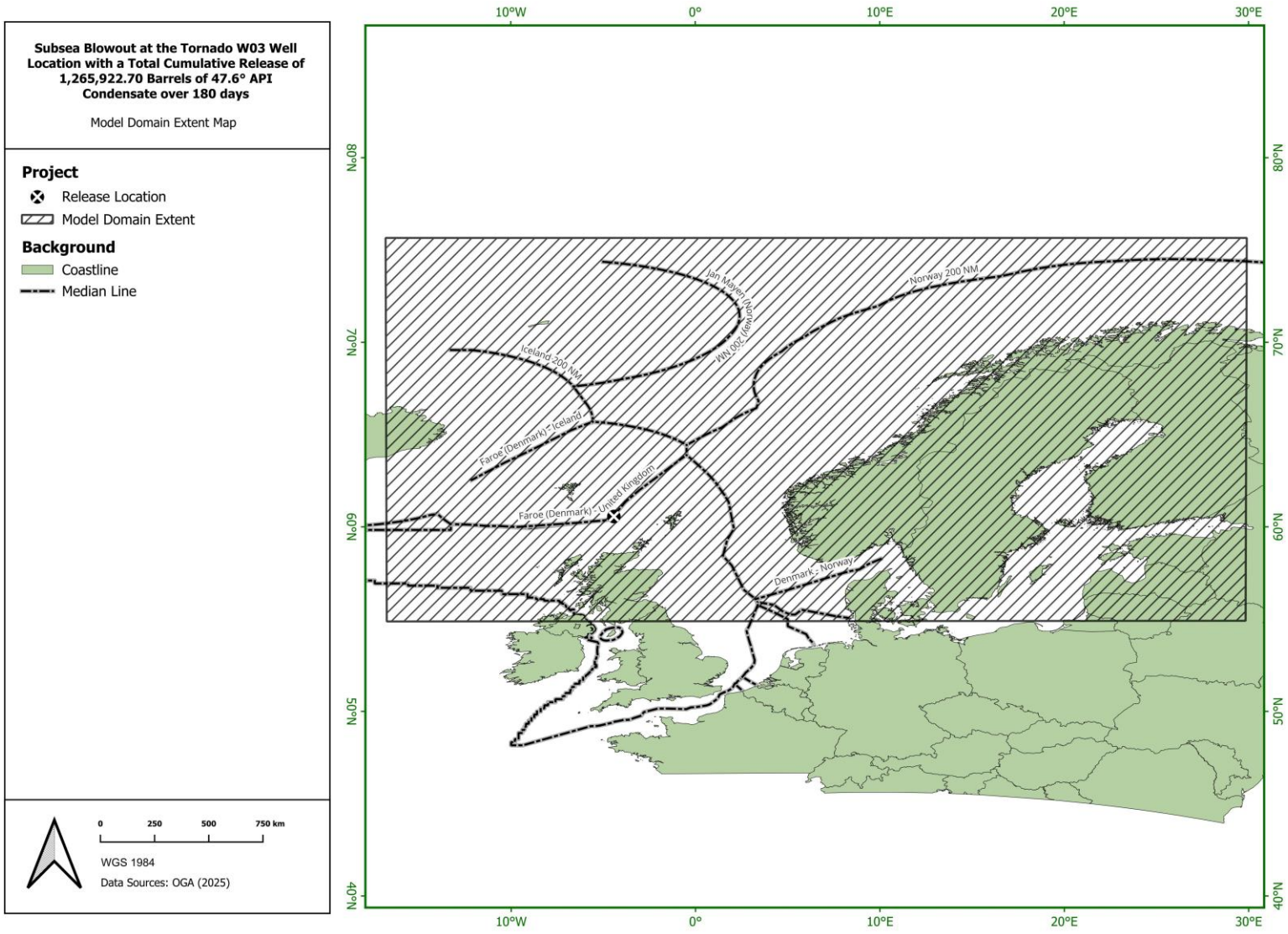
## F.6.2 Model Domain Setup

### Bathymetry

General Bathymetric Chart of the Oceans (GEBCO) ESRI ASCII files (GEBCO_2024 Grid) were retrieved from https://download.gebco.net and inputted into the OILMAP Land-Water domain grid.

The GEBCO_2024 Grid was released in July 2024. It provides global coverage of elevation data, in meters, on a 15 arc-second interval geographic grid and consists of 43200 rows x 86400 columns, giving 3,732,480,000 data points. The data values are pixel-centre registered i.e. they refer to elevations, in meters, at the centre of grid cells. The grid uses as a 'base' Version 2.6 of the SRTM15+ data set (Harper & Sandwell, 2024; Tozer et al., 2019) largely between latitudes of 50° South and 60° North. This data set is a fusion of land topography with measured and estimated seafloor topography. The SRTM15+ base grid has been augmented with the gridded bathymetric data sets developed by the four Seabed 2030 Regional Centres to produce the GEBCO_2024 Grid. The Regional Centres have compiled gridded bathymetric data sets, largely based on multibeam data, for their areas of responsibility. These regional grids were then provided to the Global Centre.

## Model Domain Extent



## F.6.3 Hydrocarbon Characteristics

The components found in crude oil are classified into two main groups: hydrocarbons and non-hydrocarbons (refer to Figure F.23). If oil is rich in C1-12 alkanes, it is particularly light, as these are lighter components than the C25+ alkanes. Conversely, if oil contains high quantities of C25+ alkanes, resins and asphaltenes, it is heavy.

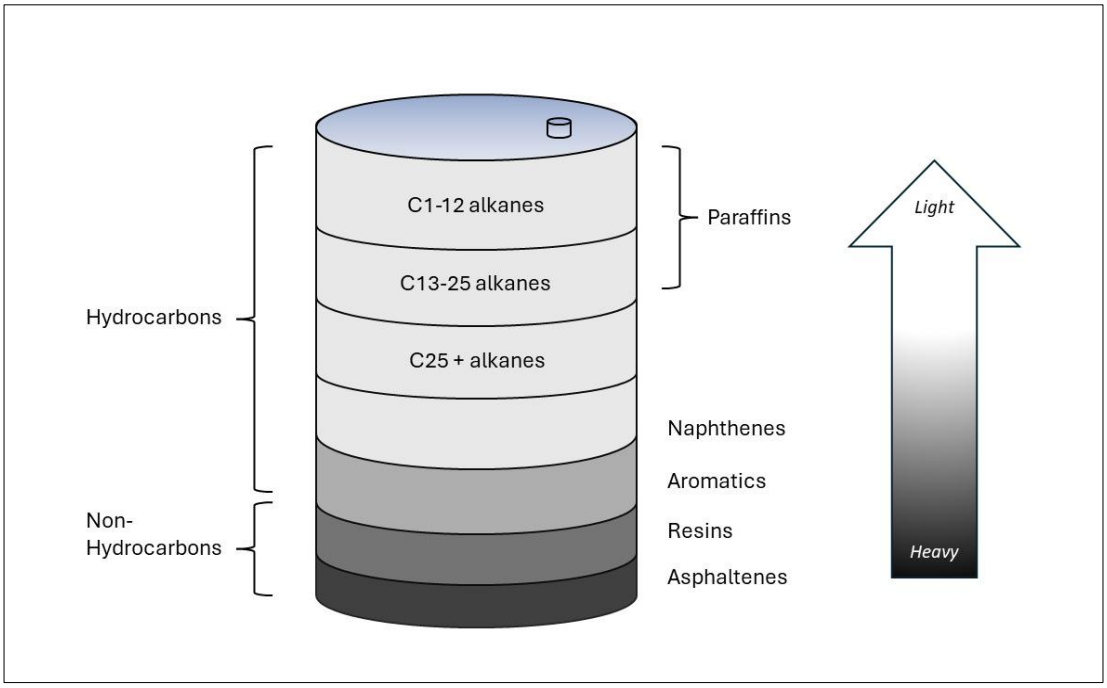



**Figure F.23: The chemical composition of oil**

The chemical composition of oil is important when predicting how it will break down or weather. For example, oil containing mostly light components is likely to lose a greater volume to evaporation than heavy oil. Oils with carbon chains exceeding 15 (C15+) cannot evaporate. Long chains (for example, C25+ alkanes) take a long time to degrade in the water column. Asphaltenes can increase the stability of oil, allowing it to take up water but preventing the oil and water emulsion from breaking down.

Ultimately, the fate of oil depends on its physico-chemical properties, which are accounted for in the in the modelling input data. OILMAP (Version 7.7) includes the most up-to-date oil database from RPS. This Master Database includes all the necessary oil property information to run the new oil spill model. The parameters stored in the oil database control the oil's spreading, evaporation, degradation and mousse formation during spill simulations. Any of the parameters can be changed and new oils can be added to the data base.

### Oil Matching and Creation

The parameters described in Table F.12 represent the minimum data required to model a specific oil using OILMAP. Note that these properties are for dead oils and condensates (i.e., without gas). OILMAP does not evaluate dissolution, and so aromatic composition data are not needed for OILMAP.

The API gravity is the most important parameter for oil creation and matching. API Gravity, like specific gravity, is a ratio between the densities of oil and water. Unlike specific gravity, API gravity is only used to describe oil, which it characterises as follows:

- Light oil: API >31.1°
- Medium oil: API between 22.3° and 31.1°
- Heavy oil: API <22.3°
- Extra heavy oil: API <10°

API Gravity is converted to Specific Gravity using the following formula:

- **API Gravity** = (141.5 / Specific Gravity) – 131.5

An API of 10° is equivalent to water, so oils with an API above 10° will float on water while oils with an API below 10° will sink.

The reliability of oil behaviour can be improved by additional data described in Table F.13. When this additional data is available its inclusion can bolster model predictive power. Asphaltene, wax and resin content are used to predict if the oil will emulsify. If the oil is known to emulsify, these data are not necessary (assumptions may be made). Although proxies can be used when data are unavailable, reliance on such proxies will necessarily introduce additional assumptions and model reliability may decrease depending on the omitted data. The properties described in Table F.13 will augment the simulation of weathering and emulsion formation.

**Table F.12: Minimum data required to run oil spill models in OILMAP**

| Property of Oil | Units | Common Range | Prediction for the Tornado Development (client supplied data) |
|---|---|---|---|
| API or Density at specified temperature | Grams per cubic centimetre ($g/cm^3$) or API | 0.7-1.1 $g/cm^3$ | Density from condensate stabilised from sample 0984-EA, recovered from gas cap found in well 204/13-1.<br>• SG = 0.7902 @ 15°C<br>• API = 47.6° |
| Dynamic viscosity at specified temperature | Centipoise (cP) | 1 – 30,000 cP | Unknown |
| Boiling Curve (True Boiling Point Distribution) | Fraction by mass or volume @ °C or °F | 0 – 0.99 | Unknown |
| Does the oil emulsify? | Yes or No | Yes or No | No |

**Table F.13: Other useful data to run oil spill models in OILMAP (to improve reliability, not mandatory)**

| Property of Oil | Units | Common Range | Prediction for the Tornado Development (client supplied data) |
|---|---|---|---|
| A second Density at a second specified temperature | $g/cm^3$ or API | 0.7-1.1 $g/cm^3$ | Unknown |
| A second Viscosity at a second specified temperature | Centipoise (cP) | 1 – 30,000 cP | Unknown |
| Maximum Water Content of emulsions | Percentage | 0 – 80% | Oil not expected to form emulsions.<br>• 0 % |
| Interfacial Tension (IFT): oil-brine and/or oil-fresh water | Dynes (mN/m) | 0 – 50 | Unknown |
| Pour Point | °C | -63 – >5 °C (semi-solid) | Based on the Andrew reservoir, Abigail Field – chosen for similar density 46 °API<br>• -24°C |

| Property of Oil | Units | Common Range | Prediction for the Tornado Development (client supplied data) |
|---|---|---|---|
| Asphaltene content | Concentration percentage | 0 – 25 % | Based on the Andrew reservoir, Abigail Field – chosen for similar density 46 °API:<br>• 0.2 % |
| Resin Content | Concentration percentage | 0 – 25 % | Unknown |
| Wax Content | Concentration percentage | 0 – 12 % | Based on the Andrew reservoir, Abigail Field – chosen for similar density 46 °API:<br>• 1 % |

The main physical properties that affect the behaviour and the persistence of an oil spilled at sea are specific gravity / API, distillation characteristics, vapour pressure, viscosity and pour point. All are dependent on chemical composition, such as the proportion of volatile components and the content of asphaltenes, resins and waxes. Of note, oil emulsification will generally only take place if the asphaltene content is greater than 0.5 %. Importantly, the formation of water-in-oil emulsions reduces the rate of weathering processes and is the main reason for the persistence of light and medium oils on the sea surface and shoreline.

The hydrocarbon properties expected from the proposed Tornado Development are anticipated to resemble a ITOPF Group 1 condensate that does not form a stable emulsion. This is based on the density (0.7902 g/cm$^3$ @ 15°C) / API (47.6°) of condensate recovered and sampled from the gas cap found in the nearby well 204/13-1 (sample: 0984-EA). In addition, the Tornado condensate pour point, wax and asphaltene content are anticipated to resemble the Andrew reservoir in the Abigail Field, based on a similar API (46°).

The 'Wonnich' analogue has been selected as a suitable proxy oil for the proposed Tornado Development because it is compositionally a non-emulsifying condensate oil (refer to Table F.14 for the key properties). For the purposes of the Tornado oil spill modelling study, the analogue has been amended where data is available (refer to Table F.12 and Table F.13) to fine tune the API gravity / density, pour point, asphaltene and wax content parameters. The amended analogue is shown in Table F.14.

**Table F.14: Key properties for the 'Wonnich' proxy oil analogue**

| Oil Name (Analogue) | API Gravity | Density | Oil-Seawater Interfacial Tension | Viscosity 1 | Viscosity 2 | Pour Point | Percent water when fully emulsified as mousse | Oil Stability Class (emulsion) | Distillation Data (fraction) | | | | Aromatics Content | Asphaltene Content | Resin Content | Wax Content |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Boiling Points: < 180°C | Boiling Points: 180°C – 264°C | Boiling Points: 265°C - 380°C | Distillation Sum | | | | |
| Wonnich (ITOPF Group 1) | 50.2 | 0.7813 g/cm³ @ 13°C | 31.2 dyne / cm | 0.7799 99971 cP @ 13°C | 0.62 cP @ 20°C | No Data | 0 % | Un-Stable | Total Hydrocarbon = 0.2032147 | Total Hydrocarbon = 0.0495055 | Total Hydrocarbon = 0.0246679 | 0.2773 88126 | No Data | No Data | No Data | No Data |
| Amended Analogue for the W3 Tornado Development Well (ITOPF Group 1) | 47.6 | 0.7902 g/cm³ @ 15°C | 31.2 dyne / cm | 0.7799 99971 cP @ 13°C | 0.62 cP @ 20°C | -24°C | 0 % | Un-Stable | Total Hydrocarbon = 0.2032147 | Total Hydrocarbon = 0.0495055 | Total Hydrocarbon = 0.0246679 | 0.2773 88126 | No Data | 0.2 % | No Data | 1 % |

Note 1: Amended oil analogue properties in red.

## F.6.4 Declining Flow Rate

Figure F.24 shows the high case open hole flow rate from the Tornado W3 well for 180 days. The worst-case condensate flow rate starts at 10,967 bbls / day on day 1 of the spill scenario and declines to 5,175 bbls / day after 180 days. The cumulative release of condensate after 180 days is 1,265,922.7 bbls.

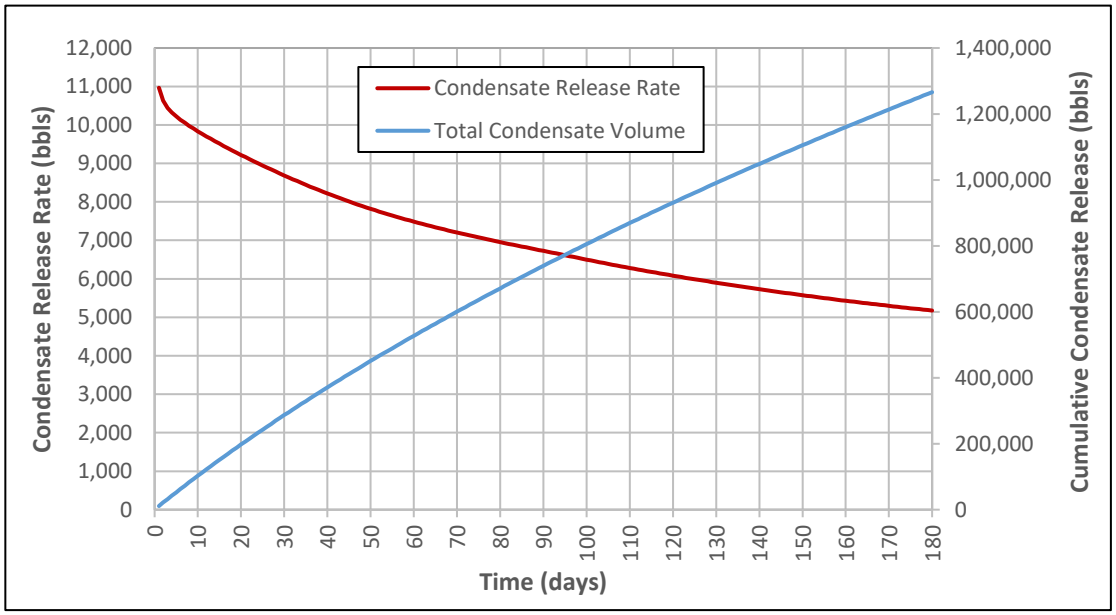



**Figure F.24: Declining flow rate for the W3 well (Reservoir Case = High) (180 days)**

**Table F.15: Variable Flow Rate (VFL file) Model Input Data**

| Time (hours) | Declining flow rate for the W3 well (Reservoir Case = High) (180 days) |
|---|---|
| | bbls |
| 0.00 | 10,966.7 |
| 24.00 | 10,635.2 |
| 48.00 | 10,437.8 |
| 72.00 | 10,322.8 |
| 96.00 | 10,223.9 |
| 120.00 | 10,135.6 |
| 144.00 | 10,054.2 |
| 168.00 | 9,977.8 |
| 192.00 | 9,905.1 |
| 216.00 | 9,835.4 |
| 240.00 | 9,768.1 |
| 264.00 | 9,702.7 |
| 288.00 | 9,638.6 |
| 312.00 | 9,576.0 |
| 336.00 | 9,514.4 |
| 360.00 | 9,454.0 |
| 384.00 | 9,394.6 |
| 408.00 | 9,336.0 |
| 432.00 | 9,278.4 |
| 456.00 | 9,221.4 |
| 480.00 | 9,165.3 |

| Time (hours) | Declining flow rate for the W3 well (Reservoir Case = High) (180 days) |
|---|---|
| | bbls |
| 504.00 | 9,109.8 |
| 528.00 | 9,054.9 |
| 552.00 | 9,000.6 |
| 576.00 | 8,947.0 |
| 600.00 | 8,893.9 |
| 624.00 | 8,841.4 |
| 648.00 | 8,789.5 |
| 672.00 | 8,738.3 |
| 696.00 | 8,687.7 |
| 720.00 | 8,637.7 |
| 744.00 | 8,588.3 |
| 768.00 | 8,539.4 |
| 792.00 | 8,491.3 |
| 816.00 | 8,444.0 |
| 840.00 | 8,397.5 |
| 864.00 | 8,351.7 |
| 888.00 | 8,306.4 |
| 912.00 | 8,261.7 |
| 936.00 | 8,217.7 |
| 960.00 | 8,174.4 |
| 984.00 | 8,132.0 |
| 1008.00 | 8,090.6 |
| 1032.00 | 8,049.9 |
| 1056.00 | 8,009.8 |
| 1080.00 | 7,970.4 |
| 1104.00 | 7,931.5 |
| 1128.00 | 7,893.3 |
| 1152.00 | 7,855.8 |
| 1176.00 | 7,819.1 |
| 1200.00 | 7,783.0 |
| 1224.00 | 7,747.7 |
| 1248.00 | 7,713.2 |
| 1272.00 | 7,679.3 |
| 1296.00 | 7,645.9 |
| 1320.00 | 7,613.1 |
| 1344.00 | 7,580.8 |
| 1368.00 | 7,549.0 |
| 1392.00 | 7,517.8 |
| 1416.00 | 7,487.0 |
| 1440.00 | 7,456.7 |
| 1464.00 | 7,426.9 |
| 1488.00 | 7,397.7 |
| 1512.00 | 7,368.9 |

| Time (hours) | Declining flow rate for the W3 well (Reservoir Case = High) (180 days) |
|---|---|
| | bbls |
| 1536.00 | 7,340.6 |
| 1560.00 | 7,312.6 |
| 1584.00 | 7,284.9 |
| 1608.00 | 7,257.6 |
| 1632.00 | 7,230.7 |
| 1656.00 | 7,204.1 |
| 1680.00 | 7,177.8 |
| 1704.00 | 7,151.9 |
| 1728.00 | 7,126.3 |
| 1752.00 | 7,100.9 |
| 1776.00 | 7,075.8 |
| 1800.00 | 7,051.0 |
| 1824.00 | 7,026.6 |
| 1848.00 | 7,002.5 |
| 1872.00 | 6,978.7 |
| 1896.00 | 6,955.0 |
| 1920.00 | 6,931.6 |
| 1944.00 | 6,908.4 |
| 1968.00 | 6,885.4 |
| 1992.00 | 6,862.6 |
| 2016.00 | 6,840.0 |
| 2040.00 | 6,817.5 |
| 2064.00 | 6,794.9 |
| 2088.00 | 6,772.4 |
| 2112.00 | 6,749.9 |
| 2136.00 | 6,727.3 |
| 2160.00 | 6,704.5 |
| 2184.00 | 6,681.7 |
| 2208.00 | 6,658.9 |
| 2232.00 | 6,636.2 |
| 2256.00 | 6,613.5 |
| 2280.00 | 6,590.9 |
| 2304.00 | 6,568.3 |
| 2328.00 | 6,545.6 |
| 2352.00 | 6,523.0 |
| 2376.00 | 6,500.3 |
| 2400.00 | 6,477.7 |
| 2424.00 | 6,455.2 |
| 2448.00 | 6,432.9 |
| 2472.00 | 6,410.8 |
| 2496.00 | 6,388.8 |
| 2520.00 | 6,367.0 |
| 2544.00 | 6,345.4 |

| Time (hours) | Declining flow rate for the W3 well (Reservoir Case = High) (180 days) |
|---|---|
| | bbls |
| 2568.00 | 6,323.9 |
| 2592.00 | 6,302.7 |
| 2616.00 | 6,281.8 |
| 2640.00 | 6,261.0 |
| 2664.00 | 6,240.4 |
| 2688.00 | 6,220.0 |
| 2712.00 | 6,199.8 |
| 2736.00 | 6,179.8 |
| 2760.00 | 6,159.9 |
| 2784.00 | 6,140.2 |
| 2808.00 | 6,120.8 |
| 2832.00 | 6,101.5 |
| 2856.00 | 6,082.3 |
| 2880.00 | 6,063.4 |
| 2904.00 | 6,044.6 |
| 2928.00 | 6,026.1 |
| 2952.00 | 6,007.6 |
| 2976.00 | 5,989.4 |
| 3000.00 | 5,971.3 |
| 3024.00 | 5,953.3 |
| 3048.00 | 5,935.4 |
| 3072.00 | 5,917.7 |
| 3096.00 | 5,900.1 |
| 3120.00 | 5,882.6 |
| 3144.00 | 5,865.2 |
| 3168.00 | 5,848.0 |
| 3192.00 | 5,830.9 |
| 3216.00 | 5,813.9 |
| 3240.00 | 5,797.1 |
| 3264.00 | 5,780.4 |
| 3288.00 | 5,763.8 |
| 3312.00 | 5,747.3 |
| 3336.00 | 5,730.9 |
| 3360.00 | 5,714.7 |
| 3384.00 | 5,698.5 |
| 3408.00 | 5,682.5 |
| 3432.00 | 5,666.6 |
| 3456.00 | 5,650.8 |
| 3480.00 | 5,635.1 |
| 3504.00 | 5,619.6 |
| 3528.00 | 5,604.2 |
| 3552.00 | 5,589.0 |
| 3576.00 | 5,573.8 |

| Time (hours) | Declining flow rate for the W3 well (Reservoir Case = High) (180 days) |
|---|---|
| | bbls |
| 3600.00 | 5,558.8 |
| 3624.00 | 5,544.0 |
| 3648.00 | 5,529.2 |
| 3672.00 | 5,514.6 |
| 3696.00 | 5,500.2 |
| 3720.00 | 5,485.8 |
| 3744.00 | 5,471.6 |
| 3768.00 | 5,457.6 |
| 3792.00 | 5,443.6 |
| 3816.00 | 5,429.9 |
| 3840.00 | 5,416.2 |
| 3864.00 | 5,402.7 |
| 3888.00 | 5,389.2 |
| 3912.00 | 5,375.9 |
| 3936.00 | 5,362.7 |
| 3960.00 | 5,349.7 |
| 3984.00 | 5,336.7 |
| 4008.00 | 5,323.8 |
| 4032.00 | 5,311.0 |
| 4056.00 | 5,298.2 |
| 4080.00 | 5,285.6 |
| 4104.00 | 5,273.0 |
| 4128.00 | 5,260.5 |
| 4152.00 | 5,248.1 |
| 4176.00 | 5,235.7 |
| 4200.00 | 5,223.4 |
| 4224.00 | 5,211.2 |
| 4248.00 | 5,199.0 |
| 4272.00 | 5,186.8 |
| 4296.00 | 5,174.8 |
| 4320.00 | 0.0 |
| ***Cumulative Condensate Release:*** | **1,265,922.7** |

# Appendix G: Tornado Production Profiles

The appendix presents the range of potential reserve volumes for Tornado (gas, oil and water production profile figures) as follows:

- Table G.1 (Max case – based on a three well development scenario)
- Table G.2 (High case - based on a two well development scenario)
- Table G.3 (Mid case - based on a two well development scenario)
- Table G.4 (Low case - based on a two well development scenario)

**Table G.1: Tornado Gas, Oil and Water Production Volumes, Max case [1,2]**

| Year | Oil (tonnes/d) | Oil ($m^3$/d) | Oil (bbl/d) | Gas ($m^3$/d) | Gas (MMscf/d) | Water ($m^3$/day) | Water (bbl/d) |
|---|---|---|---|---|---|---|---|
| 2029 | 212.4 | 268.8 | 1,691 | 2,498,089 | 88 | 0.001 | 0.0 |
| 2030 | 619.1 | 783.4 | 4,928 | 9,462,562 | 334 | 0.016 | 0.1 |
| 2031 | 315.7 | 399.5 | 2,513 | 7,678,067 | 271 | 0.027 | 0.2 |
| 2032 | 187.4 | 237.2 | 1,492 | 6,159,804 | 218 | 0.030 | 0.2 |
| 2033 | 112.7 | 142.7 | 897 | 4,906,120 | 173 | 0.030 | 0.2 |
| 2034 | 67.3 | 85.2 | 536 | 3,897,193 | 138 | 0.030 | 0.2 |
| 2035 | 44.5 | 56.3 | 354 | 3,042,199 | 107 | 0.028 | 0.2 |
| 2036 | 23.6 | 29.9 | 188 | 1,697,376 | 60 | 0.018 | 0.1 |

[1] Reflects the highest anticipated volume of hydrocarbon production from a three production well scenario (at least P10). Max case hydrocarbon profile is based on an contingency accelerated production scenario where additional capacity ullage is made available (subject to commercial negotiations) in the GLA flowline system, and the Tornado project can maximise production rates to fill the available ullage by drilling and producing from a third well at Tornado. The availability of ullage to support the Max case is uncertain at this time but has been included as a basis for the EIA as it represents the worst-case scenario in terms of total production volume, and resulting in emissions, albeit at a lower GHG intensity than all other cases.

[2] Production values presented in this table have been rounded up. All calculations in Appendix H were undertaken using the original unrounded data. Reproduction of calculations using the rounded figures in the above table may therefore result in minor discrepancies.

**Table G.2: Tornado Gas, Oil and Water Production Volumes, High case [1,2]**

| Year | Oil (tonnes/d) | Oil ($m^3$/d) | Oil (bbl/d) | Gas ($m^3$/d) | Gas (MMscf/d) | Water ($m^3$/day) | Water (bbl/d) |
|---|---|---|---|---|---|---|---|
| 2029 | 92.2 | 116.7 | 734 | 1,046,560 | 37 | 2.6 | 16 |
| 2030 | 416.6 | 527.2 | 3,316 | 5,380,201 | 190 | 16.9 | 106 |
| 2031 | 321.8 | 407.3 | 2,562 | 5,380,201 | 190 | 16.9 | 106 |
| 2032 | 230.8 | 292.1 | 1,837 | 5,291,241 | 187 | 16.6 | 105 |
| 2033 | 163.5 | 206.9 | 1,302 | 4,622,390 | 163 | 14.6 | 92 |
| 2034 | 114.5 | 144.9 | 912 | 3,938,618 | 139 | 12.4 | 78 |
| 2035 | 81.2 | 102.7 | 646 | 3,347,566 | 118 | 10.6 | 66 |
| 2036 | 57.7 | 73.0 | 459 | 2,846,018 | 101 | 9.0 | 57 |
| 2027 | 40.1 | 50.7 | 319 | 2,375,222 | 84 | 7.5 | 47 |
| 2038 | 7.8 | 9.9 | 62 | 513,676 | 18 | 2.6 | 16 |

[1] High Case - Reflects the high estimate anticipated volume of hydrocarbon production from a two production well scenario (at least P10).

[2] Production values presented in this table have been rounded up. All calculations in Appendix H were undertaken using the original unrounded data. Reproduction of calculations using the rounded figures in the above table may therefore result in minor discrepancies.

**Table G.3: Tornado Gas, Oil and Water Production Volumes, Mid case [1,2]**

| Year | Oil (tonnes/d) | Oil ($m^3$/d) | Oil (bbl/d) | Gas ($m^3$/d) | Gas (MMscf/d) | Water ($m^3$/day) | Water (bbl/d) |
|---|---|---|---|---|---|---|---|
| 2029 | 88.9 | 112.5 | 708 | 1,022,510 | 36 | 2.5 | 16 |
| 2030 | 373.1 | 472.2 | 2,970 | 5,097,033 | 180 | 15.2 | 95 |
| 2031 | 260.8 | 330.0 | 2,076 | 5,050,302 | 178 | 15.0 | 95 |
| 2032 | 167.3 | 211.7 | 1,331 | 4,394,762 | 155 | 13.1 | 83 |
| 2033 | 111.6 | 141.2 | 888 | 3,661,473 | 129 | 10.9 | 69 |
| 2034 | 74.9 | 94.8 | 596 | 3,038,649 | 107 | 9.1 | 57 |
| 2035 | 50.3 | 63.7 | 400 | 2,505,770 | 88 | 7.5 | 47 |
| 2036 | 23.9 | 30.2 | 190 | 1,419,867 | 50 | 5.6 | 35 |

[1] Mid Case - Reflects the best estimated volume of hydrocarbon production from a two production well scenario.
[2] Production values presented in this table have been rounded up. All calculations in Appendix H were undertaken using the original unrounded data. Reproduction of calculations using the rounded figures in the above table may therefore result in minor discrepancies.

**Table G.4: Tornado Gas, Oil and Water Production Volumes, Low case [1,2]**

| Year | Oil (tonnes/d) | Oil ($m^3$/d) | Oil (bbl/d) | Gas ($m^3$/d) | Gas (MMscf/d) | Water ($m^3$/day) | Water (bbl/d) |
|---|---|---|---|---|---|---|---|
| 2029 | 85.1 | 107.7 | 678 | 998,460 | 35 | 2.4 | 15 |
| 2030 | 319.4 | 404.2 | 2,542 | 4,813,683 | 170 | 13.6 | 85 |
| 2031 | 184.0 | 232.9 | 1,465 | 4,315,328 | 152 | 12.2 | 77 |
| 2032 | 111.2 | 140.7 | 885 | 3,454,842 | 122 | 9.8 | 61 |
| 2033 | 67.0 | 84.8 | 534 | 2,725,761 | 96 | 7.7 | 49 |
| 2034 | 38.2 | 48.3 | 304 | 2,009,941 | 71 | 5.9 | 37 |

[1] Low Case - Reflects the low estimate anticipated volume of hydrocarbon production from a two production well scenario (at least P90).
[2] Production values presented in this table have been rounded up. All calculations in Appendix H were undertaken using the original unrounded data. Reproduction of calculations using the rounded figures in the above table may therefore result in minor discrepancies.

# Appendix H: Quantification of GHG Emissions

## H.1 Introduction

This appendix sets out the methodology used to calculate the quantity of GHG emissions estimated to be generated from the proposed Tornado Development over the life of the field and supports the assessment documented in Section 9 (GHG Emissions) of the ES.

## H.2 Direct GHG Emissions

### H.2.1 Scope 1 Emissions (Processing of Tornado Hydrocarbons)

Once Tornado is online, Tornado production fluids will be processed onshore at the SGP. Incremental GHG emissions will be generated at the SGP, arising from the power generation requirements to treat the Tornado hydrocarbons (fuel gas is used to power the compressors) and from flaring, collectively referred to as Fuel & Flare (F&F).

#### Calculation Methodology

The following equations have been used to calculate the incremental GHG emissions generated at the SGP as a result of Tornado coming online:

1. $GHG\ Emissions_{FUEL} = Fuel\ Gas\ to\ power\ GTG_{(TONNES)} \times GHG\ Conversion\ Factor$
2. $GHG\ Emissions_{FLARE} = Volume\ of\ Gas\ Flared_{(TONNES)} \times GHG\ Conversion\ Factor$

*Therefore*,

$$Total\ GHG\ Emissions = GHG\ Emissions_{FUEL} + GHG\ Emissions_{FLARE}$$

Table H.1 lists the GHG conversion factors which have been used to calculate GHG emissions generated from fuel gas used to power the Gas Turbine Generators (GTG) and from flaring (non-routine) at the SGP.

**Table H.1: GHG Conversion Factors for Fuel Use and Flaring at the SGP (EEMS, 2008)**

| Emission Factor Source | SGP Activity | GHG Conversion Factors (tonnes) | | | |
|---|---|---|---|---|---|
| | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| 'Gas Consumption Plant' (EEMS, 2008) | Fuel Gas (GTG) | 2.86 | 0.00022 | 0.00092 | Note [1] |
| 'Natural Gas Flaring' (EEMS, 2008) | Flaring | 2.8 | 0.000081 | 0.018 | Note [1] |

[1] The GWPs used in the calculation of $CO_2e$ are based on the IPCC Fifth Assessment Report (AR5) - GWP values for 100-year time horizon: $CO_2$ GWP-100 = 1; $N_2O$ GWP-100 = 265; $CH_4$ GWP-100 = 28. $CO_2e$ is the sum of the individual GHG units post GWP calculation (e.g. $(CO_2*1_{GWP\text{-}100}) + (N_2O*265_{GWP\text{-}100}) + (CH_4*28_{GWP\text{-}100})$).

#### Quantification of Scope 1 Emissions

Table H.2 and Table H.3 detail the incremental GHG emissions generated at SGP as a result of Tornado coming online, assuming the SGP continues to operate as normal (i.e. powered by 2 x 4.75MW GTG) versus partially electrifying the SGP (replacing GTGs with grid connection). GHG emissions have been calculated for all Tornado hydrocarbon profiles, namely Max, High, Mid, and Low production cases. Partial electrification of the SGP results in a ca. 20% decrease in the Tornado incremental $CO_2e$ emissions produced.

**Table H.2: Tornado Incremental Emissions at SGP (Without Partial Electrification of SGP)**

| Year | Flare (kt/yr) | Fuel Gas (kt/yr) | Total Emissions (kt) [1] | | | |
|---|---|---|---|---|---|---|
| | | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Max Case** | | | | | | |
| 2029 | 0.85 | 25.02 | 73.92 | 0.01 | 0.04 | 76.47 |
| 2030 | 3.36 | 97.82 | 289.18 | 0.02 | 0.15 | 299.17 |
| 2031 | 3.36 | 91.45 | 270.95 | 0.02 | 0.14 | 280.40 |
| 2032 | 3.37 | 79.76 | 237.54 | 0.02 | 0.13 | 246.02 |
| 2033 | 3.36 | 58.84 | 177.69 | 0.01 | 0.11 | 184.40 |
| 2034 | 3.36 | 45.80 | 140.41 | 0.01 | 0.10 | 146.03 |
| 2035 | 3.36 | 39.77 | 123.15 | 0.01 | 0.10 | 128.26 |
| 2036 | 2.81 | 32.59 | 101.06 | 0.01 | 0.08 | 105.28 |
| **Total** | **23.84** | **471.03** | **1,413.89** | **0.11** | **0.86** | **1,466.01** |
| **Year** | **Flare (t/yr)** | **Fuel Gas (t/yr)** | **Total Emissions (kt) [1]** | | | |
| | | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **High Case** | | | | | | |
| 2029 | 0.65 | 13.33 | 39.95 | 0.00 | 0.02 | 41.41 |
| 2030 | 2.83 | 67.65 | 201.39 | 0.02 | 0.11 | 208.57 |
| 2031 | 3.29 | 77.00 | 229.42 | 0.02 | 0.13 | 237.62 |
| 2032 | 3.37 | 74.26 | 221.82 | 0.02 | 0.13 | 229.83 |
| 2033 | 3.36 | 48.68 | 148.63 | 0.01 | 0.11 | 154.49 |
| 2034 | 3.36 | 46.34 | 141.94 | 0.01 | 0.10 | 147.60 |
| 2035 | 3.36 | 41.56 | 128.29 | 0.01 | 0.10 | 133.55 |
| 2036 | 3.37 | 39.48 | 122.36 | 0.01 | 0.10 | 127.45 |
| 2037 | 3.36 | 38.98 | 120.90 | 0.01 | 0.10 | 125.94 |
| 2038 | 0.83 | 9.59 | 29.76 | 0.00 | 0.02 | 31.00 |
| **Total** | **27.78** | **456.87** | **1,384.44** | **0.10** | **0.92** | **1,437.44** |
| **Year** | **Flare (t/yr)** | **Fuel Gas (t/yr)** | **Total Emissions (kt) [1]** | | | |
| | | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Mid Case** | | | | | | |
| 2029 | 0.64 | 13.28 | 39.77 | 0.00 | 0.02 | 41.22 |
| 2030 | 2.80 | 67.01 | 199.49 | 0.01 | 0.11 | 206.60 |
| 2031 | 3.28 | 54.23 | 164.29 | 0.01 | 0.11 | 170.58 |
| 2032 | 3.37 | 47.86 | 146.31 | 0.01 | 0.10 | 152.10 |
| 2033 | 3.36 | 44.51 | 136.72 | 0.01 | 0.10 | 142.23 |
| 2034 | 3.36 | 39.77 | 123.15 | 0.01 | 0.10 | 128.26 |
| 2035 | 3.36 | 39.06 | 121.12 | 0.01 | 0.10 | 126.17 |
| 2036 | 2.52 | 29.20 | 90.59 | 0.01 | 0.07 | 94.37 |
| **Total** | **22.71** | **334.91** | **1,021.44** | **0.08** | **0.72** | **1,061.53** |

| Year | Flare (t/yr) | Fuel Gas (t/yr) | Total Emissions (kt) [1] | | | |
|---|---|---|---|---|---|---|
| | | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Low Case** | | | | | | |
| 2029 | 0.64 | 13.21 | 39.57 | 0.00 | 0.02 | 41.02 |
| 2030 | 2.77 | 65.35 | 194.67 | 0.01 | 0.11 | 201.62 |
| 2031 | 3.28 | 50.34 | 153.14 | 0.01 | 0.11 | 159.09 |
| 2032 | 3.37 | 42.67 | 131.46 | 0.01 | 0.10 | 136.82 |
| 2033 | 3.36 | 39.25 | 121.66 | 0.01 | 0.10 | 126.72 |
| 2034 | 3.36 | 38.90 | 120.68 | 0.01 | 0.10 | 125.71 |
| **Total** | **16.79** | **249.71** | **761.17** | **0.06** | **0.53** | **790.98** |

[1] Refer to GHG conversion factors in Table H.1.

**Table H.3: Tornado Incremental Emissions at SGP (With Partial Electrification of SGP)**

| Year | Flare (t/yr) | Fuel Gas (t/yr) | Total Emissions (kt) [1] | | | |
|---|---|---|---|---|---|---|
| | | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Max Case** | | | | | | |
| 2029 | 0.85 | 20.35 | 60.57 | 0.00 | 0.03 | 62.73 |
| 2030 | 3.36 | 79.30 | 236.21 | 0.02 | 0.13 | 244.65 |
| 2031 | 3.36 | 72.93 | 217.98 | 0.02 | 0.13 | 225.88 |
| 2032 | 3.37 | 61.19 | 184.43 | 0.01 | 0.12 | 191.35 |
| 2033 | 3.36 | 46.53 | 142.50 | 0.01 | 0.10 | 148.18 |
| 2034 | 3.36 | 36.54 | 113.93 | 0.01 | 0.09 | 118.77 |
| 2035 | 3.36 | 30.51 | 96.67 | 0.01 | 0.09 | 101.00 |
| 2036 | 2.81 | 24.85 | 78.93 | 0.01 | 0.07 | 82.50 |
| **Total** | **23.84** | **372.20** | **1,131.23** | **0.08** | **0.77** | **1,175.04** |
| **Year** | **Flare (t/yr)** | **Fuel Gas (t/yr)** | **Total Emissions (kt) [1]** | | | |
| | | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **High Case** | | | | | | |
| 2029 | 0.65 | 10.32 | 31.33 | 0.00 | 0.02 | 32.54 |
| 2030 | 2.83 | 52.05 | 156.79 | 0.01 | 0.10 | 162.65 |
| 2031 | 3.29 | 58.88 | 177.61 | 0.01 | 0.11 | 184.29 |
| 2032 | 3.37 | 57.24 | 173.13 | 0.01 | 0.11 | 179.72 |
| 2033 | 3.36 | 39.42 | 122.15 | 0.01 | 0.10 | 127.23 |
| 2034 | 3.36 | 37.08 | 115.46 | 0.01 | 0.09 | 120.34 |
| 2035 | 3.36 | 32.30 | 101.80 | 0.01 | 0.09 | 106.29 |
| 2036 | 3.37 | 30.20 | 95.80 | 0.01 | 0.09 | 100.11 |
| 2037 | 3.36 | 29.72 | 94.42 | 0.01 | 0.09 | 98.68 |
| 2038 | 0.83 | 7.31 | 23.23 | 0.00 | 0.02 | 24.28 |
| **Total** | **27.78** | **354.52** | **1,091.72** | **0.08** | **0.83** | **1,136.12** |

| Year | Flare (t/yr) | Fuel Gas (t/yr) | Total Emissions (kt) [1] | | | |
|---|---|---|---|---|---|---|
| | | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Mid Case** | | | | | | |
| 2029 | 0.64 | 10.28 | 31.19 | 0.00 | 0.02 | 32.39 |
| 2030 | 2.80 | 51.56 | 155.31 | 0.01 | 0.10 | 161.12 |
| 2031 | 3.28 | 43.90 | 134.74 | 0.01 | 0.10 | 140.16 |
| 2032 | 3.37 | 38.57 | 119.75 | 0.01 | 0.10 | 124.77 |
| 2033 | 3.36 | 35.25 | 110.24 | 0.01 | 0.09 | 114.97 |
| 2034 | 3.36 | 30.51 | 96.67 | 0.01 | 0.09 | 101.00 |
| 2035 | 3.36 | 29.80 | 94.64 | 0.01 | 0.09 | 98.91 |
| 2036 | 2.52 | 22.25 | 70.71 | 0.01 | 0.07 | 73.91 |
| **Total** | **22.71** | **262.12** | **813.26** | **0.06** | **0.65** | **847.23** |
| **Year** | **Flare (t/yr)** | **Fuel Gas (t/yr)** | **Total Emissions (kt) [1]** | | | |
| | | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Low Case** | | | | | | |
| 2029 | 0.64 | 10.23 | 31.04 | 0.00 | 0.02 | 32.23 |
| 2030 | 2.77 | 50.07 | 150.97 | 0.01 | 0.10 | 156.64 |
| 2031 | 3.28 | 40.04 | 123.68 | 0.01 | 0.10 | 128.77 |
| 2032 | 3.37 | 33.38 | 104.91 | 0.01 | 0.09 | 109.48 |
| 2033 | 3.36 | 29.99 | 95.18 | 0.01 | 0.09 | 99.46 |
| 2034 | 3.36 | 29.64 | 94.19 | 0.01 | 0.09 | 98.45 |
| **Total** | **16.79** | **193.34** | **599.97** | **0.04** | **0.48** | **625.04** |

[1] Refer to GHG conversion factors in Table H.1.

# H.3 Indirect GHG Emissions

## H.3.1 Upstream Scope 3 Emissions (Offshore Operations)

Upstream Scope 3 emissions are the indirect emissions which will be generated by Ithaca's contractors offshore when extracting, producing and exporting Tornado hydrocarbons to the SGP.

### Calculation Methodology

The following equation has been used to calculate the total quantity of upstream Scope 3 emissions generated from the Tornado development offshore operations:

$$GHG\ Emissions = Activity\ (Fuel\ Consumption_{(TONNES)}) \times GHG\ Conversion\ Factor$$

Table H.4 lists the GHG conversion factors which have been used to calculate GHG emissions generated from offshore transport related activity (i.e. vessel and helicopter movements).

**Table H.4: GHG Conversion Factors for Fuel used in Transport Activities (DESNZ, 2025e)**

| Fuel | Tornado Activity | GHG Conversion Factors (kg $CO_2e$ of GHG per unit)[1] | | | |
|---|---|---|---|---|---|
| | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ [2] |
| 'Marine Gas Oil' | Vessels | 3205.99000 | 38.40721 | 0.90720 | 3245.30441 |
| 'Aviation Turbine Fuel' | Helicopters | 3149.67000 | 26.50000 | 2.19520 | 3178.3652 |

[1] GHG Conversion Factor converted to tonnes before calculation.
[2] The GWPs used in the calculation of $CO_2e$ are based on the IPCC Fifth Assessment Report (AR5).

Table H.5 lists the emissions factors which have been used to calculate GHG emissions generated from well testing operations.

**Table H.5: GHG Conversion Factors for Well Testing (EEMS, 2008)**

| Emission Factor Source | Tornado Activity | GHG Conversion Factors (tonnes) | | | |
|---|---|---|---|---|---|
| | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| 'Well Testing – Gas' (EEMS, 2008) | Flaring | 2.8 | 0.00081 | 0.045 | Note [1] |

[1] The GWPs used in the calculation of $CO_2e$ are based on the IPCC Fifth Assessment Report (AR5). - GWP values for 100-year time horizon: $CO_2$ GWP-100 = 1; $N_2O$ GWP-100 = 265; $CH_4$ GWP-100 = 28. $CO_2e$ is the sum of the individual GHG units post GWP calculation (e.g. $(CO_2*1_{GWP\text{-}100}) + (N_2O*265_{GWP\text{-}100}) + (CH_4*28_{GWP\text{-}100})$).

### Quantification of Total Upstream Scope 3 Emissions

**Table H.6: Tornado Development Total Upstream Scope 3 Emissions (Offshore Operations)**

| Tornado Activity | Total Fuel Use (tonnes) [1] | GHG Emissions (tonnes) [2] | | | |
|---|---|---|---|---|---|
| | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| Drilling Operations [3] | 16,406.30 | 52,570.29 | 624.17 | 15.53 | 53,209.98 |
| Installation Operations | 18,692.00 | 59,875.68 | 717.91 | 16.96 | 60,610.54 |
| Inspection and Maintenance Operations | 700.00 | 2,244.19 | 26.89 | 0.64 | 2,271.71 |

| Tornado Activity | Total Hydrocarbons Flared (tonnes) [1] | GHG Emissions (tonnes) [3] | | | |
|---|---|---|---|---|---|
| | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| Well Test [4] | 6,000.00 [5] | 16,800.00 | 0.49 | 270.00 | 24,488.79 |
| | **Total:** | **131,490.16** | **1,369.45** | **303.12** | **140,581.03** |

[1] Total fuel use based on vessel and helicopter requirements for drilling operations (Table 3.2), installation operations (Table 3.11), inspection and maintenance operations (Table 3.13), as detailed in Section 3.
[2] Refer to GHG conversion factors in Table H.4.
[3] Assumes conventional drilling scenario (without CAN-ductors / parking CANs).
[4] Refer to GHG conversion factors in Table H.5.
[5] Assumes a well test is conducted on all three wells, with 2,000 tonnes of gas flared per well.

### H.3.2 Downstream Scope 3 Emissions (Well-to-Tank and End Use of Sold Products)

Downstream Scope 3 emissions are the indirect emissions which will be generated once the Tornado hydrocarbons have been processed to export specification and sold, including from further processing at the Sullom Voe and St Fergus terminals, transportation and distribution and from the end use of the sold product (namely, the worst case presumption that all end use Tornado hydrocarbons are eventually combusted).

#### H.3.2.1 Well-to-Tank Emissions

##### Calculation Methodology

Well-to-Tank (WTT) emissions represent the GHG emissions generated during the extraction, refinement, transport and distribution of fuels prior to their end-use. In a downstream context, this includes all emissions associated with the handling and logistical operations required to deliver refined hydrocarbons to market, but excludes combustion or end-use emissions, which are quantified separately below.

The following equations have been used to calculate the total quantity of GHG emissions generated from the further refinement, transportation and distribution of Tornado hydrocarbons:

*For Gas:*

$$WTT\ GHG\ Emissions = (Production_{GAS(TONNES)} - F\&F_{(TONNES)}) \times GHG\ Conversion\ Factor$$

*For Condensate:*

$$WTT\ GHG\ Emissions = Production_{CONDENSATE(TONNES)} \times GHG\ Conversion\ Factor$$

The sum of the above two equations (Gas WTT + Condensate WTT) is the total WTT Emissions.

Table H.7 details the GHG conversion factors used to calculate the WTT emissions. 'Natural gas (100% mineral blend)' has been assumed as the downstream proxy fuel for Tornado gas, and 'fuel oil' has been assumed as the downstream proxy fuel for Tornado condensate.

**Table H.7: Well-to-Tank GHG Conversion Factors (DESNZ, 2025e)**

| Tornado Hydrocarbon | Downstream Proxy Fuel | GHG Conversion Factor (kg $CO_2e$ of GHG per unit)[1] |
|---|---|---|
| Gas | 'Natural gas (100% mineral blend)' WTT Fuels | 423.16368 |
| Condensate | 'Petrol (100% mineral petrol)' WTT Fuels [1] | 815.93523 |

[1] GHG Conversion Factor converted to tonnes before calculation.
[2] There is no WTT conversion factor for condensate in DESNZ (2025e), therefore Petrol (100% mineral petrol) has been used as a proxy as it is considered to most closely match condensate for the purposes of this assessment.

As the WTT GHG conversion factors encompass the emissions associated with the extraction, refining and transportation of hydrocarbons prior to their end use, these already account for the incremental emissions that would be generated at SGP as a result of Tornado coming online (as presented in Section H.2). Therefore, to prevent double-counting, the Tornado Scope 1 volumes of F&F have been deducted from the gas production profile in order to calculate the WTT emissions for gas, assuming SGP continues to operate without partial electrification.

Given the nature of the Tornado hydrocarbons and the known stages of refinement prior to transport and distribution to market, particularly as gas exported from the St Fergus Gas Terminal feeds directly into the NTS, the quantity of $CO_2e$ emissions calculated for the Well-to-Tank phase is likely to be a conservative worst case estimate.

### Quantification of GHG Emissions

**Table H.8: Tornado Development WTT Scope 3 Emissions**

| Tornado Hydrocarbon | Total Quantity of Produced Hydrocarbons (kt) [1] | WTT $CO_2e$ Emissions (kt) [2] |
|---|---|---|
| **Max Case** | | |
| Tornado Gas | 10,504.60 | 4,445.16 |
| Tornado Condensate | 577.93 | 471.55 |
| **Max Case Total:** | **11,082.53** | **4,916.72** |
| **High Case** | | |
| Tornado Gas | 9,228.78 | 3,905.28 |
| Tornado Condensate | 557.37 | 454.78 |
| **High Case Total:** | **9,786.15** | **4,360.06** |
| **Mid Case** | | |
| Tornado Gas | 6,964.94 | 2,947.31 |
| Tornado Condensate | 420.22 | 342.87 |
| **Mid Case Total:** | **7,385.16** | **3,290.18** |
| **Low Case** | | |
| Tornado Gas | 4,855.04 | 2,054.48 |
| Tornado Condensate | 293.94 | 239.83 |
| **Low Case Total:** | **5,148.97** | **2,294.31** |

[1] Refer to Appendix G for Tornado production profiles. Gas converted from $m^3$ to tonnes using a density of 0.766 kg/$m^3$. F&F values subtracted from total quantity of produced gas to avoid double counting.
[2] Refer to GHG conversion factors in Table H.7.

### H.3.2.2 End Use of Sold Products

#### Calculation Methodology

The following equation has been used to calculate the total quantity of Scope 3 emissions generated from the end use of sold products (namely, the worst case presumption that all end use Tornado hydrocarbons are eventually combusted). To avoid double counting of emissions, the F&F has been subtracted from the gas combustion:

*For gas:*

$$End\ Use\ GHG\ Emissions = (Production_{GAS(TONNES)} - F\&F_{(TONNES)}) \times GHG\ Conversion\ Factor$$

*For condensate:*

$$End\ Use\ GHG\ Emissions = Production_{CONDENSATE(TONNES)} \times GHG\ Conversion\ Factor$$

Table H. lists the GHG conversion factors which have been used to calculate End Use GHG emissions.

**Table H.9: End Use GHG Conversion Factors (DESNZ, 2025e)**

| Tornado Hydrocarbon | Proxy Fuel | GHG Conversion Factors (kg $CO_2e$ of GHG per unit)[1] | | | |
|---|---|---|---|---|---|
| | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ [2] |
| Gas | 'Natural Gas (100% mineral blend)' (DESNZ, 2025e) | 2,598.26 | 3.8528 | 1.19161 | 2,603.30441 |
| Condensate | 'Petrol (100% mineral petrol)' (DESNZ, 2025e) | 3135 | 11.04320 | 8.03893 | 3154.08213 |

[1] GHG Conversion Factor converted to tonnes before calculation.
[2] The GWPs used in the calculation of $CO_2e$ are based on the IPCC Fifth Assessment Report (AR5).

Production values presented in Appendix G have been rounded for simplification in the ES. All calculations in Appendix H were undertaken using the original unrounded data. Reproduction of calculations using the rounded figures in from Appendix G may therefore result in minor discrepancies.

## Quantification of GHG Emissions

**Table H.10: GHG Emissions from Combustion of Tornado Gas and Oil (Max Case)**

| Year | Volume of Gas Produced [1] | | GHG Emissions (kt) [2] | | | |
|---|---|---|---|---|---|---|
| | $Mm^3/yr$ | kt/yr | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Combustion of Tornado Gas (Tornado Max Case)** | | | | | | |
| 2029 | 878.04 | 672.58 | 1,747.53 | 2.59 | 0.80 | 1,750.92 |
| 2030 | 3,321.74 | 2,544.46 | 6,611.16 | 9.80 | 3.03 | 6,623.99 |
| 2031 | 2,678.73 | 2,051.90 | 5,331.38 | 7.91 | 2.45 | 5,341.73 |
| 2032 | 2,139.81 | 1,639.09 | 4,258.79 | 6.32 | 1.95 | 4,267.06 |
| 2033 | 1,709.53 | 1,309.50 | 3,402.43 | 5.05 | 1.56 | 3,409.03 |
| 2034 | 1,358.29 | 1,040.45 | 2,703.36 | 4.01 | 1.24 | 2,708.61 |
| 2035 | 1,054.10 | 807.44 | 2,097.94 | 3.11 | 0.96 | 2,102.01 |
| 2036 | 573.33 | 439.17 | 1,141.09 | 1.69 | 0.52 | 1,143.30 |
| **Totals:** | **13,713.57** | **10,504.60** | **27,293.67** | **40.47** | **12.52** | **27,346.66** |
| **Year** | **Volume of Oil Produced (kt/yr) [2]** | | **GHG Emissions (kt) [2]** | | | |
| | | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Combustion of Tornado Oil (Tornado Max Case)** | | | | | | |
| 2029 | 77.53 | | 243.05 | 0.86 | 0.62 | 244.53 |
| 2030 | 225.96 | | 708.39 | 2.50 | 1.82 | 712.70 |
| 2031 | 115.23 | | 361.24 | 1.27 | 0.93 | 363.44 |
| 2032 | 68.61 | | 215.08 | 0.76 | 0.55 | 216.39 |
| 2033 | 41.15 | | 129.00 | 0.45 | 0.33 | 129.78 |
| 2034 | 24.57 | | 77.02 | 0.27 | 0.20 | 77.49 |
| 2035 | 16.25 | | 50.94 | 0.18 | 0.13 | 51.25 |
| 2036 | 8.64 | | 27.09 | 0.10 | 0.07 | 27.25 |
| **Totals:** | **577.93** | | **1,811.81** | **6.38** | **4.65** | **1,822.83** |
| | **Max Case Totals:** | | **29,105.48** | **46.85** | **17.16** | **29,169.50** |

[1] Gas volumes based on Tornado max case production profile (refer to Appendix G), with production commencing in October 2029 and cessation of production in October 2036; volumes in the start and end years are pro-rated to reflect partial-year production. F&F values subtracted from gas totals to avoid double counting. Gas converted from $m^3$ to tonnes using a density of 0.766 $kg/m^3$.

[2] Refer to GHG Conversion Factors in Table H..

[3] Oil volumes based on Tornado max case production profile (refer to Appendix G), with production commencing in October 2029 and cessation of production in October 2036; volumes in the start and end years are pro-rated to reflect partial-year production.

**Table H.9: GHG Emissions from Combustion of Tornado Gas and Oil (High Case)**

| Year | Volume of Gas Produced [1] | | Emissions (kt) [2] | | | |
|---|---|---|---|---|---|---|
| | $Mm^3/yr$ | kt/yr | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Combustion of Tornado Gas (Tornado High Case)** | | | | | | |
| 2029 | 363.74 | 278.63 | 723.95 | 1.07 | 0.33 | 725.35 |
| 2030 | 1,871.77 | 1,433.77 | 3,725.32 | 5.52 | 1.71 | 3,732.55 |
| 2031 | 1,858.96 | 1,423.96 | 3,699.83 | 5.49 | 1.70 | 3,707.01 |
| 2032 | 1,829.96 | 1,401.75 | 3,642.11 | 5.40 | 1.67 | 3,649.18 |
| 2033 | 1,619.24 | 1,240.34 | 3,222.71 | 4.78 | 1.48 | 3,228.97 |
| 2034 | 1,372.71 | 1,051.50 | 2,732.07 | 4.05 | 1.25 | 2,737.37 |
| 2035 | 1,163.21 | 891.02 | 2,315.10 | 3.43 | 1.06 | 2,319.60 |
| 2036 | 982.85 | 752.87 | 1,956.14 | 2.90 | 0.90 | 1,959.94 |
| 2037 | 811.68 | 621.75 | 1,615.46 | 2.40 | 0.74 | 1,618.59 |
| 2038 | 173.89 | 133.20 | 346.08 | 0.51 | 0.16 | 346.75 |
| **Totals:** | **12,048.01** | **9,228.78** | **23,978.76** | **35.56** | **11.00** | **24,025.32** |
| **Year** | **Volume of Oil Produced (kt/yr) [3]** | | **GHG Emissions (kt) [2]** | | | |
| | | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Combustion of Tornado Oil (Tornado High Case)** | | | | | | |
| 2029 | 33.65 | | 105.48 | 0.37 | 0.27 | 106.13 |
| 2030 | 152.06 | | 476.72 | 1.68 | 1.22 | 479.62 |
| 2031 | 117.47 | | 368.27 | 1.30 | 0.94 | 370.52 |
| 2032 | 84.47 | | 264.81 | 0.93 | 0.68 | 266.42 |
| 2033 | 59.68 | | 187.11 | 0.66 | 0.48 | 188.25 |
| 2034 | 41.80 | | 131.04 | 0.46 | 0.34 | 131.84 |
| 2035 | 29.63 | | 92.90 | 0.33 | 0.24 | 93.47 |
| 2036 | 21.12 | | 66.21 | 0.23 | 0.17 | 66.62 |
| 2037 | 14.63 | | 45.88 | 0.16 | 0.12 | 46.16 |
| 2038 | 2.85 | | 8.93 | 0.03 | 0.02 | 8.99 |
| **Totals:** | **557.37** | | **1,747.37** | **6.16** | **4.48** | **1,758.00** |
| | **High Case Totals:** | | **25,726.13** | **41.71** | **15.48** | **25,783.32** |

[1] Gas volumes based on Tornado high case production profile (refer to Appendix G), with production commencing in October 2029 and cessation of production in March 2038; volumes in the start and end years are pro-rated to reflect partial-year production. F&F values subtracted from gas totals to avoid double counting. Gas converted from $m^3$ to tonnes using a density of 0.766 $kg/m^3$.

[2] Refer to GHG Conversion Factors in in Table H.

[3] Oil volumes based on Tornado high case production profile (refer to Appendix G), with production commencing in October 2029 and cessation of production in March 2038; volumes in the start and end years are pro-rated to reflect partial-year production.

**Table H.12: GHG Emissions from Combustion of Tornado Gas and Oil (Mid Case)**

| Year | Volume of Gas Produced [1] | | Emissions (kt) [2] | | | |
|---|---|---|---|---|---|---|
| | $Mm^3/yr$ | kt/yr | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Combustion of Tornado Gas (Tornado Mid Case)** | | | | | | |
| 2029 | 355.05 | 271.96 | 706.64 | 1.05 | 0.32 | 708.01 |
| 2030 | 1,769.28 | 1,355.27 | 3,521.34 | 5.22 | 1.61 | 3,528.18 |
| 2031 | 1,768.28 | 1,354.50 | 3,519.34 | 5.22 | 1.61 | 3,526.18 |
| 2032 | 1,537.21 | 1,177.50 | 3,059.46 | 4.54 | 1.40 | 3,065.40 |
| 2033 | 1,273.94 | 975.84 | 2,535.47 | 3.76 | 1.16 | 2,540.40 |
| 2034 | 1,052.80 | 806.45 | 2,095.36 | 3.11 | 0.96 | 2,099.42 |
| 2035 | 859.23 | 658.17 | 1,710.09 | 2.54 | 0.78 | 1,713.41 |
| 2036 | 476.83 | 365.25 | 949.02 | 1.41 | 0.44 | 950.86 |
| **Totals:** | **9,092.61** | **6,964.94** | **18,096.72** | **26.83** | **8.30** | **18,131.86** |
| **Year** | **Volume of Oil Produced (kt/yr) [3]** | | **Emissions (kt) [2]** | | | |
| | | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Combustion of Tornado Oil (Tornado Mid Case)** | | | | | | |
| 2029 | 32.46 | | 101.76 | 0.36 | 0.26 | 102.38 |
| 2030 | 136.19 | | 426.95 | 1.50 | 1.09 | 429.55 |
| 2031 | 95.18 | | 298.39 | 1.05 | 0.77 | 300.21 |
| 2032 | 61.22 | | 191.92 | 0.68 | 0.49 | 193.09 |
| 2033 | 40.72 | | 127.67 | 0.45 | 0.33 | 128.45 |
| 2034 | 27.35 | | 85.74 | 0.30 | 0.22 | 86.26 |
| 2035 | 18.36 | | 57.56 | 0.20 | 0.15 | 57.91 |
| 2036 | 8.73 | | 27.38 | 0.10 | 0.07 | 27.55 |
| **Totals:** | **420.22** | | **1,317.38** | **4.64** | **3.38** | **1,325.40** |
| | **Mid Case Totals:** | | **19,414.11** | **31.48** | **11.68** | **19,457.26** |

[1] Gas volumes based on Tornado mid case production profile (refer to Appendix G), with production commencing in October 2029 and cessation of production in September 2036; volumes in the start and end years are pro-rated to reflect partial-year production. F&F values subtracted from gas totals to avoid double counting. Gas converted from $m^3$ to tonnes using a density of 0.766 $kg/m^3$.

[2] Refer to GHG Conversion Factors in in Table H..

[3] Oil volumes based on Tornado mid case production profile (refer to Appendix G), with production commencing in October 2029 and cessation of production in September 2036; volumes in the start and end years are pro-rated to reflect partial-year production.

**Table H.13: GHG Emissions from Combustion of Tornado Gas and Oil (Low Case)**

| Year | Volume of Gas Produced [1] | | Emissions (kt) [2] | | | |
|---|---|---|---|---|---|---|
| | $Mm^3/yr$ | kt/yr | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Combustion of Tornado Gas (Tornado Low Case)** | | | | | | |
| 2029 | 346.36 | 265.31 | 689.34 | 1.02 | 0.32 | 690.68 |
| 2030 | 1,668.06 | 1,277.73 | 3,319.89 | 4.92 | 1.52 | 3,326.33 |
| 2031 | 1,505.10 | 1,152.91 | 2,995.56 | 4.44 | 1.37 | 3,001.37 |
| 2032 | 1,200.92 | 919.90 | 2,390.15 | 3.54 | 1.10 | 2,394.79 |
| 2033 | 939.28 | 719.49 | 1,869.42 | 2.77 | 0.86 | 1,873.05 |
| 2034 | 678.45 | 519.69 | 1,350.30 | 2.00 | 0.62 | 1,352.92 |
| **Totals:** | **6,338.17** | **4,855.04** | **12,614.65** | **18.71** | **5.79** | **12,639.14** |
| **Year** | **Volume of Oil Produced (kt/yr) [3]** | | **Emissions (kt) [2]** | | | |
| | | | $CO_2$ | $N_2O$ | $CH_4$ | $CO_2e$ |
| **Combustion of Tornado Oil (Tornado Low Case)** | | | | | | |
| 2029 | 31.07 | | 97.42 | 0.34 | 0.25 | 98.01 |
| 2030 | 116.58 | | 365.47 | 1.29 | 0.94 | 367.70 |
| 2031 | 67.17 | | 210.58 | 0.74 | 0.54 | 211.86 |
| 2032 | 40.71 | | 127.61 | 0.45 | 0.33 | 128.39 |
| 2033 | 24.47 | | 76.71 | 0.27 | 0.20 | 77.18 |
| 2034 | 13.94 | | 43.70 | 0.15 | 0.11 | 43.96 |
| **Totals:** | **293.94** | | **921.49** | **3.25** | **2.36** | **927.10** |
| | **Low Case Totals:** | | **13,536.14** | **21.95** | **8.15** | **13,566.24** |

[1] Gas volumes based on Tornado low case production profile (refer to Appendix G), with production commencing in October 2020 and cessation of production in December 2034; volumes in the start and end years are pro-rated to reflect partial-year production. F&F values subtracted from gas totals to avoid double counting. Gas converted from $m^3$ to tonnes using a density of 0.766 $kg/m^3$.

[2] Refer to GHG Conversion Factors in in Table H..

[3] Oil volumes based on Tornado low case production profile (refer to Appendix G), with production commencing in October 2029 and cessation of production in December 2034; volumes in the start and end years are pro-rated to reflect partial-year production.

### H.3.2.3 Total Downstream Scope 3 Emissions

Table H. details the total downstream Scope 3 emissions which will be generated from the proposed Tornado Development assuming the SGP continues to operate as normal (i.e. powered by GTG(s) without partial electrification).

**Table H.14: Tornado Development Total Downstream Scope 3 Emissions**

| Downstream Activities | Total GHG Emissions (Without Electrification of SGP) (kt $CO_2e$) |
|---|---|
| **Tornado Max Case** | |
| Well-to-Tank Emissions | 4,916.72 |
| End Use of Sold Products | 29,169.50 |
| **Total Max Case:** | **34,086.21** |
| **Tornado High Case** | |
| Well-to-Tank Emissions | 4,360.06 |
| End Use of Sold Products | 25,783.32 |
| **Total High Case):** | **30,143.38** |
| **Tornado Mid Case** | |
| Well-to-Tank Emissions | 3,290.18 |
| End Use of Sold Products | 19,457.26 |
| **Total Mid Case:** | **22,747.44** |
| **Tornado Low Case** | |
| Well-to-Tank Emissions | 2,294.31 |
| End Use of Sold Products | 13,566.24 |
| **Total Low Case:** | **15,860.55** |

## H.3 Summary of Total GHG Emissions

Table H. details the worst-case total GHG emissions estimated to be generated as a result of the proposed Tornado Development, assuming the SGP continues to operate as normal (i.e. powered by GTG(s) without partial electrification).

**Table H.10: Tornado Development Total GHG Emissions (without partial electrification)**

| Emissions Category | Total GHG Emissions (kt $CO_2e$) | | | |
|---|---|---|---|---|
| | Max Case | High Case | Mid Case | Low Case |
| Total Direct GHG Emissions (Scope 1) [1] | 1,466.01 | 1,437.44 | 1,061.53 | 790.98 |
| Total Indirect Upstream GHG Emissions (Scope 3) [2] | 140.58 | 140.58 | 140.58 | 140.58 |
| Total Indirect Downstream GHG Emissions (Scope 3) [3] | 34,086.21 | 30,143.38 | 22,747.44 | 15,860.55 |
| **Grand Total** | **35,692.81** | **31,721.41** | **23,949.55** | **16,792.11** |

[1] Refer to Section H.2.1

[2] The total indirect upstream GHG emissions generated are the same for all Tornado production profiles (refer to Section H.3.1).

[3] The total indirect downstream GHG emissions generated depend on the Tornado production profiles as the methodology applies GHG conversion factors to production volumes (refer to Sections H.3.2).

In summary, the worst-case total gross GHG emissions generated over the life of the Tornado Field are estimated to be ca. 35,692.81 kilotonnes of $CO_2e$, based on the Max production case (assuming a three well development), which represents a 'worst case' emissions profile, without partial electrification of SGP.

For context, the High case scenario, which assumes a two well development, generates total GHG emissions about 11% lower than the Max case estimate. The Mid case scenario, which represents the most likely production outcome, is about 33% lower than the Max case estimate and the Low case scenario, representing a conservative, lower production outcome, is about 53% lower than the Max case estimate.

Partial electrification of the SGP results in a ca. 20% decrease in the Tornado incremental $CO_2e$ (Scope 1) emissions produced.

In contrast, a 'do-nothing' scenario (e.g. a scenario where the Tornado Development does not proceed) would result in the generation of zero GHG emissions from Tornado only.