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ENVIRONMENTAL AND SOCIAL IMPACT STATEMENT ESIS-TYRA

RAMBØLL

ESIA MAERSK OIL DBU
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ESIS-TYRA

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LIST OF ABBREVIATIONS

ALARP	As low as reasonably practicable
API	American Petroleum Institute gravity. An industry standard used to determine and classify oil according to its density
BAT	Best available technique
BEP	Best environmental practice
BOPD	Barrels of oil per day
BPD	Barrels per day
BWPD	Barrels of water per day
CFR	Cleared for Removal
CO_2	Carbon dioxide
DEA	Danish Energy Agency [Energistyrelsen]
DEPA	Danish Environmental Protection Agency [Miljøstyrelsen]
DNA	Danish Nature Agency [Naturstyrelsen]
DUC	Danish Underground Consortium, a joint venture with A. P. Møller – Mærsk, Shell, Chevron and the Danish North Sea Fund
EIA	Environmental impact assessment
EIF	Environmental impact factor
ESIA	Environmental and social impact assessment
ESIS	Environmental and social impact statement
FTEE	Full time employee equivalent
GBS	Gravity-based structure
Hz	Hertz
ITOPF	International tanker owners pollution federation
KSCF	Thousand standard cubic foot of gas
MBES	Multibeam echo sounder
MMO	Marine mammal observer
MMSCFD	Million standard cubic feet of gas per day
NMVOC	Non methane volatile organic compounds
NORM	Naturally occurring radioactive material
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	NOX is a generic term for mono-nitrogen oxides NO and NO_2 (nitric oxide and nitrogen dioxide)
OSPAR	Oslo-Paris convention for the protection of the marine environment of the North-East Atlantic
PAM	Passive acoustic monitoring
PEC	Predicted environmental concentration
PLONOR	Pose little or no risk
$PM_{2.5}$	Particulate matter less than 2.5 microns in diameter
PNEC	Predicted no-effect concentration based on ecotoxicity data
PPM	Parts per million
RBA	Risk-based approach
ROV	Remote operated vehicle
SIMOPS	Simultaneous operations
STBO	Stock tank barrels oil
SO_2	Sulphur dioxide
SO_x	Refers to all sulphur oxides, the two major ones being sulphur dioxide and sulphur trioxide
SSS	Side scan sonar

STB	Standard barrels
TEA	Tyra East A – accommodation platform
TEB	Tyra East B – wellhead and riser platform
TEC	Tyra East C – wellhead and riser platform
TED	Tyra East D – flare platform
TEE	Tyra East E – riser platform
TEF	Tyra East F – bridge module support platform
TEG	Tyra East G – new process platform
TEH	Tyra East H – new accommodation platform
TF	Tyra Future
TWA	Tyra West A – accommodation platform
TWB	Tyra West B – wellhead and riser platform
TWC	Tyra West C – wellhead platform
TWD	Tyra West D – flare platform
TWE	Tyra West E – riser and bridge module platform
WEEE	Waste Electrical and Electronic Equipment

1. INTRODUCTION

1.1 Background

In connection with ongoing and future oil and gas exploration, production and decommissioning activities by Maersk Oil in the Danish North Sea, an environmental and social impact assessment (ESIA) is being carried out. The overall aim of the ESIA is to identify, assess and mitigate the impact of Maersk Oil activities on environmental and social receptors.

This document - Maersk Oil DBU ESIS TYRA - shall replace the ESIS prepared in 2016 (ESIA-16) for TYRA. It is an update of the ESIA-16 ESIS TYRA incorporating the Tyra Future redevelopment project intended to upgrade the existing facilities at the Tyra field. The facilities have been in production for thirty years and are suffering from seabed subsidence, old age and increasing operational expenditure.

The ESIS contains a description of ongoing and planned projects (from exploration to decommissioning), a description of potential impact on the environmental and social receptors and measures taken to avoid, prevent or reduce impact. The ESIS is supported by seven generic technical sections that describe the typical activities (seismic, pipelines and structures, production, drilling, well stimulation, transport and decommissioning; provided in appendix 1).

The ESIS TYRA covers the activities related to existing and planned projects for the Tyra (East and West) facilities and their satellite platforms (Tyra Southeast, Valdemar A, Valdemar B, Roar and Svend) up to 2042. The platforms are located in the North Sea about 230 km from the west coast of Jutland, Denmark (Figure 1-1).

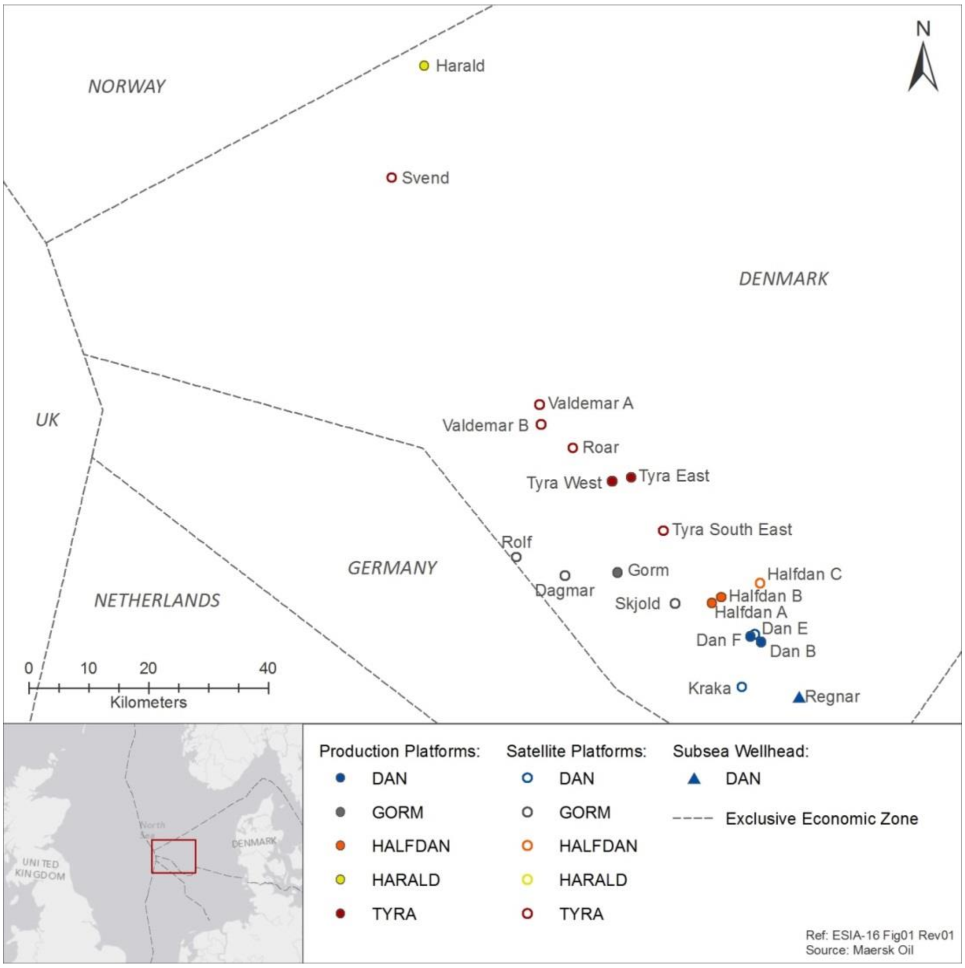


Figure 1-1 Maersk Oil/DUC platforms in the North Sea

2. LEGAL BACKGROUND

2.1 EU and national legislation

2.1.1 Environmental impact assessment directive (EIA directive)

The directive on the assessment of the effects of certain public and private projects on the environment (directive 85/337/EEC), as amended by directives 7/11/EC, 2003/35/EC and 2009/31/EC, requires an assessment of the environmental impacts prior to consent being granted. This directive is implemented in Denmark as act 425/2016 on environmental assessment of plans and of projects and executive order 434/2017 on appropriate assessment related to offshore hydrocarbon activities. This ESIS is processed subject to regulation in force at time of notification, being executive order 1419 dated 03/12/2015 on environmental assessment of offshore exploration and recovery of hydrocarbons.

This ESIS has been prepared in accordance with order 1419 dated 03/12/2015 on environmental impact assessment (EIA) and appropriate assessment (AA) for the hydrocarbon activities [Bekendtgørelse om VVM, konsekvensvurdering vedrørende internationale naturbeskyttelsesområder og beskyttelse af visse arter ved efterforskning og indvinding af kulbrinter, lagring i undergrunden, rørledninger, m.v. offshore]. The ESIS fulfils the requirements set in appendix 2 of order 1419/2015 and includes:

- Article 8: Transboundary adverse impacts are assessed and adequately communicated in accordance with the ESPOO convention (section 0),
- Article 9 and 10: A Natura 2000 screening is presented in this ESIS (section 10)
- Article 12: Protection of certain species mentioned in the habitats directive, cf. section 2.1.3 (section 6)

The ESIS and its non-technical summary shall be made available for public consultation for a period of at least 8 weeks, in accordance with article 6 of order 1419/2015.

2.1.2 Protection of the marine environment

The consolidation act 963 dated 03/07/2013 on protection of the marine environment aims to protect the environment and ensure sustainable development.

The consolidation act and associated orders regulate e.g. discharges and emissions from platforms. Relevant orders include: Order 394 dated 17/07/1984 on discharge from some marine constructions, order 270/2008 on discharges of blackwater, order 9840/2007 on prevention on air pollution from ships, and order 909/2015 on contingency plans.

2.1.3 Natura 2000 (Habitats and Bird protection directive)

The "Natura 2000" network is the largest ecological network in the world, ensuring biodiversity by conserving natural habitats and wild fauna and flora in the territory of the EU. The network comprises special areas of conservation designated under the directive on the conservation of natural habitats and of wild fauna and flora (Habitats Directive, Directive 1992/43/EEC). Furthermore, Natura 2000 also includes special protection areas classified pursuant to the Birds Directive (Directive 2009/147/EC). The directives have been transposed to Danish legislation through a number of orders (or regulatory instruments).

The Natura 2000 protection is included in the Order 1419/2015 (section 2.1.1).

2.1.4 National emissions ceiling directive

The national emission ceiling directive (directive 2001/81/EC) sets upper limits for each Member State for the total emissions of the four pollutants nitrogen oxide NO_x, volatile organic compound (VOC), ammonia (NH_3) and sulphur dioxide (SO_2). The directive is under revision to include particulate matter less than 2.5 microns in diameter ($PM_{2.5}$). The directive has been implemented by order 1325 dated 21/12/2011 on national emissions ceilings.

2.1.5 Marine strategy framework directive

The marine strategy framework directive (Directive 2008/56/EC) aims to achieve "good environmental status" (GES) of the EU marine waters by 2020. The directive has been implemented in Denmark by the act on marine strategy (act 522/2010). A marine strategy has subsequently been developed by the Danish Agency of Water and Nature Management, now Environmental Protection Agency, Nature, with an overall assessment of the state of the environment including a definition of GES at regional level and the establishment of environmental targets and monitoring programs (www.svana.dk).

2.1.6 Industrial emissions directive

The industrial emissions directive (Directive 2010/75/EU) is about minimising pollution from various industrial sources. The directive addresses integrated pollution prevention and control based on best available technique (BAT). The directive has been implemented by the consolidation act 879/2010 on protection of the environment and with respect to offshore, order 1449/2012.

2.1.7 Emission allowances

The European Union Emissions Trading Scheme was launched in 2005 to combat climate change and is a major pillar of EU climate policy. Under the 'cap and trade' principle, a cap is set on the total amount of greenhouse gases that can be emitted by all participating installations.
The trading scheme is implemented by act 1605/2016 on CO_2 emission allowances.

2.1.8 Safety directive of oil and gas operations

The directive 2013/30/EU on safety of offshore oil and gas operations aims to ensure that best safety practices are implemented across all active offshore regions in Europe. The directive has recently been implemented in Denmark by consolidated act 831/2015 on offshore safety.

2.1.9 Waste framework directive

The Directive 2008/98/EC of 19 November 2008 on waste provides a framework of waste management requirements to prevent or reduce impacts of generation and management of waste and to encourage the re-use and recycling of waste materials. The directive is implemented in Denmark as order 1309/2012 on waste.

2.1.10 Shipment of waste regulation

Regulation (EC) No. 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste, establishes procedures and control regimes for the shipment of waste, depending on the origin, destination and route of the shipment, the type of waste shipped and the type of treatment to be applied to the waste at its destination. The regulation applies to shipment of waste between member States within the Community, transit through third countries and waste exported from the Community to third countries. The regulation implements the Basel Convention in the EU.

2.1.11 Waste electrical and electronic equipment (WEEE)

Directive 2012/19/EU of 4 July 2012 on Waste electrical and electronic equipment (WEEE) lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste from electrical and electronic equipment (WEEE) and by reducing overall impacts of resource use and improving the efficiency of such, thereby contributing to sustainable development

BEK 132 af 06/02/2014. Bekendtgørelse om overførsel af affald og overførsel af brugt elektrisk og elektronisk udstyr, subject to the Danish environmental protection law, stipulates regulation on transboundary transport of waste electrical and electronic equipment, hereunder specifically import to Denmark for disposal.

2.2 International conventions

2.2.1 Espoo convention

The convention on environmental impact assessment in a transboundary context (Espoo Convention) entered into force in 1991. The convention sets out the obligations of Parties to assess the environmental impact of certain activities at an early stage of planning. It also lays down the general obligation of States to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across national boundaries.

The Espoo convention is implemented in the EIA Directive. In Denmark, the Ministry of Environment administrate the Espoo Convention rules and is the responsible authority for the process of exchanging relevant information from the project owner to the potentially affected countries and possible comments from those countries in connection with the Espoo Consultation Process.

2.2.2 Convention on the prevention of marine pollution by dumping of wastes and other matter

International maritime organization (IMO) convention on the prevention of marine pollution by dumping of wastes and other matter (London Convention) has been in force since 1975. Its objective is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matter.

2.2.3 The MARPOL Convention

The International Convention for the Prevention of Pollution from Ships adopted in November 1973 at IMO (International Maritime Organization). The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. Annexes I - V regulates respectively prevention of pollution by oil, noxious liquid substances in bulk, harmful substances in packaged form, sewage from ships and garbage from ships.

2.2.4 Convention for the control and management of ships' ballast water and sediments

The convention for the control and management of ships' ballast water and sediments (ballast water management convention) was adopted in 2004. The convention aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments.

2.2.5 Ramsar convention

The Ramsar convention aims at the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world.

2.2.6 The convention for the protection of the marine environment of the North-East Atlantic

The convention for the protection of the marine Environment of the North-East Atlantic (the ‘OSPAR Convention') entered into force in 1998. Contained within the OSPAR Convention are a series of Annexes which focus on prevention and control of pollution from different types of activities. OSPAR has a focus on application of the precautionary principle, and on use of best available technique (BAT), best environmental practice (BEP) and clean technologies.

A number of strategies and recommendations from OSPAR are relevant to the TYRA project, most notably:

- Annual OSPAR report on discharges, spills and emissions from offshore oil and gas installations.
- Reduction in the total quantity of oil in produced water discharged and the performance standard of dispersed oil of 30 mg/l (OSPAR Recommendation 2001/1).
- Harmonised mandatory control system for the use and reduction of the discharge of Offshore chemicals (OSPAR decision 2005/1).
- List of substances/preparations used and discharged offshore which are considered to pose little or no risk to the environment (PLONOR) (OSPAR decision 2005/1).
- To phase out, by 1 January 2017, the discharge of offshore chemicals that are, or which contain substances, identified as candidates for substitution, except for those chemicals where, despite considerable efforts, it can be demonstrated that this is not feasible due to technical or safety reasons (OSPAR Recommendation 2006/3).
- Risk based approach to assessment of discharged produced water (OSPAR recommendation 20012/5).
- Decision 98/3 on the disposal of disused offshore installations.

2.2.7 The convention on access to information, public participation in decision-making and access to justice in environmental matters

The UNECE convention on access to information, public participation in decision-making and access to justice in environmental matters (Aarhus convention) was adopted in 1998. The convention is about government accountability, transparency and responsiveness. The Aarhus convention grants the public rights and imposes on parties and public authorities obligations regarding access to information and public participation. The Aarhus convention is among others implemented in Denmark by act 960/2013.

2.2.8 The Convention on Biological Diversity (CBD)

The Convention on Biological Diversity (CBD or Rio convention) entered into force in 1993. It has three main objectives:

- The conservation of biological diversity
- The sustainable use of the components of biological diversity
- The fair and equitable sharing of the benefits arising out of the utilization of genetic resources.

2.2.9 The Convention on the Conservation of Migratory Species of Wild Animals

The Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or Bonn Convention) is an intergovernmental treaty, concluded under the United Nations Environment Program. The Convention aims to conserve terrestrial, aquatic and avian migratory species throughout their range.

CMS acts as a framework Convention. The Agreements may range from legally binding treaties to less formal instruments, such as Memoranda of Understanding, and can be adapted to the requirements of particular regions. Under the convention on the conservation of migratory species of wild animals, a number of agreements and memoranda of understanding have been signed. Agreements under the auspices of CMS, aim to conserve:

- Populations of European Bats
- Cetaceans of the Mediterranean Sea, Black Sea and Contiguous Atlantic Area
- Small Cetaceans of the Baltic, North-East Atlantic, Irish and North Seas
- Seals in the Wadden Sea
- African-Eurasian Migratory Water birds
- Albatrosses and Petrels
- Gorillas and their Habitats

The Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) was concluded under the auspices of the Convention on Migratory Species in 1991.

2.3 Industry and national authority initiatives

2.3.1 Offshore action plan

An offshore action plan was implemented by the Danish Environmental Protection Agency and the Danish operators in 2005 in order to reduce the discharge of chemicals and oil in produced water. A revised action plan for 2008-2010 was implemented to reduce emissions to air and further reduce discharges.

2.3.2 Action plan on energy efficiency

An action plan on energy efficiency was implemented by the Danish Energy Agency and the Danish oil and gas operators for 2008-2011 and 2012-2014 to improve energy efficiency for the oil and gas industry. More specifically, the action plan included measures on energy management and initiatives to reduce flaring and energy consumption.

3. DESCRIPTION OF THE PROJECT

This ESIS covers both planned redevelopment projects and future operations of the Tyra field. A larger redevelopment project, the Tyra Future redevelopment project, is planned to start in 2019 consisting of installation of new facilities and decommissioning of redundant installations and pipelines. The field is planned to be operated until 2042. The TYRA project concerns the remaining operational lifetime of projects at the Tyra field, including Tyra Future redevelopment project.

TYRA project

TYRA refers to the project that covers activities for the expected remaining lifetime of operation at the Tyra facilities, until 2042. It covers existing and planned projects for the Tyra East and West facilities and their satellite platforms Tyra South East, Valdemar (A and B), Roar and Svend, including all pipelines that are departing from any of those platforms.

The TYRA project consists of activities relating to each of the seven technical sections (appendix 1): seismic data acquisition, regular maintenance and new developments of pipelines and structures, continued production and maintenance and adjustment of production facilities for the remaining Tyra field lifetime, drilling of new wells, well stimulation, transport of personnel and cargo to support production and operations, and decommissioning of facilities at end of lifetime.

Tyra Future

Tyra Future refers to the redevelopment project of the existing Tyra East and Tyra West facilities, planned for execution in the period 2019-2023.

The Tyra field has been in production for 30 years, and the facilities are suffering from seabed subsidence, old age and increasing OPEX. It is therefore planned to upgrade the existing facilities with new topside facilities installed at higher elevations in order to continue production of existing reserves from Tyra and the associated satellites. A new processing and a new accommodation platform will also be installed.

The following sections provide a description of existing Tyra facilities and a description of planned redevelopment projects and future operation of the field:

Section 3.1 Existing facilities (up to ca.2020)
Section 3.2 TYRA project - Tyra Future redevelopment (ca. 2019-2022)
Section 3.3 TYRA operation until 2042
Section 3.4 TYRA project – other planned activities

A description of accidental events and of project alternatives is presented in sections 3.5 and 3.6.

3.1 Existing facilities

3.1.1 Overview

The main processing and production facilities Tyra East and West and the satellite platforms Tyra Southeast, Valdemar (A and B), Roar and Svend are connected by subsea pipelines, through which oil, gas and water are transported between the Tyra facilities and to Gorm E (oil) and to the Netherlands (gas) for further processing or export to shore. Pipelines departing from the Tyra (East, West and Southeast), Valdemar (A and B), Roar and Svend platforms are considered part of the TYRA project.

An overview of the existing pipelines and structures for the TYRA project is provided in Figure 3-1.

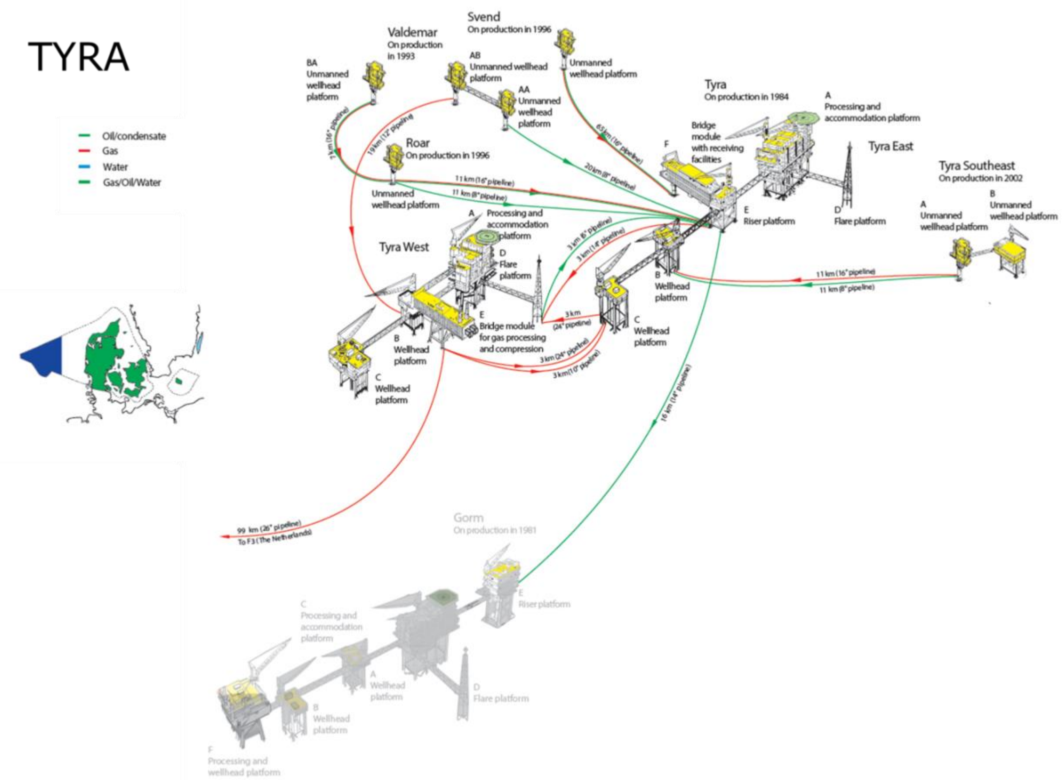


Figure 3-1 Overview of existing facilities at the TYRA project (not to scale)

3.1.2 Pipelines and structures

3.1.2.1 Tyra

Tyra is located in the South-Western part of the Danish sector of the North Sea, approximately 230 km west of Esbjerg. The water depth at Tyra is 39-41 m.

There are two main processing facilities for the TYRA project: Tyra East (Figure 3-2) and Tyra West (Figure 3-3).

Tyra East consists of six platforms, which are connected by bridges, where all interconnecting pipes and services are run.

- Tyra East A (TEA) is the main platform which holds accommodation facilities, utility and life support systems as well as processing facilities for treatment of the gas/condensate production from the Tyra East reservoir and facilities for receiving and treatment of the raw well production from the Valdemar, Roar, Svend and Tyra SE satellites and condensate from Tyra W
- Tyra East B (TEB) is a wellhead platform which accommodates 24 well slots
- Tyra East C (TEC) is a wellhead platform which accommodates 12 well slots
- Tyra East D (TED) is a flare platform
- Tyra East E (TEE) is a riser platform for the subsea pipelines from Roar, Valdemar and Tyra W as well as for the gas pipelines from Dan FB and Gorm E and the gas pipeline to Nybro
- Tyra East F (TEF) is a bridge module which serves as support for the gas and liquid receiving module TEE and as riser platform for the Svend/Harald pipeline

Figure 3-2 Tyra East

Tyra West consists of five platforms, which are connected by bridges where all interconnecting pipes and services are run.

- Tyra West A (TWA) is the main platform which holds accommodation facilities, utility and life support systems as well as processing facilities for treatment of the gas/condensate production from the western flank of the Tyra reservoir, wet gas from Valdemar AB, Low Pressure (LP) gas from Roar and Tyra SE, High Pressure (HP) gas from Halfdan (mixed with gas from Dan) and raw gas from Tyra East including its satellites and Harald, Lulita and Trym (Norwegian field)
- Tyra West B (TWB) is a wellhead platform which accommodates 12 well slots and riser platform for the incoming 18 km 12" gas pipeline from Valdemar AB
- Tyra West C (TWC) is a wellhead platform which accommodates 24 well slots
- Tyra West D (TWD) is a flare platform
- Tyra West E (TWE) is a combined bridge module and riser platform which holds the main gas compression and gas conditioning facilities module and serves as riser platform for two gas pipelines to Tyra East C; the gas pipeline from Halfdan BA and the gas export pipeline to F3 (NOGAT)

Figure 3-3 Tyra West

The Tyra East and West platforms form the export centre for all gas produced by Maersk Oil in Denmark. The bulk of the gas produced is compressed and exported in two ways; either via Tyra East to Nybro in Denmark, or from Tyra West through the NOGAT pipeline to Den Helder in the Netherlands.

Continuous control and monitoring of the satellite platforms Tyra South East, Roar, Valdemar and Svend is carried out remotely from Tyra East and West.

3.1.2.2 Tyra Southeast

Tyra Southeast is situated around10 kilometres Southeast of Tyra East. The water depth at Tyra SE is 38 metres.

The Tyra Southeast facilities have been developed as a satellite to Tyra East. Tyra Southeast includes TSA, an unmanned wellhead STAR platform with no helideck and TSB, a wellhead platform installed in 2014 (Figure 3-4). After separation, the production is transported to Tyra East in two pipelines to be processed and subsequently exported ashore.

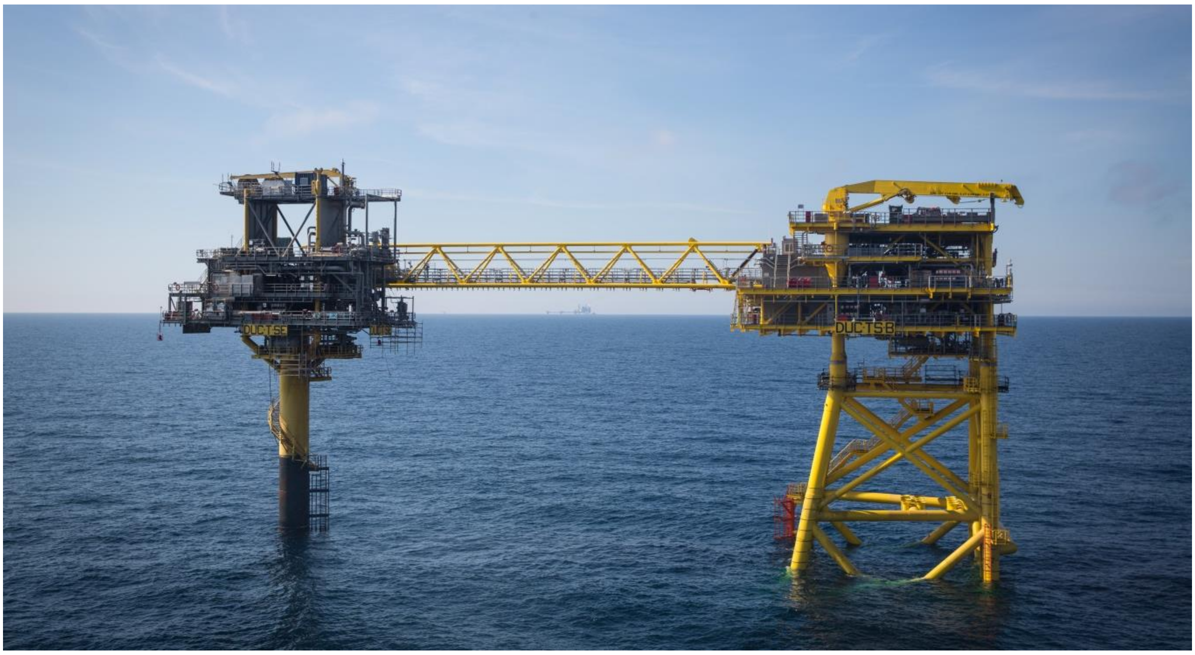


Figure 3-4 Tyra Southeast

3.1.2.3 Roar

Roar is situated around 11 kilometres Northwest of Tyra East. The water depth at Roar is 41 metres.

Roar is a satellite platform to the Tyra East installation. Roar is an unmanned wellhead STAR platform with no helideck. After separation, the hydrocarbons produced are conveyed through two pipelines to Tyra East for processing and export.

Figure 3-5 Roar

3.1.2.4 Valdemar

Valdemar is situated around 17 kilometres Northwest of Tyra East. The water depth at Valdemar is 40 metres.

Valdemar is two satellite installations to Tyra East, Valdemar A and Valdemar B. Valdemar A comprises two unmanned wellhead STAR platforms (VAA and VAB) with no helideck, connected by a bridge. After separation the production is transported to Tyra West for processing and transportation ashore/export, while condensate is transported to Tyra East for processing and export ashore.

Figure 3-6 Valdemar A

Valdemar B comprises an unmanned wellhead STAR platform (VBA) with no helideck, about 4 kilometres from the Valdemar VAA/VAB facility. The production from Valdemar VBA is conveyed to Tyra East via Roar through a multiphase pipeline. The production from the Valdemar VBA platform is transported to Tyra East for processing and export ashore.

Figure 3-7 Valdemar B

3.1.2.5 Svend

Svend is situated around 64 kilometres northwest of Tyra East. The water depth at Svend is 64 metres.

Svend is a satellite platform to Tyra East. Svend is an unmanned STAR wellhead platform with no helideck (Figure 3-8). The hydrocarbons produced are conveyed to Tyra East for processing and export.

Figure 3-8 Svend

3.1.2.6 Pipelines

The production facilities are connected by subsea pipelines where the well fluids and produced products are transported. Pipelines are trenched typically to a depth of 2 m or covered by rock situated above the seafloor. An overview of the existing pipelines and their content appears in Figure 3-1.

3.1.3 Wells

The TYRA project currently has a total of 111 wells: 36 at Tyra East, 36 at Tyra West, 7 at Tyra Southeast, 5 at Svend, 4 at Roar, 14 at Valdemar A and 9 at Valdemar B.
There are 24 free well slots which are available for drilling: 16 at Tyra South East, 2 at Svend, 3 at Roar, 2 at Valdemar A and 1 at Valdemar B.

3.1.4 Processing capabilities

The processing capabilities of the TYRA facilities (Tyra West and Tyra East) are provided in Table 3-1. The facilities are designed for continuous operation 24 hours a day. Maintenance is generally planned so only part of the facility is shut down, thus only reducing the production. The facilities will only be shut down in case of major emergencies or major maintenance operations.

Table 3-1 Processing capacity of the Tyra facilities (Tyra West and Tyra East)

Process	Unit	Tyra West	Tyra East
Liquid separation	BOPD	94,350	182,410
Gas separation	MMscfd	634	933
Produced water treatment	BWPD	82,399	88,060
Gas dehydration	MMscfd	933	709
HP gas compression	MMscfd	933	597
LP gas compression	MMscfd	485	n/a
Hydrocarbon dew point control	MMscfd	n/a	597
Stabilization	BPD	n/a	70,448

At the Tyra West facility, there are 2 main processes:

- Separation process
- Gas compression and dehydration process including water dehydration and hydrocarbon stabilization

The drawing shown in Figure 3-9 shows the overall process as a simplified process block diagram of the oil condensate and gas production facilities on Tyra West. A more detailed produced water treatment process diagram of the water treatment is provided in section 9.4.

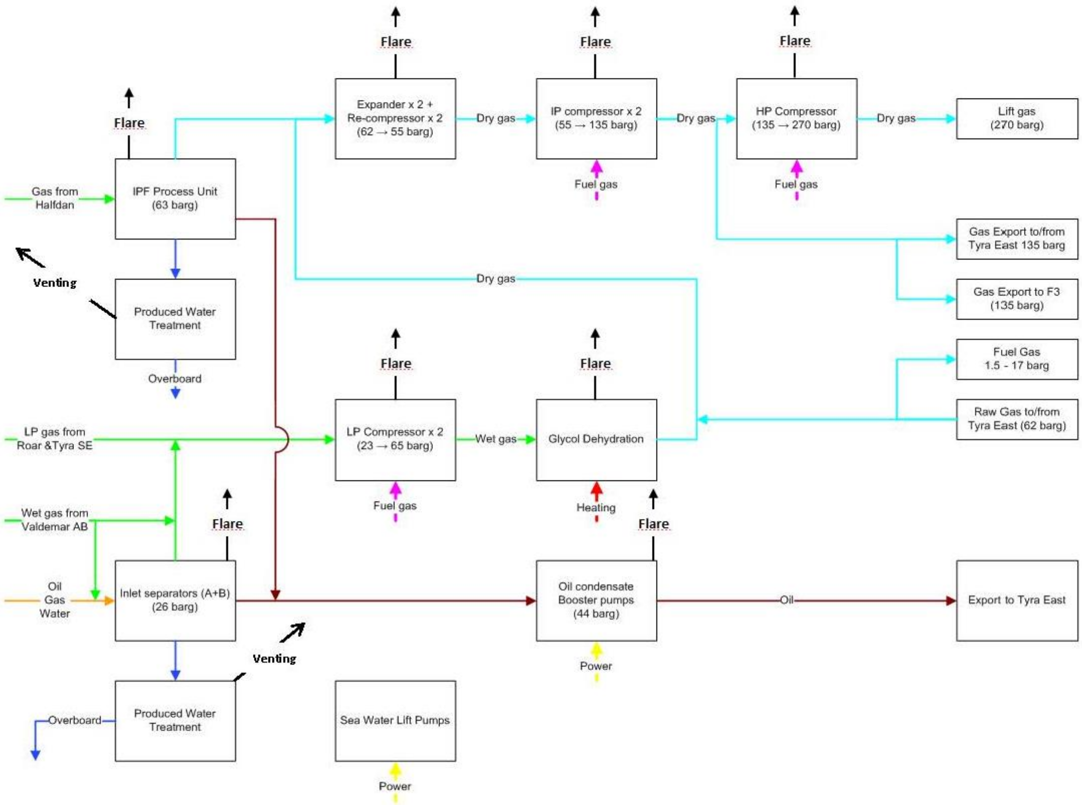


Figure 3-9 Simplified diagram of the process at Tyra West

At the Tyra East facility, there are 2 main processes:

- Separation process
- Gas compression and dehydration process

Figure 3-10 shows the overall process as a simplified process block diagram of the oil and gas production facilities on Tyra East. A more detailed produced water treatment process diagram is provided in section 9.4.

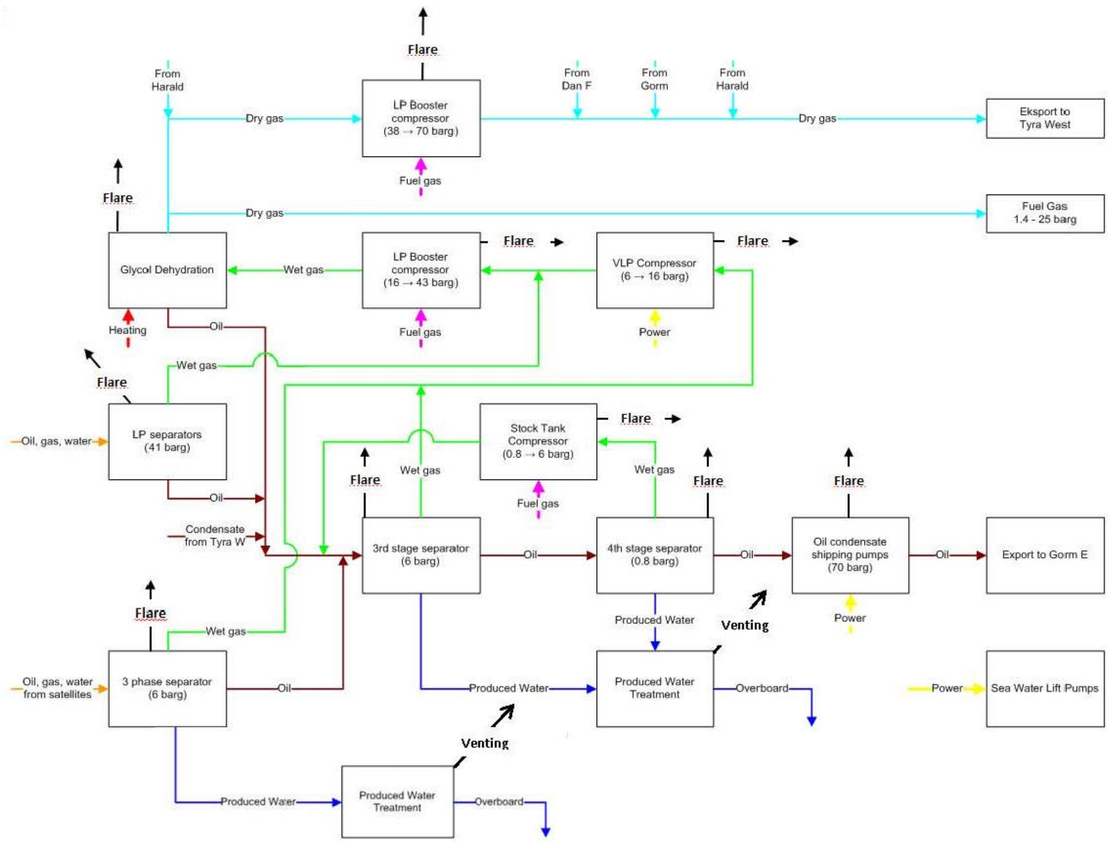


Figure 3-10 Simplified diagram of the process at Tyra East

The energy supply to the TYRA facilities consists of self-produced natural gas, and diesel supplied by ship.

Natural gas is used as fuel gas in gas turbines operating as drives for e.g. power generators, gas compressors and high-pressure water injection pumps.

Diesel is used in dual-fuel gas turbines, for cranes and for emergency equipment such as fire pumps.

Flaring of gas at compressor inlet/outlet might be required for short periods of time in relation to planned and controlled process operations (e.g. start-up) and for safety reason in relation with unforeseen process upsets which causes overpressure of process equipment and emergency depressurization of platform equipment. The most important source of cold venting is degassers.

3.1.5 Waste

Maersk Oil transports all operational waste from its Danish North Sea facilities to shore where it is recycled, incinerated or landfilled in accordance with current legislation. The last five years, an average of about 12,000 tonnes of waste were collected and brought onshore from all Maersk Oil facilities. In the last five years, about 99 % of the waste was recycled or incinerated. Landfilled waste is partly made up of sandblasting materials. Since 2014, most of the sand is being reused for roads construction and other building materials leading to a significant reduction in the amount of landfilled waste.

3.1.6 Naturally occurring radioactive material (NORM)

Naturally occurring radioactive material (NORM) such as sand, scale, clean-up materials from tubing, valves or pipes are collected and brought onshore, where they are treated to remove traces of hydrocarbons or scale formation. After treatment, the NORM is securely stored. The yearly average quantity of NORM brought for storage in 2013-2014 was approximately 70 tons. The quantity of NORM is expected to increase as fields are maturing and Maersk Oil is currently evaluating the best options for handling of NORM waste.

3.1.7 Discharges

A number of discharges are expected to occur as part of the planned activities, including drilling mud and cuttings, produced water and cooling water. These are described in section 3.3 and Appendix 1.

In addition, main liquid effluents generated by the vessels and platforms will comprise:

- Greywater (water from culinary activities, shower and laundry facilities, deck drains and other non-oily waste water drains (excluding sewage))
- Treated Blackwater (sewage)
- Drainage water
- Service water / vessel engine cooling water.

3.2 TYRA project - Tyra Future redevelopment

Tyra Future is a redevelopment project aiming to prolong the field production life. The wells will be temporarily plugged before redevelopment operations begin. New process and accommodation platforms will be installed at Tyra East which will be the new field centre, while Tyra West will be an unmanned satellite. Six of the existing jackets will be reused as substructure for new wellheads after elongation of the jackets to mitigate current and future subsidence. All redundant installations will be decommissioned and returned to shore for recycling and disposal. The wells will be unplugged again after completion of redevelopment. Non-producing wells with potential integrity issue will be suspended or abandoned.

An overview of the changes is shown in Figure 3-11 and Figure 3-12.

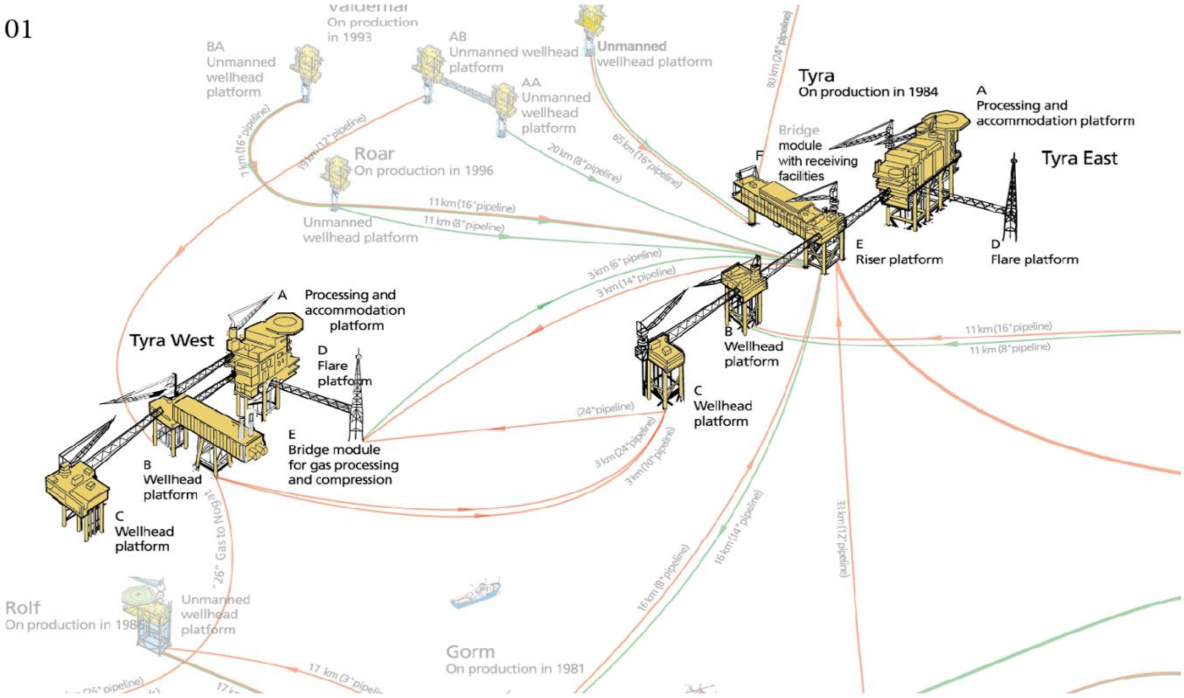


Figure 3-11 General arrangement of the Tyra field – present facilities

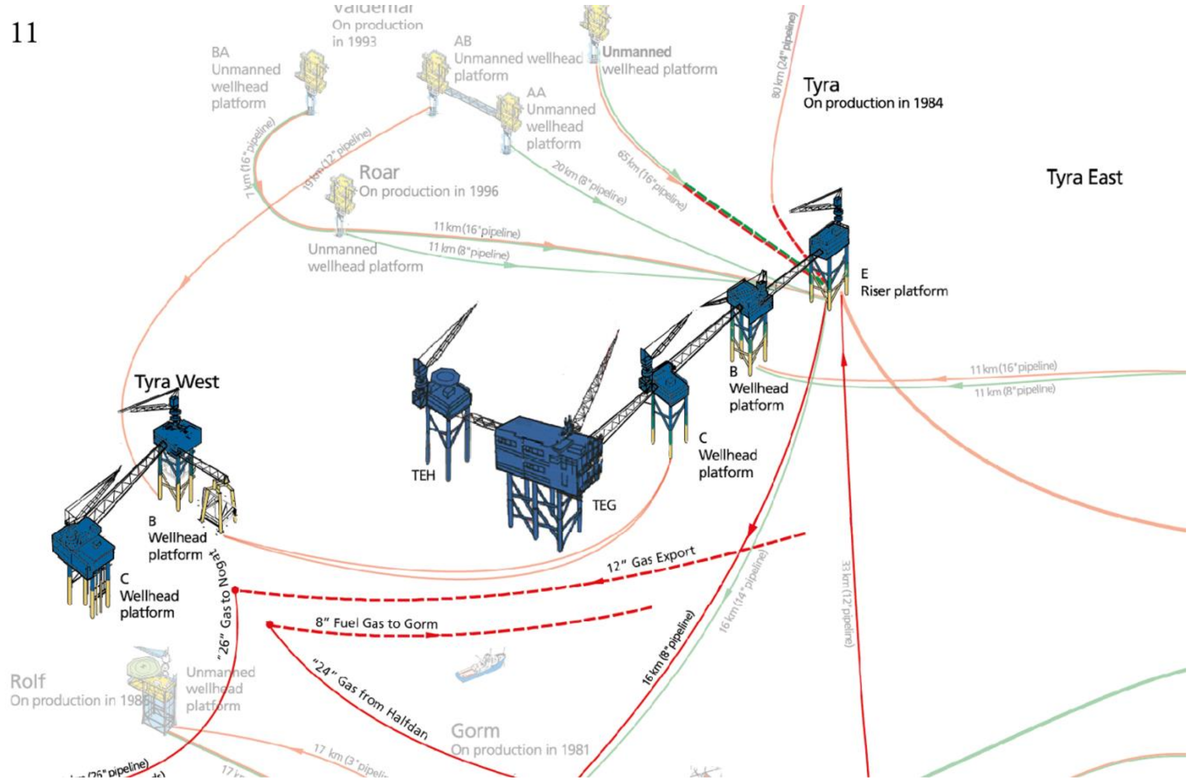


Figure 3-12 General arrangement of the Tyra Field following Tyra Future redevelopment

The redevelopment is planned for execution in the period 2019 – 2023 (Table 3-2). Production at Tyra East, West and satellite platform producers (incl. Harald) will be stopped for approximately two years in 2019-2020.

Table 3-2 Installation schedule

Campaign	
2016-2018	Well workovers and abandonments Temporary subsea bypasses
2019	Route Dan/Halfdan gas to Nogat Gorm fuelgas supply from Halfdan Shutdown all producers in Tyra and suspend Tyra resource wells
2020	Install TEG and TEH jackets Remove existing wellheads, riser modules and bridges Install new wellhead and riser modules Reroute Harald pipeline to TEE Install umbilical from TEG to TWE
2021	Install TEG and TEH modules Complete hook-up and commissioning of new facilities Reroute Dan/Halfdan gas to TEG
2021+	Remove TEA and TWA topsides Remove TEA, TED, TEF, TWA and TWD jackets

3.2.1 Pipelines and structures

3.2.1.1 Tyra East

A new gas and oil processing module, TEG, and a new accommodation and utility platform, TEH, with room for 80 persons, will be installed at Tyra East. TEG and TEH will be bridge connected and TEG will be bridge connected to TEC.

New elevated topsides and bridges will be installed on TEC, TEB and TEE. The X-mas trees will be raised and risers will be extended to the elevated topside modules.

Harald, Lulita, Trym, and Svend production will be re-routed from TEF to TEE.

The existing accommodation and processing platform TEA, the flare platform TED and the TEF module, including the jackets, will be decommissioned.

Five new bridges will be installed: two permanent bridges for replacement of existing bridges (TEB-TEC, TEE-TEB), two new permanent bridges (TEH-TEG and TEC-TEG), and one temporary bridge (TEA-TEE).

The resulting field layout is illustrated in Figure 3-13.

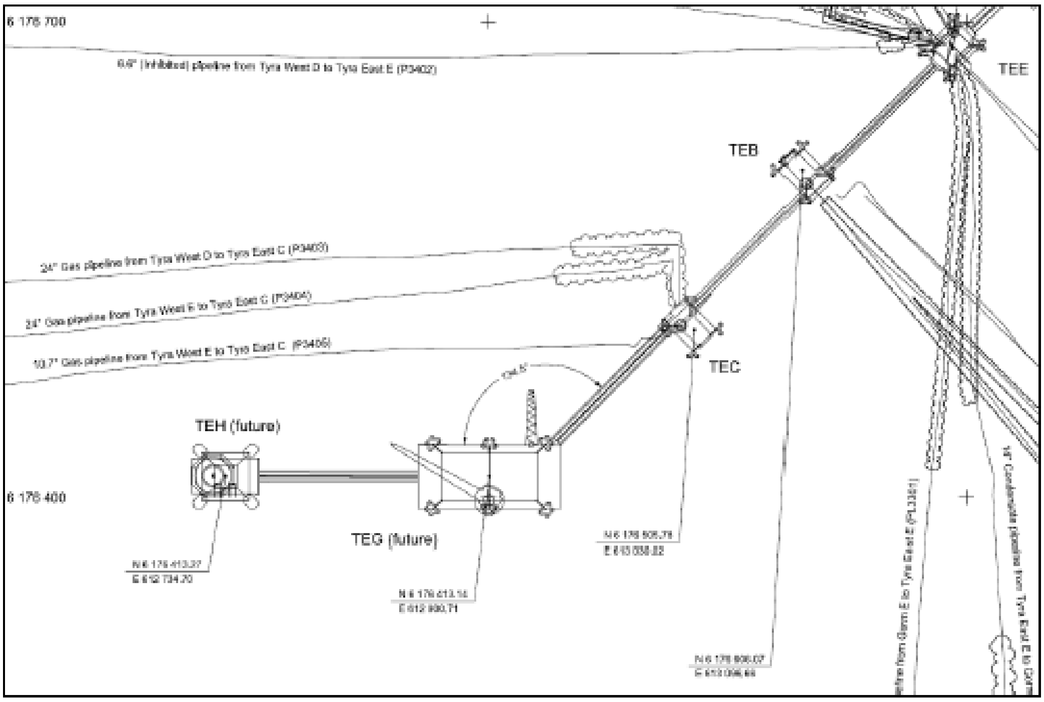


Figure 3-13 Tyra East field layout

3.2.1.2 Tyra West

New elevated topsides and bridges will be installed on TWC and TWB. The X-mas trees will be raised and risers will be extended to the elevated topside modules.

The TWE module will be replaced with a new, lighter module at higher elevation, which will use the existing TWE jacket. TWE will serve as a riser platform for existing pipeline risers. Additionally, a new riser caisson will be installed for services from Tyra East: power cable, control and communication cable, methanol import line and corrosion inhibitor import line.
TWB and TWE will be bridge connected.

The existing accommodation and processing platform, TWA, and the flare platform, TWD, will be decommissioned.

Three new bridges will be installed: two permanent bridges for replacement of existing bridges (TWB-TWC and TWE-TWB), and one temporary bridge (TWA-TWB) for use during hook-up.

The resulting field layout is illustrated in Figure 3-14.

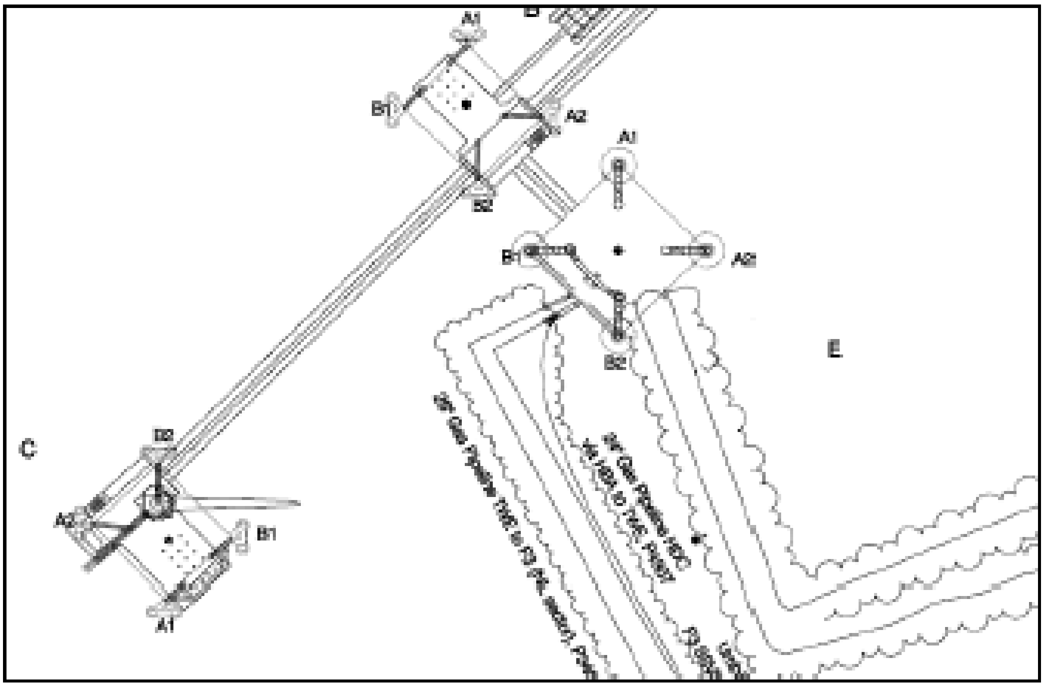


Figure 3-14 Tyra West field layout

A summary of new installations and decommissioning of obsolete facilities is given in Table 3-3.

Table 3-3 Summary of new installations and facilities decommissioning

Facilities	Installation	Decommissioning
Topsides and Jackets	TEG – Liquid and gas process TEH – Accomodation and utility	
Topside	TEB/TEC – Elevated wellhead TEE – Elevated riser TWB/TWC – Elevated wellhead TWE – Elevated riser	TEB/TEC – Wellhead TEE – riser TEF – Liquid process TWB/TWC – Wellhead TWE – Gas process
Topsides and Jackets		TEA – Accommodation and process TED – Flare platform TWA – Accommodation and process TWD – Flare platform
Jacket		TEF – Liquid process

3.2.1.3 Pipelines

Pipeline modifications will be made as follows, see Figure 3-15:

- a 26”, app. 3.4 kilometre bypass, will be installed between Tyra East and Tyra West via tie-in to 12” pipeline (P3004) at Tyra East and 26” pipeline (P3406) at Tyra West. Current gas export from southern fields is from Halfdan through 24” pipeline (P4307) to Tyra West and further to Tyra East via 24” pipeline (P3404) and via 30” pipeline to Nybro. The new pipeline is necessary to enable gas export in the Tyra Future construction phase.

  After redevelopment completion the 26” bypass will be disconnected from the 12” pipeline and connected to new riser at TEE. The southern fields will continue using the 12” pipeline (P3004) for gas export to Nybro.

- a temporary 8”, app. 3.1 kilometre pipeline will be installed between P4307 and the 8” pipeline (P3301) to Gorm to enable fuel gas supply to Gorm in the period when Tyra is not in operation, when gas export via NOGAT is implemented, and the 24” pipeline (P4307) is no longer used for gas export.

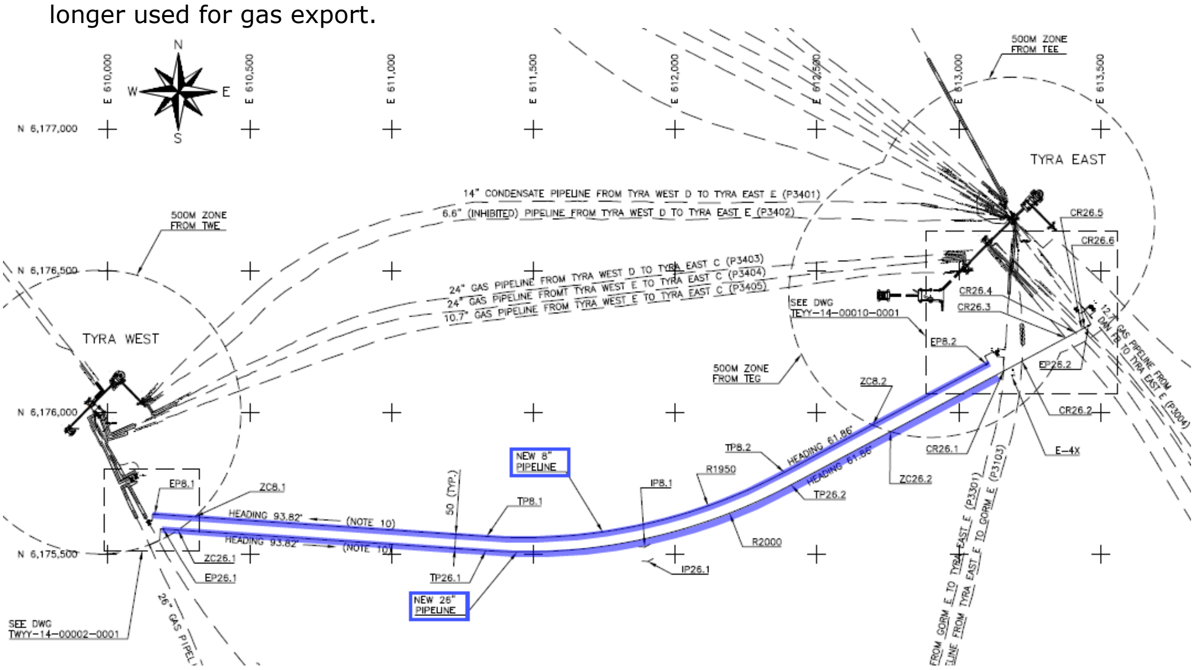


Figure 3-15 Temporary pipelines

Pipelines will be buried.

Pipeline tie-in to existing pipelines will be with a TEE connection and valves will be installed to control the flow through the main line or the bypass. A subsea structure will be installed to protect the valves from impact from e.g. trawl and dropped objects. The subsea spools connecting to the subsea valve assembly will be protected by rock dump.

There will be 4 structures, all within the 500 metre safety zone around the platforms. The structures will be secured to the seafloor by piles, 24” diameter, driven to approximately 10 metre below seabed. The installation will be made using a CSV (Construction Support Vessel) and typical duration of installing one structure is approximately 36 hours.

Tyra west will be supplied in power and chemicals by a 6.5’’ new 3.5 kilometre umbilical installed between Tyra East and Tyra West, see Figure 3-16. The umbilical will be buried.

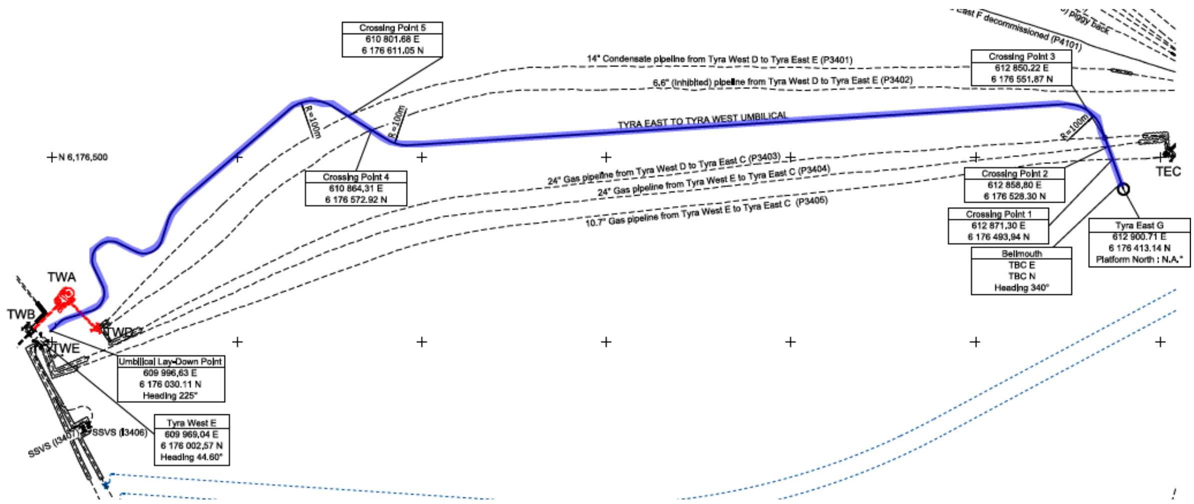


Figure 3-16 Umbilical between Tyra East and Tyra West

3.2.2 Wells

Of 36 wells at Tyra East, 28 will be suspended (21 TEB, 7 TEC) and 8 will be abandoned (3 TEB, 5 TEC).

Of 36 wells at Tyra West, 30 will be suspended (11 TWB, 19 TWC) and 6 will be abandoned (1 TWB, 5 TWC).

As explained in section 3.1.3, some original well slots are still not drilled. The Tyra Future redevelopment project does not currently plan to produce from all wells as several of the wells are already empty. Nevertheless, it remains an option to drill new producing wells to replace empty wells.

3.2.3 Transport

Transport of new facilities from the fabrication yard to the Tyra field is typically on barges tugged from shore to site. Origin of the new facilities is not decided but anticipated to be Asia for TEG and TEH topsides and Europe for TEB, TEC, TWB, TWC topsides and TEG and TEH jackets.

Transport and installation efforts are outlined in technical section: pipelines and structures (Appendix 1) and /183/.

3.2.4 Decommissioning

A total of 5 platforms and jackets are to be decommissioned: TEA, TED, TEF, TWA and TWD. The jackets from remaining platforms: TEB, TEC, TEE, TWB, TWC and TWE will be reused but the topsides will be replaced. An overview of facilities and their weights (approximate dry weight, clean steel weight) is given in Table 3-4.

Table 3-4 Facilities and their weights

	Topside weight (tonnes)	Legs (no)	Jacket weight (tonnes)
TEA	14,832	8	6,578
TED	170	3	690
TEF	2,359	3	1,476
TWA	8,021	4	2,826
TWD	241	3	1,076
TEB	1,227		Jackets to be reused
TEC	869		
TEE	1,224		
TWB	719		
TWC	932		
TWE	4,337		

The platforms will be cleaned to achieve approximate hydrocarbon free conditions to establish cold platform and hazardous materials will be identified and secured. All platforms on the field will be shut down simultaneously to achieve safe work environments and to minimise simultaneous operations and reduce interfaces. The facilities will be handed over to contractors to perform offshore removal and onshore disposal work.

The decommissioning work is arranged in phases consisting of installations with similarity and independency to enable the full range of potential contractors to perform parts of the scope. During a prequalification and tender process, removal contractors industry is invited to design innovative, safe and effective solution to execute the scope. The removal of smaller installations will be performed as single lifts, while the two larger process and accommodation modules may be removed either by the industry standards piece small, reversed installation or as a single lift.

All installations will be transported to shore for recycling and disposal. The disposal will be performed in accordance with the waste hierarchy and opportunities to reuse, recycle and recover equipment and materials will be sought.

The following pipelines will be redundant and decommissioned, see Figure 3-17:

P3401, 14”, 3 kilometre gas pipeline from TWD to TEE
P3402, 6”, 3 kilometre condensate pipeline from TWD to TEE
P3403, 24”, 3 kilometre gas pipeline from TWD to TEC
P4307, 30 kilometre gas pipeline from Halfdan to TWE
8” gas pipeline from Tyra West to Tyra East (temporary bypass)
Section of 26” gas pipeline from Tyra East (P3004) to Tyra East (NOGAT) (temporary pipeline)

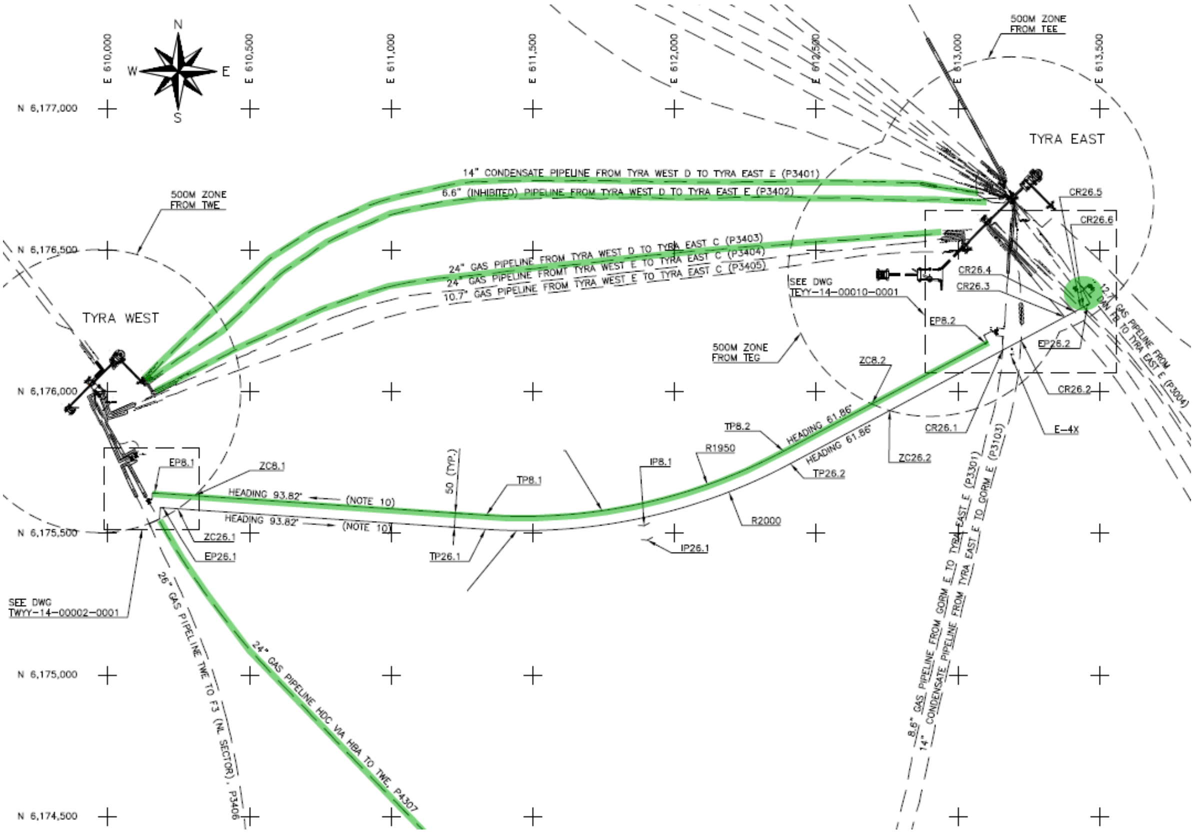


Figure 3-17 Pipelines for decommissioning

Decommissioning methods

Decommissioning methods are generally as per the technical sections, appendix 1. Site specific decommissioning operations are summarised below, building on specific decommissioning program /175/.

3.2.4.1 Platforms

Cleaning

Platforms will be shut down after cease of production in order to remove or secure hazardous materials and establish safe conditions for preparatory work and waste management. Wells will be sealed off with temporary plugs and X-mas trees will be removed.

The platforms will systematically be shut down and containments in pipelines, vessels and equipment will be identified, cleaned and secured. Containments in their original packaging will be sent to shore for reuse. Flushing water and residuals in pipework and vessels will be processed in the existing water treatment system and disposed to sea, subject to discharge permits, or to other platform. Residual will be sent to shore for disposal if no other options are available.

After initial flushing, selected systems will be steam-cleaned to establish hydrocarbon free conditions. Residual from the cleaning and the cleaning water will be processed through a cleaning skid or sent to shore.

Removal
All topsides, bridges and jacket which are not reused will be removed. Systems will be isolated and equipment and cables disconnected to prepare for removal. Removal method is in three groups:

Group 1: Wellhead and bridges which are relatively light weight items ranging from 180 tonnes to 3,660 tonnes. Topsides are cut from jackets and lifted in single lift to barge for transport to shore.

Group 2: Processing and accommodation platforms TEA and TWA weighing 16,000 tonnes and 7,500 tonnes respectively. Two options for removal are considered, i.e. single lift or piece large. Piece large requires removal in several lifts, as when originally installed. The heaviest topside lift is approximately 3,100 tonnes.

Group 3: Jackets with weights ranging from 500 tonnes to 3,500 tonnes. The jackets are removed in single lift to barge for transport to shore.

Onshore disposal and recycling
Structures will basically be loaded to barge or vessel and transported to shore for delivery to disposal at onshore disposal yard. Here the structures shall be dismantled, scrapped and decontaminated and materials managed for recovery and downstream waste flows.

3.2.4.2 Pipelines

A comparative assessment /188/ was carried out between two options: removal and leave in place. The aim of the comparative assessment was to evaluate the best decommissioning option based on safety, environmental, technical, societal and economic criteria. The leave in place option contemplates removal of everything above seabed and sealing and rock covering of pipe ends. It is concluded that the "leave in place" option is safer, with fewer environmental impacts, and is technically less complex and less costly than removal.

The activities for "leave in place" decommissioning include cleaning by water flushing, disconnection of pipelines from risers, removal of valve stations, sealing and rock covering of pipeline ends and monitoring of decommissioned pipelines.

3.2.4.3 Waste management

A material inventory is prepared as part of the decommissioning programme /176/ /177/. Materials are broken down in waste types as shown in Figure 3-18.

All of the platform materials will be taken to a licenced onshore disposal yard for recycling and disposal in compliance with waste hierarchy principle. Generally, hazardous waste present on the platforms will be sealed "in situ" offshore to be removed at the onshore disposal site, which is safer and more cost efficient. All trans-border shipments of hazardous materials to disposal yards will be subjected for applications for consent and required notifications to national authorities will be given. An overview of the waste streams is given in below.

Hazardous waste will be classified by its content of dangerous properties to the European waste list /192/, based on samples taken from the materials and analysed at a licenced laboratory. The waste will be removed, packed and transported to a final treatment facility for recovery or disposal to landfill. Temporary storage of hazardous waste shall be subjected to control.

Process pipework will cleaned from residual hydrocarbons by use of HP jetting or steam cleaning to achieve cleanliness suitable for metals recycling. Potential NORM and Hg contamination will be removed and collected.

Process chemicals are basically used to support the process in various applications, such as scavenges, inhibitors, biocides, detergents and various support functions, such as temperature control. The chemicals are normally ranging from acids, bases and organic solutions such as MEG, glycol and methanol. The process chemicals will as far as possible be returned to shore in its original consignments.

Oils and fuels are used as lubricants and power supply and are present in rotating equipment, hydraulic systems and engines. Generally, these products are well defined and present as contained compartments as part of an equipment. It should be noted that used oil is often a complex mixture of paraffinic, naphthenic and aromatic petroleum hydrocarbons that may contain one or more hazardous substances including carcinogenic compounds. Used oils and fuels shall be drained off and transported to shore for waste treatment.

Radioactive sources present in level transmitters, smoke detectors and small amounts present in luminescent signs will be collected and disposed at special licenced depositories.

Hazardous fibres such as asbestos and ceramic fibres have been commonly used in a variety of construction and insulation applications on offshore platforms due to their fire resistance, insulation, chemical resistance and tensile strength. Asbestos may be mixed with other materials such as cement in fire walls or woven into fabric such as pipe sealing and gaskets. Hidden asbestos should be expected since record of asbestos is often scarce and may be lacking from original vendor documentation.

Hazardous construction material is present in various applications. Prioritised chemicals such as PCB and chlorinated paraffin may be present in sealing and cooling fluids. Brominated flame retardants and Phthalates may be found in cell foam, pipe insulation, textiles and flooring. Heavy metals additives may be found in plastics and paint.

Paint systems may contain several types of hazardous materials such as heavy metals, asbestos, PCB and polyurethane. Most paint systems contain polyurethane which will generate isocyanates when exposed to thermal treatment (hot cutting). From a waste management point of view, paint coated scrap steel, based on chemical analysis and assessment of the overall risk, shall, to the extent possible not be classified as hazardous material. Paint may therefore be in the scrap steel delivered to re-melting in compliance with industry practice.

WEEE will be segregated from the waste stream and provided for material recovery. Hazardous substances such as heavy metals, asbestos, flame retardants and plastics will be removed and valuable trace metals and alloys will be recovered.

The majority of materials present on the platforms are non-hazardous waste such as scrap metals and various construction materials. These materials will be segregated at the onshore disposal site and be recovered according to the waste hierarchy to its purest possible waste category. After options for reuse are exhausted, the scrap metal will be segregated and treated to be recycled. Other material such as plastic, glass, concrete, wood and paper will be segregated for material recovery. Marine growth disposal options include recovery or recycling.

Combustible waste to energy recovery and inert waste for landfill disposal will be minimised as far as possible. However, after all other treatment options are exhausted; rest materials such as mixed combustible waste not suitable for material recovery and lightweight concrete fire protection and mineral isolation materials may be incinerated, if possible, or deposited at landfills respectively.

Table 3-5 Summary of hazardous waste stream management methods

Waste Stream	Removal and Disposal method
Hydrocarbons	Bulk hydrocarbon liquids from pipework, vessels and tanks will be drained and routed to Gorm. Process systems will be flushed with sea water. Additional cleaning will be performed in selected areas depending on removal method. Required additional decontamination will be performed onshore prior to recycling / re-use.
Potential contaminants: NORM and Hg	Potential NORM and Hg contamination will be identified offshore and stored "in situ" for removal at an onshore disposal site prior to recycling / re-use. Waste will be deposited at special licenced depository.
Process chemicals	Scavenges, inhibitors, biocides, detergents and organic solutions such as MEG, glycol and methanol will as far as possible be returned to shore in its original consignment. Residuals will be removed at the onshore disposal site.
Oils and fuels	Lubricants such as engine oils and hydraulics will basically be sealed off and stored "in situ" for removal at an onshore disposal site. Fuels will be drained and transported to shore for disposal. Oils and fuels will be provided for material recovery or destructed by incineration.
Asbestos and ceramic fibres	Potential asbestos such as CAF gaskets and Bestobells pipe sealing and ceramic fibres in fire door insulations will be sealed off and stored "in situ" for removal at an onshore disposal site and deposited to landfill depository.
Hazardous construction materials	BRF's in pipe insulation, phthalates in floorings, chlorinated paraffin's and PCB sealing will be identified offshore. The material will be left "in situ" for removal by manual decontamination at an onshore disposal site and destructed by incineration.
Paint	Scrap steel coated with paint will be delivered to recycling. No additional cleaning requirements. Awareness around hot work on painted surfaces due to generation of isocyanate fumes will be implemented into safe work procedures.
WEEE	Electrical cables, equipment, leave in for decontamination by manual removal at an onshore disposal site. Through national waste route for WEEE

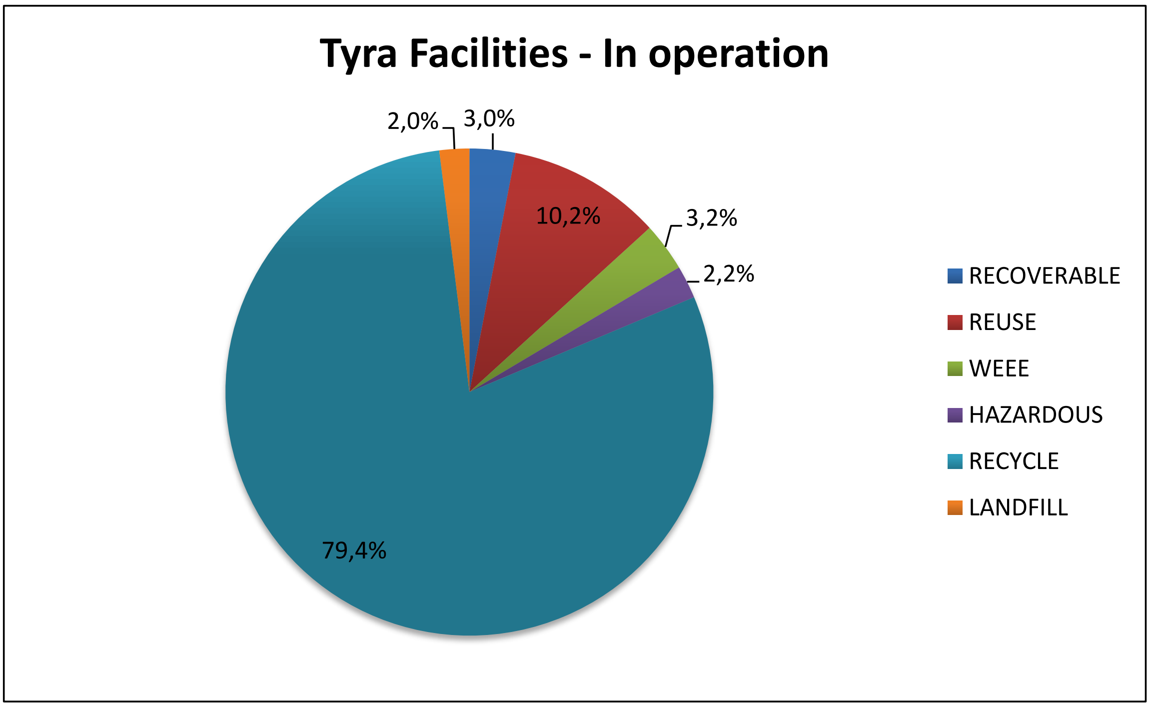
Table 3-6 Summary of non-hazardous waste stream management methods

Summary Non-Hazardous Waste Stream Management Methods	
Waste Stream	Removal and Disposal method
Scrap metal	Segregated from other construction materials and treated to be suitable for recycling. Scrap metals shall cease to be waste according to waste framework.
Segregated materials	Waste fraction such as plastic, glass, concrete, wood and paper will be segregated for material recovery.
Marine growth	Bulk removal of marine growth onshore. Small quantities removed offshore to allow cutting and lifting operations. Disposed of in agreement with authorities and local practice. Options for disposal according to waste hierarchy: recovery, recycling, landfill, composting, land-spreading or still attached to the jacket for steel melting.
Mixed combustible waste	Mixed combustible waste not suitable for material recovery such as mixed construction materials, GRP cabinets and cable insulations will be provided for energy recovery by incineration.
Inert waste	Residual materials after all other recovery options are exhausted consist of mixed rock wool insulation, light concrete fire protection and sweeping remains from the scrapping operations. These materials may be used as backfill materials in construction applications depending on heavy metal contamination or be deposited to landfills.

Initial inventory mappings indicate that the decommissioning of the facilities (topsides and jackets) will be generating about 60,000 tonnes in the main waste categories recoverable, reuse, WEEE, hazardous, recycle and landfill, but not including marine growth estimated to a total about

2.500 Tones. When the facilities have been cleared for removal the weight will decrease to around 51,000 tonnes. The weight % distribution is shown in Figure 3-18.

It must be noted that waste weight and material breakdown represents preliminary estimates of the segregation into waste types (Level 1 inventory mapping). During the next mapping level and finally at the demolition yard, the hazardous waste details will be refined and the recycling fraction is expected to increase, e.g. in this Level 1 mapping, the WEEE waste type includes steel trays and copper from cables which can be recycled.



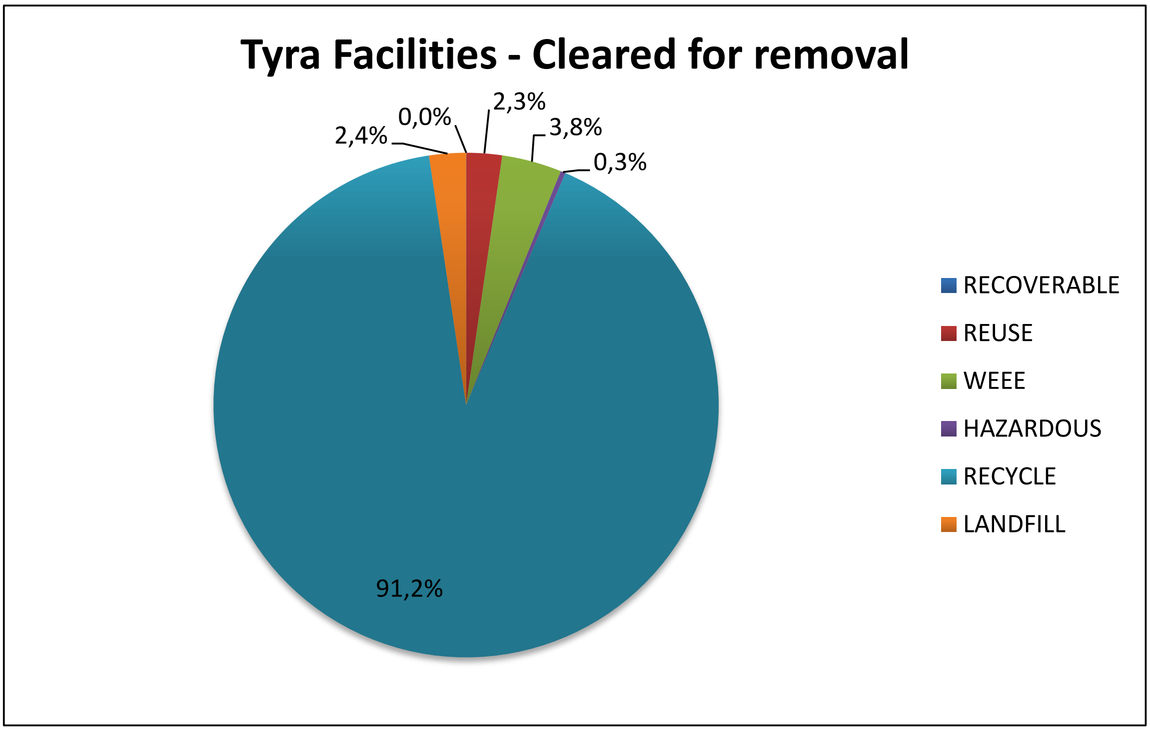


Figure 3-18 Tyra waste and materials breakdown, in operational condition and when cleared for removal, weight %

A waste management plan shall be established for safe handling of materials and to optimise recycling and minimise amount of waste classified as hazardous and inert waste to landfill.

3.3 Tyra operation until 2042 – new facilities

3.3.1 Description of new facilities

Following Tyre Future redevelopment, the resulting facilities are:

Tyra East:

TEG	Central processing platform
TEH	Accommodation and utility platform
TEC	Wellhead and riser platform
TEB	Wellhead and riser platform
TEE	Riser platform including reception facilities and slug catchers

Tyra West:

TWC	Wellhead platform
TWB	Wellhead platform, incoming risers and cable J-tube
TWE	Riser platform with boat landing

The general arrangement appears in Figure 3-12.

For satellites: Tyra Southeast, Roar, Valdemar, and Svend no redevelopment within Tyra Future project is planned and facilities remain and continue producing as under existing conditions, cf. section 3.1.2.2 to 3.1.2.5; planned activities other than Tyra Future redevelopment, see 3.4.

3.3.2 Wells

Following Tyra Future redevelopment there will be 38 producers, 20 suspended wells and 14 abandoned wells:

18 wells will be reopened as producers after redevelopment (15 TEB, 3 TEC), while 10 will be left suspended (6 TEB, 4 TEC), and 8 will be abandoned (3 TEB, 5 TEC).

20 wells will be reopened as producers after redevelopment (6 TWB, 14 TWC), while 10 will be left suspended (5 TWB, 5 TWC), and 6 will be abandoned (1 TWB, 5 TWC).

3.3.3 Production

The main functionalities of the process facilities shall be to:

- Separate produced gas, oil and water
- Compress and treat the combined DUC sales gas stream to sales specification and export to markets
- Provide lift gas to Tyra and Tyra satellite fields
- Dewater and stabilize the Tyra Asset oil production to transport and sales specification and export to Gorm E
- Clean the produced water to specifications acceptable for discharge to sea

The gas dominated satellite and local well fluid streams are gathered in LP gas separator at the TEG platform. Downstream of the LP gas separator, gas is compressed, then dehydrated, HC dewpoint controlled to sales specification and export compressed. Dehydrated gas is compressed for liftgas circulation. Imported chilled gas from Harald is entered downstream the LP compressor. Imported dehydrated gas from Dan/Halfdan is entered downstream the dehydration column. The configuration in the main gas stream is assumed as 1 x 100% with exception of gas HC dewpoint processing and export compressors which are assumed 2 x 50%.

The liquid dominated satellite well fluid streams are gathered in liquid slug catcher at TEE. Downstream of the liquid slug catcher, the liquids are heated and dewatered in the liquid separator, then stabilized in two stages to sales specification and pumped to Gorm. Flash gas from liquid stabilisation is compressed in 2 x 100% flash gas compressors and routed to inlet of LP gas separator. Liquids from LTS and scrubbers are routed to liquid stabilisation. Produced water is treated to overboard specification.

Gas export will be from TEE platform to Nybro, utilizing the existing 30” pipeline. Condensate export will be from TEE to Gorm utilising the existing 14” pipeline (P3103). In final configuration the existing 12” pipeline between Dan and TEE (P3004) and 8” pipeline between Gorm and Tyra East E, will be brought back to the original service.

New risers to accommodate Harald, Svend and Adda production will be installed on TEE.
Gorm will continue to receive fuel gas from Tyra East via P3301.

Dan and Halfdan dehydrated gas export will be exported from Dan FB to TEE via P3004.

The re-developed Tyra West will receive power and control, and communication via cable from Tyra East. Tyra West will continue to receive the gas from Valdemar A field. The gas will however simply be comingled into Tyra West production and exported to Tyra East.

The multiphase produced at TWC and TWB are merged in the production manifold on TWB and then exported from TWE to Tyra East for processing. Gas produced at Valdemar is received at TWB and exported from TWE to Tyra East together with the produced multiphase from TWB and TWC. Liftgas for TWB and TWC is supplied from Tyra East.

Production chemicals are used to optimise the processing, and traces of chemicals and oil will be present in the produced water (PW) that is discharged, cf. section 3.4. Maersk Oil has since 2008 been phasing out the use of red chemicals which contains components that bioaccumulate or degrade slowly (section 8.1.3). Presently, about 70.000 BWPD of produced water is discharge to sea at Tyra.

The discharged water contains app. 9 mg/l of oil, resulting in 37 tons of oil pr. year discharged to sea with the produced water. The produced water associated with oil and gas production from the Tyra asset is forecast to about 95.000 BWPD following Tyra Future redevelopment, and it is expected to meet a monthly average target of 6 mg/l oil in water.

Maersk Oil is frequently re-evaluating the best practical options to reduce the risk and impacts associated with PW discharges (see mitigation measures in section 8).

Chemicals use and discharge to sea is only permitted after authorisation from the DEPA.

3.3.3.1 Processing capabilities

The processing capabilities of the Tyra facilities following the Tyra Future redevelopment are provided in Table 3-7.

Table 3-7 Processing capacity of the Tyra facilities following the Tyra Future redevelopment

Process	Unit	
HC Liquid production	BOPD	40,000
Gas production, sales gas	MMscfd	300
Gas production, lift gas	MMscfd	140
Water production	BWPD	115,000

The process on Tyra Future facilities are shown as a simplified block diagram in Figure 3-19.

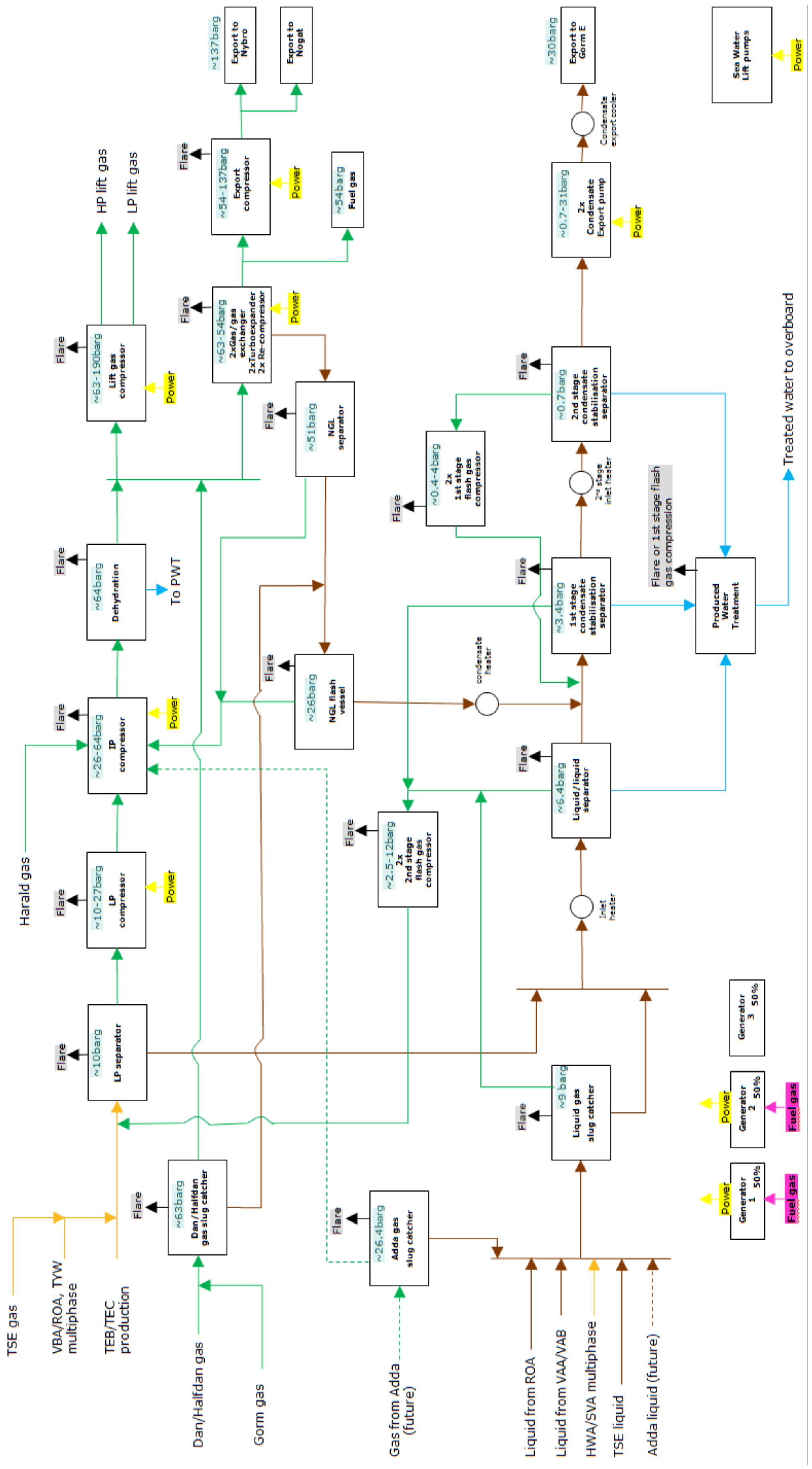


Figure 3-19 Simplified diagram of the process at Tyra East following the Tyra Future redevelopment

3.3.4 Waste
See 3.1.5.

3.3.5 Naturally occurring radioactive material (NORM)
See 3.1.6.

3.3.6 Discharges
See 3.1.7.

3.4 TYRA project - planned activities additional to Tyra Future

3.4.1 Seismic
Seismic surveys are performed to provide information about the subsurface geological structure to identify the location and volume of potential hydrocarbon reserves, and to ensure that seabed and subsurface conditions are suitable for planned activities (e.g. drilling and construction of production facilities).

For the TYRA project, several types of seismic data acquisition may be carried out at a later stage:

- 4D seismic surveys are 3D seismic surveys repeated over a period of time, and can take several months to complete. A 4D seismic covering an area of a few hundred km^2. The latest survey has been carried out in 2016, and expected to be repeated about every 4 years.
- Drilling hazard site surveys (one per year expected) may include 2D high-resolution multi-channel and single-channel seismic, side scan sonar, single and multi-beam echo-sounder, seabed coring and magnetometer. Typical duration of such a survey is 1 week covering an area of 1x1 kilometres.
- Borehole seismic surveys (one per year expected) are conducted with a number of geophones that are lowered into a wellbore to record data. The duration is usually one to two days.

3.4.2 Pipelines and structures
Regular maintenance of the existing pipelines and structures at the TYRA project will be undertaken including external visual inspections by remotely operated vehicles (ROVs) and an internal inspection/cleaning of pipelines (pigging). If inspection surveys reveal that the replacement of existing pipelines is necessary, a separate project and environmental screening will be carried out.

For the TYRA project a number of development projects are considered. The aim of the projects is to optimise the current TYRA production and possibly access new resources. The development projects are not all specified in detail at this stage, and only an outline is provided:

- Valdemar LC development optimization: a wellhead platform (SLIC type, 8 well slots) with 6 new oil producing wells, and a 1 kilometre multiphase pipeline to the existing Valdemar BA platform
- Bo South development: a wellhead platform (SLIC type, 4 well slots) with 4 new oil producing wells, and a 5 kilometres multiphase pipeline to the existing Valdemar BA platform
- Adda Phase I + II: a wellhead platform (4 legged type, 16 well slots) with 8 new wells (7 gas producing and one oil producing), and 2 new gas pipelines (each 12 kilometres) to Tyra
- Tyra LC development: a wellhead platform (SLIC type, 4 well slots) with 3 new oil producing wells (no new pipelines)

3.4.3 Production
Tyra production was initiated at Tyra in 1984, Valdemar in 1993, Roar in 1996, Svend in1996 and then later at Tyra Southeast in 2002. The production at Tyra from 1984 to 2014 adds to a total of

342 million barrels of oil (stbo) and 4,472 billion standard cubic feet of gas. The total annual production for the TYRA project peaked in 2005 and is now on a natural decline. This reflects the fact that the majority of the fields are in a relatively mature stage in the production cycle. In 2015, TYRA had an annual production of 4 million barrels of oil and 64 billion standard cubic feet of gas.

Throughout their productive life, most oil wells produce oil, gas, and water. Initially, the mixture coming from the reservoir may be mostly hydrocarbons but over time, the proportion of water increases and the fluids separation and processing becomes more challenging. Simultaneously, the total volume of fluid to be processed decreases. Processing is required to separate the fluid produced from the reservoirs. Separation of oil, gas and water usually takes place in several stages by use of gravity.

The expected production of oil, gas and water from the TYRA project is shown in Figure 3-20 to Figure 3-22. The production will be stopped in 2020 during the major redevelopment operations. There is currently no water re-injection as part of the TYRA project.

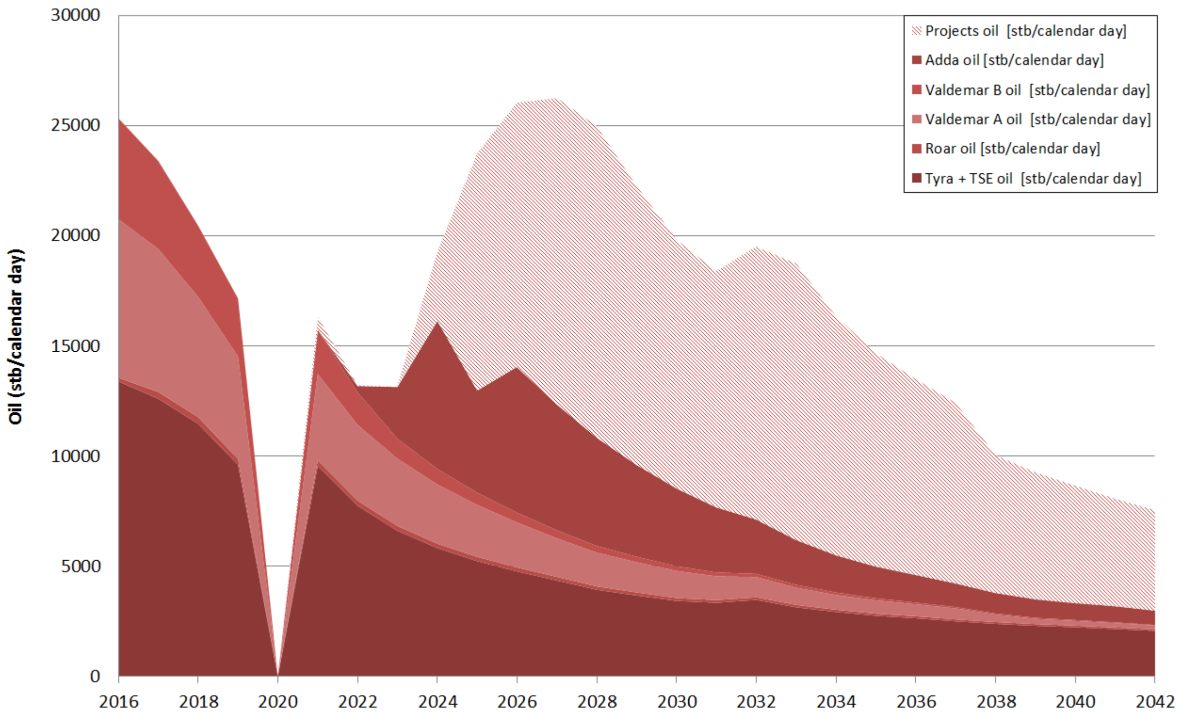


Figure 3-20 Total expected production of oil from the TYRA project given as standard barrels per day (uptime 90%)

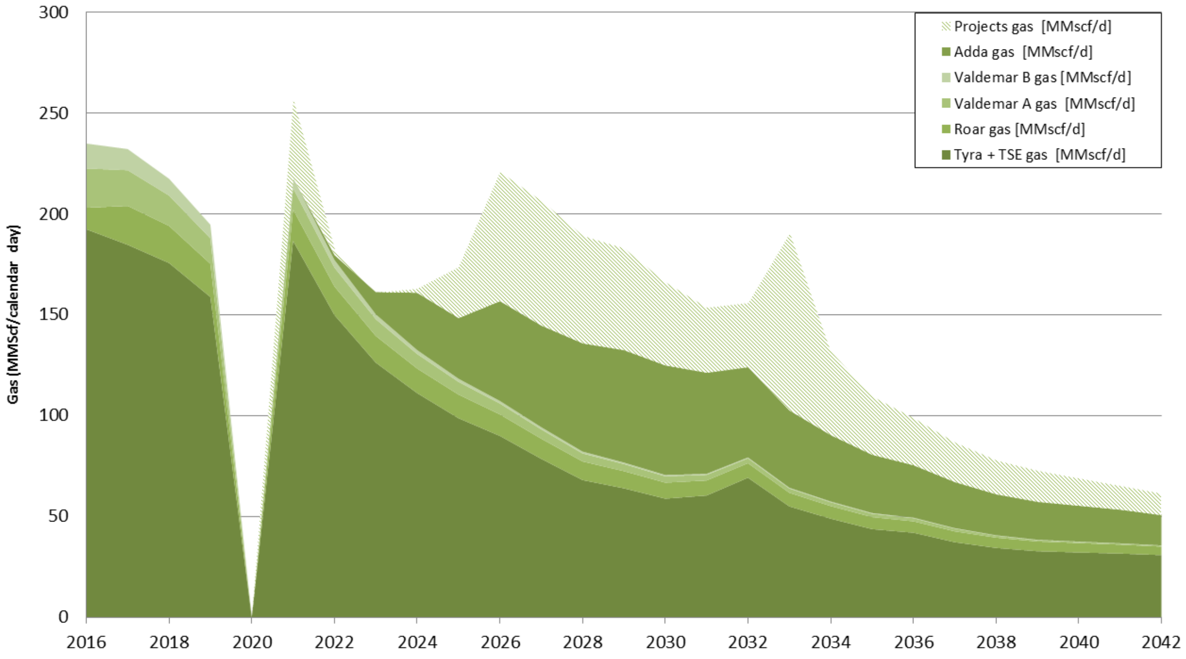


Figure 3-21 Expected production of gas from the TYRA project given in million standard cubic feet per day (uptime 90%)

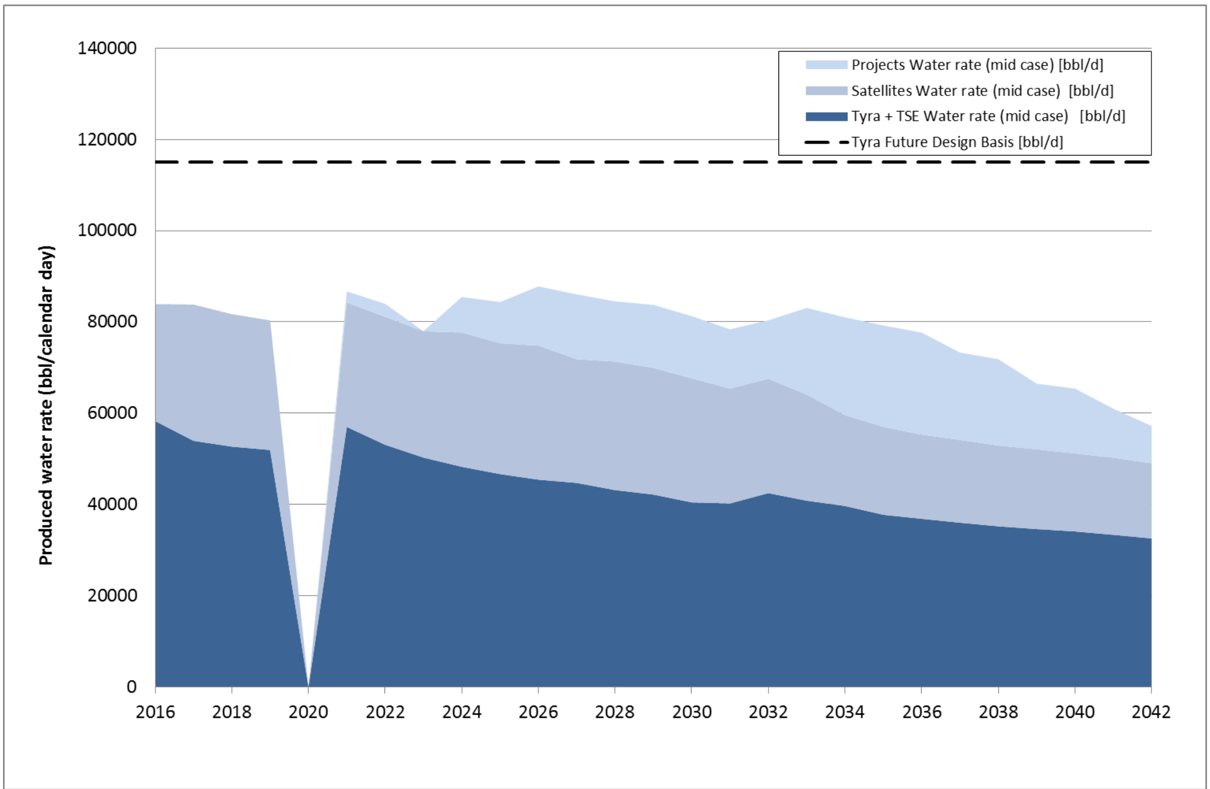


Figure 3-22 Expected production of water from the TYRA project given in standard barrels per day; no re-injection is undertaken and all produced water is discharged (uptime 90%)

Maersk Oil uses production chemicals (e.g. H_2S scavenger, biocides) to optimise the processing of the produced fluids. Chemicals are required for an efficient separation of oil and water, reducing the concentration of oil in the produced water being discharged to the sea. The inventory of the main chemicals used by Maersk Oil, their general use and partitioning in water/oil phase is presented in technical sections, appendix 1. A fraction of the oil and chemicals is contained in the treated produced water which is discharged. Discharge of produced water to sea is permitted only after authorisation from the Danish Environmental Protection Agency (DEPA).

The amount of chemical used is related to the production and the produced water. The nature, type and quantities of chemicals that are used in production and discharged to sea are expected to be adjusted to follow changes in production and technical development. In the period 2012-2015, about 4,250 tonnes of chemicals were used for production at the TYRA project and an estimated 3,950 tonnes of chemicals were discharged to sea.

In the future, Maersk Oil will continue to aim at reducing the environmental risk associated with the production discharges on the marine environment, by reducing the volume of chemicals discharged, improving the treatment processes or selecting alternative chemicals (see mitigating measures in section 8).

The nature, type and quantities of chemicals that are used and discharged to sea are reported to the DEPA. The latest discharge permit is available at the DEPA website.

Oil content in produced water is regulated by the DEPA based on OSPAR regulations. Maersk Oil's discharge permit includes a ceiling for the discharge of oil discharge with produced water from the existing Maersk Oil facilities. In 2016, the ceiling is set to 202 tons. The TYRA project contributes to the total amount of oil in produced water discharges to sea. The estimate of oil discharges at TYRA ranges between 35 and 65 tonnes until 2020 and between 20 and 50 tonnes following the Tyra Future redevelopment (low and high, Figure 3-23).

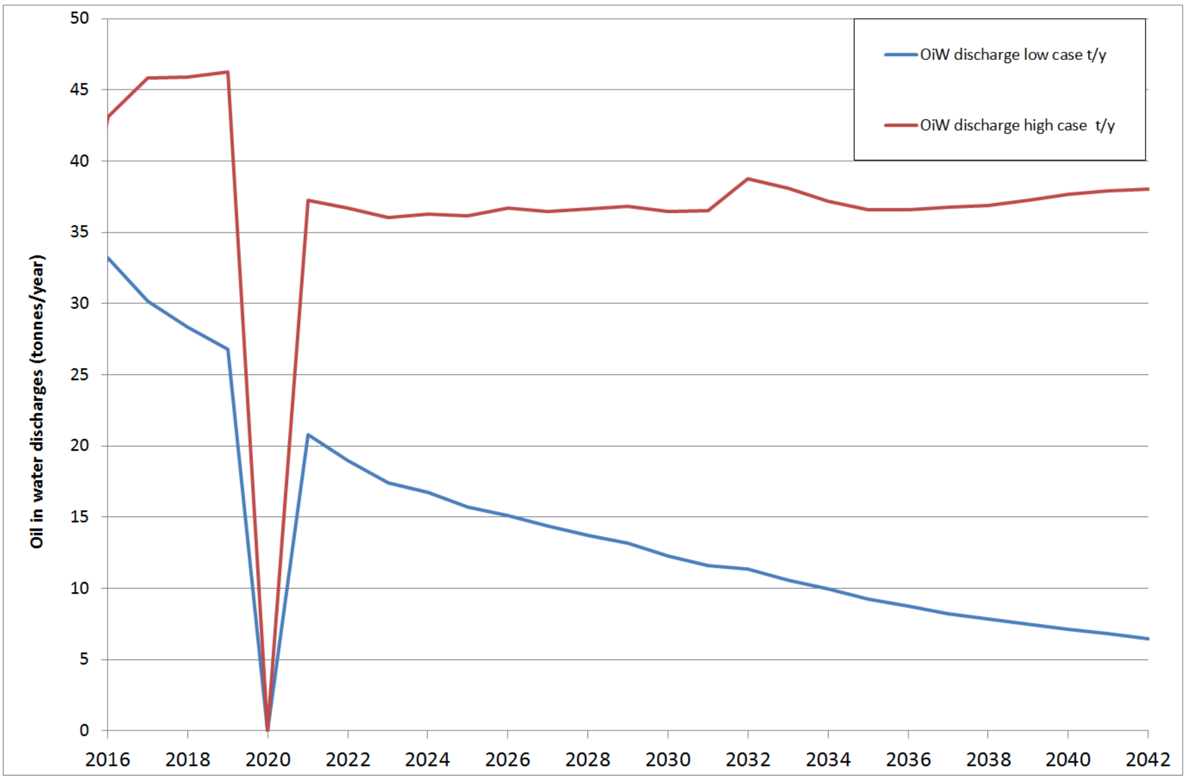


Figure 3-23 Oil in water discharge high and low case forecasts based on high and low produced water forecasts. Oil-in water content is expected to be in average 8 mg/l until 2019 for existing facilities and 6 mg/l after Tyra Future redevelopment project is implemented

During the past 5 years the oil discharge from Tyra has been stable below 40 tonnes per year. The volume of produced water following Tyra future redevelopment is forecast to potentially increase to approximately 100.000 BWDP, however, the aim is to maintain or reduce the total oil discharge via a produced water treatment package designed to reduce oil-in-water concentration to 6 mg/l. Additional requirements to upstream equipment are made to provide for successful functioning of the water treatment.

On the existing facilities, Maersk Oil has placed flowmeters that measures continuously the volume of discharged produced water, and water samples are taken daily for measurement of oil content. Similar monitoring equipment and procedures will be implemented on the new facilities.

The amount of oil in produced water discharged to sea is reported to the DEPA, according to the requirements in the Discharge Permit. New water treatment facilities at Tyra will be designed to treat the water to a levetl acceptable for discharge. Other facilities shall meet OSPAR requirements and are continuously adjusted to operate within oil in water limits.

3.4.4 Drilling

Drilling of wells is necessary for extracting oil and gas resources. Wells are used for transporting the fluid (a mixture of oil, gas, water, sand and non-hydrocarbon gasses) from the geological reservoir to Maersk Oil installations, where fluid processing takes place. Wells are also used for injection of water (seawater or produced water) or gas to increase reservoir pressure and enhance the oil and gas recovery rate.

For TYRA, 24 existing well slots are available for drilling (16 at Tyra South East, 2 at Svend, 3 at Roar, 2 at Valdemar B and 1 at Valdemar A). Maersk Oil has not decided whether all free well slots will be drilled. In addition, up to 32 well slots are expected to be drilled in relation with the possible TYRA development projects. For the TYRA project, no wells are expected to be subjected to slot recovery or re-drill, cf. technical sections, appendix 1.

Typical well types are presented in technical sections, appendix 1. It has not been decided which type of well will be applicable for the TYRA project. Drilling is performed from a drilling rig, which is placed on the seabed (with an expected area of a few hundred m^2). Drilling of a well starts with hammering a conductor into the seabed. A new well will typically take up to 150 days to drill. Different types of drilling mud will be used based on the well and reservoir properties. Water-based mud and cuttings will be discharged to the sea, whereas oil-based mud and cuttings will be brought onshore to be dried and incinerated. Discharges to sea are permitted only after authorisation from the Danish Environmental Protection Agency. Water-based drilling mud and drill cuttings may contain traces of oil from the reservoir sections. The oil content in the water-based drilling mud and drill cuttings is monitored regularly to ensure it does not exceed 2%, on average. It is estimated that on average 7 tonnes of oil per 1,000 m reservoir section can be discharged to sea corresponding to a maximum discharge of 28.8 tonnes of oil per well.

3.4.5 Well stimulation

The purpose of well stimulation is to improve the contact between the well and reservoir, thereby facilitating hydrocarbon extraction (for a production well) or water injection (for an injection well). Well testing is performed to evaluate the production potential of a well after stimulation.

At the TYRA project, the new wells (up to 24 in existing well slots and up to 32 wells in new structures) may be subjected to matrix acid stimulation or acid fracturing. The existing wells at the TYRA project may be subjected to matrix acid stimulations (in total up to 2 per year). Use and discharge (e.g. drilling and maintenance) of chemicals are presented in technical sections, appendix 1. Discharge to sea is permitted only after authorisation from DEPA.

3.4.6 Transport

Personnel and cargo are transported daily to support Maersk Oil’s production and drilling operations via helicopters, supply vessels and survey vessels. Personnel will be reduced from around 180 to 80 people when Tyra West becomes unmanned. Standby vessel may be employed in connection with drilling and tasks requiring work over the side of the installation.

3.4.7 Decommissioning

Overall principles and methods of decommissioning are as per technical sections, appendix 1 Decommissioning will be done in accordance with technical capabilities, legislation, industry experience, international conventions and the legal framework at the time of decommissioning. Decommissioning will be planned in accordance with the OSPAR decision 98/3 on the disposal of disused offshore installations.

It is expected that:

- Wells will be permanently plugged towards the reservoir and the casing above the seabed will be removed.
- The platform facilities and jackets will be cleaned, removed and brought to shore for dismantling. Hydrocarbons and waste will be sent to shore for disposal.
- Buried pipelines will be cleaned, filled with seawater and left in situ.

Decommissioning of the TYRA facilities is expected to generate around 60,000 tonnes of waste which will be brought onshore and treated accordingly. It is expected that the material breakdown will be similar to the breakdown shown for Tyra Future, cf. section 3.2.4, i.e. the majority of materials, around 90 %, are steel from jackets and topside facilities.

The waste management onshore will be performed by an approved recycling and disposal site. The majority of the waste, such as scrap steel, will be recycled. In addition, hazardous waste shall be documented and some waste (e.g. NORM) shall be returned to its country of origin in case of transboundary transport of the platforms. A material account will be developed for documentation and traceability of all waste streams from the platforms.

3.5 Accidental events

The accidental events, considered here, are accidents that could take place during exploration, production and decommissioning activities at the TYRA project that can lead to environmental or social impacts.

Major loss of primary containment (oil, gas or chemical) may also occur. Generally, the sequence of events leading to such events are unlikely and complex and several scenarios can be envisioned (e.g. /136//137/). The scenarios associated with Maersk Oil activities at the TYRA project that can lead to accidents with a major significant impact are listed in the technical sections and include vessels collisions, pipeline rupture due to corrosion, erosion or impact, well blow out and impact on major platform equipment.

Small operational accidental spills of oil or chemical or gas release could also occur.

3.6 Alternatives

3.6.1 Project alternatives

The offshore oil and gas production is important to Danish security of supply and Danish economy. Tyra has an estimated production reserve equivalent to 250 million barrels of oil equivalent. About 500 people are employed with and on the Tyra facilities and another 4,000 Danish jobs are dependent on Tyra. Tax revenue to the state of Denmark is significant. The state’s total revenue is estimated to DKK 20 billion per year.

The Danish government has set a target of 30 % of the Danish energy use is provided from renewable energy by 2020. As part of a long-term Danish energy strategy, the oil and gas production is considered instrumental in maintaining high security of supply. Denmark is expected to continue being a net exporter of natural gas up to and including 2025 and Maersk Oil has a license to operate until 2042 /35/.

The TYRA project has been subject to clarification of the economic framework for continued production of oil and gas from TYRA. For the project at hand no alternatives exist for provision of a similar redevelopment.

3.6.2 Facility re-use

Early in the project maturation process a number of studies were carried out to assess the possibility of re-use/continued use of existing facilities. Such options included inter alia construction of a barrier wall, similar to the concrete storage tank, Ekofisk 2/4T and jacking of the platforms, similar to the Ekofisk steel jackets. The studies concluded that such options were either technically in-feasible, economically un-viable or both. The conclusion is that the existing facilities are without value for continued use. The remaining value is attributed to the wells and the objective is to continue the production from existing wells, to new facilities.

3.6.3 Technological alternatives

Best technology selection for the design of the new facilities is evaluated through BAT/BEP studies cf. 9.4.

3.6.4 Technical alternatives

Technical alternatives for seismic, pipelines and structures, production, drilling, well stimulation, transport and decommissioning are presented in technical sections, appendix 1.

4. METHODOLOGY

The ESIS is based on information collected from the 2014 North Sea Atlas, technical reports, EIAs, peer-reviewed scientific literature, Maersk Oil monitoring and modelling reports and industry reports.

4.1 Rochdale envelope approach

The adoption of the Rochdale Envelope approach allows meaningful ESIA to take place by defining a ’realistic worst case’ scenario that decision makers can consider in determining the acceptability, or otherwise, of the environmental impacts of a project.

The Rochdale Envelope Approach allows a project description to be broadly defined. The project can be described by a series of maximum extents – the ‘realistic worst case’ scenario. The detailed design of the scheme can then vary within this ‘envelope’ without invalidating the corresponding ESIA.

Where a range is provided, e.g. amounts of produced water or volume of drilling mud, the most detrimental is assessed in each case. For example, the impact assessment for the TYRA project is based on the likely maximum volume of discharged produced water, the maximum number of wells and the maximum number of new structures.

4.2 Methodology for assessment of impacts

The potential impacts of the TYRA project on the environmental and social receptors (e.g. water quality, climate and fishery) are assessed for exploration, production and decommissioning.

The assessment covers the direct and indirect, cumulative and transboundary, permanent or temporary, positive and negative, impacts of the project. Impacts are evaluated based on their nature, type, reversibility, intensity, extent and duration in relation to each receptor (social and environmental).

The proposed methodology used for assessment of impacts includes the following criteria for categorizing environmental and social impacts:

- Value of the receptor
- Nature, type and reversibility of impact
- Intensity, geographic extent and duration of impacts
- Overall significance of impacts
- Level of confidence

4.2.1 Value of receptor

Various criteria are used to determine value/sensitivity of each receptor, including resistance to change, rarity and value to other receptors (Table 4-1).

Table 4-1 Criteria used to assess the value of receptor

Value	
Low	A receptor that is not important to the functions/services of the wider ecosystem/socioeconomy or that is important but resistant to change (in the context of project activities) and will naturally or rapidly revert to pre-impact status once activities cease.
Medium	A receptor that is important to the functions/services of the wider ecosystem/socioeconomy. It may not be resistant to change, but it can be actively restored to pre-impact status or will revert naturally over time.
High	A receptor that is critical to ecosystem/socioeconomy functions/services, not resistant to change and cannot be restored to pre-impact status.

4.2.2 Nature, type and reversibility of impacts

Impacts are described and classified according to their nature, type and reversibility (Table 4-2).

Table 4-2 Classification of impacts: Nature, type and reversibility of impacts

Nature of impact	
Negative	Impacts that are considered to represent an adverse change from the baseline (current condition).
Positive	Impacts that are considered to represent an improvement to the baseline.
Type of impact	
Direct	Impacts that results from a direct interaction between a planned project activity and the receiving environment.
Indirect or secondary	Impacts which are not a direct result of the project, but as a result of a pathway (e.g. environmental). Sometimes referred to as second level or secondary impacts.
Cumulative	Impacts that result from incremental changes caused by past, present or reasonably foreseeable human activities with the project.
Degree of reversibility	
Reversible	Impacts on receptors that cease to be evident after termination of a project activity.
Irreversible	Impacts on receptors thatare evident following termination of a project activity.

4.2.3 Intensity, geographic extent and duration of impacts

Potential impacts are defined and assessed in terms of extent and duration of an impact (Table 4-3).

Table 4-3 Classification of impacts in terms of intensity, extent and duration

Intensity of impacts	
None	No impacts on the receptor within the affected area.
Small	Small impacts on individuals/specimen within the affected area, but overall the functionality of the receptor remains unaffected.
Medium	Partial impacts on individuals/specimen within the affected area. Overall, the functionality of the receptor will be partially lost within the affected area.
Large	Partial impacts on individuals/specimen within the affected area. Overall, the functionality of the receptor will be partially or completely lost within and outside the affected area.
Geographical extent of impacts	
Local	Impacts are restricted to the area where the activity is undertaken (within 10 kilometres).
Regional	There will be impacts outside the immediate vicinity of the project area (local impacts), and more than 10 kilometres outside project area.
National	Impacts will be restricted to the Danish sector.
Transboundary	Impacts will be experienced outside of the Danish sector.
Duration of impacts	
Short-term	Impacts throughout the project activity and up to one year after.
Medium-term	Impacts that continue over an extented period, between one and ten years after the project activity.
Long-term	Impacts that continue over an extented period, more than ten years after the project activity.

4.2.4 Overall significance

The definition of the levels of overall significance of impact is separated for environmental and social receptors (Table 4-4).

Table 4-4 Classification of overall significance of impacts

Overall significance	Impacts on environmental receptors	Impacts on social receptors
Positive	Positive impacts on the structure or function of the receptor	
None/Negligible negative	No measurable impacts on the structure or function of the receptor.	
Minor negative	Impact to the structure or function of the receptor is localised and immediate or short-term. When the activity ceases, the impacted area naturally restores to pre-impact status.	Impact that is inconvenient to a small number of individual(s) with no long-term consequence on culture, quality of life, infrastructure and services. The impacted receptor will be able to adapt to change with relative ease and maintain pre-impact livelihood.
Moderate negative	Impact to the structure or function of the receptor is local or regional and over short- to medium-term. The structure or ecosystem function of the receptor may be partially lost. Populations or habitats may be adversely impacted, but the functions of the ecosystem are maintained. When the activity ceases, the impacted area restores to pre-impact status through natural recovery or some degree of intervention.	Impact that is inconvenient to several individuals on culture, quality of life, infrastructure and services. The impacted receptor will be able to adapt to change with some difficulties and maintain pre-impact livelihood with some degree of support.
Major negative	Impact to the structure or function of the receptor is regional, national or international and medium- to long-term. Populations or habitats and ecosystem function are substantially adversely impacted. The receptor cannot restore to pre-impact status without intervention.	Impact that is widespread and likely impossible to reverse for. The impacted receptors will not be able to adapt or continue to maintain pre-impact livelihood without intervention.

4.2.5 Level of confidence

It is important to establish the uncertainty or reliability of data that are used to predict the magnitude of the effects and the vulnerability of the receptors, as the level of confidence in the overall level of significance depends on it.

There are three levels of confidence for the impact:

- Low: Interactions are poorly understood and not documented. Predictions are not modelled and maps are based on expert interpretation using little or no quantitative data. Information/data have poor spatial coverage/resolution.
- Medium: Interactions are understood with some documented evidence. Predictions may be modelled but not validated and/or calibrated. Mapped outputs are supported by a moderate negative degree of evidence. Information/data have relatively moderate negative spatial coverage/resolution.
- High: Interactions are well understood and documented. Predictions are usually modelled and maps based on interpretations are supported by a large volume of data. Information/data have comprehensive spatial coverage/resolution.

5. ENVIRONMENTAL AND SOCIAL BASELINE

The environmental and social baseline contains a general description of each potential receptor, and site-specific information to the TYRA project where applicable.

The baseline includes the following potential receptors:

- **Environmental**
  - Climate and air quality
  - Bathymetry
  - Hydrographic conditions
  - Water quality
  - Sediment type and quality
  - Plankton (phytoplankton and zooplankton)
  - Benthic communities (fauna and flora)
  - Fish
  - Marine mammals
  - Seabirds

- **Social**
  - Cultural heritage
  - Protected areas (Natura 2000, UNESCO world heritage, national nature reserves)
  - Marine spatial use
  - Fishery
  - Tourism
  - Employment
  - Tax revenue
  - Oil and Gas dependency

5.1 Climate and air quality

The North Sea is situated in temperate latitudes with a climate characterised by large seasonal contrasts. The climate is strongly influenced by the inflow of oceanic water from the Atlantic Ocean and by the large scale westerly air circulation which frequently contains low pressure systems /10/.

Air quality in the North Sea is a combination of global and local emissions. Industrialisation of the coast and inshore area adjacent to certain parts of the central North Sea has led to increased levels of pollutants in these areas which decrease further offshore, though shipping and platforms provide point sources of atmospheric pollution /141/.

5.2 Bathymetry

The North Sea is a part of the north-eastern Atlantic Ocean, located between the British Isles and the mainland of north-western Europe. The western part of the Danish North Sea is relatively shallow, with water depths between 20 – 40 metres, while the Northern part is deeper (e.g. the Norwegian Trench and the Skagerrak; Figure 5-1).

The TYRA project is located in the shallowest part of the Maersk oil activity area, with depths ranging from about 38 - 64 metre /3/.

The depths decrease further to the south-west of TYRA project, where the large sandbank Dogger Bank is located within the German, Dutch, and UK EEZ.

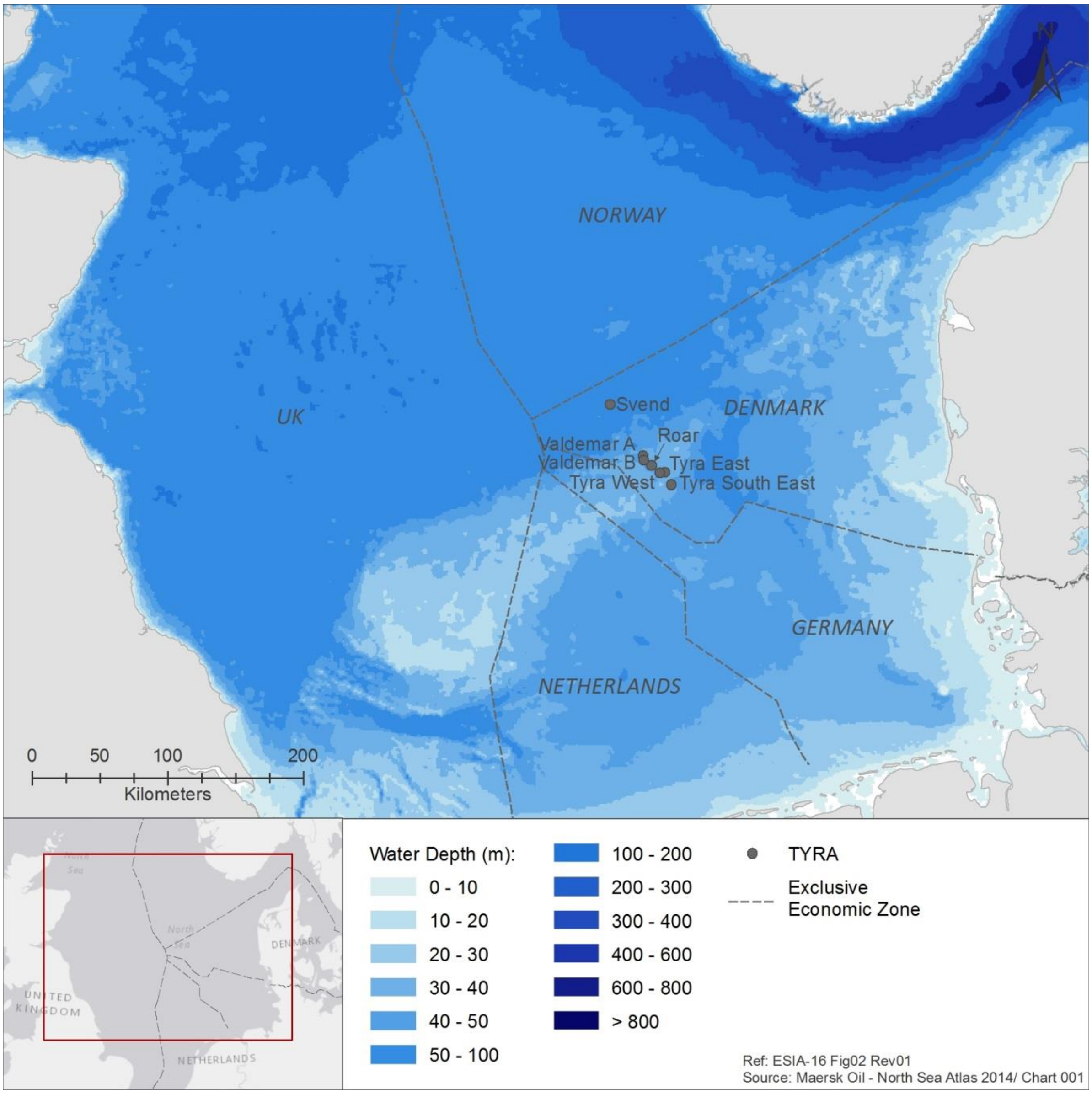


Figure 5-1 Bathymetry of the North Sea. Figure redrawn from Maersk Oil Atlas /3/

5.3 Hydrographic conditions

The North Sea is a semi-enclosed sea. The water circulation is determined by inflow from the North Atlantic, water through the English Channel, river outflow from the Rhine and Meuse and the outgoing current from the Baltic Sea through Skagerrak (Figure 5-2). These inputs of water, in close interaction with tidal forces and wind and air pressures, create a complicated flow pattern in the North Sea. The TYRA project is in the central North Sea, where the dominant water circulation is eastward.

Hydrographic fronts are created where different water masses meet, and include areas of upwelling, tidal fronts, and saline fronts. Hydrographic fronts are considered of great importance to the North Sea ecosystems. No potential for hydrographic fronts has been identified in the central North Sea where the TYRA project is located.

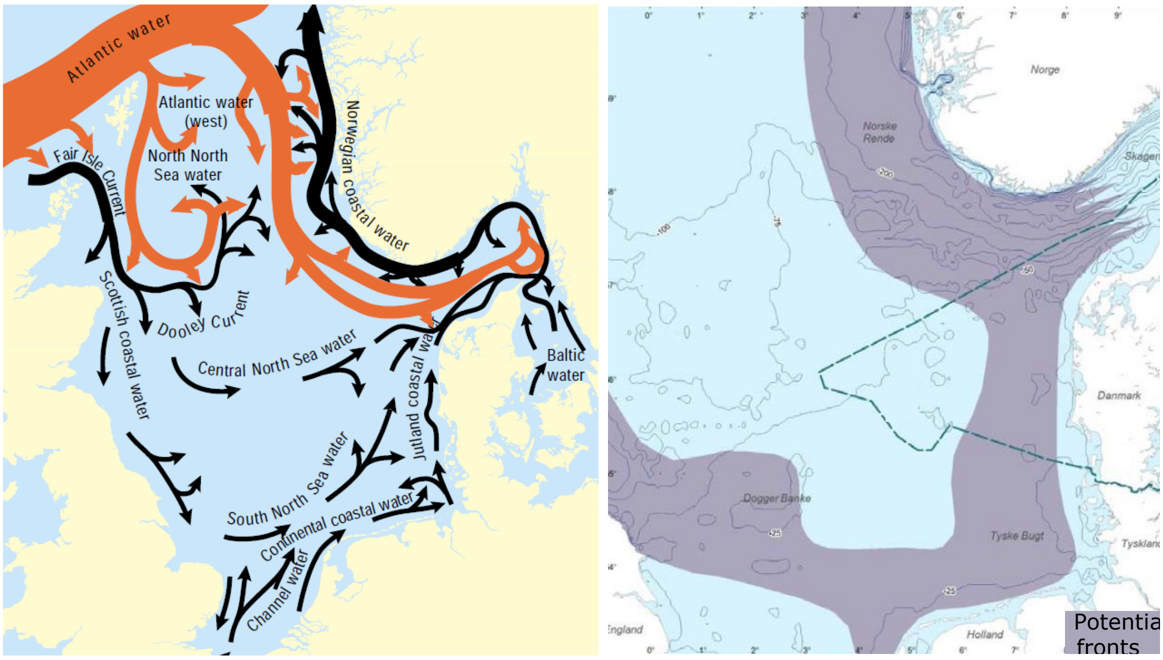


Figure 5-2 Left: General water circulation in the North Sea. The width of arrows is indicative of the magnitude of volume transport /10/. Right: Potential for hydrographic fronts in the North Sea /10//2/

5.4 Water quality

Salinity: Salinity in the North Sea varies from saline water in the west to brackish water along the coastal areas in the East. In the TYRA project area, the salinity does not show much seasonal variation with surface and bottom salinity of 34-35 psu /3/.

Temperature: Temperature in the North Sea varies seasonally. The lowest temperatures are found in the Northern part of the North Sea, and the highest temperature in the shallower areas in the Southern North Sea. In the TYRA project area, the surface temperature is approximately 7 °C in winter (January) and between 15-19 °C in summer (August), while the bottom temperature varies from 6-8 °C in winter (January) and 8-18 °C in summer (August) /3/.

Nutrients: Concentrations of nutrients in the North Sea surface layer have been modelled /3/. The concentrations are highest (>0.04 mg/l for phosphate, and >0.30 mg/l for nitrate) along the coastal areas, near output of large rivers. The concentrations in the surface layer in the TYRA project area ranges between 0.025-0.035 mg/l for phosphate and between 0.1-0.15 mg/l for nitrate/3/.

Heavy metals: Water concentrations of metals in North Sea for cadmium ranges 6-34 ng Cd/l, copper 140-360 ng Cu/l, lead 20-30 ng Pb/l, mercury 0.05-1.3 ng Hg/l and nickel 100-400 ng Ni/l /29/. Metal cycles in the ocean are governed by seasonally variable physical and biological processes. The biologically driven metals (Cd, Cu, Ni) follow nutrient like distributions with higher concentration found in deep water. Certain metals, including Cd and Cu, exhibit higher concentrations near and on the shelf compared to the open sea areas /29/. No site-specific information on metals in seawater is available.

5.5 Sediment type and quality

The Danish sector of the North Sea is generally characterized by sediments consisting of sand, muddy sand and mud, with smaller areas of till with coarse sediments. The TYRA project is situated in an area with the substrate types “mud to sandy mud” and “sand to muddy sand” (Figure 5-3).

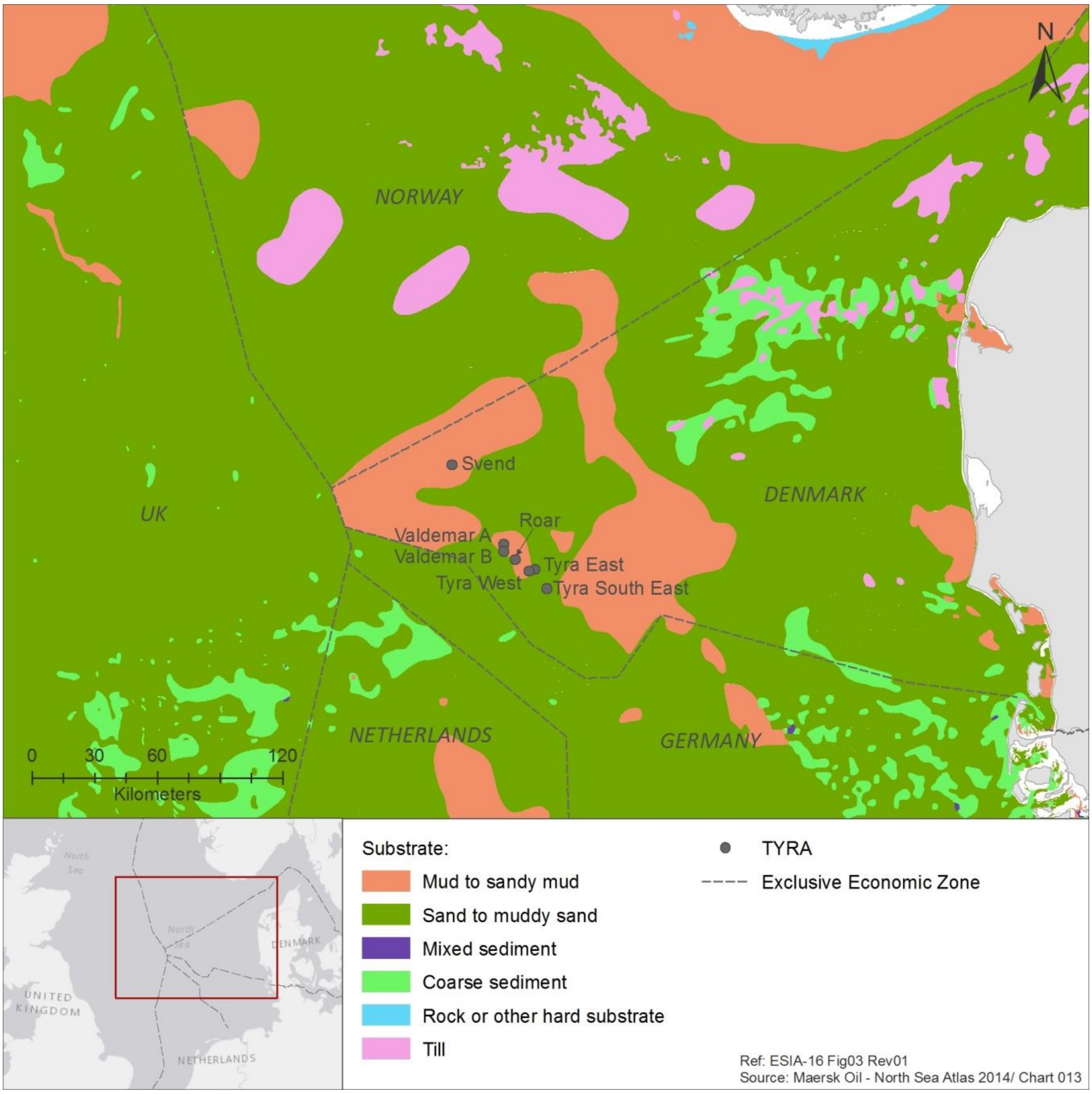


Figure 5-3 Seabed sediments in the North Sea. Figure redrawn from North Sea Atlas /3/

Monitoring in May 2009 at the Tyra E platform shows that the surface consists of medium to fine sand with a median grain size between 0.15 - 0.31 millimetres. The silt/clay content of the sediment is generally below 1 % of the dry matter (DM) content. The dry matter content of the sediment is high, about 80%, which is typical for sand. The content of organic matter measured as loss on ignition (LOI) is below 0.5% of the dry matter of the sediment. The content of total organic carbon (TOC) is low and varies between <0.50 and 1.4 g/kg DM /6/.

The concentrations of THC in the surface sediment is between <1 - 18 mg/kg DM, the concentration of polycyclic aromatic hydrocarbons (PAH) are low, between <0.001-0.003 mg/kg DM while the concentrations of alkylated aromatic hydrocarbons (NPD) in general are below the detection limit (0.001 mg/kg DM) /6/.

Concentrations of metals (Cd, Cr, Cu, Pb and Zn /6/) are below the Lower Action Levels for dumping of seabed material defined by the Danish EPA, and thus characterised as having average background levels or insignificant concentrations with no expected negative impact on marine organisms /8/.

5.6 Plankton

The plankton community may be broadly divided into a plant component (phytoplankton) and an animal component (zooplankton). Via photosynthesis, phytoplankton constitute the main contributor of organic matter in the North Sea, and thus for the whole marine food web. Apart of light carbon fixation is determined by the availability of nutrients, primarily nitrogen and phosphorous. The source of nutrients may either be imported from outside to the euphotic zone where photosynthesis occurs or derived from local remineralisation. Due to the grazing by zooplankton and subsequent decomposition of organic matter the metabolism of zooplankton and phytoplankton is mutually connected.

In the North Sea, the phytoplankton is mainly light-limited in winter and nutrient-limited in the water above the thermocline in summer /10/. Figure 5-4 shows the average annual phytoplankton colour index (PCI) for the North Sea over across a thirty year period (1983-2003). PCI is a visual proxy directly related to the biomass and abundance of the phytoplankton close to the surface. The highest biomass and abundance of phytoplankton is found in the Eastern and Southern parts of the North Sea. The TYRA project is located in an area with an average biomass and abundance comparable to the rest of the North Sea. The phytoplankton community is typically dominated by dinoflagellates and diatoms /3/.

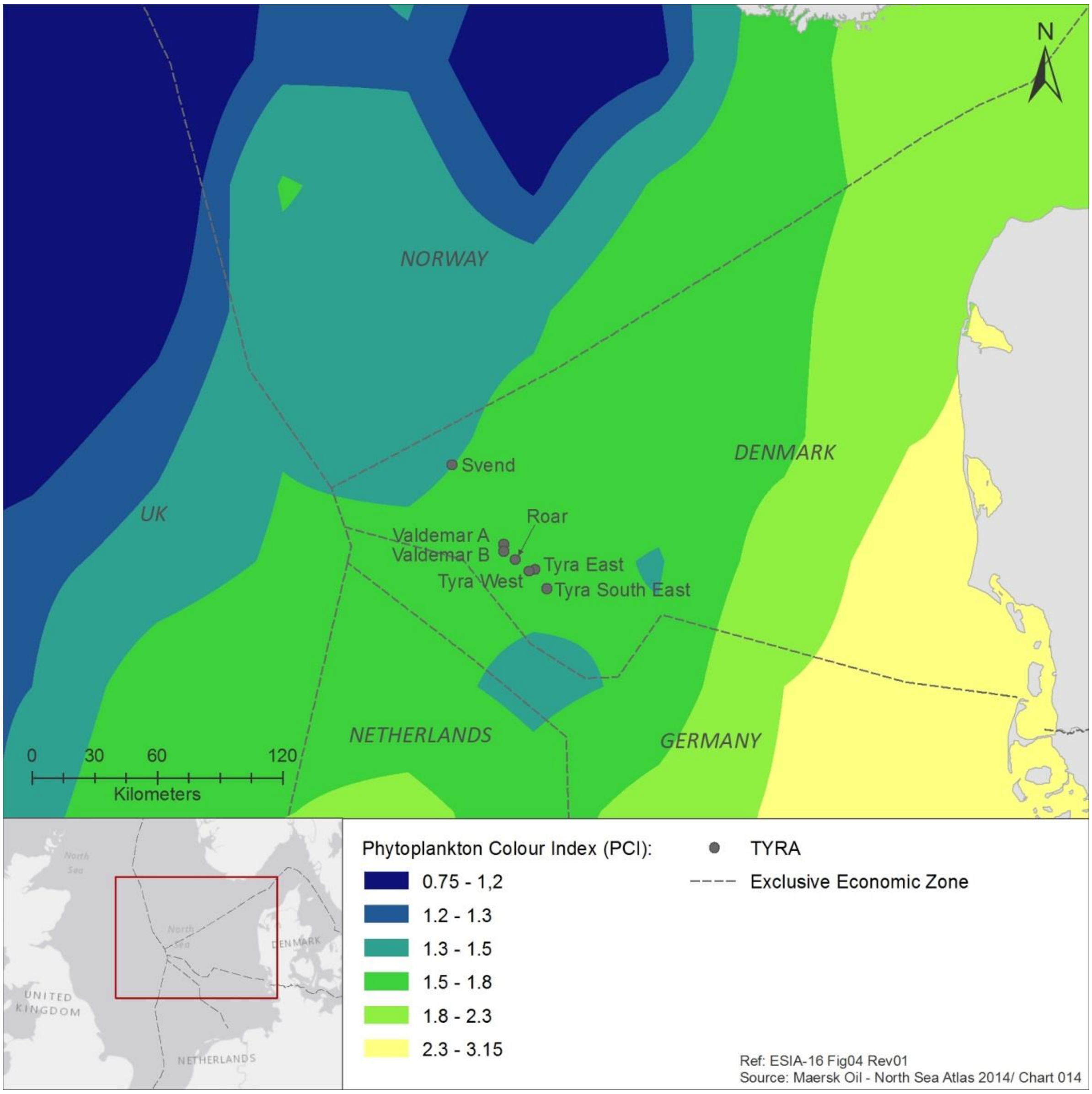


Figure 5-4 Phytoplankton colour index (PCI) for the North Sea. Figure redrawn from North Sea Atlas /3/

The Dogger Bank is a highly productive area due to its shallowness, topography, hydrography and sediment types /166/. It is influenced by cool Atlantic water masses coming from the north and warmer inflow from the Channel to the south resulting in the creation of a front in the northerly region where these two masses meet. Phytoplankton production on the bank occurs throughout the year supporting a high biomass of species at higher trophic levels year-round and creating a region that is biologically unique in the North Sea /178/.

Zooplankton forms the link between primary production and higher trophic levels in the pelagic marine food web. Organic production of phytoplankton is thereby channelled to pelagic fish such as herring (*Clupea harengus*), mackerel (*Scomber scombrus*), and sandeels (*Ammodytes* spp.). Generally, zooplankton abundance varies between areas owing to differences in production, predation, and transport. Tthe zooplankton community in the central North Sea is generally considered homogeneous /12/.

The zooplankton communities in the North Sea are dominated in terms of biomass and productivity by copepods, particularly *Calanus* species such as *C. finmarchicus* and *C. helgolandicus* /3/. Calanoid copepods are large crustaceans (in a planktonic context) which range in size between 0.5 - 6 mm and are an important prey item for many species at higher trophic levels. In the TYRA project area, the abundance of copepods is intermediate compared to the North Sea, with 5.5 – 9.5 ind/m^3 of *C. finmarchicus* and 6.5 – 12 ind/m^3 for *C. helgolandicus* /3/.

The larger zooplankton, known as megaplankton, includes euphausiids (krill), thaliacea (salps and doliolids), siphonophores and medusae (jellyfish). Meroplankton comprises the pelagic larval stages of benthic organisms and fish that spend a short period of their lifecycle in the free water mass before settling on the benthos. Important groups within this category include the larvae of starfish and sea urchins, crabs and lobsters and some fish /11/.

5.7 Benthic communities

5.7.1 Benthic flora

Macrophytes (macroalgae and higher plants) grow in conditions that feature relatively diverse and dynamic light regimes. The water transparency and hydrodynamic conditions have profound effects on the quantity and quality of the light available for benthic flora, thus directly influencing the biomass, production and species composition of the benthic communities in the North Sea. The depth of the photic zone for benthic plants is as rule of thumb defined as the depth where 1 % of the surface irradiance is available for photosynthesis /10/.

The water depth at the TYRA project and in its vicinity is approximately 40 m (64 m at Svend). At this depth, there is no growth of macrophytes. On the submerse surfaces of the jacket legs seaweeds especially in form of brown and red macroalgae grow to ca. 10 metres beneath the sea surface. Their overall contribution to primary production is however negligible compared to the planktonic production taking place in the passing water masses.

5.7.2 Benthic fauna

The benthic fauna consists of epifauna and infauna (organisms living on or in the seabed, respectively) such as crustaceans, molluscs, annelids, echinoderms.

In studies of the benthic fauna distribution in the North Sea it had been shown that the 50 m, 100 m, and 200 m depth contours broadly define the boundaries between the main benthic communities, with local community structure further modified by sediment type /13//14/. Descriptions of the spatial distribution of infaunal and epifaunal invertebrates show that the diversity of infauna and epifauna is lower in the southern North Sea than in the central and northern North Sea. Epifaunal communities are dominated by free-living species as brittle stars, starfish and bryozoans in the south and sessile species as sponges and corals in the north. Large-scale spatial gradients in biomass are less pronounced /15/.

The benthic habitats of the Dogger Bank are composed of moderately mobile, clean sandy sediments (sands and gravelly sands) in full salinity. It is non-vegetated which means that the organic supply to the benthic communities is based on primary production in the overlying surface water. The biological communities are typical of fine sand and muddy sand sublittoral sediments /166/.

Biological monitoring in May 2009 in the TYRA project area recorded a total of 82 species in 154 samples collected around the Tyra E platform and reference stations. With respect to species richness the benthic fauna was dominated by polychaetes followed by crustaceans, bivalve and other taxonomic groups (sea anemones, phoronids and nemerteans) /6/.

Polychaetes accounted for 46% of the benthic abundance, crustaceans for 22%, other taxa, for 12% and echinoderms for 11%. Bivalves and gastropods contributed with 6% and 3%, respectively, of the abundance. Bivalves were the most important component of the benthic biomass (42%), followed by echinoderms (29%) and crustaceans (21%).

Table 5-1 Composition of the benthic fauna around Tyra E in May 2009 /6/

Taxonomic group	Number of species*		Abundance		Biomass	
	$2.2\ m^{-2}$	%	$ind.m^{-2}$	%	$gDWm^{-2}$	%
Polychaeta	31	38	281	46.3	1.3	5.4
Bivalvia	13	16	36	5.9	10.4	42.4
Gastropoda	5	6	20	3.3	0.18	0.7
Crustacea	18	22	133	21.8	5.2	21.1
Echinodermata	7	9	64	10.6	7.0	28.5
Other taxa	8	10	73	12.0	0.42	1.8
Total	**82**	**100**	**607**	**100**	**24.4**	**100**

* Sum of species in the 154 samples collected (143 cm^2 each = 2.2 m^2)

In comparison with other studies of macrofauna in the North Sea /166//167/ the number of species and biomass found around the Tyra E is at the high end of the range. Figure 5-5 shows benthic fauna in the North Sea by indicator species. The TYRA area is classified by the two indicator species namely the polychaetes *Ophelia borealis* and *Nephtys longosetosa*.

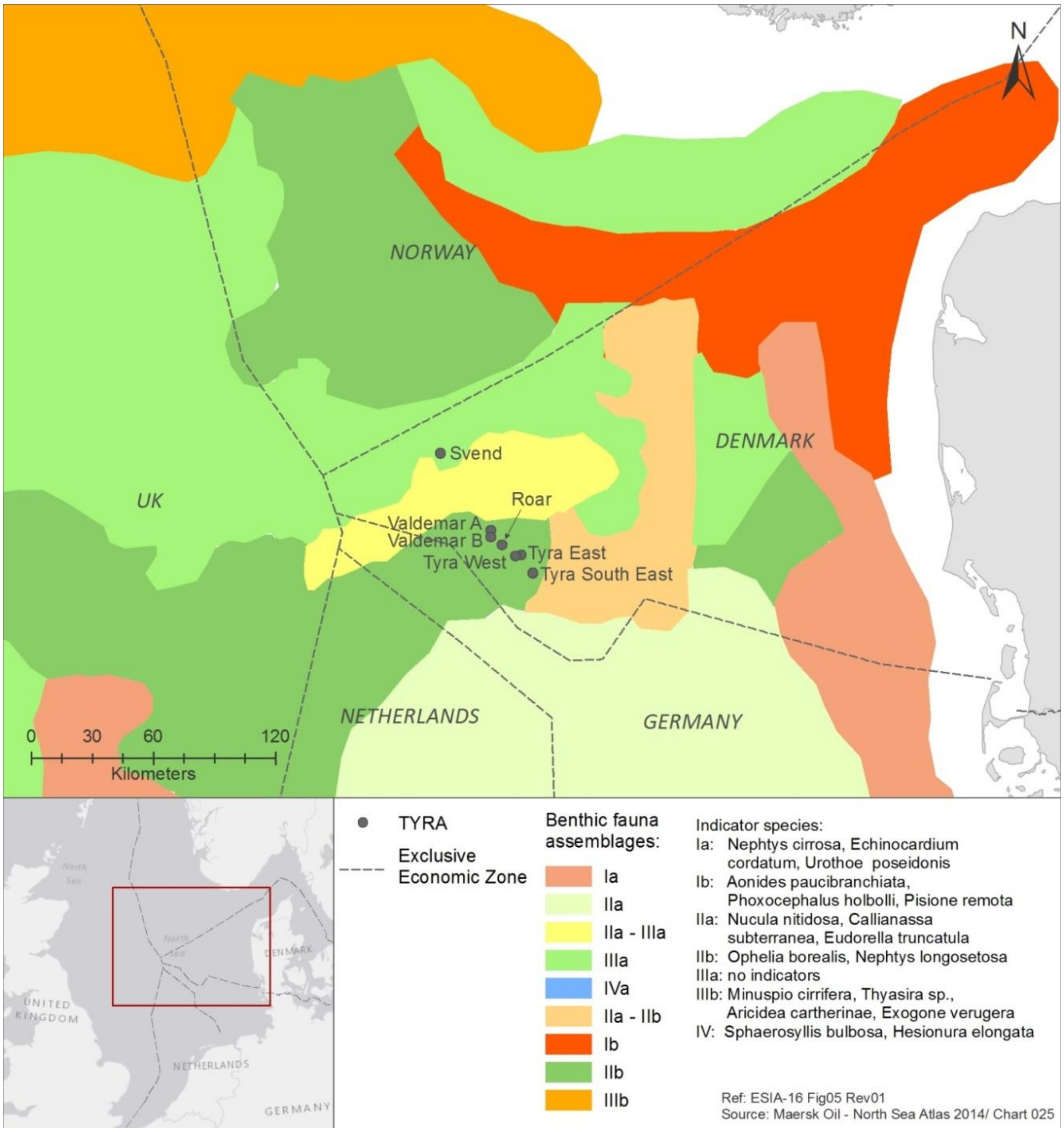


Figure 5-5 Assemblages of the benthic fauna in the North Sea. Figure redrawn from North Sea Atlas /3/

5.8 Fish

Approximately 230 species of fish are found in the North Sea. Fish species diversity is low in the shallow southern North Sea and eastern Channel and increases westwards. Species diversity is also generally higher close to shore as the habitat diversity increases. Most of the variability of the fish stocks is due to variation in egg and larval survival which is thought to be regulated by a number of factors, such as sea temperature and currents affecting larval drift to nursery grounds, as well as density-dependent predation on the eggs and larvae. Annual variability in recruitment of juveniles can differ by a factor of 5 for plaice, 50 for sole and more than 100 for haddock. Most species show annual or inter-annual movements related to feeding and spawning /10/.

A fish survey was carried out in the period from November 2002 to July 2003 at the Halfdan platform located about 25 km from the TYRA project (Tyra East and Tyra West). A total of 16 species of fish were registered: Eight pelagic or semi-pelagic (Atlantic horse mackerel, Atlantic mackerel, cod, grey gurnard, herring, sandeel, sprat, whiting), and eight benthic species (American plaice, common dab, common dragonet, European plaice, haddock, hooknose/armed bullhead, lemon sole, lumpfish) /19/.

The dominating species were: sprat, herring, whiting, grey gurnard, Atlantic horse mackerel, Atlantic mackerel, common dab, American plaice and European plaice. Herring and sprat were registered during autumn, whereas Atlantic horse mackerel and Atlantic mackerel were registered in the summer period. Common dab, American plaice and grey gurnard were registered all time of the year.

The biology of the dominating species registered in the area is described in Table 5-2.

Table 5-2 Distribution and biology of the dominating species registered in the area /23//24/. Further information on spawning areas and catch are presented for selected species in /3/

Species	Distribution and biology
Atlantic horse mackerel *(Trachurus trachurus)*	Horse mackerel has a restricted distribution during summer, with the greatest densities in the south-eastern North Sea and adults also being found along the shelf edge in the northern North Sea. The species is notably absent from the central North Sea. Juvenile horse mackerel are pelagic feeders that prey on planktonic organisms. Larger individuals feed on small fish (e.g. herring, cod and whiting). Peak spawning in the North Sea falls in May and June. Spawning occurs off the coasts of Belgium, the Netherlands, Germany, and Denmark.
American plaice *(Hippoglossoides platessoides)*	American plaice can be found throughout the North Sea. It prefers soft bottoms. Larvae feed on plankton, diatoms and copepods. Preferred food items for larger fish incudes sea urchins, brittle stars, polychaetes, crustaceans and small fish. Spawning takes place during spring at 100-200 metre depth.
Atlantic mackerel *(Scomber scombrus)*	Mackerel are widespread throughout the North Sea. Mackerel feed on a variety of pelagic crustaceans and small fish. In the North Sea, mackerel overwinter in deep water along the edge of the continental shelf and, in the spring, adult mackerel migrate south to the spawning areas in the central North Sea with extensions along the southern coast of Norway and in the Skagerrak. Spawning takes place between May and July.
Common dab *(Limanda limanda)*	Dab is a demersal fish. It lives on sandy bottoms down to depths of about 150 metres. Preferred food items incudes sea urchins, brittle stars, polychaetes, crustaceans, mussels and small fish. In the North Sea spawning takes place between April and June.
European plaice *(Pleuronectes platessa)*	European plaice has a preference for sandy sediments although older age groups may be found on coarser sand. During summer juvenile plaice are concentrated in the Southern and German Bights and also occur along the east coast of Britain and in the Skagerrak and Kattegat. Juveniles are found at lower densities in the central North Sea and are virtually absent from the north-eastern part. Plaice is an opportunistic species which primarily forage on molluscs and polychaetes. Plaice spawns in winter from January to

Species	Distribution and biology
	March. Spawning areas occur in the central part of the North Sea and in the English Channel.
Grey gurnard *(Eutrigla gurnardus)*	Grey gurnard occurs throughout the North Sea. Most common on sandy bottoms, but also on mud, shell and rocky bottoms. During winter, grey gurnards are concentrated to the northwest of the Dogger Bank at depths of 50-100 m, while densities are low in areas off the Danish coast, and in the German Bight and eastern part of the Southern Bight. Juveniles feed on a variety of small crustaceans. The diet of older specimens mainly consists of larger crustaceans and small fish. The distribution maps indicate a marked seasonal northwest-southeast migration pattern that is rather unusual. The population is concentrated in the central western North Sea during winter and spreads into the south eastern part during spring to spawn. In the northern North Sea, such shifts appear to be absent. Spawning takes place in spring and summer.
Herring *(Clupea harengus)*	Within the North Sea herring may be found everywhere. The pelagic larvae feed on copepods and other small planktonic organisms while juvenile mainly feeds on Calanoid copepods but euphausids, hyperiid amphipods, juvenile sandeels and fish eggs are also eaten. Larger herring also consuming predominantly copepods with small fish, arrow worms and ctenophores as an aside. After spending their first few years in coastal nurseries, two-year-old herring move offshore into deeper waters, eventually joining the adult population in the feeding and spawning migrations to the western areas of the North Sea. Herring is a demersal spawner on relatively shallow water depositing sticky eggs on coarse sand, gravel, shells and small stones. The fish congregate on traditional spawning grounds, many of which are on shoals and banks and in relatively shallow water.
Sprat *(Sprattus Sprattus)*	Sprat is most abundant south of the Dogger Bank and in the Kattegat. Larvae feed on diatoms, copepods and crustacean larvae. After metamorphosis larger planktonic organisms are also eaten. Spawning occurs in both coastal and offshore waters during spring and late summer, with peak spawning between May and June.
Whiting (*Merlangius merlangus)*	High densities of both small and large whiting may be found almost everywhere throughout the North Sea. The species is typically found near the bottom in waters at 10 to 200 m depth. Pelagic larvae feed on nauplii and copepodite stages of copepods. Immature whiting feed on crustaceans such as euphausids, mysids and crangonid shrimps whereas mature whitings feed almost entirely on fish. Spawning takes place from January in the southern North Sea to July in the northern part.

There are two main forms of spawning: Demersal and pelagic spawning.

Demersal spawners lay their eggs on the seafloor, algae or boulders. The preferred habitat for demersal spawners is species specific.

Pelagic spawners have free floating eggs that are fertilized in the water column. Spawning grounds for pelagic spawners are often large and less well defined as they can move from year to year. Hydrographic conditions that are essential for the pelagic spawning have an important role regulating the boundaries of the spawning grounds. Pelagic spawning takes place mostly at depths of 20-100 m. Pelagic eggs and larvae are more or less passively carried around by ocean currents. Some are carried to nursery areas others stay in the water column. Larval growth and transport of larvae and eggs are regulated by a variety of environmental factors e.g. current, wind and temperature.

A fish survey was carried out in the period from November 2002 to July 2003 at the Halfdan platform located about 25 km from the TYRA project area (Tyra East and Tyra West). Fish eggs from the following 13 species were registered: Common dab, European plaice, American plaice, cod, lemon sole, Atlantic mackerel, whiting, turbot, greater weever, grey gurnard, Mediterranean scaldfish, Arctic rockling and common dragonet /19/. Since Halfdan and the TYRA project is relatively near each other (25 km) it is likely that these species also spawn at the TYRA project.

The TYRA project is in an area designated as a relatively important spawning ground for cod and whiting. Mackerel and plaice are also known to be spawning in the area (Figure 5-6), but it does not seem to be an important spawning and nursery area for other commercial species /3//22/.

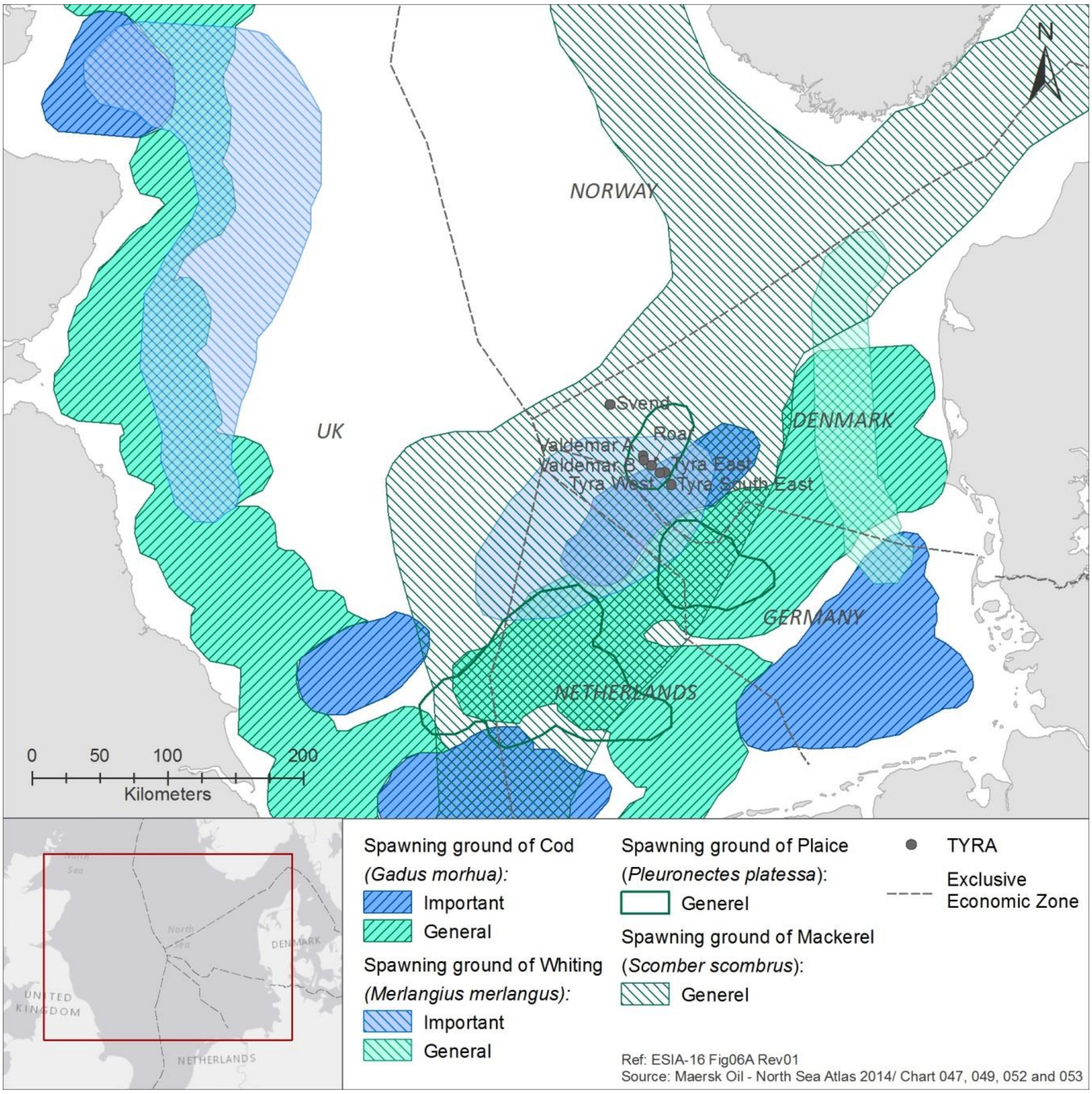


Figure 5-6 Spawning grounds for cod, whiting, mackerel and plaice in the North Sea. Figure redrawn from North Sea Atlas /3/

5.9 Marine Mammals

Harbour seal, grey seal, white-beaked dolphin, minke whale and harbour porpoise are the most common marine mammals in the North Sea /28/. The distribution and biology of these species as well as their habitat preference is related to the food availability and are described in Table 5-3. The site fidelity varies among species, and the distribution of marine mammals show both intra- and interannual variations.

Table 5-3 Distribution and biology of the most common marine mammals; harbour seal, grey seal, harbour porpoise, white-beaked dolphin and minke whale /30//31//32//33//40//144/

Species	Distribution and biology
Harbour seals (*Phoca vitulina*)	Harbour seals are one of the most widespread of the pinnipeds. They are found throughout coastal waters of the Northern Hemisphere, from temperate to Polar Regions. Harbour seals are mainly found in the coastal waters of the continental shelf and slope, and are also commonly found in bays, rivers, estuaries and intertidal areas. At sea, they are most often seen alone, but occasionally occur in small groups. Haul-out sites include rocks, sand and shingle beaches, sand bars, mud flats, vegetation and a variety of man-made structures /30/. Harbour seals feed primarily on fish such as herring, mackerel, cod, whiting and flatfish, and occasionally upon shrimp, crabs, molluscs and squid/144/
Grey seals (*Halichoerus grypus*)	Grey seals have a cold temperate to sub-Arctic distribution in North Atlantic waters over the continental shelf. They often haul out on land, especially on outlying islands and remote coastlines exposed to the open sea /32/.The grey seal feeds on a wide variety of fish including sand eels, cod and other gadoids, flatfish, herring and skates. They may also take octopus and lobster/144/
White-beaked dolphin (*Lagenorhynchus albirostris)*	White-beaked dolphins have a wide distribution and inhabit cold temperate to subpolar waters of the North Atlantic. White-beaked dolphins inhabit continental shelf and offshore waters of the cold temperate to subpolar zones, although there is evidence suggesting that their primary habitat is in waters less than 200 m deep. The species is found widely over the continental shelf, but especially along the shelf edge /33/. They primarily feed on fish such as herring, cod, haddock, whiting and hake but may also feed on squid, octopus and benthic crustaceans /144/. Two white-beaked dolphins were observed during aerial surveys in the Southern Maersk area in March 2008. No animals have been registered by acoustic monitoring, and the species is considered uncommon in the Southern Maersk area /40/.
Harbour porpoise (*Phocoena phocoena*)	Harbour porpoise are found in cold temperate to sub-polar waters of the Northern Hemisphere. They are usually found in continental shelf waters, and frequent relatively shallow bays, estuaries, and tidal channels /31/. Harbour porpoise is the most common whale species in the North Sea, and the only marine mammal which frequently occurs in the Maersk Oil area /40/. The North Sea harbour porpoise population is estimated at 320,000 – 340,000 /31/. They are mostly found in the eastern, western and southern parts of the North Sea, and generally found in low densities in the central part of the North Sea (Figure 5-7). The TYRA project area is not of particular importance as a breeding site to harbour porpoise, and few individuals are observed. Aerial surveys in the Southern Maersk area in May show densities of 0.25-0.4 harbour porpoises/km^2 near the platforms, and few animals in autumn. However, acoustic monitoring shows high activity in autumn /40/. A recent study at the Dan platform /139/ showed that harbour porpoises are present around the platform all year with the highest echolocation activity during fall and winter. Harbour porpoises feed mainly on fish such as cod, whiting, mackerel, herring and sprat/144/.
Minke whale (*Balaenoptera acutorostrata*)	The minke whale is a cosmopolitan species found in all oceans and in virtually all latitudes, including the Northeast Atlantic. Minke whale occurs in both coastal and offshore waters and preys on a variety of species in different areas. Less than 0.025 animals/km^2 is expected in the central North Sea /33/. Minke whale feed primarily on pelagic fish like herring and sprat and on small crustaceans /144/.

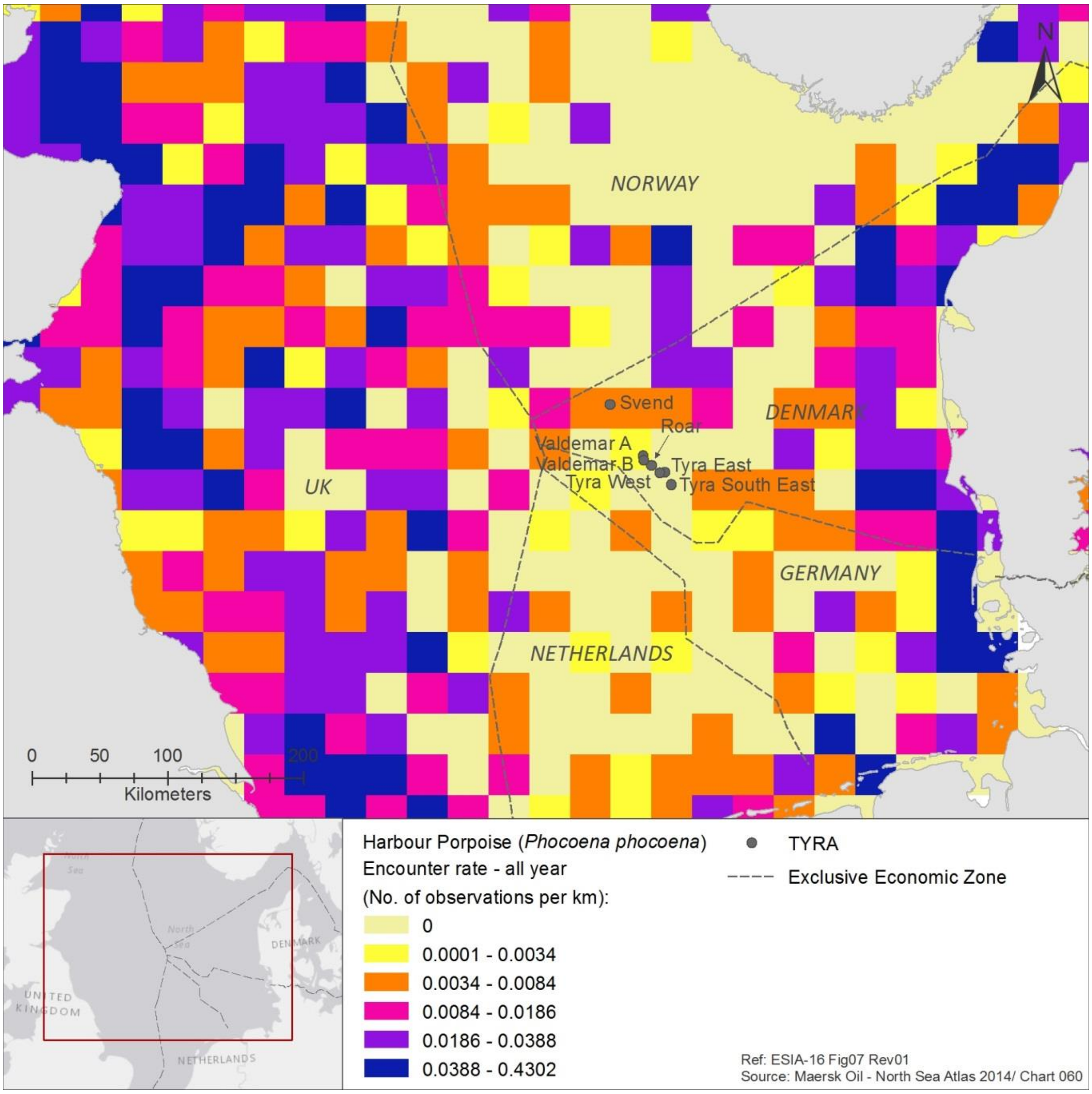


Figure 5-7 Distribution of harbour porpoise in the North Sea. Figure re-drawn from North Sea Atlas /3/

The periods where the animals may be particularly vulnerable to disturbance are related to the reproductive cycle (Table 5-3). The reproductive cycle of seals is primarily on land, while harbour porpoise is at sea.

Table 5-4 Time of year where animals are breeding (B), moulting (M) or mating (A). No data available for the other North Sea species

Species	J	F	M	A	M	J	J	A	S	O	N	D
Grey seal		B	BA	A		M	M	M				
Harbour seal						B	BA	M	M			
Harbour porpoise					B	B	A	A				

A recent study has shown that harbour porpoises have a high energy need and thus need to forage nearly continuously day and night /165/. If they are disturbed by anthropogenic activities during feeding activities in a way that results in lower food intake it may have severe fitness consequences for harbour porpoises /165/.

5.10 Seabirds

Seabirds spend most of their life at sea but breed on rocky coasts and cliffs. In the North Sea region, common seabirds include fulmars, gannets and auk species, kittiwakes and skuas.

The spatial distribution of the key species of seabirds is related to food availability and is summarized in Table 5-5, based on the distribution presented in the North Sea Atlas /3/ and a three-year aerial seabird monitoring survey in 2006-2008 covering the TYRA project area /40/.

Table 5-5 Spatial distribution of key species /3//40/

Species	Spatial distribution and biology in the North Sea
Red and black-throated diver (*Gavia stellata, G. arctica*)	The two species, which are sensitive to oil pollution due to their pursuit-diving behaviour and low fecundity rate, are non-breeding visitors to the North Sea. Their sensitivity to oil pollution increases during October-November (Red-throated) and March-April (Black-throated) when the birds are undergoing moult of their flight feathers. In spring, the highest densities of red- and black-throated divers are found along the coast of Denmark, in the Wadden Sea and in the English Channel. In winter, the distribution is more restricted and the highest densities are found along the coast of Denmark and northern part of the shallow area off the Wadden Sea. Almost all birds are found in waters of riverine influence shallower than 35 m, and both species are rare (0 birds/km^2) in the TYRA project area /3/, with few observations during the aerial survey /40/. Both species feed on fish during their visit to the North Sea, primarily cod, herring and sandeels.
Northern fulmar (*Fulmarus glacialis*)	The species is the most abundant seabird in the North Sea. In summer, relatively high densities of Northern fulmar are found at many locations throughout the North Sea with the peak densities located along the southern edge of the Norwegian Trench. In winter, the highest densities are found west of Norway and northwest of Jutland Bank. In the southern part of the North Sea Northern Fulmars are found in lower densities in winter than during summer. In the TYRA project area, Northern Fulmar occurs at relatively high densities (up to 24 birds/km^2 /40/ or up to 10 birds/km^2 /3/). Northern fulmar feed on crustaceans, fish and fish waste and other waste normally collected from the surface.
Northern gannet (*Morus bassanus*)	Northern gannets are found in high densities east and north of the UK from spring to autumn. In late summer-autumn high density areas are also found near the German and Dutch coasts. In winter, the northern gannet is patchily distributed and found at low to high densities throughout the North Sea. In the TYRA project area, northern gannets occur mainly in low densities (< 0.5 birds/km^2) all year round /3//40/, but relatively high densities (up to 23 birds/km^2) were observed during autumn /40/. Feeds mainly on fish up to a size of 30 cm - often herring, sandeels , cod and squid. Can pursue prey underwater for up to 20 seconds and to depths of up to 22 metres.
Great skua (*Stercorarius skua*)	Great skua occurs in low densities from northeast of Greater Fisher Bank to the Norwegian Trench, north of the UK coast, and in few small isolated patches. Unlike in spring-summer, the great skua occurs over much of the North Sea during late summer-autumn. In the TYRA project area, the species occurs in low densities (0-0.1 birds/km^2 /3/), with few observations during the aerial surveys /40/. Feeds mainly on fish by taking them from other birds or by finding dead fish. Are also know to feed on small seabirds (e.g. puffins). Occasionally catches live fish or follows fishing vessels.
Common gull (*Larus canus*)	The common gull is not observed over much of the North Sea, but with intermediate to high densities along the eastern part of the North Sea (e.g. Wadden Sea, German Bight, Jutland Bank, and some isolated patches bordering the eastern UK coast). In the TYRA project area, the species is rare (0 birds/km^2 /3/). The common gull is very versatile in its feeding preferences and feed on almost anything including fish and fish waste from fishing vessels.
Lesser black-backed gull	Lesser black-backed gulls are largely absent from much of the central and north-

Species	Spatial distribution and biology in the North Sea
(*Larus fuscus*)	western parts of the North Sea, and are concentrated mostly in the eastern parts of the North Sea. In the TYRA project area, the species occurs in low densities (0 birds/km^2 /3/). Like most gulls it is very versatile in its feeding preferences and can eat both fish and other smaller birds.
Herring gull (*Larus argentatus*)	The herring gull occurs throughout most of the coastal areas in the eastern North Sea, particularly around Norway and in Skagerrak. Relatively high densities are found in the German Bight, off the coast of the Netherlands, and in winter also in areas further offshore like areas around Dogger Bank: Both the distribution and the abundance of herring gulls seem mainly to be determined by working trawlers. The species is rare in the TYRA project areas (0 birds/km^2 /3/). The herring gull is omnivorous but feeds mainly on fish, invertebrates, plants, smaller birds, carrion and waste.
Great black-backed gull (*Larus marinus*)	The distribution and the abundance of great black-backed gull in the activity areas seem mainly to be determined by working trawlers. The species is common throughout the North Sea during winter, and the highest densities are found south and west of the Dogger Bank. In the TYRA project area, the species is rare (0 birds/km^2 /3/). The main diet for great black-backed gulls is fish, bird eggs, young birds, carrion and waste.
Black-legged Kittiwake (*Rissa tridactyla*)	In summer, the species is concentrated primarily in the western North Sea. Outside the breeding season, the species occurs throughout the North Sea with widespread intermediate to high density areas. Most extensive concentrations are found along the southern edges of the Norwegian Trench, northwest of Dogger Bank, off Borkum and in the Channel. In the TYRA project area, the species is found in intermediate density (0–5 birds/km^2 /3//40/), and in spring and autumn large flocks are observed /40/. Feeds on smaller fish like sandeels and small vertebrates by catching them at the water surface.
Sandwich tern (*Sterna sandvicensis*)	The species is mainly distributed in coastal waters on both sides of the North Sea. In spring highest densities are found off the German coast and the Netherlands. In summer-autumn highest densities are shown off the British coast just north of the Wash. In the TYRA project area, the species is rare (0 birds/km^2 /3/), and the few observations during the aerial surveys confirm the low densities /40/. Feeds primarily on small fish like sandeels, sprat and herring but also feed on crustaceans, molluscs and worms. The foraging grounds are further offshore than other tern species.
Common tern (*Sterna hirundo*)	The species is absent throughout most of the offshore parts of the North Sea. In spring highest densities are found off the northern German coast and the Netherlands. In late summer highest densities are found off the Danish coast and the Netherlands. In the TYRA project area, the species is rare (0 birds/km^2 /3/), and the few observations during the aerial surveys confirm the low densities /40/. Feeds primarily on small fish by plunge-diving.
Common guillemot (*Uria aalge*)	The common guillemot is the second most abundant seabird in the North Sea. In early summer, high densities are found in the western parts, whereas the species is found in lower densities in other parts of the North Sea. In late summer, the species occurs in high densities in the central and eastern parts as they move across the North Sea to moulting areas south of the Norwegian Trench. The species is very sensitive to oil pollution due to its pursuit diving behaviour, and during August and September both the adults and the accompanying young are flightless, and hence highly sensitive to pollution. As seen for many other species of seabirds, the highest numbers in the activity areas seem to be associated with the areas of lowest water depth. In the TYRA project areas, the species occurs in intermediate densities (0-5 birds/km^2) /3/. The common guillemot mainly feeds on small fish 20 cm long or less, such as polar cod, capelin, sprat, sandeels, Atlantic cod and Atlantic herring.
Razorbill	In early and late summer, the razorbill is largely absent in most of the North Sea and

Species	Spatial distribution and biology in the North Sea
(*Alca torda*)	the birds are concentrated in its western part. Higher densities are observed in late- than in early-summer. The razorbill is largely absent in most of the northern and central North Sea in winter when most birds are found in the Skagerrak and Kattegat and off the coasts of the UK and NL. In the TYRA project area, the species is found in densities of up to 2.5 birds/km^2. The diet of a razorbill is very similar to that of the common guillemot. It consists generally of fish such as capelin, sandeel, juvenile cod, sprats and herring. It may also include crustaceans and polychaetes.
Little auk (*Alle alle*)	The little auk is concentrated along the Norwegian Trench and NW of Dogger Bank during winter, and the species occurs in intermediate densities (<5 birds/km^2 /3/) in the TYRA project area. The little auk primarily feed on krill and other small crustaceans but also on small fish.

The four species of gulls (common gull, lesser black-backed gull, herring gull, great black-backed gull) are presented as rare (0 birds/km^2) /3/. However, aerial surveys show frequent observations and density estimates for gulls range up to 11 gulls/km^2, with the highest densities in autumn /40/.

5.10.1 Important Bird Areas (IBAs)

Important Bird Areas (IBAs) are key sites for future conservation. A site is recognised as an IBA only if it meets certain criteria, based on the occurrence of key bird species that are vulnerable to global extinction or whose populations are otherwise irreplaceable. The Wadden Sea (in Dutch, German and Danish waters) and Skagerrak/Southwest Norwegian trench are both recognised as important areas for birds, more than 100 km from the TYRA project. There are no IBAs in the central North Sea /34/.

5.11 Cultural heritage

Cultural heritage in the North Sea includes submerged prehistoric sites that were once land, other coastal features such as early fish-traps, submerged structures from defending coast in the World Wars, and shipwrecks from all ages. Part of the seabed of the North Sea is submerged land, and quite a number of villages in the Southern Bight have been submerged by the sea.

5.12 Protected areas

Protected areas are shown in Figure 5-8. Protected areas include Natura 2000 sites, Ramsar sites, UNESCO world heritage sites and nationally designated areas.

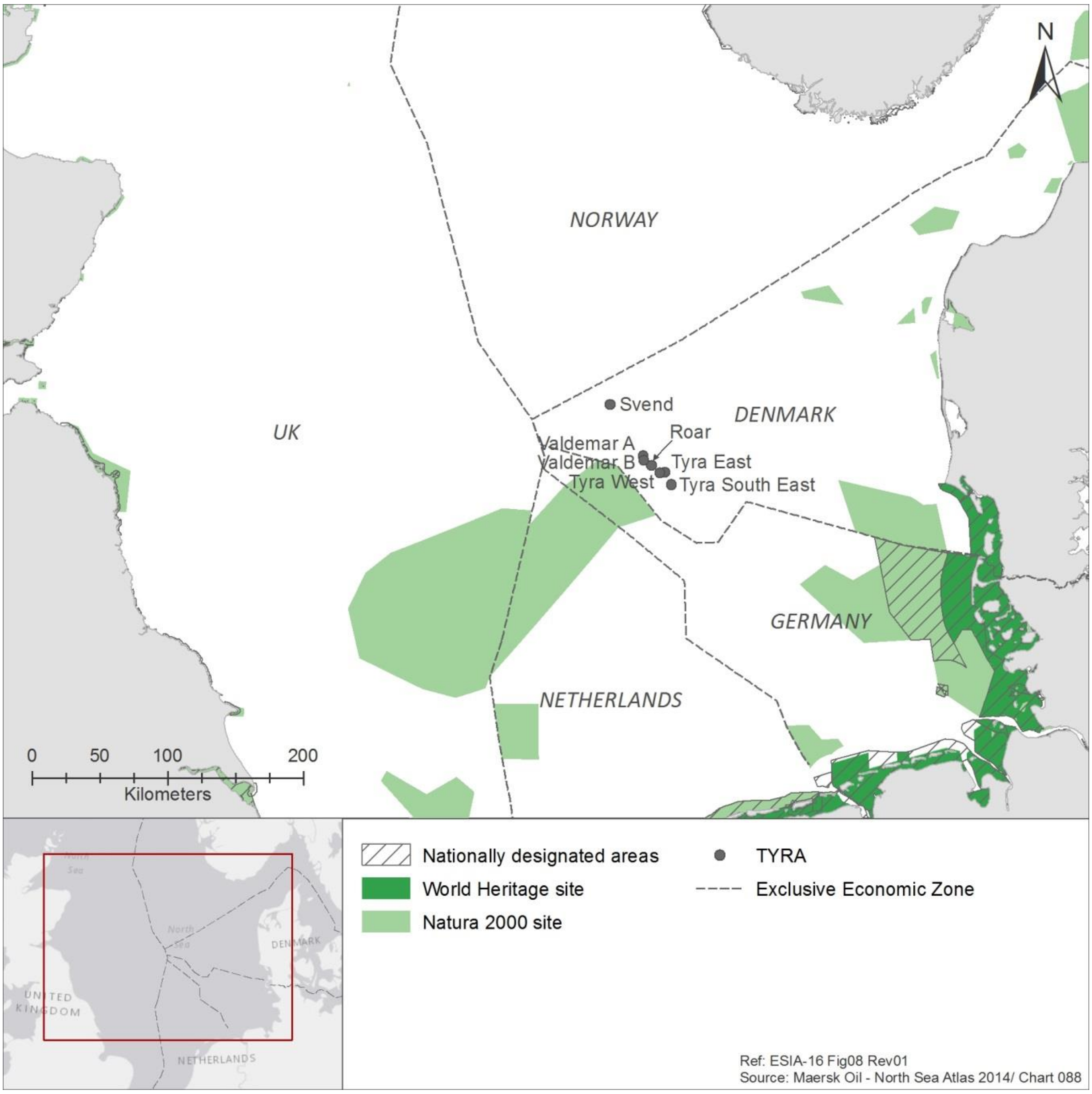


Figure 5-8 Protected areas. Figure redrawn from North Sea Atlas /3/

5.12.1 Natura 2000 sites

The Natura 2000 network comprises:

- Habitats Directive Sites (Sites of Community Importance and Special Areas of Conservation) designated by Member States for the conservation of habitat types and animal and plant species listed in the Habitats Directive
- Bird Directive Sites (Special Protection Areas) for the conservation of bird species listed in the Birds Directive as well as migratory birds

Natura 2000 sites have been designated in the central North Sea for Dogger Bank in UK, the Netherlands and Germany (Figure 5-8). The basis for designation is presented in section 10.

5.12.2 Ramsar sites

Ramsar sites are wetlands of international importance, and are present in coastal areas of the North Sea. The Ramsar Convention requires Contracting Parties to 'formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and as far as possible the wise use of wetlands in their territory' (article 3.1).

All Ramsar sites in the Danish sector of the North Sea are also designated Natura 2000 areas.

5.12.3 UNESCO world heritage sites

The Wadden Sea in Denmark, Germany and the Netherlands have been appointed UNESCO world heritage site (Figure 5-8).

The Wadden Sea is the largest unbroken system of intertidal sand and mud flats in the world. It is a large, temperate, relatively flat coastal wetland environment, formed by the intricate interactions between physical and biological factors that have given rise to a multitude of transitional habitats with tidal channels, sandy shoals, seagrass meadows, mussel beds, sandbars, mudflats, salt marshes, estuaries, beaches and dunes. The area provides a habitat for numerous plant and animal species.

5.12.4 Nationally designated areas

In Denmark, the Wadden Sea is designated as a national park. In addition, several nature reserves ("natur- og vildtreservat") have been appointed in Denmark along the west coast of Jutland, several inshore nature reserves (e.g. Nissum Fjord and Ringkøbing Fjord) (Figure 5-8).

5.13 Marine spatial use

The TYRA project is not in an area with important shipping routes for the largest ships equipped with automatic identification systems (Figure 5-9, < approximately 100 per year) /3/.

The infrastructure of oil and gas and wind includes both existing and planned installations. In the North Sea, a number of oil and gas facilities are operational, and additional facilities are planned. Operational wind farms are only present in Danish waters off Esbjerg, while a number of wind farms are planned in UK and German waters. Pipelines and cables connecting platforms are not shown in the figure, but should also be considered when planning new projects.

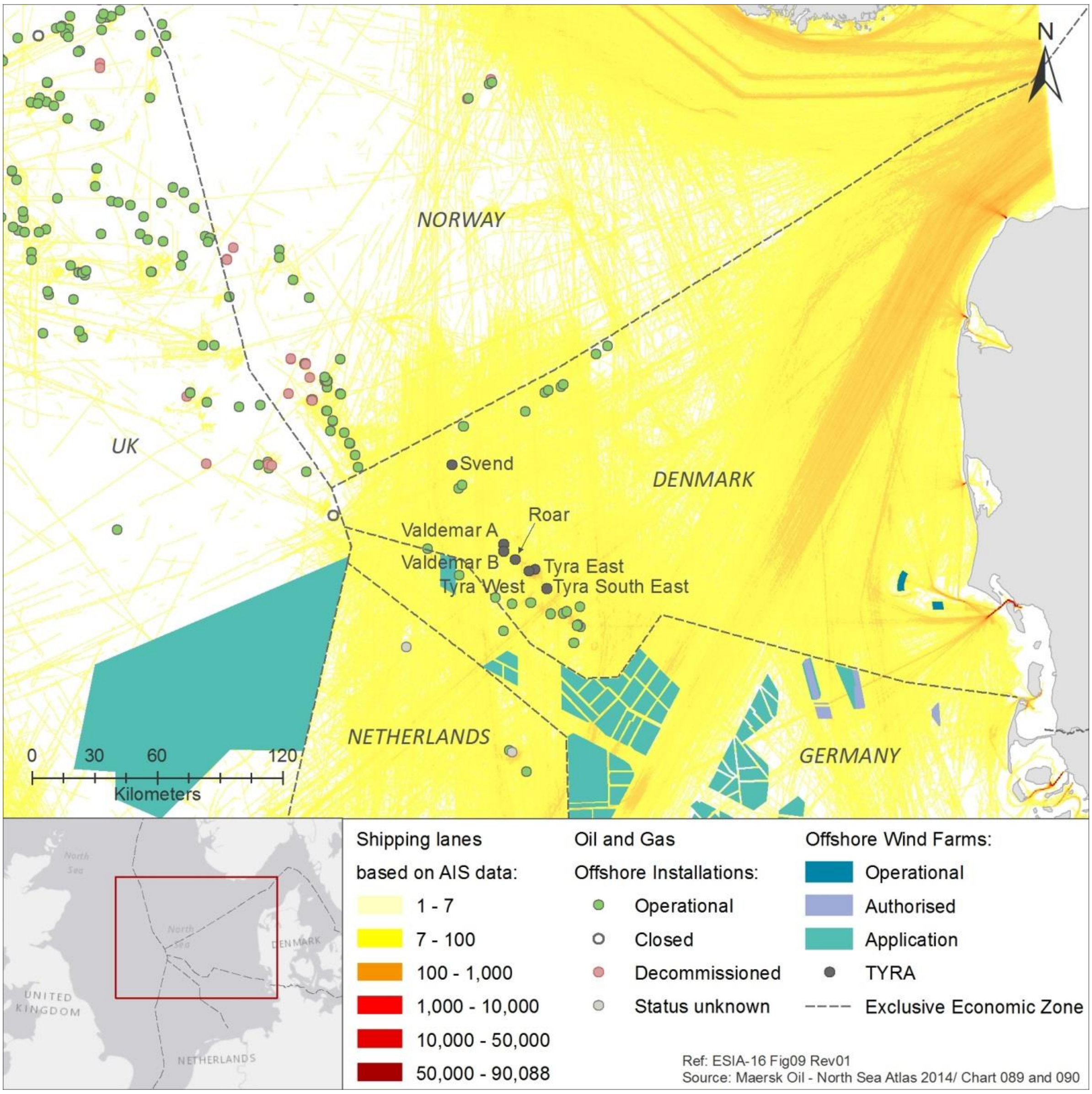


Figure 5-9 Ship traffic and infrastructure in 2012. Figure re-drawn from North Sea Atlas /3/. Ship traffic is based on all ships fitted with AIS system i.e. ships of more than 300 gross tonnage engaged on international voyages, and cargo ships of more than 500 gross tonnage not engaged on international voyages and all passenger ships irrespective of size. Missing data in the middle of the North Sea is due to poor AIS receiving coverage and not lack of ships. Germany does not participate in the North Sea AIS data sharing program

Further spatial restrictions include military areas, dump sites and reclamation areas. Dump sites and reclamation areas are mainly located at a relatively short distance from the coast, and are not present in the central North Sea. Military uses constitute a small part of the sea-borne and coastal activities around the North Sea. There are extensive exercise areas, mainly in the United Kingdom, but also along the west coast of Jutland (Denmark).

5.14 Fishery

Fishery is an important industry in the North Sea. The main targets of major commercial fisheries are cod, haddock, whiting, saithe, plaice, sole, mackerel, herring, Norway pout, sprat, sandeel, Norway lobster, and deep-water prawn. Norway pout, sprat and sandeel are predominantly the targets of industrial fisheries for fish meal and oil, while other species are the targets of fisheries for direct human consumption /10/.

A historic overview of production, trade, employment and fleet size for fishery in Denmark is provided in Table 5-6 /36/.

Table 5-6 Historic overview of production, trade, employment and fleet for fishery in Denmark /36/

	1990	2000	2010
Production (thousand tonnes)			
Inland	36	37	23
Marine	1482	1541	840
• Aquaculture	42	44	35
• Capture	1476	1534	828
Total	1518	1578	863
Trade (USD million)			
Import	1116	1806	2958
Export	2166	2756	4140
Employment (thousands)			
Aquaculture	0	0.8	0.4
Capture	6.9	4.6	2.4
Total	6.9	5.4	2.9
Fleet (thousands)			
Total	3.8	4.1	2.8

Landings of sandeel, European plaice, herring, cod, sprat and Norway pout are presented in the North Sea Atlas /3/. The landings are presented for one year (2013), and show that the central North Sea, including the TYRA project area, has some importance to the Danish fishery for sandeel. In addition, some fishery takes place in the central North Sea, in particular for cod, sprat and European plaice.

As inter-annual variation can be significant, fishery data for a period of ten years have been extracted from the Danish AgriFish Agency /37/. The data has been extracted for Danish vessels for area IVB, which covers an area of 280,000 km^2 from the west coast of Jutland to the Eastern coast of the UK.

Estimated value for the landing from Danish vessels in the North Sea for the last ten years shows that the area IVB, where the TYRA project is located, is important for the fishing industry (Table 5-7) /37/.

Table 5-7 Total landings and value of fishery, as landed catch for important commercial species in the central North Sea (area IVB) /37/. Data from 2015 is not available for the central North Sea (area IVB)

	Overall		Species-species landed catch (tonnes)			
	Total landed catch (tonnes)	Total value (DKK)	Sandeel	Cod	Sprat	European plaice
2005	405,067	824,527,622	129,776	4,365	233,306	9,382
2006	376,174	894,837,171	239,144	3,556	97,208	9,721
2007	239,469	700,252,302	142,309	2,317	64,047	6,918
2008	320,488	696,990,031	231,321	2,596	62,680	6,854
2009	409,143	652,075,835	272,865	2,792	110,650	6,827
2010	344,744	858,381,192	250,676	3,359	68,827	7,837
2011	388,927	990,124,457	263,971	2,736	98,484	9,932
2012	160,556	746,792,906	47,439	2,547	70,907	9,557
2013	263,373	875,992,562	183,330	1,917	46,258	10,707
2014	328,063	855,349,857	147,963	2,712	135,366	9,551

5.15 Tourism

Tourism is a multi-disciplinary feature, and includes both traditional tourism such as hospitality as well as events within conferences, music and sports. Tourists in Denmark are primarily Danish and German, and to a minor extent tourists from Sweden, Norway and the Netherlands.

Based on recent report with 2012 data from VisitDenmark /38/, tourism creates 122,500 FTEE (full time employee equivalent), which corresponds to ~4 % of the total FTEE in Denmark. These jobs are typically within hospitality, transport and trade. Tourism creates a direct economic added value of 24 billion DKK.

Tourism is associated with land and the coast, and no tourism is present in the central North Sea.

5.16 Employment

According to Statistics Denmark /39/, the largest employment sectors in 2013 are the public sector and trade/transport.

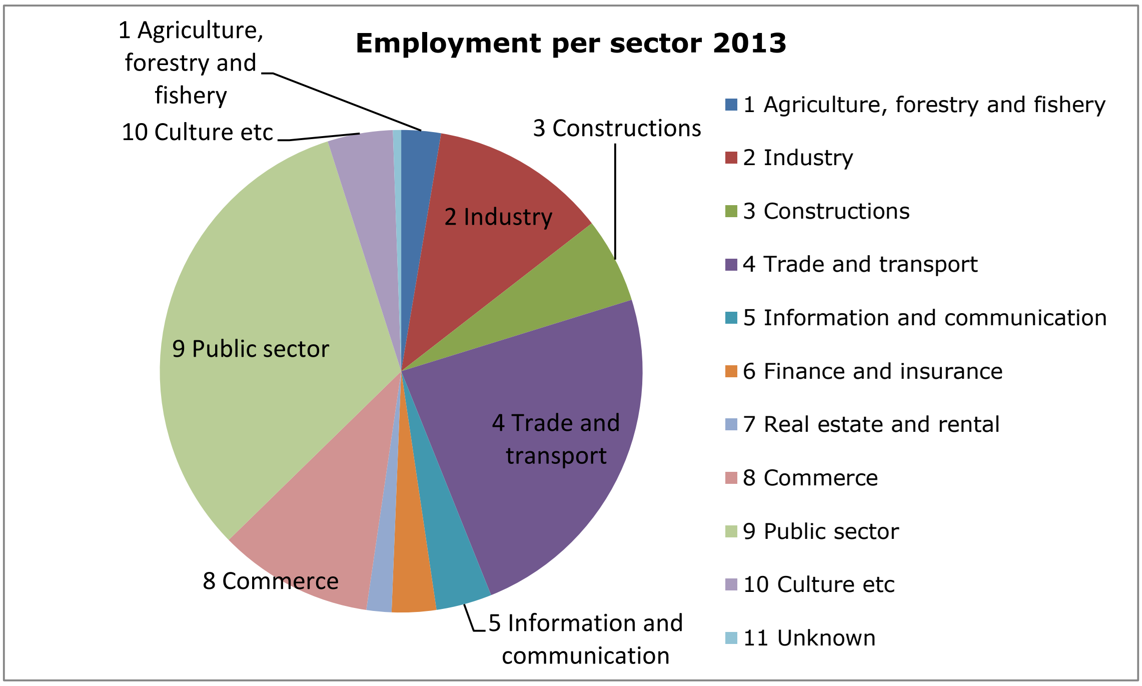


Figure 5-10 Employment per sector in Denmark in 2013 /39/

Oil and gas activities in the North Sea create a significant number of workplaces both on-and offshore /35/. The oil and gas sector employs approx. 15,000 persons in Denmark /53/. Of these, approx. 1,700 employees are directly employed at the oil companies. This means that when one employee is employed in the oil and gas companies, approx. 8 jobs are created in related industries. A large part of the indirect activities lies in e.g. the engineering consultancy and other consulting assistance. Employment in the sector ranges widely across types of job, but generally a high level of education is seen and approx. 60% of the jobs are located around Esbjerg.

5.17 Tax revenue

Tax revenue and the profits made by the oil and gas sector have a positive impact on the danish economy. The state’s total revenue is estimated to range from DKK 20 to DKK 25 billion per year for the period from 2014 to 2018 /35/.

The sector’s impact in relation to taxes and dues are also substantial, as is the business sector, which by far contributes the largest share of taxes and dues. In 2010, the total contribution of direct taxes and dues was approx. DKK 24 billion /53/.

5.18 Oil and gas dependency

Denmark has been supplied with gas from its North Sea fields since the 1980s and has also exported natural gas, primarily to Sweden and Germany. This production has significantly impacted the security of supply and balance of trade. Denmark is expected to continue being a net exporter of natural gas up to and including 2025 and Maersk Oil has license to operate until 2042 /35/.

As part of a long-term Danish energy strategy, the oil and gas production is instrumental in maintaining high security of supply, at the same time as renewable energy represents an increasing share of the Danish energy mix /53/.

6. IMPACT ASSESSMENT: PLANNED ACTIVITIES

6.1 Impact mechanisms and relevant receptors

6.1.1 Potential impact mechanisms

Potential impact mechanisms associated with the planned activities at the TYRA project are summarised based on the project description (section 3) and the technical sections (appendix 1).

Potential impact mechanisms include:

- Underwater noise
- Physical disturbance of seabed
- Suspended sediment
- Discharges (physical and chemical)
- Solid waste
- Emissions
- Light
- Resource use
- Restricted zones
- Employment and tax revenue
- Oil and gas dependency

The source of the potential impact mechanisms is provided in Table 6-1. The sources of impacts are related to the activities described in the seven technical sections (appendix 1).

Table 6-1 Sources of potential impact mechanisms for the TYRA project. "X" marks relevance, while "0" marks no relevance

Potential impact mechanism	Sesimic	Pipelines and structures	Production	Drilling	Well stimulation	Transport	Decommissioning
Underwater noise	X	X	X	X	X	X	X
Physical disturbance of seabed	X	X	0	X	0	0	X
Suspended sediment	X	X	0	X	0	0	X
Discharges	X	X	X	X	X	X	X
Solid waste	X	X	X	X	X	X	X
Emissions	X	X	X	X	X	X	X
Light	X	X	X	X	X	X	X
Presence/removal of structures	0	X	X	0	0	0	X
Resource use	X	X	X	X	X	X	X
Restricted zones	X	X	X	X	0	0	X
Employment and tax revenue	X	X	X	X	X	X	X
Oil and gas dependency	X	X	X	X	X	X	X

6.1.2 Relevant receptors (environmental and social)

The relevant environmental and social receptors described in the baseline for the TYRA project are listed below.

- Environmental receptors: Climate and air quality, hydrographic conditions, water quality, sediment type and quality, plankton, benthic communities (flora and fauna), fish, marine mammals, seabirds.
- Social receptors: Cultural heritage, protected areas, marine spatial use, fishery, tourism, employment, tax revenue, oil and gas dependency.

The relevant receptors have been assessed based on the project description (section 3) and the potential impact mechanisms (section 6.1). Relevant receptors for the impact assessment are summarised in Table 6-2.

Table 6-2 Relevant receptors for the impact assessment of planned activities for the TYRA project. "X" marks relevance, while "0" marks no relevance

	Environmental Receptors									Social Receptors							
Potential impact mechanism – planned activities	**Climate and air quality**	**Hydrographic condition**	**Water quality**	**Sediment type and quality**	**Plankton**	**Benthic communities**	**Fish**	**Marine mammals**	**Seabirds**	**Cultural heritage**	**Protected areas***	**Marine spatial use**	**Fishery**	**Tourism**	**Employment**	**Tax revenue**	**Oil and gas dependency**
Underwater noise	0	0	0	0	X	X	X	X	X	0	0	0	0	0	0	0	0
Physical disturbance of seabed	0	0	0	X	X	X	X	0	X	X	0	0	X	0	0	0	0
Suspended sediment	0	0	X	0	X	X	X	X	X	0	0	0	0	0	0	0	0
Discharges	0	0	X	X	X	X	X	X	X	0	X	0	0	0	0	0	0
Solid waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emissions	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Light	0	0	0	0	X	0	X	X	X	0	0	0	0	0	0	0	0
Presence/removal of structures	0	X	0	X	0	X	X	X	0	0	0	0	0	0	0	0	0
Resource use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Restricted zones	0	0	0	0	0	0	0	0	0	0	0	X	X	X	0	0	0
Employment and tax revenue	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	X	0
Oil and gas dependency	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X

* Note that a separate assessment for Natura 2000 is undertaken in section 10.

6.2 Assessment of potential environmental impacts

Impact assessment for planned activities for each relevant environmental receptor is presented in the following sections.

6.2.1 Climate and air quality

Impacts on climate and air quality relate to atmospheric emissions.

6.2.1.1 Emissions

Emissions have been estimated for the planned activities at the TYRA project, and are presented in Table 6-3 for each of the activities.

Table 6-3 Overview of estimated emissions for planned activities at the TYRA project, provided per activity or per year. TF refers to Tyra Future. The maximum emissions have been used."-" refers to an emission which has not been quantified

Activity (frequency)	Unit	Emissions, tonnes					
		CO_2	NO_x	N_2O	SO_2	CH_4	nmVOC
Seismic							
4D seismic (1 every 4 years)	Per survey (1 month)	3,329	62	0.2	2.1	0.3	2.5
Site survey (1 per year)	Per survey (1 week)	38	0.7	0.003	0.02	0.003	0.03
Borehole seismic (1 per year)	Per survey (2 days)	11	0.2	0.001	0.007	0.001	0.01
Pipelines and structures							
New SLIC/STAR structures (TF: 0; Other: 3)	Per platform	3,402	63	0.2	2.1	0.3	2.5
New 4–legged structures (TF: 1; Other: 1)	Per platform	3,723	69	0.3	2.3	0.3	2.8
New 6-legged structures (TF: 1; Other: 0)	Per platform	4,253	79	0.3	2.7	0.3	3.2
New topsides (TF: 6; Other: 0)	Per topside	1,913	36	0.1	1.2	0.1	1.4
New pipelines* (37 km, TF: 2, total 7 km; Other: 4, total 30 km)	Per km	74	1.4	0.005	0.05	0.006	0.05
	Per pipeline	1,096	20	0.08	0.7	0.08	0.8
Drilling							
Drilling (TF: 0; Other: 56)	Per well (150 days)	8,441	152	0.6	5.8	0.6	7.0
Well test, workover	Not quantified	-	-	-	-	-	-
Well stimulation							
Matrix acid well stimulation of existing wells (2 per year)	Per well stimulation (2 weeks)	625	12	0.04	0.4	0.05	0.5
Production							
Flaring, fuel, vent	Per year, pre-TF	492,900	1375	34	5.0	2207	44
	Per year, post-TF	290,000	245	6	40	40	5
Transport							
Vessels, helicopters	Per year**	23	0.4	0.002	0.02	0.002	0.02

Decommissioning* **							
Well abandonment (TF: 8; Other: 159)	per well (20 days)	1,125	20	0.08	0.8	0.08	0.9
SLIC/STAR structures (TF: 1; Other: 9)	Per platform	5,103	95	0.3	3.2	0.5	3.8
3–legged structures (TF: 2; Other: 0)	Per platform	5,103	95	0.3	3.2	0.5	3.8
4–legged structures (TF: 1; Other: 9)	Per platform	5,585	104	0.5	3.5	0.4	4.2
6-legged structures (TF: 0; Other: 1)	Per platform	6,380	119	0.5	4.1	0.5	4.8
8 legged structures (TF: 1; Other: 0)	Per platform	6,380	119	0.5	4.1	0.5	4.8
Topsides (TF: 6; Other: 0)	Per topside	2,869	54	0,2	1,8	0,2	2,1

*Emissions from pipelay, survey, trenching and DOS vessels amount to 74 tonnes CO_2 per km. Guard and diving support vessels are responsible for additional 1096 tonnes CO_2 per pipeline (see technical section B for details).
** The calculation for vessels and helicopters are assuming equal distribution among the 20% for each of Maersk Oil's five platform complexes Tyra, Harald, Dam, Gorm and Halfdan.
*** Emissions during decommissioning is approximately 150% of the emissions during installation.

Emissions are primarily caused by venting, flaring of gas and the use of fossil fuels for production.

Table 6-4 provides an overview of the estimated annual emissions (from production, well stimulation, transport and seismic), and total emissions for drilling, new structures and decommissioning from the TYRA project, along with the annual Danish emissions in 2012. Activities associated with Tyra Future are shown separately in the columns "Construction" and "Decommissioning".

Table 6-4 Emissions in tonnes from activities at the TYRA project and national emissions numbers for Denmark /20//21/. "-" refers to an emission which has not been quantified

Emis-sions	Annual Danish emissions 2012	Total annual emissions related to production		Total emissions				
				Construction		Decom-missioning		Drilling
		Pre Tyra future	Post Tyra future	Tyra Future	Other	Tyra Future	Other	
CO_2	39,412,000	495,059	292,154	22,164	20,533	53,488	281,447	472,696
NO_x	-	1,416	286	414	380	992	5,090	8,512
N_2O	116,071	34	6	1	1	4	20	34
SO_x	12,510	6	41	14	13	34	192	325
CH_4	-	2,207	40	1	2	4	21	34
nmVOC	-	46	7	16	15	40	220	392

6.2.1.2 CO_2, N_2O and CH_4 emissions

Greenhouse gases such as CO_2, N_2O and CH_4 have a direct impact on climate and air quality.

The greenhouse gasses have different warming potential /141/, as some have a longer lifetime in the atmosphere and a higher heat absorption than others. Per definition, CO_2 has a global warming potential (GWP) of 1, whereas the GWP is 21 for CH_4 and 310 for N_2O /141/. Including these GWP corrections, CO_2 emission is responsible for about 94% of the greenhouse effect caused by the TYRA project.

The annual emissions related to production at the TYRA project (excluding new structures, drilling and decommissioning) currently contributes up to 1.2 % of the total annual CO_2 emission for Denmark in 2012, falling to around 0.9 % post Tyra Future. Additional emissions associated with drilling, construction and decommissioning will add to this percentile, but considering that the emissions summarised in columns 4-6 in Table 6-4 are totals for a period of 25 years, this addition is small.

The impact is considered to be of small intensity, a transboundary extent and long-term duration. The overall impact on climate change from emissions at the TYRA project is assessed to be of moderate negative significance.

6.2.1.3 NO_x, SO_x and nmVOC emissions (air pollution)

NO_X and SO_x are air pollutants which are spread by the wind and deposited in the surrounding environment. The compounds have potential acidification effects that can impact the environment in terms of defoliation and reduced vitality of trees, and declining fish stocks in acid-sensitive lakes and rivers. Non methane VOCs can have a number of damaging impacts on human health. Some have direct toxic effects (e.g. carcinogenic), but nmVOCs can also have indirect effects on health by contributing to the formation of ground-level ozone, which causes respiratory and cardiovascular problems.

Emissions of NO_x from the TYRA project production corresponds to 1.2 % and SO_x correspond to 0.06 % of total annual emission for Denmark in 2012. These percentages change post Tyra Future to 0.2 % for NO_x and 0.4 % for SO_x. The impact is considered to be of small intensity, transboundary extent and long-term duration. The overall impact on air pollution from emissions at the TYRA project is assessed to be of moderate negative significance.

6.2.1.4 Overall assessment

The overall assessment of impacts on climate and air quality from planned activities at the TYRA project is summarised in Table 6-5.

Table 6-5 Potential impacts on climate and air quality from planned activities at the TYRA project

Impact mechanism	Intensity	Extent	Duration	Overall significance	Level of confidence
CO_2, N_2O, SO_x and CH_4 emissions (climate change)	Small	Transboundary	Long-term	Moderate negative	Medium
NO_x, SO_x and nmVOC emissions (Air pollution)	Small	Transboundary	Long-term	Moderate negative	Medium

6.2.2 Hydrography

Impacts on hydrography relate to presence and removal of structures.

6.2.2.1 Presence and removal of structures

Pipelines are buried to a depth of about 1.5-2 metres. In places where the pipelines are at the sediment surface (upheaval buckling or near platforms), they may block or redirect currents of bottom water affecting local hydrographical regimes. Surfacing pipelines are covered by rocks to prevent accident with, for example, trawler.

The presence of jackets will cause flowing water to accelerate as it passes around the structure.

The impact to hydrography of the presence of structures is assessed to be of small intensity, local extent and of a short-term duration. The alteration of the hydrographical conditions for the region comprising the Dogger Bank area (Figure 5-1) is considered almost non-existing. The overall impact to hydrography from presence of structures is assessed to be of minor negative significance.

When the TYRA project is decommissioned, it is expected that platforms will be fully removed and disposed, while pipelines will be left in situ. Removal of the jackets will eliminate the minor effect they had on the local hydrography, which can be considered a small positive impact. The impact to hydrography of removal of structures is assessed to be of small intensity, local extent and of a short-term duration. The overall impact to hydrography from removal of structures is assessed to be of positive significance.

6.2.2.2 Overall assessment

The overall assessment of impacts on hydrography from planned activities at the TYRA project is summarised in Table 6-5.

Table 6-6 Potential impacts on hydrography from planned activities at the TYRA project

Impact mechanism	Intensity	Extent	Duration	Overall significance	Level of confidence
Presence of structures	Small	Local	Long-term	Minor negative	Medium
Removal of structures	Small	Local	Short-term	Positive	Medium

6.2.3 Water quality

Potential impacts on water quality (turbidity, chemical composition etc.) are related to suspended sediment and chemical discharges.

6.2.3.1 Suspended sediment

Various activities at the TYRA project are expected to lead to sediment re-suspension, resulting in increased water turbidity as well as nutrients addition (mainly ammonium and phosphate) that can stimulate growth of bacteria and phytoplankton in the water. Other constituents of the sediment such as sulphide and organic material may also affect the water quality.

Disturbances of the seabed occur during trenching for pipelines, placement and decommissioning of jackets and anchoring of various vessels. Surface sediments can be swept by buoy and anchor lines. The most intense effect is caused by trenching, during which new pipelines are buried to a depth of ca. 1.5-2 metres below the seabed surface. Trenching of the pipeline into the seabed is done either by ploughing, water jetting or as mechanical cutting. During this process seabed sediment is suspended into the water column. Based on experience from other pipeline projects, it is estimated that the suspended sediment will settle within a few hundred metres of the disturbed area /131//158//191/.

The impact to water quality is assessed to be of small intensity, local extent and of a short-term duration. Overall, the impact to water quality from suspended sediment at the TYRA project is considered to be of minor negative significance.

6.2.3.2 Discharges

Discharges during production

The forecast volume of discharged produced water and oil at the TYRA project is shown in Figure 3-22 and Figure 3-23.

In addition to the residual oil, produced water will contain traces of production chemicals. The discharged production chemicals are typically categorized as ‘green’ or ‘yellow’ chemicals (see Appendix 1, technical section C). Under special circumstances, red chemicals may also be used. A list of production chemicals, their function and their partitioning in oil/water phase is presented in appendix 1.

The content of oil in produced water at the TYRA project is currently between 8 mg/l and 13 mg/l. After the implementation of Tyra Future redevelopment, the oil content is expected to decrease to between 6 and 9 mg/l. The expected amounts of discharged oil and chemicals are provided in section 3. Flowmeters measure continuously the volume of produced water discharged, and water samples are taken daily for analysis of the oil content in the produced water.

Produced water may have toxic effects to the marine environment due to its content of BTEX , PAH, dispersed oil, metals etc. Results from laboratory experiments suggest that the existing discharge of produced water should be diluted from 10 to 10,000 times to reach a concentration where no acute toxic effects are expected. Discharges of substances that are persistent or bio-accumulative will in principle increase the general background level of the substance, but due to the relatively small amounts discharged, it is expected that such increases will not be measured in practice /1/.

A hydrodynamic dispersion modelling of produced water for the TYRA project suggests that produced water discharges are diluted relatively rapidly /42/. The modelling further suggests that there could be an environmental impact up to a distance of 14 km from the Tyra platform /42/. It should be noted that the calculations are highly conservative and that monitoring data in other areas of the North Sea have demonstrated that the environmental impacts of produced water discharges are local, confined to within 1-2 km from the outlet, and that environmental impacts associated with produced water discharges are low /46/.

The discharged water, oil and chemicals also include compounds that may serve as nutrient sources for phytoplankton and Bacteria in the water.

The impact to water quality is assessed to be of small intensity, with a local to regional extent and of a long-term duration due to the constant discharge during the lifetime of the field. Overall, the impact to water quality from discharge of produced water at the TYRA project is assessed to be of minor negative significance.

During production other minor negative discharges take place, these include discharges from vessels, and cooling water from production platforms. These discharges are considered negligible in comparison with the produced water, and are not assessed further.

Discharges during drilling
There are currently 24 free well slots at the TYRA project. The planned development projects at Valdemar, Bo South, Adda, and Tyra C, includes the construction up to 4 satellite wellhead platforms, with a total of 32 new well slots. Typically, a well takes between 60 and 150 days to drill. Water-based mud and cuttings will be discharged to the sea, whereas oil-based mud and cuttings will be brought onshore to be dried and incinerated.

Cuttings from the formation collected in the water-based mud section of the well will be discharged to the sea, along with the drilling mud and material used for cementing (mostly cement and chemicals).

Discharges of cuttings can amount to 1,800 tonnes of cuttings per well (appendix 1). When discharged to the sea water-based mud and cuttings, which are slurries of particles of different sizes and densities in water containing dissolved salts and organic chemicals, form a plume that dilutes rapidly as it drifts away from the discharge point with the prevailing water currents. Field studies of the concentration of suspended solids in plumes of drilling mud and cuttings at different distances from the drilling activity have confirmed this pattern, concluding that the concentration of suspended drill cuttings and mud in the water column drops very quickly due to sedimentation and dilution of the material /45//46/.

Discharges of drilling mud and cement per well are shown in Table 6-7. The discharges shown are based on the worst case - defined as the well that leads to the largest amount of discharges. Chemicals expected to be used are categorised in Denmark as ‘green’ or ‘yellow’ chemicals in accordance with OSPARs classification system for offshore chemicals (section 2.2.2 and 8.1.3).

Table 6-7 Use and discharge tonnes of drilling mud and cement per well in a worst case discharge scenario. The classification colour code is explained above

	OSPAR classification	Use per well	Discharge per well
		Tonnes	Tonnes
Drilling mud		2421	2421
		994	994
Cement		631	76
		14	1.7

Based on a review of results of modelling and field studies of drilling mud and cuttings it has been concluded, that offshore discharges of water-based mud and associated cuttings will have little or no harmful effects on water column organisms. This conclusion is based on the rapid dilution in the water column and low toxicity to marine organisms of water-based mud and cuttings /45/. The chemicals discharged to sea during Maersk Oil drilling have been modelled in the EIA for Adda and Tyra /2/. The modelling was performed for a typical well and showed that the predicted effect concentration in the water column extended up to 7 km downstream from the platform /2/. These estimates are very conservative. Monitoring results in other areas of the North Sea confirms that the environmental impacts of drilling discharges are local, in general confined to within 1 - 2 km from the point of discharge /46/.

The impact to water quality is assessed to be of small intensity, local extent and of a short-term duration due to dilution. Overall, the impact to water quality from discharge of drilling mud and cuttings at the TYRA project is assessed to be of minor negative significance.

Discharges during well stimulation

The potential 56 new wells at the TYRA project may be subjected to well stimulation. In addition to stimulation of the new wells, it is anticipated that approximately two well stimulations of existing wells may take place per year at the TYRA project.

Expected discharges of chemicals during well stimulation at the TYRA project include chemicals categorized as ‘green’ or ‘yellow’ chemicals (See Technical Section D). Typical discharges during well stimulation are presented in Table 6-8.

Table 6-8 Use and discharge of chemicals per well stimulation. The classification colour code is explained above

	OSPAR classification	Use per well	Discharge per well
		Tonnes	Tonnes
Matrix well stimulation		220	140
		2603	522
Acid fracturing well stimulation		194	134
		2816	564

The amount of discharge per well stimulation (Table 6-8) is significantly less than discharges during drilling (Table 6-7). Modelling was undertaken for well stimulation as part of the Adda EIA, suggesting that there could be an environmental impact up to a distance of 7 km from the discharge point /2/. The modelled well stimulation had a duration of two days.

The impact to water quality is assessed to be of small intensity, local extent and of a short-term duration due to dilution. Overall, the impact to water quality from discharges during well stimulation at the TYRA project is assessed to be of minor negative significance.

Discharges during testing of new pipelines

During pre-commissioning the pipeline is flooded with treated seawater that contains low concentration of corrosion inhibitor (typically max 500 ppm) to prevent pipeline damage. Thereafter, the pipeline is cleaned and impurities are removed by pigging. After cleaning, the pipeline is pressure-tested using treated seawater. During those operations a total volume of treated seawater, corresponding to about 305 % of the pipeline volume, is discharged to the sea.

Experience from large pipeline projects show that the environmental impact (defined as a concentration exceeding NOEC) is negligible at distances more than a few hundred metres from the discharge point /162//163/. It is estimated that the discharge associated with the pre-commissioning of a 11.6 km pipeline could have an environmental risk to a distance up to 2.8 km from the discharge /2/.

The impact to water quality is assessed to be of small intensity, local extent and of a short-term duration due to dilution. Overall, the impact to water quality from discharges during pre-commissioning at the TYRA project is assessed to be of minor negative significance.

Discharges during decommissioning

Minor discharges are expected during decommissioning activities. In general, all structures (jacket and topside) will be cleaned before transport to shore. The minor discharges during decommissioning (e.g. cooling water, grey wastewater from vessels) are assessed to be of small intensity, local extent and of a short-term duration due to dilution. Overall, the impact to water quality from discharges during decommissioning at the TYRA project is assessed to be of minor negative significance.

6.2.3.3 Overall assessment

The overall assessment of impacts on water quality from planned activities at the TYRA project is summarised in Table 6-9.

Table 6-9 Potential impacts on water quality from planned activities at the TYRA project

Impact mechanism	Intensity	Extent	Duration	Overall significance	Level of confidence
Suspended sediment	Small	Local	Short-term	Minor negative	High
Discharges	Small	Local/Regional	Short-term	Minor negative	High

Minor cumulative effects on the water quality between production, drilling and construction discharges cannot be ruled out, however due to the low toxicity of the discharges and the rapid dilution in the seawater, the impact is estimated to be local and short-term. A review of the cumulative impact of discharges from the Norwegian offshore petroleum industry based on monitoring data demonstrates that the cumulative impacts of discharges remains local, in general confined to few kilometres from the platforms /46/.

As mentioned above, no environmental effects of produced water discharge are expected outside a radius of a few km from the discharge point at the TYRA project. The closest other oil field where discharges may occur is Gorm, which is approximately 16 km away. Most of the produced water at Gorm is re-injected into the reservoir, and no cumulative effects in regards to water quality are expected from discharges from other Oil and Gas facilities in the North Sea.

6.2.4 Sediment type and quality

Potential impacts on the sediment type and quality are related to physical disturbance on the seabed and discharges settling on the seabed that may affect the chemical and physical composition.

6.2.4.1 Physical disturbance on the seabed

Physical disturbance on the seabed may occur during site surveys, 4D seismic, drilling, installation of platforms and pipelines and decommissioning. The physical disturbances from these activities are not expected to occur simultaneously.

During site surveys, which are expected to occur annually, seabed coring will be undertaken and disturbance of seabed will occur where the sample is acquired, typically with an area of 0.1-0.25 m^2. During 4D seismic surveys, presence of bottom nodes and cables may impact the seabed. The area of such nodes and cables is expected to be small, as each node is 0,40-0,50 metre broad. During drilling (up to 56 wells), a drilling rig will be present. The rig legs will be placed on the seabed, and are expected to sink 1–2 metre into the seabed. The rig legs typically cover a few hundred m^2.

New pipelines are trenched and buried to a depth of ca. 1.5-2.0 metre below the seabed surface, resulting in sediment suspension along the pipeline route.

Minor amounts of sediment will be re-suspended during installation of new platforms, when the supporting jackets are placed on the seabed. During decommissioning, physical disturbance will be related to removal of the existing structures.

Disturbance of small areas of sandy sediments is expected to be short term, as sand will rapidly re-settle in the vicinity of the disturbed areas. The impact to sediment type and quality is assessed to be of small intensity, local extent and of a short-term duration. The overall impact to sediment type and quality from physical disturbance is therefore assessed to be of minor negative significance.

6.2.4.2 Discharges during drilling

Water-based drilling mud and drill cuttings are expected to be discharged to sea from up to 56 wells. The discharges may settle on the seabed and impact the sediment quality.

Several field studies that have measured the concentration of suspended solids in plumes of drilling mud and cuttings at different distances from the drill rigs have confirmed that the concentration of suspended drill cuttings and mud in the water column decreases with distance due to sedimentation and dilution of the material /45//46/.

Modelling of drilling mud and cuttings sedimentation for drilling of a typical Maersk Oil well shows that most of the drilling mud will settle in the vicinity of the discharge point (1 - 2 kilometres) (Figure 6-1). The layer of drilling mud settling on the seabed will be less than 1 millimetre thick. Drill cuttings are heavier than the drilling mud and will settle more rapidly. Model data shows that for a similar well discharge, a 50 millimetre layer of cuttings could be expected within 50 metres of the well. The thickness of the layer is expected to decrease to <1 millimetre beyond 200 metres of the discharge (Figure 6-2).

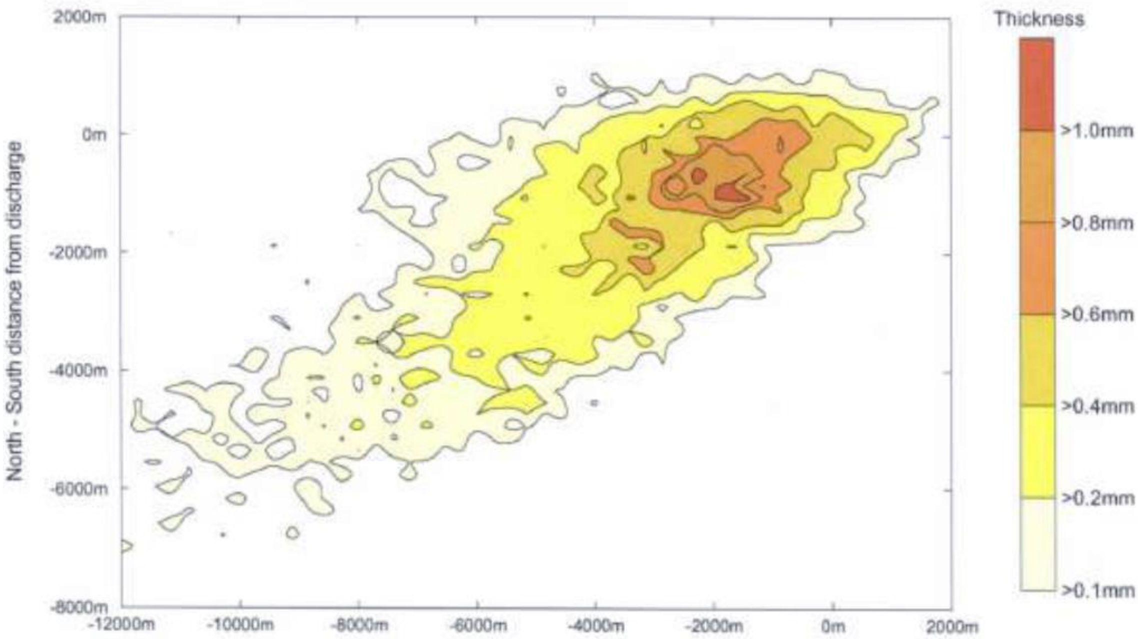


Figure 6-1 Sedimentation of discharged water based drilling mud modelled for a typical well /1/.

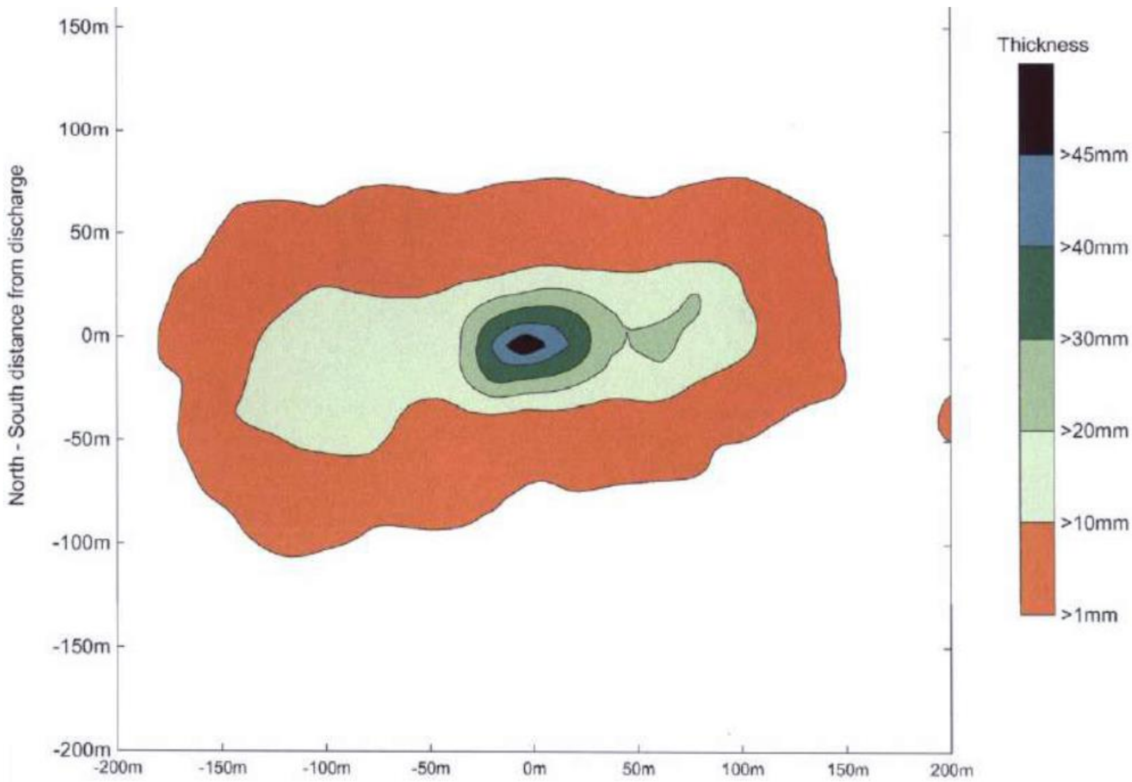


Figure 6-2 Sedimentation of water based drill cuttings modelled for a typical well /1/.

Worst case scenario discharges from drilling of one well is approximately 1,800 tonnes of cuttings and approximately 3,500 tonnes of water based drill mud and cement. If all 56 existing and planned well slots at the TYRA project are being used it would result in a total discharge of 101,000 tons of cuttings and 196,000 tons of water-based drill mud. The worst case scenario is estimated to be the case where the wells are drilled consecutively. However, it is noted that the wells are located at 14 different locations at distances of 4 to 64 kilometres (see section 3).

The chemicals which are discharged with the mud and cuttings are categorized as 'green' or 'yellow' chemicals (section 6.2.2.1 and 8.1.3). The mud usually contains barite or trace of heavy metals, while the cuttings may contain small quantities of oil. Chemical and biological seabed monitoring around Tyra E shows that elevated concentrations of metals, THC, PAH and NPD in the sediment are local (typical within a few hundred metres) and rapidly decreasing in all directions with increasing distance from the platform /6/. According to this report contaminants in the sediment around Tyra East do not exceed in advance OSPAR's environmental assessment criteria (EAC) or EU's environmental quality standards (EQS) for which relevant threshold values exist. It is therefore expected that concentration of contaminants will remain below these threshold values with the activity connected to this project.

Sedimentation of drilling mud and cuttings may change the sediment grain size. However, seabed monitoring shows that the median grain size variation after drilling at Tyra East and Valdemar platform fall within the natural range /6/.

The water based drilling mud may contain biodegradable organic additives, which may stimulate growth of microbial communities leading to depletion of oxygen in the sediments. Anaerobic, sulphate-reducing bacteria may further degrade the organic matter, producing hydrogen sulphide /45/. The seabed monitoring campaign of the seabed around the Tyra East platform reported that sulphide was detected at a few of the station closest to the platform (less than 1 kilometre) /6/.

Based on the modelling results, the type of chemicals in the drilling mud and cuttings and the results from the seabed monitoring, the impact is assessed to be of small intensity, local extent and of a long-term duration. In conclusion, the overall impact to sediment type and quality from discharges is assessed to be of minor negative significance.

6.2.4.3 Presence/removal of structures

Pipelines can cause water to accelerate in front of the pipeline, thus eroding the seabed and/or depositing sedimentary material behind it. Water motion can also create free-spans of the pipeline. Pipelines associated with the TYRA project are trenched into the bottom or covered by rocks, which would minimize scouring effects.

Jackets may cause the water to accelerate around the piles, creating a scour hole around the base. The changes may be visible at the seabed as erosion or deposition of sand close to the jackets.

Existing and planned pipelines and jackets of the TYRA project provides a hard substrate for growth of animals, plants and algae in an area where previously only sand was present. All jackets will be removed as the TYRA project is decommissioned, whereas pipelines may be left in place, but covered by sediment and/or rock dumping.

The impact to sediment type and quality is assessed to be of small intensity, local extent and of a short-term duration. The overall impact to sediment type and quality from presence of structures is assessed to be of minor negative significance.

6.2.4.4 Overall assessment

The overall assessment of impacts on sediment type and quality from planned activities at the TYRA project is summarised in Table 6-10.

Table 6-10 Potential impacts on sediment type and quality from planned activities at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Physical disturbance on seabed	Small	Local	Short -term	Minor negative	Medium
Discharges of drill cuttings	Small	Local	Long-term	Minor negative	High
Presence/removal of structures	Small	Local	Short-term	Minor negative	High

Minor cumulative effects between the various discharges at the TYRA project can take place e.g. from sedimentation of drilling mud and cuttings, which may settle on top of the previous discharged drilling mud and cuttings (when drilling in the same area). However, based on Maersk Oil knowledge from surveys of structures it is known that the cuttings and mud are eventually dispersed. Overall, the cumulative impacts are estimated to be local.

6.2.5 Plankton

Potential impacts on plankton (phyto- and zooplankton) are related to underwater noise, suspended sediment, discharges and light.

6.2.5.1 Underwater noise

Underwater noise is a form of energy which may in extreme cases impact plankton, due to e.g. disruption of cells (cell lysis). Underwater noise at the TYRA project may be generated from seismic activities (airguns, multibeam and sidescan), pile-driving during construction of new platforms, driving of conductors, drilling, decommissioning and various vessels. Table 6-11 shows typical frequency and noise levels for these activities.

Little research has been conducted in relation to impacts of underwater noise to plankton, primarily focussed on emitted energy from airguns during seismic surveys. Mortality of plankton has been observed at close range (within 5 metre) of the source of the seismic gun /54//55/. A study found that close range (2 metre) seismic sound emission on snow crab eggs had impacts on larval development and settlement /66/. Based on field measurements, it is expected that impact on invertebrates and planktonic larvae, behaviour and physiology will only occur within a few metres from a noise source of 240 dB re 1 μPa /61/. In general, effects of noise are only expected to impact organisms close to (within a few metres) powerful noise sources e.g. seismic surveys and pile-driving /64/ /65/.

Based on the ubiquitous abundance, productivity and size of planktonic populations and their high reproductive rate, plankton populations will fast recover after disturbance. The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on plankton from underwater noise is assessed to be of negligible negative significance.

Table 6-11 Typical frequency and noise levels of activities at the TYRA project (based on appendix 1 (Technical Sections), /2//48//140//180/). RMS is the sound pressure averaged over a discrete period of noise and SEL is the sound exposure level expressing the total energy in a distinct sound. Peak-to-peak reflects the actual maximum sound pressure.

Activity	Frequency	Unit	Noise level extrapolated back to 1m distance from source (@1m)
Seismic			
Airgun (2D/3D/4D seismic)	0.005-0.200 kHz	Peak-to-peak (dB re 1μPa)	244 (ca.)
	0.005-80 kHz	RMS (dB re 1μPa)	179-266
		SEL (dB re 1μPa²s)	202-216
Multibeam echosounder	70-100 kHz	RMS (dB re 1μPa)	225-232
Sidescan sonar	100-900 kHz	Peak-to-peak (dB re 1μPa)	220 (ca.)
	100-500 kHz	RMS (dB re 1μPa)	220-226
Pipelines and structures			
Jacket piling	0.001-170 kHz	Peak-to-peak (dB re 1μPa)	230
Production			
Production platform	0.01-10 kHz	RMS (dB re 1μPa)	162
Drilling and well stimulation			
Driving of conductors	0.03-20 kHz	Peak-to-peak (dB re 1μPa)	219
Drilling rig	0.1-0.4 kHz	RMS (dB re 1μPa)	195
Transport			
Support vessel	0.01-20 kHz	RMS (dB re 1μPa)	122-192
Decommissioning* **			
Underwater jet cutting		RMS (dB re 1μPa)	195

***Use of explosives for the decommissioning of facilities not planned

6.2.5.2 Physical disturbance on the seabed

Regarding the sessile organism living on the solid underwater structures, these will function as filtering curtains for the plankton associated the passing water masses. This will alter the local food chain and hence change the local biological production and decomposition of organic matter in the area. Although this will affect the ecology in an area several fold larger than occupied by the fields, it still remains a minor impact of the regional ecosystem.

6.2.5.3 Suspended sediment

Suspended sediments could potentially reduce light availability to phytoplankton and affect the ingestion rate, egg production, egg-hatching success and survival rate of zooplankton. However, only relative small amounts of sediment are expected to be suspended as part of the construction of new platforms and pipelines as well as from decommissioning (see section 6.2.3.1).

The sediment spread will be local, temporary and spatially distributed along new pipelines and structures during pipeline trenching and decommissioning and will mainly be limited to the lower parts of the water column. It is assessed that any impact on phytoplankton and zooplankton from suspended sediment will be negligible.

6.2.5.4 Discharges

Potential impacts on plankton from discharges are related to the impacts of different activities on the water quality, which are described in section 6.2.3.

Studies show that discharges of water based drilling chemicals may have short-term effects on phyto- and zooplankton communities /45//46//58/. The discharges of chemicals associated with production, drilling, stimulation and cleaning of pipelines before in-situ decommissioning may thus affect the phyto- and zooplankton communities. In general, it is expected that offshore discharges dilute rapidly and that only plankton found in the vicinity of the discharge will be affected. Laboratory and field data confirms that the risk of significant biological impact is limited to 1 – 2 kilometres from the points of discharges /46/. The effect of chemical discharges on plankton is expected to be small, local and short-term; therefore, the overall impact on planktonic communities is assessed to be of minor negative significance.

6.2.5.5 Light

Vertical migration in the water column by some large zooplankton species may be influenced by light from manned platforms.

Light is a factor controlling the daily vertical migration of large forms of zooplankton /60/. It has been shown that some migrates closer to the surface on dark nights than they do on clear, moonlit nights /62/. It is recognised that copepods foraging in darkness to avoid predation, only to be intensively predated when illuminated by a rising full moon /63/. Planktonic organisms are otherwise characterised to be almost entirely subjected to the prevailing ambient currents and turbulence, and light is expected to be detectable for zooplankton organism only in the immediate vicinity of the platforms.

The potential effects are expected to be local /190/, and may impact individuals but will not impact plankton populations in the North Sea. The overall impact on plankton from light at the TYRA project is assessed to have negligible negative significance.

6.2.5.6 Overall assessment

The overall assessment of impacts on plankton from planned activities is summarised in Table 6-12.

Table 6-12 Potential impacts on plankton from planned activities at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Underwater noise	Small	Local	Short-term	Negligible negative	Medium
Physical disturbance on seabed	Small	Local	Medium-term	Minor negative	High
Suspended sediment	Small	Local	Short-term	Negligible negative	High
Discharges	Small	Local	Short-term	Minor negative	Medium
Light	Small	Local	Immediate	Negligible negative	Low

6.2.6 Benthic communities

Potential impacts on the benthic community are related to underwater noise, physical disturbance on seabed, suspended sediment, discharges and physical presence/removal of structures.

6.2.6.1 Underwater noise

Underwater noise may potentially impact benthic communities through e.g. behavioural and physiological effects.

Many invertebrates can detect and utilise sounds, and therefore may be susceptible to a changing regime of noise. The behaviour of benthic fauna in response to noise is almost unknown. Invertebrates typically do not have organs or tissues whose acoustic impedance is significantly different from water. Unlike e.g. fish with swim bladders, the general consensus regarding underwater noise effects on invertebrates and planktonic larvae, is, that very few direct damage effects are expected unless the organisms are within a few metres of noise sources around 240 dB re 1 μPa /61/.

The masking of natural sound is likely one of the overall most serious threats associated with man-made sound for the living conditions of animals in aquatic environments /179/. Masking is the reduction in the detectability of given sound waves as a result of the simultaneous occurrence of another sound. The critical question with regard to the behavioural effects of sound is whether artificial noise interferes with, or masks, the ability of an animal to detect and respond to biologically relevant sounds. For instance, carnivorous polychaetes are known to use low frequency sounds for locating their prey. There is, however, a complete lack of data on the masking of biologically important signals in polychaetes and other groups of benthic invertebrates by man-made activities. However, taking the short-term impact of noise from the different activities associated the TYRA Project into consideration; the harmful effect on the living conditions for macrozoobenthos will probably be insignificant.

Long-term effects are thus not envisioned. Impacts on macrozoobenthos from noise are considered to be small of intensity, local and short-term. It is assessed that there may be a minor impact on single individuals, but no overall impacts on the population. The overall significance of the noise from the project is assessed negligible negative.

6.2.6.2 Physical disturbance on the seabed

Physical disturbance on the seabed may physically impact the benthic fauna. At the TYRA project, the disturbed area relates to pipe lay, cables from seismic surveys and legs from the drilling rig and new platforms. During decommissioning, physical disturbance will be related to removal of the existing structures.

The solid structures may impair its surrounding natural environments by modifying the pre-existing ecosystem. The benthic communities inhabiting the adjacent soft bottom can be affected by increased oxygen consumption of the sediment as a function of the accumulation of detritus and detached epifaunal organisms from the submerse structures, by modification in grain size or by predation by the organism attracted by the field constructions.

The placement of the spudcan of the drilling rig and the installation of the new platform will result in the localised disturbance of the seabed and associated benthic fauna. Re-establishment of the benthic fauna will depend on the species present and their life cycle, but studies from the North Sea show that benthic communities on a sandy seabed generally re-establish within a period of 2-3 years after disturbance /67/.

The shape of pipelines and legs on the seabed may affect the water column currents and alter local sediment erosion and deposition patterns, e.g. due to scour. The scour effects on accretion and erosion processes on soft seabeds can be predicted to the immediate surroundings, i.e. up to

10-12 times the area of the solid emerging structure /171/. The possible change of the bottom texture in the immediate vicinity of the pipeline as result of its shelter effects for transverse current will not have any significance for the overall ecological conditions prevailing in the region.

The appearance of solid construction emerging from the seabed in a vast soft bottom area mainly consisting of muddy sand will attract sessile organisms that otherwise are rare in the region. This is a general observation obtained in studies of artificial marine installations /172//173/. The colonisation of epifauna (and epiphytes when the light conditions allow) will attract other organisms such as mobile crustaceans and gastropods looking for food and/or shelter /174/.

The majority of sessile organism colonising the legs and other of the submerge structures has no significant role as prey for higher trophic levels in the marine food. Most part of the produced biomass on these structures will end in the decomposition food web, mainly on the seafloor beneath the rigs – cf. /181/. This will represent oxygen consumption but because of the usually good existing water exchange anoxic condition will only appear in close proximity of the decaying organism.

Although the introduction of an artificial solid habitat in a soft bottom environment generally appears positive the beneficial impact of the construction on the ecological conditions in the region must not be overestimated. Its contribution to the overall productivity in the region is limited and will therefore hardly have any significance for the abundance of the marine life. This again is because the solid structures only occupy a negligible part of the total productive volume dominating the region and which sustains the ecosystem in this part of the North Sea. In comparison to the adjacent Dogger Bank area the impact from TYRA on the productive volume is estimated to represent less than 1 ‰. The impact magnitude of the TYRA project on the adjacent benthic community is thus evaluated to be low. Consequently, this will also be the case in the absence of the structures after they have been decommissioned.

In summary the intensity of the impact from physical disturbance on the seabed is assessed to be small with a local extent and of medium-term duration. Overall, the impact on benthos is assessed to be minor negative.

6.2.6.3 Suspended sediment

Following the installation and decommissioning of platforms and pipelines, sediments will be dispersed to the water column. The impact will depend on the concentration of suspended sediments and the duration. Increased concentrations of suspended sediment in the water column may negatively affect benthic fauna by e.g. clogging of respiratory system or feeding apparatus. Smothering by re-suspended sediment as it settles may have direct mechanical effects.

Marine benthic invertebrates generally have poor if any visual ability and are unlikely to be adversely affected by suspended matter. Suspension feeders may be considered as the most sensitive to sediment suspension and sedimentation. The impact from a sand-extraction site on suspension feeders resulted in lower activities and a reduced feeding rate up to a distance of 1-1.5 kilometre, and no long-term impact was detected /75/.

The impact of sediment re-suspension on the benthic fauna is generally expected to be short term. A study of the effects of pipeline construction on benthic invertebrates showed that six months after disturbance there was no significant difference between the mean number of total individuals in the impacted site and in the reference areas /72/. Other studies have shown that benthic invertebrate communities began to re-colonise a disturbed seabed area quickly, but that it could take up to five years for the structure of the community to recover to its original composition /73/.

Due to the limited amount of dispersed sediment and sedimentation during construction of new platforms and pipelines impacts are assessed to be very local. Any measurable impacts to the benthic community are estimated to be within 10 metres from the area of activity.

The intensity of the impact from suspended sediment is assessed to be small with a local extent and short-term duration. Overall, the impact is assessed to be of minor negative significance.

6.2.6.4 Discharges

Potential impacts on the benthic communities are related to discharges which can lead to changes in water (section 6.2.2.1) and sediment quality (section 6.2.4).

Studies show that the effects of drilling discharges and of seawater used for cleaning on the benthic fauna communities are minor and nearly always restricted to a zone within about 100 metre of the discharge of water based drilling mud and cuttings /45//46/. There is no evidence of ecologically significant bioaccumulation of metals or hydrocarbons by benthic fauna residing or deployed in cages near water based drilling mud and cuttings discharges. The lack of bioaccumulation or toxicity of drilling waste components indicates that effects of water based drilling mud cuttings piles are highly localized and will not be exported to the local food web /45//46/. Monitoring at Tyra E and Valdemar platforms in 2009 showed a weak impact to the benthic fauna from the drilling operation of the platform. The benthic fauna at the 100, 250 and 750 metre stations was significantly different from the benthic fauna at the reference stations. The observed significant spatial difference in benthic similarity combined with the lower number of species and abundance close to the platform compared to the reference stations may be interpreted as an impact related to platform discharges. However, the contamination of the sediment was low and sensitive species were common close to the platform /6/.

Sedimentation of water based drilling mud and cuttings on the seabed may bury some of the sessile benthic fauna. Changes in the sediment grain size and texture may render the sediment unsuitable for settling and growth of some species, while rendering the substrate more suitable for other, opportunistic species. Organic enrichment can cause changes in the abundance, species composition and diversity of the benthic community /45/. A higher content of silt/clay and a weak smell of hydrogen sulphide in the sediment close to the platform are likely due to drilling related discharges /6/.

Discharges of water based drilling mud and cuttings in the water column will shortly increase turbidity and then settle on the seabed. Discharges have been determined to cause impacts at concentrations above 0.5 mg/l, typically restricted to a radius of less than 1 kilometre from the discharge point /46/. Marine benthic invertebrates generally have poor if any visual ability and are unlikely to be adversely affected by suspended matter. However, smothering by settling sediment has direct mechanical effects on epifauna and infauna and may result in the modification of the substratum. Sediment may directly clog the feeding or respiratory apparatuses of suspension feeders. The impact level depends on the grain-size distribution of the settled sediments and on species-specific tolerances to increased rates of sedimentation and accumulation. Water based drilling mud and cuttings have been found to affect the benthos at a thickness of at least 3 millimetre or more. Such layer thicknesses will normally be confined to a distance of 100-500 metres /46/. Mud and cuttings for a typical Maersk Oil well has been modelled to settle at a thickness of above 1 millimetre only wwithin 200 metres of the discharge (section 6.2.4).

The risk of widespread, long term impact from the operational discharges during construction, operation and decommissioning on benthic populations is presently considered low /46/. A monitoring campaign of the seabed around the Tyra E and Valdemar platforms shows that measurable impacts on the benthic community are limited to the vicinity (a few hundred metres) of the discharge point, but likely with a long-term duration /6/.

The impact is assessed to be of small intensity, local extent and long-term duration. The overall impact on benthic communities from discharges is assessed to be of minor negative significance.

6.2.6.5 Presence/removal of structures

The platform jacket provides a new habitat for hard substrate benthic communities that are not normally present in soft sediment environments. Structure inspections have shown that marine growth (e.g. sea anemones, seaweed, soft corals, sea squirts and sponges) are found on most jackets at Tyra. Depending on the season (and the solid surface properties) the colonisation starts almost immediately after the structures being submerged and are visible for the naked eye within a few months.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on benthic communities from presence (or absence) of structures is assessed to be of minor negative (or positive) significance and consequently on the existing benthic ecosystem.

6.2.6.6 Overall assessment

The overall assessment of impacts on benthic communities from planned activities at the TYRA project is summarised in Table 6-13.

Table 6-13 Potential impacts on the benthic communities from planned activities at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Underwater noise	Small	Local	Short-term	Negligible negative	Low
Physical disturbance on seabed	Medium	Local	Medium-term	Minor negative	High
Suspended sediment	Small	Local	Short-term	Negligible negative	High
Discharges	Small	Local	Long-term	Minor negative	High
Presence/removal of structures	Small	Local	Short-term	Minor negative	High

6.2.7 Fish

Potential impacts on fish are related to underwater noise, physical disturbance on seabed, suspended sediment, discharges, light and physical presence/removal of structures.

6.2.7.1 Underwater noise

The extent to which underwater noise may impact fish is dependent upon a number of factors including the level of noise produced at the source, the frequencies at which the sound is produced, the rate at which sound attenuates (which will vary for different frequencies and environmental conditions), the sensitivities of different species and individuals to different volumes and frequencies of noise. Noise can impact fish in several ways, including:

- Damage to non-auditory tissue
- Damage to auditory tissues (generally sensory hair cells of the ear)
- Hearing loss due to temporary threshold shift
- Masking of communication
- Behavioural effects (e.g. avoidance)

Fish behaviour in response to noise is not well understood. Sound pressure levels that may deter some species, may attract others. The fish may also freeze and stay in place, leaving it exposed to potential impact. When the fish swims away, it could minimise the impact. On the other hand, it could lead to a fish swimming away from an important feeding ground, mating or spawning area. This could lead to significant impact if there are long term effects /46/.

Very few investigations on the responses of eggs and larvae to man-made sounds have been performed. But it appears that the hearing frequency range of fish larvae is similar to that of adults /182/.

There are several sources of noise emitting from the planned activities, including drilling activities (conductor driving), seismic surveys, construction of new platforms (pile driving), decommissioning and vessels.

Underwater noise from seismic
Noise emitted during seismic survey can have an impact either directly through harmful physiological effects or behavioural effects.

Research has shown that injuries and increased mortality can occur at distances less than 5 m from the air guns, with fish in the early stages of life being most vulnerable. The risk of injuries to individual from seismic is assessed to be low and it is further not considered to have a significant negative impact on fish at the population level /99/. Some findings also indicated harmful effects on the sensory cells of adult fish /92/. The fish were kept in cages and the seismic vessel passed the cages along course lines running from 400-800 metre distance at the beginning and up to 5-15 metres from the cages. Since the experimental fish were so close to the air guns, one could discuss whether these types of injuries are representative for adult, free-swimming fish.

Behaviour of herring schools exposed to 3D seismic survey was observed. No changes were observed in swimming speed, swimming direction, or school size that could be attributed to the transmitting seismic vessel as it approached from a distance of 27 to 2 kilometres, over a 6 hours period /96/. The unexpected lack of a response to the seismic survey was interpreted as a combination of a strong motivation for feeding, a lack of suddenness of the air gun stimulus, and an increased level of habituation to the seismic shooting.

Behavioural change of fish may have implications for spawning and migration to the spawning grounds. This can change the time of the arrival of fish to the spawning areas, so that spawning conditions become less favourable. It must be emphasised that effects must be interpreted in the light of the fact that they will be unique for each species, and that the vulnerability and effect of external stimuli depend on the life stage. However, as spawning areas in the North Sea are large (section 5.8), and the change in behaviour is within a few kilometres, impact to spawning is not expected.

Seismic airguns may affect the behaviour of fish in the area close to the seismic vessel. However it is expected that seismic will not lead to long term changes to the size of fish stocks in the North Sea in general /97/.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on fish from underwater noise from seismic is assessed to be of minor negative significance.

Underwater noise from pile-driving and conductor driving
There are several examples of pile driving of mono-piles for wind farms resulting in the death of caged fish in the immediate vicinity of the pile driving activity in the literature. Typically, mortality is reported within a distance of 50 metres from pile driving activity /93/. Fish will most

likely move away from the sound source. It is estimated that, for example, flounder and cod will respond within a distance of 500 m and 2 km, respectively /95/.

There is a substantial difference between pile driving for a wind farm monopile and pile and conductor driving for an oil and gas installation. Typically wind farm monopiles have diameter of 5 – 10 metres and driving time 4 - 6 hours compared to jacket piles diameter up to 2.4 metres (96''). Conductors are of smaller dimension, usually 26-30" and the noise level from driving of conductors is considerably lower than of pile driving. The hammering will usually be done within 2 hours for the pile used for the jacket (6 new platforms) and 6-8 hours for conductors (56 new wells) that will be used for drilling of a new well. Conductor driving may occur either as batch or separately after completion of the individual well.

The effects on the fish from pile-driving are assessed to be small, local and short-term. It is concluded that the overall impacts will be minor negative. Mitigation measures such as ramp-up/slow start procedures, where the first hammer blows are at reduced impact energy allowing noise sensitive fish species to escape the immediate vicinity, impact are further reduced.

Underwater noise from other activities
Because blasting is not planned for the decommissioning, noise related to the removal of rigs and pipelines will be rather limited and mainly connected to the use of the operation vessels and jet-cutting.

Field studies have shown that some species may be disturbed by noise from passing ships, while others are not affected. Species such as cod and haddock, which often occurs in large schools around offshore platforms, do not respond to noise from passing vessels. Other species tend to move away from a passing vessel. Reaction range varies from 100 - 200 metres for many typical vessels but 400 metres for noisy ones /77/. The drilling rigs and offshore platforms attracts fish indicating that the noise from drilling or processing and production platform generally does not affect fish or that the fish tolerate the noise /78//79//80/. Observations from the platform and underwater inspections at the TYRA project also confirm the presence of fish schools.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on fish from underwater noise from other activities is assessed to be of negligible negative significance.

6.2.7.2 Physical disturbance on seabed

Potential impact to fish caused by physical disturbance of the seabed could be related to demersal fish or habitat fragmentation caused by changes to the seabed.

The physical disturbance on seabed is limited to pipe lay, sediment sampling and disturbance of the seabed by the presence of cables during 4D seismic surveys, the placement of spud cans from drilling rigs or of new platforms, and from decommissioning. Pipelines are expected to be buried to depths of 1.5-2.0 metres below the sea floor and subsequently in-situ decommissioned. The impacted area is expected to be small. It is estimated that natural processes such as erosion or sedimentation will restore the disturbed seabed to its original state within a few years.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on fish from physical disturbance is assessed to be of negligible negative significance.

6.2.7.3 Suspended sediment

The sensitivity of fish to suspended particles varies highly between species and their life stages and depends on sediment composition, concentration and duration of exposure. High levels of suspended sediment for a short period of time may be less of a problem than a lower level that persists longer. Depending on the exposure the severity of impacts may go from behavioural effects, to sub lethal and lethal effects.

Both laboratory and field investigations have showed that herring and smelt began to flee areas with fine-grained suspended sediment when the concentration reached approximately 10 mg/l and 20 mg/l, respectively /82/. Flatfish are especially tolerant to relatively high concentrations of suspended sediment. Studies of plaice with concentrations of 3,000 mg/l showed no increased lethality during a 14-day period /83/.

Many species use their vision for feeding, and the feeding activity of herring fry is shown to be affected by concentrations of suspended matter of 20 mg/l /85/. The most likely effects due to suspended material will be avoidance reactions or fish species fleeing an area during construction activities. Larvae can live a few days without food /86//119/, and a short-term increase in suspended sediment is expected to be of negligible impact.

Pelagic fish eggs may be affected if suspended matter adheres to eggs, causing them to sink to the bottom, where there is a risk of oxygen depletion /85/. A laboratory study on herring eggs has shown that short term exposure to relatively high concentration of suspended matter do not affect the development of fish eggs /87/. Benthic eggs are associated with soft sediments, and are assessed to be less sensitive to suspended particles than pelagic eggs. In addition, as the TYRA project area is small compared to the vast uniform surrounding in the central North Sea, no effect on plankton at population level is anticipated.

Based on the limited amounts of sediment dispersed during pipe lay and other activities at the TYRA project, any impacts would be limited to the vicinity of the disturbed seabed sediment. Food sources living in the seabed e.g. polychaetes will become exposed during pipe lay/trenching, and fish that are not affected by noise and higher turbidity are likely to be attracted to the construction site /88//89//90/.

The sensitivity of fish in relation to sediment spreading in the water column is assessed to be low. The overall effects on fish from increased turbidity are assessed to be small, local and short-term. It is concluded that the overall impacts on fish and fish stocks from sediment spreading will be minor negative.

6.2.7.4 Discharges

Potential impacts on fish from discharge are related to a number of discharges, which may change the water quality (section 6.2.2.1).

Calculation of the environmental risk from the discharged produced water at the TYRA project suggests that risk may occur up to 14 kilometres from the combined discharges at the Tyra East and West platforms /42/. However, a recent review of environmental impacts of produced water and drilling waste discharges based on monitoring from the Norwegian offshore petroleum industry suggests that the measured impacts of discharges are local, and in general confined to within 1-2 kilometres from an outlet both in the waters and on the seabed, and that the risk of widespread impact from the operational discharges is low /46/. The discharge of treated wastewater resulting from the cleaning of structures during operation or decommissioning is minor compared to the discharge of produced water.

Studies have showed that compounds present in produced water have a potential to exert endocrine effects in fish. The experimental exposure levels studied cover a range of produced water concentrations that are typically found in close proximity to the discharge points. They might therefore elicit effects on fish standing close to platforms. However, it is concluded that widespread and long lasting effects of produced water on the population level on fish are unlikely /46/.

Modelling results shows that drilling mud generally settles on the seabed within a distance of 12 km downstream of the discharge point, with the majority settling within a few km. Drill cuttings settle within a distance of 200 metre (section 6.2.4). Several field studies that have measured the concentration of suspended solids in plumes of drilling mud and cuttings at different distances from the drill rigs have confirmed this pattern. The measurements have shown that the concentration of suspended drill cuttings and mud in the water column drops very quickly due to sedimentation and dilution of the material /45//46/. A monitoring campaign of the seabed around the Tyra East platform shows that measurable impacts on contaminants in the sediment are limited to the vicinity of the discharge point /6/, and any impacts on fish are considered to fall within this range.

Based on the modelling results and the type of chemicals discharged, the intensity of the impact from discharges is assessed to be small with a local extent and of medium-term duration. Overall, the impact is assessed to be of minor negative significance.

6.2.7.5 Light

Though safety lights are present at all satellite platforms and vessels, only manned platforms Tyra East and West are illuminated and following Tyra Future redevelopment, when Tyra West will be unmanned, only Tyra East will be illuminated. Platforms may be providing an enhanced foraging environment for larval, juvenile and adult fishes by providing sufficient light to locate and capture prey, as well as by concentrating positively phototaxic prey taxa. For juvenile fish there is probably a trade-off between living and foraging in an artificially illuminated nocturnal environment. The increased illumination likely allows them to feed on zooplankton that has concentrated within the light field near the surface; however, the same light may make them more vulnerable to predators.

The potential disturbance to fish of light emissions from rigs, platforms and vessels is expected to be local, extending 90-100 metres from the source /98//190/. As such, any impacts on fish arising from light emissions are considered to be minor and localised to a small proportion of the population.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on fish from light at the TYRA project is assessed to be of negligible negative significance.

6.2.7.6 Presence/removal of structures

It is known that fish density is higher in proximity of platforms and other structures in comparison to the surrounding open water areas. However, the underlying mechanisms that attract fishes around these structures are still not fully understood.

The artificial reef introduced by the existing and new jacket or the area covered by rock dumping provide new habitats for fish to find hiding places and food areas /148/. Reef fish such as e.g. goldsinny wrasse, corkwing wrasse and lumpsucker will profit from the new habitat. The fish are attracted to the solid structures with their heterogeneous variety which creates a wealth of cavities where e.g. small fish and fry can hide from predators. Also bentho-pelagic fish as cod and whiting are attracted of the larger food supply and the sheltering offered by the rig constructions and boulder reefs /149/.

The impact from platforms and connected installations on fish is assessed to be of small intensity, local extent and short-term duration as most structures are removed during decommissioning. The overall impact on fish from presence of structures is therefore assessed to be of negligible negative significance to species which are associated to sand sediment. For fish species living in reef habitats and which can be attracted by artificial solid structures a negligible positive impact is expected due to a local reef effect. A negligible impact on fish population will also be the consequence of the removal of these structures.

6.2.7.7 Overall assessment

The overall assessment of impacts on fish from planned activities at the TYRA project is summarised in Table 6-14.

Table 6-14 Potential impacts on fish from planned activities at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Underwater noise	Small	Local	Short-term	Minor negative	Low
Physical disturbance on seabed	Small	Local	Short-term	Negligible negative	Low
Suspended sediment	Small	Local	Short-term	Minor negative	Low
Discharges	Small	Local	Medium-term	Minor negative	High
Light	Small	Local	Short-term	Negligible negative	Low
Presence/removal of structures	Small	Local	Short-term	Negligible negative/positive	Low

6.2.8 Marine mammals

Potential impacts on marine mammals are related to underwater noise, physical disturbance, suspended sediment, discharges, lights and presence of vessels and platforms.

All species of cetaceans are listed in the habitats directive appendix IV, and special protective measures apply regarding deliberate capture or killing of individuals of these species in the wild; and deterioration or destruction of breeding sites or resting places. The TYRA project area is not a known breeding site for cetaceans, and no deliberate capture or killing is foreseen. Some pinnipeds such as grey seal and harbour seal are listed in the habitats directive appendix II and V. Appendix II species are strictly protected and habitat areas must be designated where special needs for the species are respected and where there is no intervention on the species distribution. Appendix V species must maintain a favourable conservation status.

6.2.8.1 Underwater noise

Hearing is the primary sense for many marine mammals for detecting prey, predators, communication and navigation in the environment. Underwater noise introduced into the environment has the potential to impact marine mammals.

Marine mammals are usually defined per functional hearing groups, based on their auditory bandwidth /41/. The hearing groups and auditory bandwidth of mammals in the North Sea are shown in Table 6-15.

Table 6-15 Functional hearing groups and auditory bandwidth for typical species found at the TYRA project area/164/

Species in the North Sea	Functional hearing group	Auditory bandwidth
Pinnipeds		
Grey seal, harbour seal	Pinnipeds in water	50 Hz to 86 kHz
Cetaceans		
Harbour porpoise	High frequency	275 Hz to 160 kHz
White beaked dolphin	Mid-frequency	150 Hz to 160 kHz
Minke whale	Low-frequency	7 Hz to 35 kHz

The effect of underwater noise on marine mammals can generally be divided into four broad categories that largely depend on the individual's proximity to the sound source: Detection, masking, behavioural changes and physical damages /41/. The limits of each zone of impact are not distinct, and there is a large overlap between the zones.

- Detection is where the animals can hear the noise. Detection ranges depend on background noise levels as well as species specific audible threshold profiles /41/.
- Masking is where the noise conceals other sounds, e.g. communication between individuals. The impact to e.g. communication is not well understood /41/.
- Behavioural changes are difficult to evaluate. They range from very strong reactions, such as avoidance, to more moderate negative reactions where the animal may orient itself towards the sound or move slowly away. However, the animals' reaction may vary greatly depending on season, behavioural state, age, sex, as well as the intensity, frequency and time structure of the sound causing behavioural changes /41/.
- Physical damage to marine mammals relate to damage to the hearing apparatus. Physical damages to the hearing apparatus may lead to permanent changes in the animals' detection threshold (permanent threshold shift, PTS). This can be caused by the destruction of sensory cells in the inner ear, or by metabolic exhaustion of sensory cells, support cells or even auditory nerve cells. Hearing loss can also be temporary (temporary threshold shift, TTS) where the animal will regain its original detection abilities after a recovery period. For PTS and TTS the sound intensity and profile is an important factor for the degree of hearing loss, as is the frequency, the exposure duration, and the length of the recovery time /41/.

Outside the generalised hearing range, the risk of auditory impacts from sounds is considered highly unlikely or very low (the exception would be if a sound above/below this range has the potential to cause physical injury, i.e., lung or gastrointestinal tract injury from underwater explosives)/164/.

In connection with the development of offshore wind in Denmark, an expert working group for marine mammals and underwater noise have recommended thresholds for permanent hearing loss (PTS), temporary hearing loss (TTS) as well as behavioural changes for seals and harbour porpoise in Danish waters /138/. Threshold values are shown in Table 6-16. Threshold values for inflicting impact have been determined from an assessment of available data from the scientific literature, based on laboratory studies of animals. The working group was not able to recommend a threshold value for behavioural effects on seal, as there is very limited evidence on how and when seals react to underwater noise.

Table 6-16 Threshold values for permanent threshold shift (PTS), temporary threshold shift (TTS) and behavioural effects in grey and harbour seals (Phocid pinnipeds (Phocids in Water PW)) and in harbour porpoise (high frequency (HF) cetaceans) related to pile driving as recommended by a Danish expert working group /138/. All levels are un-weighted SEL. (- indicate that no threshold is available). Data for minke whale and white beaked dolphins are from low frequency (LF) and mid frequency (MF) cetaceans because specific values for these species have not been documented /164/.

Species	**Behavioural response** (dB re 1 μPa^{2}s SEL)	**TTS** (dB re 1 μPa^{2}s **SEL** cum)	**PTS** (dB re 1 μPa^{2}s SEL cum)
Grey seal and harbour seal (PW pinnipeds)	-	176	200
Harbour porpoise (HF cetaceans)	140 (single strike)	≥164	≥183
Minke whale (LF cetaceans)		168	185
White beaked dolphin (MF cetaceans)		170	183

A recent review concluded that very few data are available for assessment of impact on other species relevant for Danish waters, primarily white-beaked dolphin and minke whale /142/. The general TTS and PTS limits for LF and MF cetaceans from the Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing /164/ are therefore used. No firm data is available to base recommendations regarding behavioural reactions for both species.

The highest noise levels in the North Sea are caused by seismic activity in relation to oil and gas industry and by pile driving associated with selected structures, in particular wind farms. Sonars used during military activities or echolocation by fishing vessels to locate fish may also cause high noise levels /142/. The possible impacts of noise on the North Sea harbour porpoise population was recently evaluated by modelling the porpoise population sizes and distributions in relation to different pile-driving scenarios. Although the results should be considered preliminary, the patterns generated by the current version of the model did not suggest long-lasting effects of wind farm pile-driving noise on the average porpoise population size and dynamics in the North Sea /152/.

There is a substantial difference between pile driving for the construction of wind farm and oil and gas construction operation. Monopiles for wind farms may be up to 10 metres in diameter whereas platform piles may have a diameter of up to 2 metres and thus lower noise is expected here /189/. The hammering of platform piles will typically have duration up to 2 hours (6 new structures are planned under the TYRA project of which 2 in the Tyra Future redevelopment project). The project also includes piles for support of subsea structures to protect pipeline tie-in valves (4 structures, cf. section 3.2.1) and conductors for new wells (24 existing slots and 32 new wells, 56 wells in total); both of smaller dimensions though. Conductor driving may occur either as batch or between each well.

Underwater noise from seismic

The planned seismic data acquisition in the TYRA project includes a 4D seismic survey with airguns (an area of a few hundred km^2, with a duration of few months), borehole seismic surveys conducted with geophones (with a duration of some days) and drilling hazard site surveys which may include 2D high-resolution multi-channel and single-channel seismic, side scan sonar, single and multi-beam echo-sounder, seabed coring and magnetometer (typical area of 1 km^2, with a duration of around 1 week). Typical noise levels and frequencies for the planned activities at the TYRA project are presented in Table 6-11 (section 6.2.5).

The underwater noise levels generated during seismic activities at the TYRA project can potentially be above the threshold values established for PTS, TTS and behavioural impacts. The loudest noise levels are generated by the sources used for 2D, 3D and 4D marine seismic surveys.

An impact assessment was undertaken for a similar 4D marine seismic survey in the area /144/. This concluded that:

- The probability of the survey vessel encountering any marine mammals and other marine species is small.
- The risk of impacts on the marine species, if any, will take place at or within 30 metres from the airgun. It was assessed that no marine animals would be exposed to sound levels which could cause PTS, and that only TTS and behavioural impacts would occur.

At the TYRA project, the extent of the impact will depend on the final set-up for the seismic survey. The 2012 impact assessment concluded that the effects of a seismic survey were local. A study of behavioural response in harbour porpoise during a 2D seismic survey in the Moray Firth found that animals showed short term avoidance within 5-10 km surrounding the area of seismic data acquisition /150/. Overall, the risk of impacts on marine mammals may be local (PTS, TTS) or regional (behavioural).

PTS, TTS and behavioural impacts are considered of small intensity as the probability of encounters between survey vessels and marine mammals, at a range where there is a risk of impact, are small. The TYRA project area is not of particular importance to harbour porpoise, and few individuals are observed (0.4 harbour porpoises/km^2 in the platforms areas), and it is assessed that harbour porpoise populations in the North Sea will not be affected by seismic activities at the TYRA project. In the study from the Moray Firth on potential impacts of seismic survey on behavioural response in harbour porpoise, the harbour porpoises were typically detected again within a few hours or even during the seismic survey /150/ which shows that the tolerance to underwater noise may vary over time. Overall, the potential impacts of seismic activities to marine mammals are considered of medium-term (TTS and behavioural) to long-term (PTS) duration.

The impact is assessed to be of small intensity, local or regional extent and medium to long-term duration. The overall impact on marine mammals from underwater noise from seismic is assessed to be of moderate negative significance.

If mitigating measures (section 8.1) are implemented such as soft start and by implementing an exclusion zone where operations will be delayed when the presence of marine mammal is detected before start-up of the operations, the risk to marine mammals from seismic surveys can be alleviated.

Underwater noise from drilling and pile driving

Underwater noise is primarily associated with ramming of conductor piles, with duration of approximately 6-8 hours pr. pile, and ramming of jacket piles for new structures, with duration of approximately ½ hour pr. pile. The planned drilling activities are associated with the drilling of up to 56 wells, and six new platforms.

The impact assessment for drilling activities at the TYRA project is largely based on /140/, where underwater sound monitoring was performed for background levels, drilling operations and conductor ramming. Based on the monitoring results, potential impacts on marine mammals were assessed:

- Underwater drilling sound: The underwater noise from the drilling rig were masked by background sound within 500 -1000 metres from the rig. It was concluded that no harmful effects (threshold shifts or behavioural response) on marine mammals could be expected.
- Ramming of conductors: The noise levels where there is a risk of causing hearing damage to marine mammals is restricted to an area close to the drilling rig. However, behavioural effects are most likely to be found within a few kilometres from the rig, and permanent exclusions are not expected.

Modelling of underwater noise generated by pile driving and conductor driving activities in the TYRA area has been carried out /184/. The method used is described in detail by the Danish working group in /138/. The number of affected mammals is a result of the calculated cumulative sound exposure (SELcum) including site specific underwater sound propagation curves, applicable sound source levels (TTS or PTS), soft-start procedures with intensity of hammering increasing linearly /184/. The calculation of cumulative SEL is performed with a ‘virtual animal’-fleeing receptor with an initial distance from the pile at the onset of piling. The cumulative SEL is calculated as the summation of the total sound energy to which the receptor is exposed during the duration of the piling. The model calculates distances from pile or conductor driving to the applicable threshold levels specified in Table 6-16, i.e. the maximum distance from the noise source where the mammals can potentially be affected by noise above their PTS or TTS threshold. The number of animals is found by multiplying the population density with the area affected by noise being a circle with radius equal to the specified distance to threshold limits. Results for pile driving are shown in Table 6-17 (winter) and Table 6-18 (summer) and results for conductor driving are shown in Table 6-19 for winter conditions and Table 6-20 for summer conditions.

Table 6-17 Number of marine mammals affected by underwater noise from jacket piling over TTS and PTS levels during winter. The number of animals is the density multiplied with the area affected by noise being a circle with radius equal to the specified distance to threshold limits.

Species	Distance from noise source to threshold limits PTS (metres)	Number of potentially PTS affected animals	Distance from noise source to threshold limits TTS (metres)	Number of potentially TTS affected animals
Seals (N = 0,01/km^2)	0	0	5,000	1
Harbour porpoise (N = 0,4/km^2)	1,200	2	30,000	1,129
Minke whale (N = 0,025/km^2)	400	0	18,000	25
White beaked dolphin (N = 0,025/km^2)	0	0	0	0

Table 6-18 Number of marine mammals affected by underwater noise from jacket piling over TTS and PTS levels during summer. The number of animals is the density multiplied with the area affected by noise being a circle with radius equal to the specified distance to threshold limits.

Species	Distance from noise source to threshold limits PTS (metres)	Number of potentially PTS affected animals	Distance from noise source to threshold limits TTS (metres)	Number of potentially TTS affected animals
Seals (N = 0,01/km^2)	0	0	4,500	1
Harbour porpoise (N = 0,25/km^2)*	800	<1(0,5)	26,000	531
Minke whale (N = 0,025/km^2)	300	0	14,000	15
White beaked dolphin (N = 0,025/km^2)	0	0	0	0

*lower densities during summer

Table 6-19 Number of marine mammals affected by underwater noise from conductor driving over TTS and PTS levels during winter. The number of animals is the density multiplied with the area affected by noise being a circle with radius equal to the specified distance to threshold limits.

Species	Distance from noise source to threshold limits PTS (metres)	Number of potentially PTS affected animals	Distance from noise source to threshold limits TTS (metres)	Number of potentially TTS affected animals
Seals (N = 0,01/km^2)	0	0	300	0
Harbour porpoise (N = 0,4/km^2)	0	0	18,000	407
Minke whale (N = 0,025/km^2)	0	0	7,000	4
White beaked dolphin (N = 0,025/km^2)	0	0	0	0

Table 6-20 Number of marine mammals affected by underwater noise from conductor driving over TTS and PTS levels during summer. The number of animals is the density multiplied with the area affected by noise being a circle with radius equal to the specified distance to threshold limits.

Species	Distance from noise source to threshold limits PTS (metres)	Number of potentially PTS affected animals	Distance from noise source to threshold limits TTS (metres)	Number of potentially TTS affected animals
Seals (N = 0,01/km^2)	0	0	200	0
Harbour porpoise (N = 0,25/km^2)*	0	0	15,000	177
Minke whale (N = 0,025/km^2)	0	0	5,000	2
White beaked dolphin (N = 0,025/km^2)	0	0	0	0

*lower densities during summer

Harbour porpoises located within a distance of 1,200 metres in winter or 800 metres in summer from the jacket pile driving can potentially experience noise levels over their permanent threshold shifts. No seals, minke whales or white beaked dolphins are at risk of experiencing noise levels above their PTS. Given the low number of harbour porpoises in the Tyra area (Table 5-3) the possibility of harbour porpoises being within a distance of 1200 metre from the noise source is relatively low and the modelling result indicates that based on worst case scenario, there could be up to two PTS affected harbour porpoises.

The potential risk of marine mammals to be affected by noise levels above their TTS level varies in geographical distribution and numbers depending on species (Table 6-17). Based on worst case scenario, harbour porpoises located within a distance of 30 kilometres in winter and 26 kilometres in summer are at risk of experiencing noise levels above the defined TTS limit.

Contour plots of the distribution of underwater noise for pile driving and conductor driving from the TYRA area (Figure 6-3 to Figure 6-10) show propagation of sound above defined sound levels (TTS or PTS) for seals and harbour porpoise /184/. Figure 6-3, Figure 6-4, Figure 6-5 and Figure 6-6 shows results from jacket piling on seals and harbour porpoise during winter and summer, while Figure 6-7, Figure 6-8, Figure 6-9 and Figure 6-10 shows results from conductor driving on seals and harbour porpoise during winter and summer.

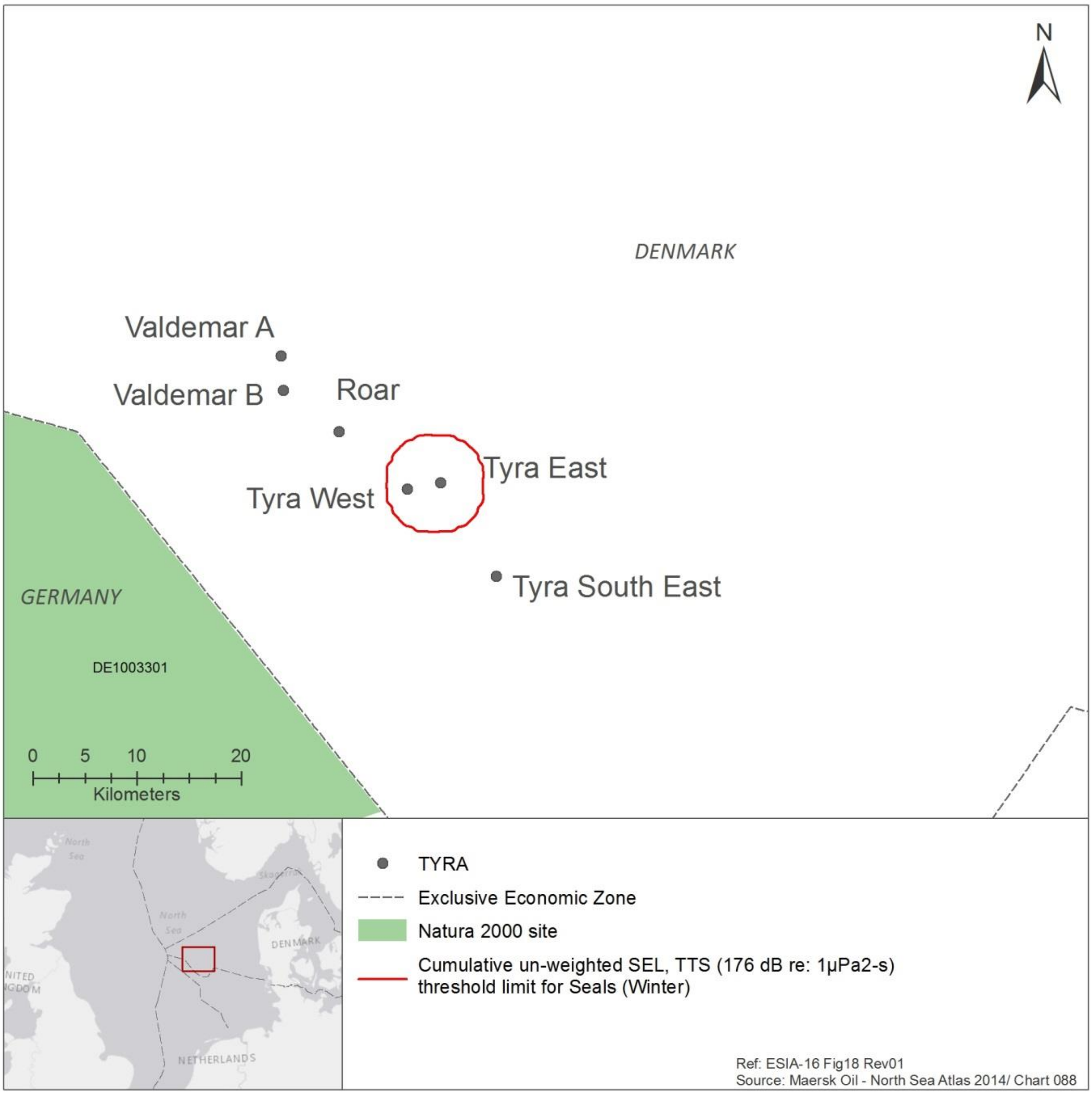


Figure 6-3 Jacket pile driving unweighted cumulative SEL threshold level limit contour plots for seals including animal fleeing for the whole driving period (Tyra, winter conditions)

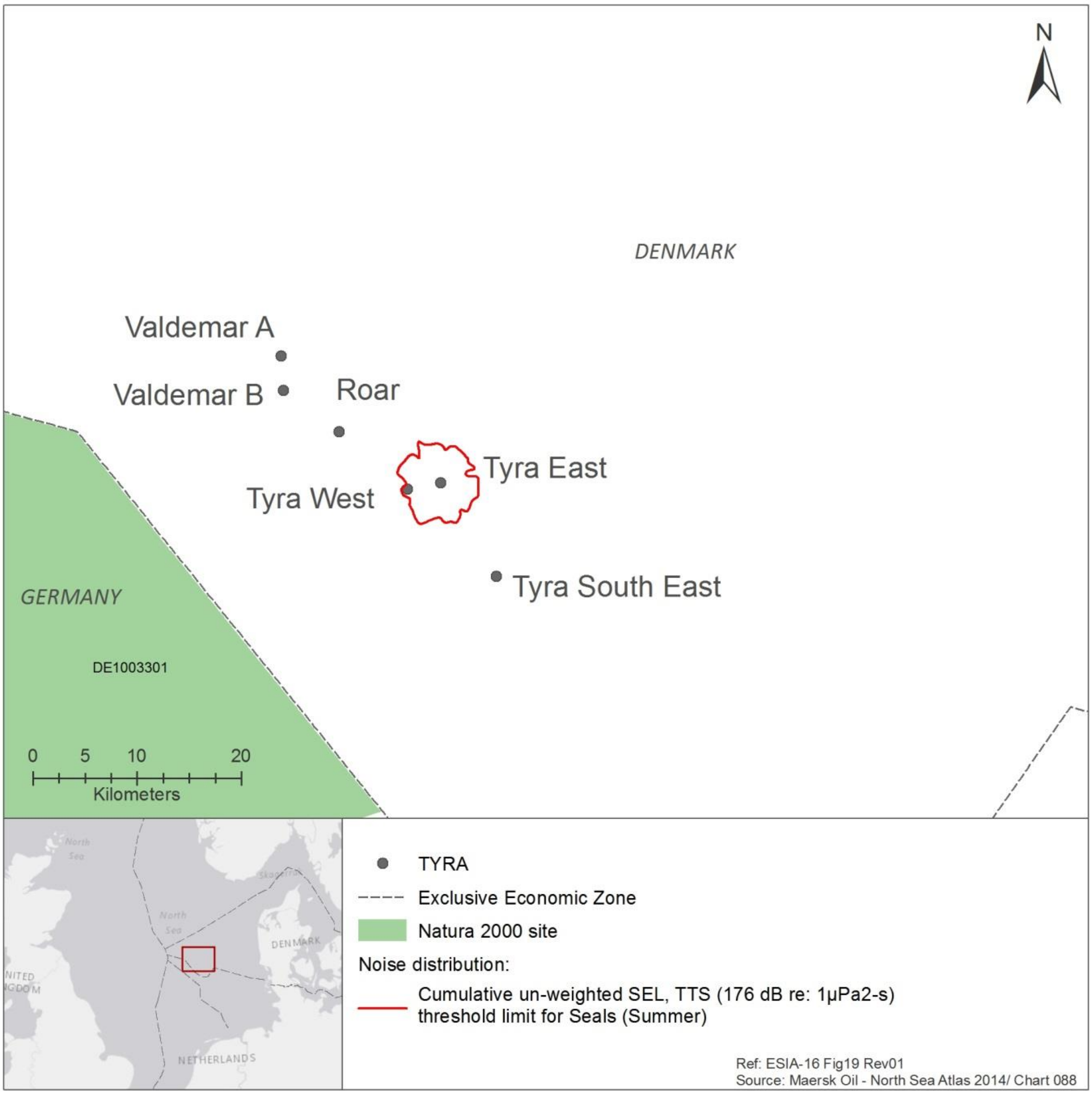


Figure 6-4 Jacket pile driving unweighted cumulative SEL threshold level limit contour plots for seals including animal fleeing for the whole driving period (Tyra, summer conditions)

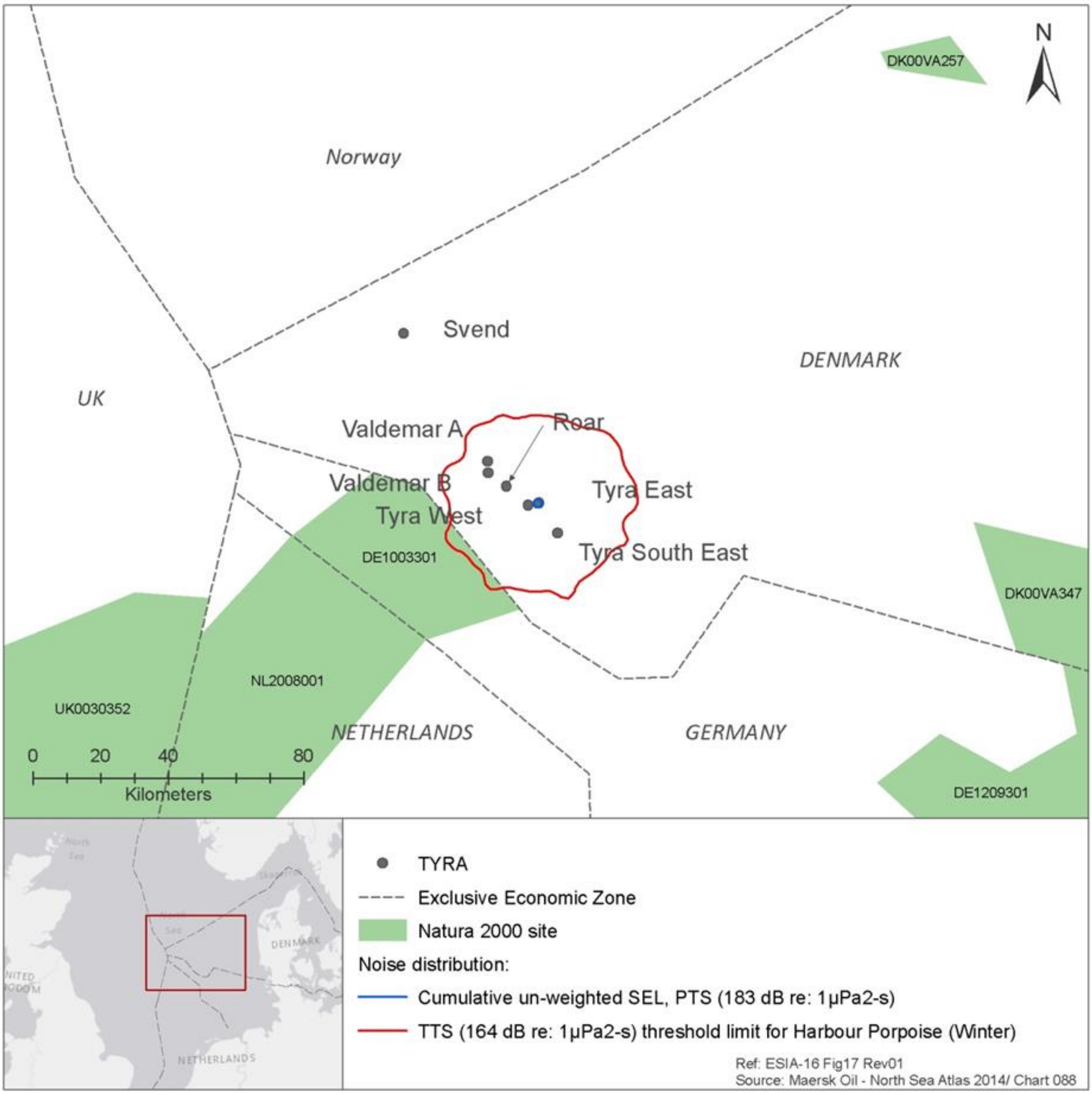


Figure 6-5 Jacket pile driving unweighted cumulative SEL threshold level limit contour plots for harbour porpoise including animal fleeing for the whole driving period (Tyra, winter conditions)

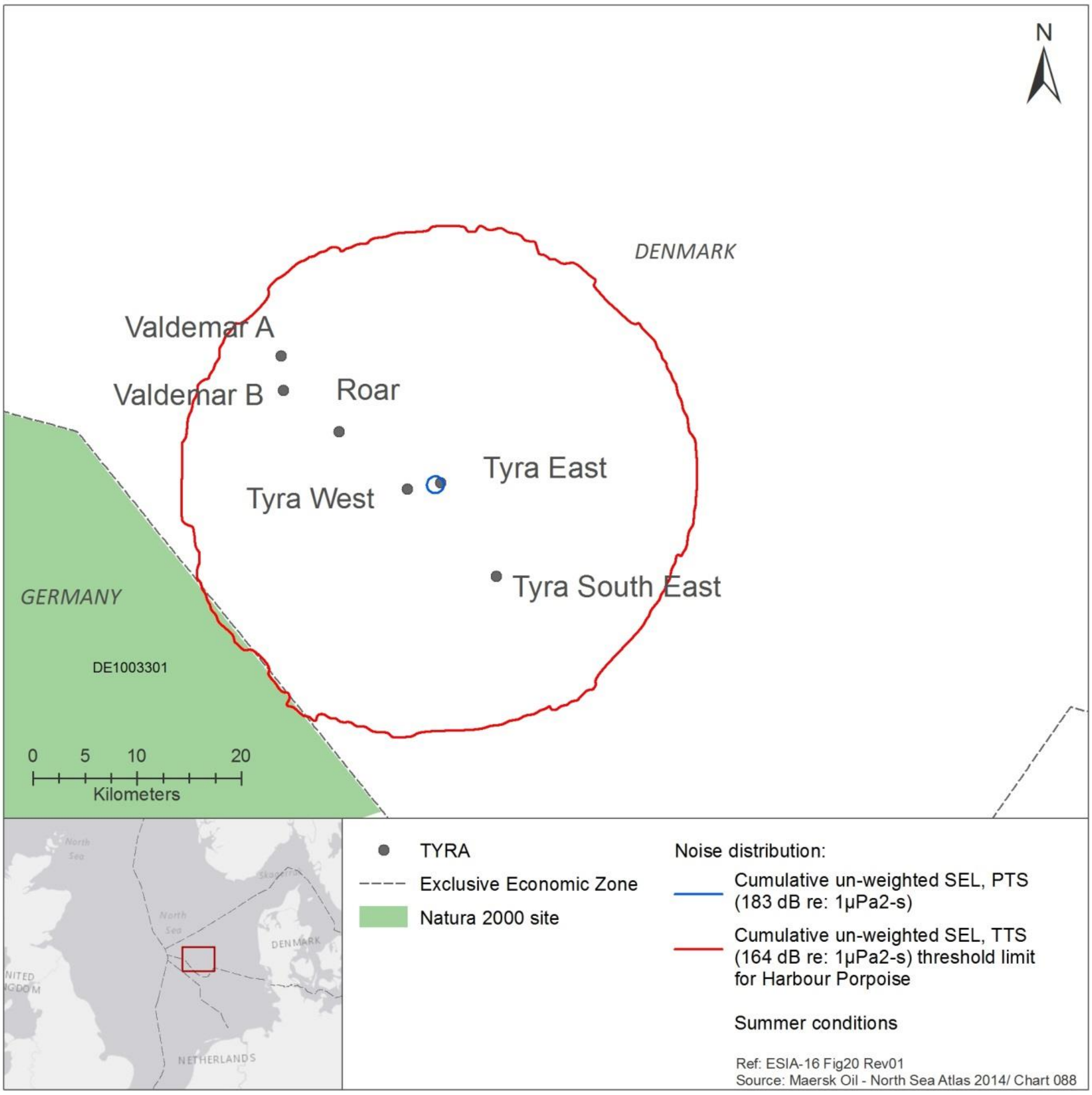


Figure 6-6 Jacket pile driving unweighted cumulative SEL threshold level limit contour plots for harbour porpoise including animal fleeing for the whole driving period (Tyra, summer conditions)

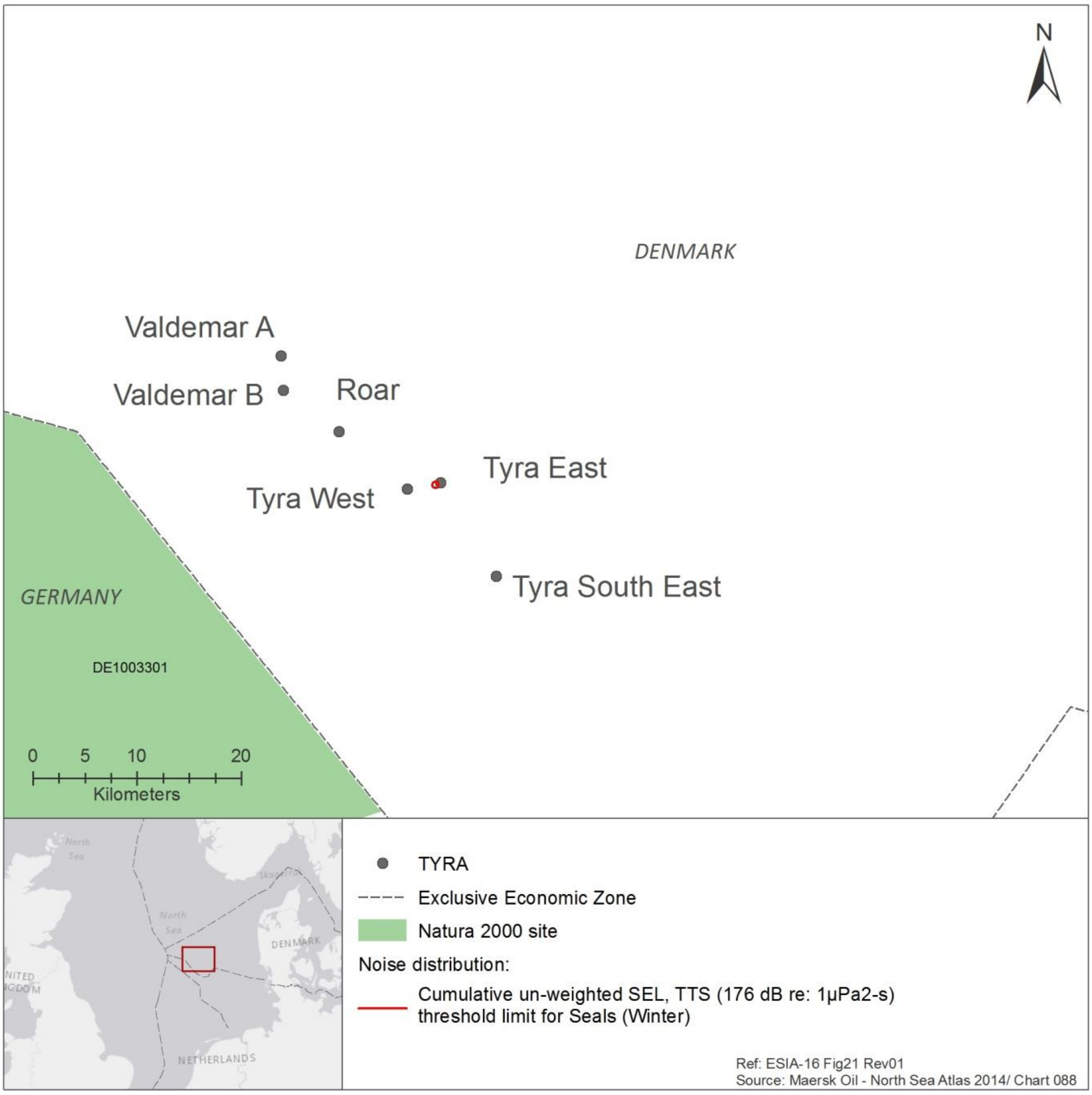


Figure 6-7 Conductor driving unweighted cumulative SEL threshold level limit contour plots for seals including animal fleeing for the whole driving period (Tyra, winter conditions)

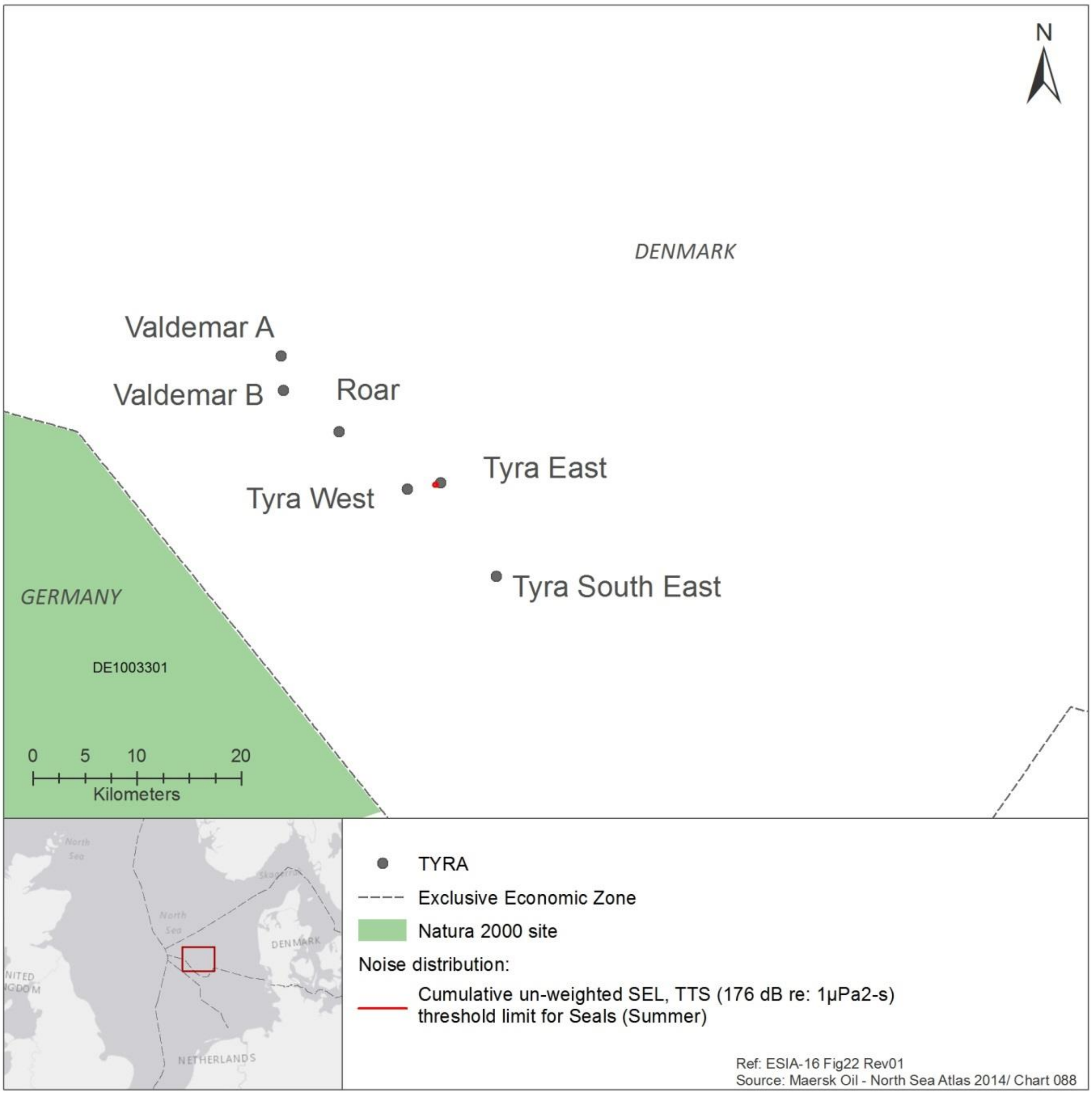


Figure 6-8 Conductor driving unweighted cumulative SEL threshold level limit contour plots for seals including animal fleeing for the whole driving period (Tyra, summer conditions)

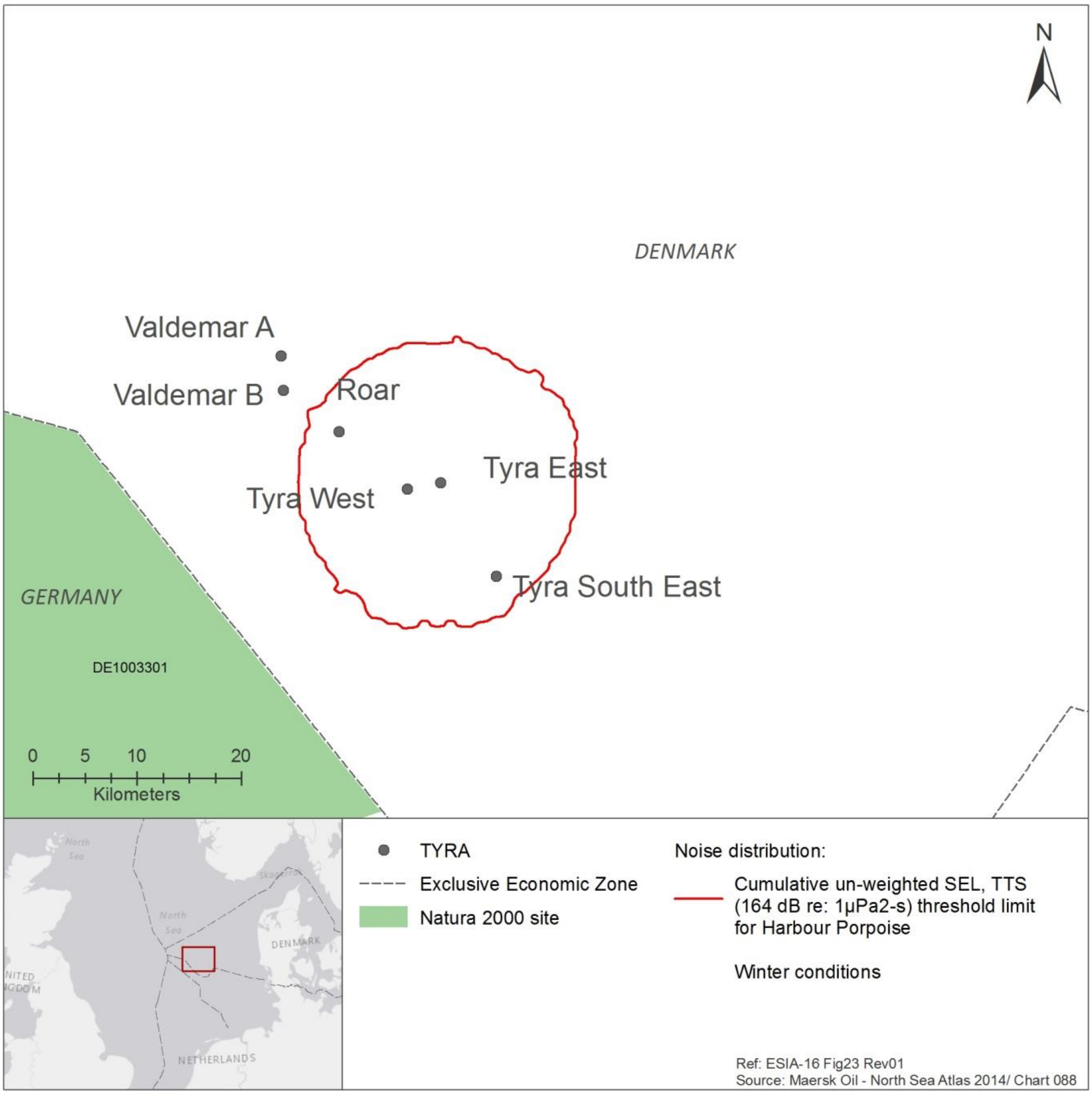


Figure 6-9 Conductor driving unweighted cumulative SEL threshold level limit contour plots for harbour porpoise including animal fleeing for the whole driving period (Tyra, winter conditions)

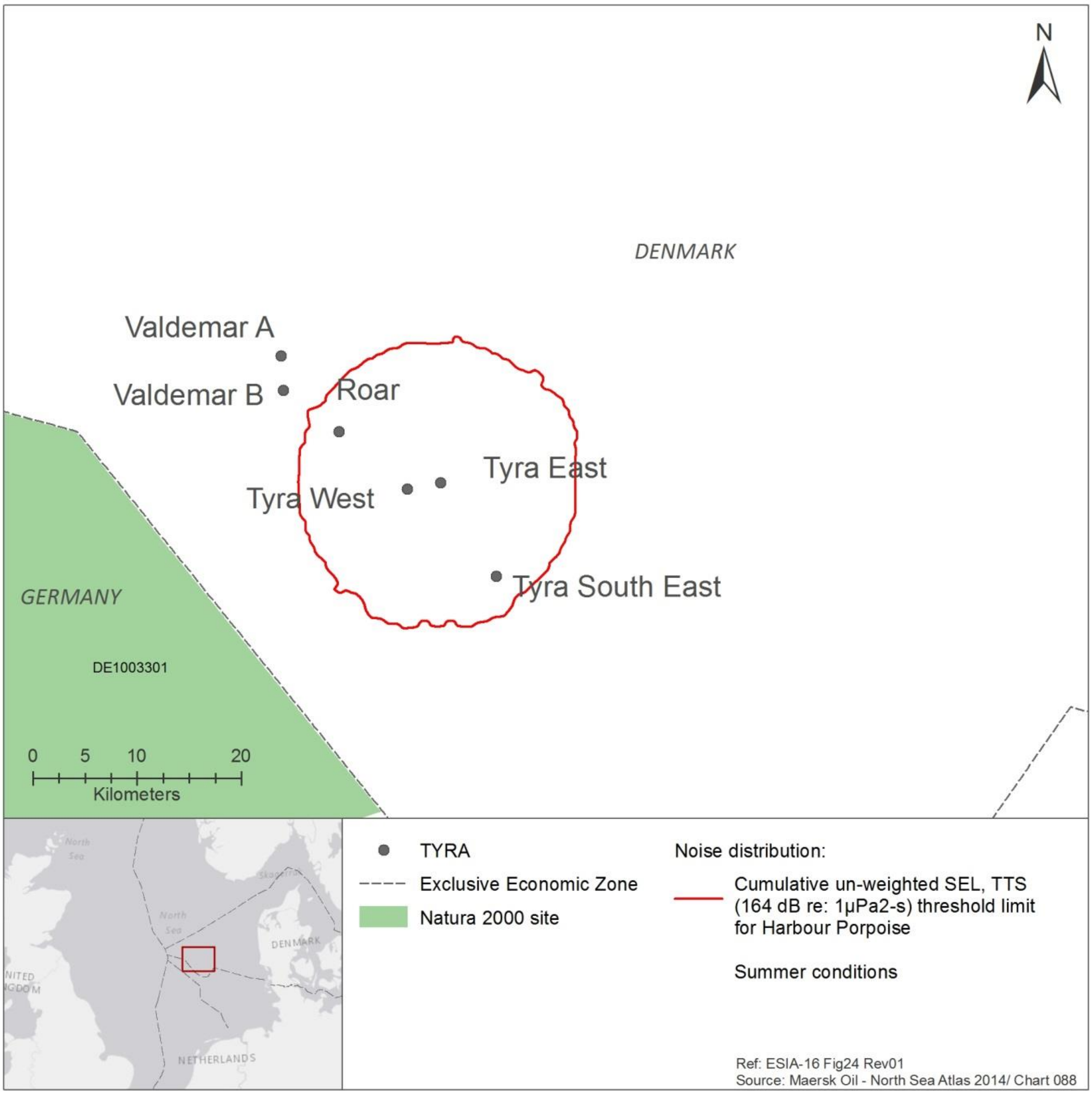


Figure 6-10 Conductor driving unweighted cumulative SEL threshold level limit contour plots for harbour porpoise including animal fleeing for the whole driving period (Tyra, summer conditions)

"PTS" and "TTS" distances were significantly shorter for conductor driving due to the smaller size of the hammer being used for driving the conductor in the seabed.

Potential effects of noise levels above TTS will disappear again after a short time (minutes) or longer (hours) depending on time of exposure /138/. The potential risk of TTS is not considered critical for the population of harbour porpoises in the North Sea as the duration of the pile driving is limited to a short period.

The extent of the impact for drilling and pile driving is expected to be local /140/, of moderate intensity and with a short-term duration. Based on the modelling results in Table 6-17 to Table 6-20 the overall impact caused by noise from drilling and construction activities is assessed to be of moderate negative significance.

Further potential mitigating measures to reduce the risk of injury to marine mammals are presented in section 8.1.2 /184/.

Underwater noise from production, vessels and associated activities and decommissioning

Noise will also be present from production and associated activities, and from vessels in the area, with typical noise levels and frequencies presented in Table 6-11 (section 6.2.5). Vessels such as barges and supply ships produce noise with energy content primarily below 1 kHz, as do the rigs and platforms. The marine mammals in the area (harbour porpoise, mid-frequency cetaceans, harbour seals and grey seals) are more sensitive to noise at higher frequencies. Some of the most trafficked areas in Danish waters are also areas with a very high abundance of harbour porpoise /120/.

Year-round presence of marine mammals observed at the Maersk Oil platforms show that the animals make a trade-off between the noise levels and likely higher prey abundance /139/. In this study noise from the operating oil field was measured with the 63 and 125 Hz frequency band as required in the Marine Strategy Framework Directive. Preliminary results show medium noise levels around 100 dB re 1µPa rms at a distance of 12,800 metres from the platform /139/ which is below the level of behavioural response in harbour porpoises. Any possible risk of impacts on harbour porpoises due to this type of noise are thus expected to be short term, and over relatively short distances.

During decommissioning there will be noise related to the removal of rigs and pipelines. Blasting is not planned for the decommissioning, and therefore underwater noise will be connected to the use of operation vessels and jet-cutting.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on marine mammals from underwater noise from production, vessels and associated activities is assessed to be of minor negative significance.

6.2.8.2 Suspended sediment

Suspended sediments could potentially reduce the visibility in the water and thus affect the species, such as seals, relying on sight to prey. Relative small amounts of sediment are expected to be suspended for the TYRA project as part of the construction of a total of six new platforms and connecting pipelines as well as from decommissioning (see section 6.2.3.1).

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on marine mammals from suspended sediment due to construction and decommissioning is assessed to be of negligible negative significance.

6.2.8.3 Discharges

As part of the planned activities a number of discharges are expected to occur (section 6.2.3.2). The main discharges are related to the production at Tyra East and West and drilling activities at Tyra Southeast, Svend, Roar, Valdemar B and Valdemar A, and six potential new wellhead platforms. During decommissioning minor discharges of e.g. cooling water and grey waste water from vessels are expected to occur. Conservative estimates suggest that there could be a risk to some species up to a maximum of 14 km from the production discharges and up to a maximum of 7 km from the drilling discharges (section 6.2.2.1). Any potential impacts on marine mammals are thus confined to the local environment near the platforms, drilling rigs and vessels. The risk of bioaccumulation will be species-specific and depend on the type of prey. Bioaccumulation is not anticipated from the chemicals potentially being used (section 8.1.3).

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on marine mammals from discharges is assessed to be of minor negative significance.

6.2.8.4 Light

Though safety lights are present at all platforms and vessels only the manned Tyra East and West platforms are fully illuminated and once the decommissioning is finished only Tyra East will be illuminated. Navigational and deck working lights used to illuminate working areas, are sources of artificial light into the environment. Light may locally attract plankton and fish (section 6.2.5 and 6.2.7), serving as prey for marine mammals.

A recent study at the Dan platform /139/ showed that harbour porpoises near the platform had variable diurnal acoustic activity, but a general trend showed higher acoustic activity during the night close to the platform. At further distance from the platform this pattern was not observed. The presence of marine mammals at Maersk Oil platforms indicates that marine mammals do not avoid light and may be following attracted prey /190/.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on marine mammals from light is assessed to be of negligible negative significance.

6.2.8.5 Presence/removal of structures and vessels

Presence of structures and vessels may contribute to the animals increased tolerance to human activities, and could potentially increase the risk of e.g. collisions. Marine mammal responses to vessels often include changes in general activity (e.g., from resting or feeding, to active avoidance), changes in surfacing-respiration-dive cycles, and changes in speed and direction of movement. Behavioural reactions tend to be reduced when animals are actively involved in a specific activity such as feeding or socialising /122/.
In addition to the existing structures at the TYRA project, six new platforms are planned, with connecting with pipelines. Year-round presence of marine mammals observed at the Maersk Oil platforms /139/ show that the animals are not deterred from the platforms.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on marine mammals from presence of vessels is assessed to be of negligible negative significance.

Once the structures are decommissioned, no impact to marine mammals is foreseen.

6.2.8.6 Overall assessment

The overall assessment of impacts on marine mammals from planned activities at the TYRA project is summarised in Table 6-21.

Table 6-21 Potential impacts on marine mammals from planned activities at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Underwater noise from seismic	Small/ medium	Local or regional	Medium-term Long-term	Moderate negative	Medium
Underwater noise from drilling and pile driving	Small	Local	Short-term	Moderate negative	Medium
Underwater noise from production, vessels, associated activities and decommissioning	Small	Local	Medium-term	Minor negative	Medium
Suspended sediment	Small	Local	Short-term	Negligible negative	High
Discharges	Small	Local	Medium-term	Minor negative	High
Light	Small	Local	Short-term	Negligible negative	High
Presence/removal of structures and vessels	Small	Local	Short-term	Negligible negative	High

Regarding cumulative impact to marine mammals little geographical overlap is expected between the activities (section 6.2.2.1 and 6.2.3), and it is expected that cumulative impacts will be minor, see section 6.6. The current data from a long term marine mammals monitoring program around several of Maersk Oil platforms suggest that there must be a trade-off between the potential cumulative impact associated with the current offshore activities and the additional foraging ground provided by the presence of the platforms /139/.

6.2.9 Seabirds

Seabirds may potentially be impacted by noise, physical disturbance of seabed, suspended sediment, discharges and light.

6.2.9.1 Underwater noise

Noise may negatively affect the seabirds as physical damage or behavioural response.

Very little is known about underwater hearing in diving seabirds and information on effects from underwater sound on birds are sparse, but observations from seismic vessels in the Irish Sea did not reveal any behavioural response of seabirds to seismic survey activities /146/. Birds diving a few metres to an air gun array, may potentially suffer damage to the auditory system. However, birds have the ability to regenerate the sensory cells in the inner ear and a possible hearing impairment would thus be temporary.

Due to the highly mobile nature of birds, they are generally not considered to be sensitive to noise from surveys /147/.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on seabirds from noise is assessed to be of negligible negative significance.

6.2.9.2 Physical disturbance of seabed

Physical disturbance of the seabed can be expected under production and decommissioning activities. This can potentially impact some fish species that seabirds may feed on (sections 6.2.6.2 and 6.2.7.2). Any potential impacts on seabirds are thus confined to the local environment near the platforms and pipelines.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on seabirds from physical disturbance of seabed is assessed to be of negligible negative significance.

6.2.9.3 Suspended sediment

Suspended sediments could potentially reduce the visibility in the water and thus the ability for seabirds to locate their prey. However, only small amounts of sediment are expected to be suspended for the TYRA project as part of the construction of six new platforms and pipelines as well as from decommissioning (see section 6.2.3.1).

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on seabirds from suspended sediment due to construction and decommissioning is assessed to be of negligible negative significance.

6.2.9.4 Discharges

Discharges have been described in section 6.2.2.1 and are assessed to have a minor negative impact on water quality.

Seabirds may be impacted if they come into contact with the discharges. The impact can include both direct impacts (contact) and indirect impacts (digestion of contaminated organisms), and will depend on the oil or chemicals encountered. Any potential impacts are thus confined to the local environment near the point of discharge. Bioaccumulation is not anticipated from the chemical potentially being used (section 8.1.3).

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on seabirds from discharges is assessed to be of minor negative significance.

6.2.9.5 Light

Though safety lights are present at all platforms and vessels only the manned platform Tyra East and West are fully illuminated and once the decommissioning is finished only Tyra East will be illuminated. Light and illumination may attract seabirds when it is dark or under certain weather conditions. There are observations at Maersk Oil showing that the platforms may function as a resting place for seabirds. The potential attraction is related to individuals, and is not assessed to have an effect on the North Sea population.

The impact is assessed to be of small intensity, local extent and short-term duration. The overall impact on seabirds from light is assessed to be of negligible negative significance.

6.2.9.6 Overall assessment

The overall assessment of impacts on seabirds from planned activities at the TYRA project is summarised in Table 6-22.

Table 6-22 Potential impacts on seabirds from planned activities at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Underwater noise	Small	Local	Short-term	Negligible negative	High
Physical disturbance of seabed	Small	Local	Short-term	Negligible negative	Medium
Suspended sediment	Small	Local	Short-term	Negligible negative	Medium
Discharges	Small	Local	Short-term	Minor negative	Medium
Light	Small	Local	Short-term	Negligible negative	High

6.3 Marine strategy frameworks directive

The list of receptors and impact mechanisms described in the ESIS (cf. section 6.1.2) can be directly related to the descriptors set within the Marine Strategy Framework Directive (MSFD; section 2.1.5). The MSFD outlines 11 descriptors used to assess the good environmental status of the marine environment (**Error! Reference source not found.**). The environmental status of the Danish North Sea waters is described in details in /157/.

The descriptors embrace both receptors and sources of impacts for identifying human impact on marine ecosystems. This combination of causes and effects are described in rather general terms. The MSFD does not include clear criteria that define "good" environmental status. The impact assessment of the TYRA project on the descriptors in the MSFD is therefore anchored on more specific thresholds (e.g. OSPAR convention).

The receptors identified in the ESIS are especially related to the MSFD state descriptors i.e. D1, D4, D6 and D7 which more specifically relate to marine mammals porpoise, fish, benthic communities and hydrography.

The impact mechanisms for planned activities in the ESIS are related to the MSFD pressure descriptors D6, D8, D9 and D11 which more specifically relate to seabed disturbance, discharges and underwater noise (Descriptor 11). The impact mechanisms are assessed for the relevant receptors in sections 6.2 and 7.2.

The identified impacts of TYRA project on the physical-chemical, biological and socio-economic environment have been generally summarised and further assessed for the overall impact in accordance with the descriptors of the MSFD, see **Error! Reference source not found.**. The overall conclusion is that the project will have no or negligible impact on the issues given by the descriptors in the Directive.

Table 6-23 Potential impacts and overall impact assessment of TYRA project based on the project relevant descriptors set within the MSFD (Directive 2008/56/EC) and outlined in the EU Commission Decision 2017/848 of 17 May 2017 describing criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment (Repealing Decision 2010/477/EU). The impact assessment of the descriptors follows the ESIS assessments described in section 6.1.2.

Descriptors based on the MSFD	Motivation	Possible effect or impact	Overall impact assessment
Descriptor 1. Biodiversity: The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	To ensure the biodiversity in the project area, the associate habitats must be kept in line with their natural preconditions. Safe guarding the living conditions for sensitive species living in the area (as harbour porpoise), will provide a toll for achieving this goal.	• Noise from intervention works and ships. • Temporary effect from sedimentation. • Redistribution of contaminants and discharge of solids and chemicals	No or negligible impact
Descriptor 2 Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.	Discharge of ballast water or hull fouling	Ship based transportation within the same biogeographical region. By establishing standards and procedures for the management and control of ships' ballast water and sediments in accordance to the Ballast Water Management Convention (adopted in 2004 and enter into force 8 Sep.2017) will prevent the spread of harmful aquatic organisms from one region to another,	No or negligible impact
Descriptor 3 Commercial fish and shellfish: Populations of commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.	Important areas for fishing occur nearby	• Noise from intervention works. • Temporary effect from sedimentation. • No-fishing zone.	No or negligible impact
Descriptor 4 Food webs: All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.	Top predator areas occur near project. Their presence is indicative for the well function of the local food web	Local temporary effect from sedimentation on benthic fauna and pelagic environment. Temporary effect from noise on fish and mammals. Change of food webs (reef effect).	No or negligible impact

Descriptor 5 Eutrophication: Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters.	Temporary effect from sedimentation spread and emission of nutrients.	• Discharge from grey/black water. • Short term supply or redistribution of nutrients. • Temporary redistribution of sea bed particles. • Redistribution of contaminants.	No or negligible impact
Descriptor 6 Sea-floor integrity: Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	Rock placement, platform structures and trenching will occupy and locally change the habitat conditions related to the seabed	Permanent local and regional effect of the living conditions due to the presence of solid structures.	No or negligible impact
Descriptor 7 Hydrographical conditions: Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.	Blocking effect from construction and pipelines. Temporary sediment dispersion during construction.	Permanent strictly local effect on physiochemical properties of the water masses (oxygen levels, salinity, etc.)	No or negligible impact
Descriptor 8 Contaminants are at levels not giving rise to pollution effects.	Temporary effect from sedimentation spread. Metallic part exposed to saltwater may cause release of metals to marine environment. Oil and chemicals discharge	• Temporary redistribution of seabed particles and contaminants. • Short-term effect, no bioaccumulation. • Negligible concentration levels of oil, metals and chemicals. • Redistribution of contaminants.	No or negligible impact
Descriptor 9 Contaminants in seafood: Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.	Tainting from discharged water based drilling mud and cuttings.	• Short term effect, no bioaccumulation. • Negligible concentration levels of metals, oil and chemicals. • Redistribution of contaminants.	No or negligible impact
Descriptor 10 Marine litter: Properties and quantities of marine litter do not cause harm to the coastal and marine environment.	Disposals connected to construction work and operation	Not relevant because measures are taken to ensure that all disposals will be returned to land	No impact
Descriptor 11 Energy including underwater noise: Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.	Areas with sensitive species occur in the project area	No permanent impact. Temporary impact from seismic survey, intervention works and ships. It is assumed that OSPAR's guidelines regarding noise emission at sea is followed /194/	No or negligible impact

6.4 Assessment of potential social impacts

Impact assessment for planned activities for each relevant social receptor is presented in the following sections.

6.4.1 Cultural heritage

Potential impacts on cultural heritage relate to physical disturbance of seabed.

National authorities have laws and procedures to avoid impacts on cultural heritage from construction projects. Knowledge of cultural heritage in the North Sea is scarce, but inspection surveys are performed prior to construction activities.

6.4.1.1 Physical disturbance

Prior to drilling or construction, a site survey will be undertaken to investigate whether any objects are present in the area. In case of a finding proper action will be taken, in order to assess the found object(s) and evaluate proper handling. This includes involving The Danish Agency for Culture which is the responsible authority for cultural heritage in Denmark. Wrecks that are more than 100 years are protected by the museum law.

The impact from physical disturbance on cultural heritage is assessed to be of no significance.

6.4.1.2 Overall assessment

The overall assessment for impacts on cultural heritage from planned activities is summarised in Table 6-24.

Table 6-24 Potential impacts on cultural heritage from planned activities at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Physical disturbance of seabed	-	-	-	None	High

6.4.2 Protected areas

Potential impacts on protected areas relate to discharges.

The Natura 2000 sites are assessed in a separate screening (section 10). Other protected areas include nature reserves along the west coast of Jutland, and the UNESCO reserve Wadden Sea located more than 100 kilometres from the project area.

6.4.2.1 Discharges

As the distance between the TYRA project and the Wadden Sea is more than 100 km, and the distance to the nature reserves along the west coast are more than 200 km, no impacts are anticipated from planned activities.

6.4.2.2 Overall assessment

The overall assessment of impacts on protected areas (excluding Natura 2000 –see section 10) from planned activities at the TYRA project is summarised in Table 6-25.

Table 6-25 Potential impacts on protected areas (excluding Natura 2000 – see section 10) from planned activities at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Discharges	-	-	-	None	High

6.4.3 Marine spatial use

Potential impacts on marine spatial use are related to restricted zones. Note that impacts on fishery are addressed separately (see section 6.4.4).

6.4.3.1 Restricted zones

A safety exclusion zone of 500 m surrounds the platforms i.e. no unauthorised vessels permitted), while a safety zone of 200 m is placed along each side of pipelines where no anchoring and no trawling are authorised.

For the TYRA project, six new platforms could be expected, and the new safety exclusion zones could be extended up to approximately 4,7 km^2 and 14,8 km^2 where anchoring or trawling is restricted. Survey and drilling activities may pose a limited temporary restriction during the short period (days-months) the activities occur.

Once the TYRA project is decommissioned, the structures will be removed and restriction zones around the decommissioned platforms will be terminated.

The impact is assessed to be of small intensity, local extent and short-term (survey or drilling) or long-term (platform safety zones) duration. The overall impact on marine spatial use from restricted zones is assessed to be of minor negative significance.

6.4.3.2 Overall assessment

The overall assessment of impacts on marine spatial use from planned activities at the TYRA project is summarised in Table 6-26.

Table 6-26 Potential impacts on marine spatial use from planned activities at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Restricted zones	Small	Local	Short-term long-term	Minor negative	High

6.4.4 Fishery

Potential impacts on fishery are related to occupation of seabed, restrictions and an indirect impact in case the target fish species are affected.

6.4.4.1 Physical disturbance on seabed

For the TYRA project, six new platforms and 37 kilometre of pipeline are planned. In addition, physical disturbance to seabed is related to site survey and temporary placement of drilling rig legs on the seabed.

The disturbance is expected near new and existing structures which are or will be covered by a restriction zone for fishery. Overall, it is assessed that the physical disturbance will have no impacts on fishery.

6.4.4.2 Restricted zones

Temporary restricted zones may be imposed during survey and drilling activities. Extension of the restricted zone may pose a temporary restriction to fishery during the short period (days-months) the activities occur.

The landed catch for fishery in the area IVB (280,000 km^2), where the TYRA project area is located is shown in section 5.14. The total area of the new permanent exclusion zone is expected to be up to 4,7 km^2 around the new platforms and the total area of the new restricted zone is expected to be approximately 14,8 km^2 for new pipelines (6.4.3) and these areas are small compared to the total fishing area (<0,0017% and <0.01%, respectively)

The impact is assessed to be of small intensity, local extent and short-term (survey or drilling) or long-term (platform safety zones) duration. The overall impact on fishery from restricted zones is assessed to be of minor negative significance.

6.4.4.3 Changes to target fish

Potential impacts on fishery could e.g. include seismic surveys resulting in target fish temporarily moving away from the sound source, potentially causing a localized reduction in fish catch in close proximity to the seismic source. Impacts on fish have been assessed in section 6.2.7 to be negligible - minor negative. The impact is thus considered of small intensity, local extent and short-long term duration. The overall impact on fishery from changes to target species is assessed to be of negligible negative significance.

6.4.4.4 Overall assessment

The overall assessment of impacts on fishery from planned activities at the TYRA project is summarised in Table 6-27.

Table 6-27 Potential impacts on fishery from planned activities at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Physical disturbance on seabed	None	-	-	None	High
Restricted zones	Small	Local	Short-long term	Minor negative	High
Changes to target species	None	-	-	Negligible negative	High

6.4.5 Tourism

Potential impacts on tourism relate to restriction zones at the TYRA project.

6.4.5.1 Restricted zones

The planned activities at the TYRA project take place offshore, at a distance of 200 kilometres from shore. Tourism is related to the nearshore (and onshore) areas and no impacts of restricted zones on tourism are expected.

6.4.5.2 Overall assessment

The overall assessment of impacts on tourism from planned activities at the TYRA project is summarised in Table 6-28.

Table 6-28 Potential impacts on tourism from planned activities at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Restricted zones	None	-	-	None	High

6.4.6 Employment and tax revenue

Potential impacts on employment and tax revenue relate to employment at the TYRA project.

6.4.6.1 Employment

The future developments of Maersk oils activities in the TYRA project includes seismic surveys, maintenance of pipelines and structures, drilling of up to 56 new wells, establishment of up to six new platforms, as well as production at the existing facilities at the TYRA project. All these activities will contribute positively to the employment.

The offshore oil and gas production is important to Danish economy. The state's revenue from oil and gas production is estimated to DKK 20 billion per year. About 4,500 people are directly or indirectly employed with and on the Tyra facilities and jobs dependent on Tyra, cf. section 3.6 and5.16).

The impact is assessed to be of medium intensity, from local to national extent and medium-term duration. The overall impact on employment from activities at the TYRA project is assessed to be of positive significance.

6.4.6.2 Tax revenue

The tax revenue from the TYRA project has not been quantified, but the tax revenue to the state of Denmark from oil and gas activities is significant. The state's total revenue is estimated to DKK 20 billion per year (section3.6).

The impact is assessed to be of medium intensity, from local to national extent and medium-term duration. The overall impact on tax revenue from activities at the TYRA project is assessed to be of positive significance.

6.4.6.3 Overall assessment

The overall assessment of impacts on employment and tax revenue from planned activities at the TYRA project is summarised in Table 6-29.

Table 6-29 Potential impacts on employment from planned activities at the TYRA project

Impact mechanism	Intensity	Extent	Duration	Overall significance	Level of confidence
Employment	Medium	Local/national	Medium term	Positive	Medium
Tax revenue	Medium	Local/national	Medium term	Positive	Medium

6.4.7 Oil and gas dependency

6.4.7.1 Dependency

As part of a long-term Danish energy strategy, the oil and gas production is considered instrumental in maintaining high security of supply. Denmark is expected to continue being a net exporter of natural gas up to and including 2025 and Maersk Oil has a license to operate until 2042 (section 3 and 5).

If no production is undertaken by Maersk Oil for the TYRA project in the North Sea, there will be no contribution to the Danish economy or security of supply from the TYRA project.

The impact is assessed to be of medium intensity, local or national extent and medium-term duration. The overall impact on dependency from activities at the TYRA project is assessed to be of positive significance.

6.4.7.2 Overall assessment

The overall assessment of impacts on oil and gas dependency from planned activities at the TYRA project is summarised in Table 6-30.

Table 6-30 Potential impacts on oil and gas dependency from planned activities at the TYRA project

Impact mechanism	Intensity	Extent	Duration	Overall significance	Level of confidence
Oil and gas dependency	Medium	Local/national	Medium term	Positive	Medium

6.5 Summary

The potential impacts on environmental and social receptors from planned activities at the TYRA project are summarised in Table 6-31. The impact with the largest overall significance is provided for each receptor.

Table 6-31 Summary of potential impacts on environmental and social receptors from planned activities at the TYRA project. The impact with the largest overall significance is provided for each receptor

Receptor	Worst case potential impact
Climate and air quality	Moderate negative
Hydrography	Minor negative
Water quality	Minor negative
Sediment type and quality	Minor negative
Plankton	Minor negative
Benthic communities	Minor negative
Fish	Minor negative
Marine mammals	Moderate negative
Seabirds	Minor negative
Cultural heritage	None
Protected areas*	None
Marine spatial use	Minor negative
Fishery	Minor negative
Tourism	None
Employment and tax revenue	Positive
Oil and gas dependency	Positive

* A separate assessment for Natura 2000 is presented in section 10.

6.6 Cumulative effects

Cumulative impacts include impacts from the Tyra project, evaluated in conjunction with existing or anticipated impacts from other projects. This comprises the total effect on the surroundings from the Tyra field, in interaction with other projects or plants with similar effects.

In association with the Tyra project a preliminary review of projects that could contribute to the cumulative effects has been conducted. Of this three projects has been identified which are considered to be relevant (i.e. overlapping the zone and time of influence) and therefore included in the assessment of cumulative effects. The project is the three neighboring oil/gas fields, i.e. Gorm, Dan and Halfdan (Table 6-32).

Table 6-32 showing the distance in kilometres from Tyra to the closest neighbouring fields

Project	Tyra East	Tyra West	Tyra Southeast
Gorm	16	15	10
Dan	33	34	23
Halfdan	24	26	14

The receptors identified as relevant for consideration are:

- Environmental receptors climate and air quality, marine mammals and sea birds with regard to impact mechanisms air emission, noise and oil spill, the latter related to an accidental oil spill, cf. section 7
- Social receptors marine spatial use, fishery, and employment and tax revenue with regard to impact mechanisms physical disturbance of seabed, restricted zones, and employment and tax revenue

Other receptors and impact mechanisms are not considered relevant in a cumulative context.

6.6.1 Climate and air quality

Impacts on climate and air quality relate to atmospheric emissions of greenhouse gases such as CO_2, N_2O and CH_4. Because of the transboundary nature of this emission, cumulative effect should in principle account for all man-made emission for Denmark. In this assessment, however, only the emission from similar type of constructions to Tyra is considered as part of the cumulative impact. The emissions of greenhouse gasses from the fields of Halfdan, Gorm and Dan are in total within the same order of magnitude as from Tyra. In this respect a cumulative impact of approximately four times the emission for Tyra is still assessed of moderate negative significance.

The environmental impact of the airborne pollutants NOx, SOx and nmVOC is restricted to the areas where they are deposited. This may be several hundreds of kilometres why the contribution of this emission from the other three fields in the region has to be included as part of the cumulative impact. The emission of NO_x, SO_x and nmVOC from Halfdan, Gorm and Dan is rather similar to that of Tyra. The overall cumulative effect on the zone of influence of Tyra from the emission of NO_x, SO_x and nmVOC is assessed to be of moderate negative significance.

6.6.2 Marine Mammals

For marine mammals cumulative effects can be important regarding levels of underwater noise that can cause permanent hearing loss. Temporary hearing loss or behavioral response are not considered to be detrimental to the overall population of porpoises or seals.

Pile driving activities on the Tyra project is anticipated unlikely to occur in parallel with other nearby fields. Likewise, there are no indications that seismic surveys will take place simultaneous at the other fields. Therefore, it is unlikely that there will be marine mammals, which will be potentially exposed to cumulative effects of critical noise levels, which may result in permanent hearing loss.

6.6.3 Birds

Cumulative impacts on birds will occur in case of simultaneous accidents involving oil spills. This could affect sea living birds living in open sea as auks, murres and gulls which will be at risk of getting infected feathers and thus lose their plumage protective effect. Affected birds will likely include species of international importance. Overall it is estimated that the cumulative effect of several oil spill incidents at the same time together on these species will be comparable to the effects of an oil spill from Tyra, alone. However it is very unlikely that several oil spills will occur at the same time.

6.6.4 Marine spatial use

Marine spatial use is affected by the area occupied by the facilities and the safety zones established around the facilities. This may potentially affect traffic and other spatial use, and the effect will be increasing with increasing congestion of the marine territory. Given the limited use as shipping routes of the project area, and the relatively large distance to other facilities or activities and the impact of the facilities being assessed as small and local, a cumulative effect on the marine spatial use is unlikely.

6.6.5 Fishery

Fishery is potentially affected by physical disturbance of seabed, restricted zones and indirectly if target fish species are affected. The disturbance of seabed and restricted zones are directly related insofar the disturbance will be within the restricted zones. The area affected by restrictions for Tyra is relatively small compared to the total fishing area, cf. 6.4.4, and the impact from Tyra is assessed as small and local. The total area of new exclusion zones from Tyra together with the neighboring oil/gas field projects considered to potentially contribute cumulative effects is around 24 km^2, which is small (0.01%) compared to the total fishing area in the Central North Sea fishing area, and the impact is assessed to be of minor significance.

Potential changes to target species is identified as a possible consequence of activities creating underwater sound, resulting in local reduction of fish that has temporarily moved away from the underwater sound. The possible impact form Tyra is assessed to be of negligible significance, likewise for the other projects considered, and the overall cumulative effect is assessed to be negligible.

6.6.6 Employment and tax revenue

Employment and tax revenue related to the TYRA project are both assessed of positive impact, and the combined effect of Tyra and the other projects considered is of positive impact.

7. IMPACT ASSESSMENT: ACCIDENTAL EVENTS

7.1 Impact mechanisms and relevant receptors

7.1.1 Potential impact mechanisms

Potential impact mechanisms associated to the accidental events at the TYRA project are screened based on the project description (section 3) and the technical sections (appendix 1).

Potential impact mechanisms include:

- Minor accidental events (gas release, spill of chemical, diesel or oil)
- Major accidental events (oil spill or gas release)

The source of the potential impact mechanisms is provided in Table 7-1.

Table 7-1 Sources of potential impact mechanisms for the TYRA project. "X" marks relevance, while "0" marks no relevance

Potential impact mechanism	Seismic	Pipelines and structures	Production	Drilling	Well stimulation	Transport	Decommissioning
Minor accidental events (gas, chemical, diesel or oil)	X	X	X	X	X	X	X
Major accidental events (oil or gas)	0	0	X	X	X	0	0

7.1.2 Relevant receptors (environmental and social)

The environmental and social receptors described in the baseline are listed below.

- Environmental receptors: Climate and air quality, hydrographic conditions, water quality, sediment type and quality, plankton, benthic communities (flora and fauna), fish, marine mammals, seabirds.
- Social receptors: Cultural heritage, protected areas, marine spatial use, fishery, tourism, employment, tax revenue, oil and gas dependency.

The relevant receptors have been assessed based on the project description (section 3) and the potential impact mechanisms (section 7.1). Relevant receptors are summarized in Table 7-2.

Table 7-2 Relevant receptors for the impact assessment of accidental events for the TYRA project. "X" marks relevance, while "0" marks no relevance

Potential impact mechanism – accidental events	Environmental Receptors									Social Receptors							
	Climate and air quality	Hydrographic conditions	Water quality	Sediment type and quality	Plankton	Benthic communities	Fish	Marine mammals	Seabirds	Cultural heritage	Protected areas**	Marine spatial use	Fishery	Tourism	Employment	Tax revenue	OandG dependency
Gas release	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chemical spill*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil spill	0	0	X	X	X	X	X	X	X	X	X	X	X	X	0	0	0

*a worst case chemical spill is very local, and not assessed further (sections 7.1.4.1).

** a separate assessment for Natura 2000 is presented in section 10.

7.1.3 Marine strategy frameworks directive - descriptors

The list of receptors and impact mechanisms described in the ESIS can be generally related to the descriptors set within the Marine Strategy Framework Directive (MSFD; section 2.1.5). The MSFD outlines 11 descriptors used to assess the good environmental status of the marine environment (see presentation of descriptors in section 6.3).

The receptors identified in the ESIS are related to the MSFD state descriptors i.e. D1, D4, D6 and D7 and the impact mechanisms are related to the MSFD pressure descriptors D6, D8, D9 and D11, cf. section 6.1.

7.1.4 Minor accidental events

A minor accidental event is a spill where the spilled volume is finite.

Minor spill could be chemical or diesel, and could occur following e.g. vessel collision, pipeline leakage or rupture of a chemical container. Statistical analysis shows that collisions between vessels, platforms, riser etc. are very unlikely, typically in the range of 1.4 10^{-7} to 6.5 10^{-4} per year (Appendix 1).

Minor gas release of several m^3 may also occur during venting.

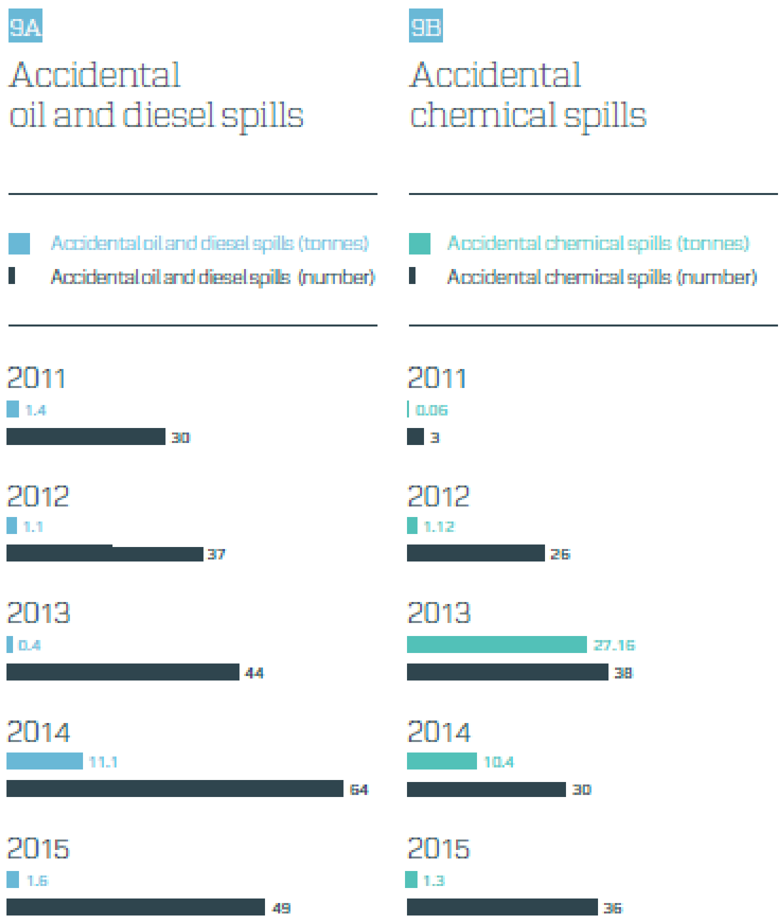


Figure 7-1 Minor accidental oil, diesel and chemical spills, Maersk Oil platforms in the North Sea /160/

Figure 7-1 presents an overview of the accidental spills over Maersk oil facilities from the period 2011 - 2015. The number of yearly reported spills ranged from 30 to 64 from 2011-2015 and on average were less than 100 litres. In 2015 accidental discharges of oil into the sea decreased significantly from 11.1 to 1.6 tonnes. However, two large spills occurred in the southern fields Gorm and Halfdan in 2015, which accounted for 68% of the total volume. The number of oil spills in total decreased from 64 in 2014 to 49 in 2015, and the main part of these were small.

In 2013 and 2014, methanol spills at Tyra and Harald contributed to more than three quarter of the total volume of chemical spills during those years. The volume of chemical spills decreased to just 1.3 tonnes in 2015 and almost half this was caused by two methanol spills in the northern fields, Tyra and Harald – both of which were caused by defective bunker hoses – and a cooling agent spill on Halfdan. Methanol is classified as a green chemical (see section 8.1.3).

Actions have been taken to eliminate the risk of such spills occurring again and a working group has been established to solve the problem with accidental spills during bunkering. Since 2011, all accidental discharges of oil and chemicals, regardless of volume, are reported. During 2014, the company introduced a more systematic way of reporting spills which may partly contribute to the observed increase in the number of spills being reported.

7.1.4.1 Minor chemical spill (rupture of chemical container)

A chemical spill was modelled for biocide at the DONG operated Hejre platform /43/. The spill was defined for loss of biocide from a container, which was considered worst case regarding potential impact. The modelled spill was for 4,500 litre of biocide to the sea, which corresponds to the volume of a typical chemical container. Results showed that the distance, to which impacts may occur (PEC/PNEC ratio of 1), was 500 m /43/. A minor chemical spill is thus confined, with impacts within 500 m. Due to the short distance where potential impacts may occur, a minor chemical spill is not assessed further.

7.1.4.2 Minor oil spill (vessel collision)

A diesel spill following a vessel collision has been modelled for a spill of marine diesel volume corresponding to a typical tank size of 1,000 m^3 during 1 hour, corresponding to the volume of the vessels tank /5//25/. The modelling results show that no shoreline impact would occur, and impacts are only expected in the local area. The results further show that most of the oil would evaporate or emulsify into the water column after 7 days, and by day 20 all of the released oil is no longer mobile; it has evaporated or biodegraded /5//25/.

7.1.4.3 Minor oil spill (full pipeline rupture)

A full rupture of a pipeline at the TYRA project in a worst case scenario is a rupture of pipeline from Tyra East to Gorm E. Emergency valves will automatically close to isolate the pipeline, and the expected maximum volume from a ruptures pipeline is a spill of 10,000 stbo crude oil.

A full bore pipeline rupture has been modelled for a spill of 10,000 stbo over 1 hour at the TYE to Gorm midpoint /151/. The results show that the oil will spread locally (Figure 7-2) , and that it is unlikely that the oil will cross a maritime border. The results show no risk of any shoreline being impacted by oil.

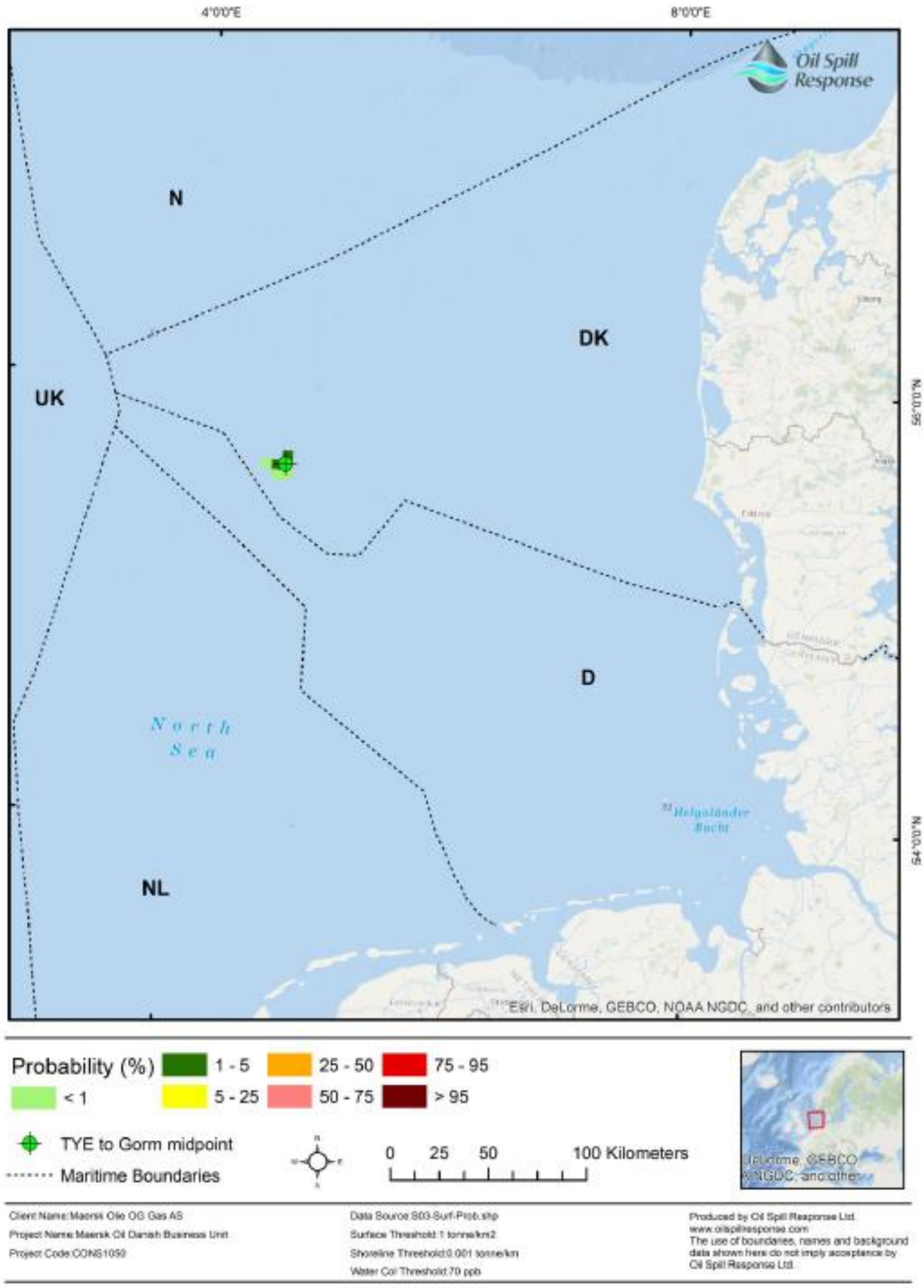


Figure 7-2 Probability that a surface of 1 km^2 cell could be impacted by oil in case of full pipeline rupture /151/

7.1.5 Major accidental events

A major spill results from an uncontrolled loss of a large volume of oil which often require intervention to be stopped. The main source of major spill is related to blow out events. Blow out events are highly unlikely and may occur during the drilling and completion phase or any operational phase of a well. Well blowout and well release frequencies are in the range (lowest frequency blow out – highest frequency well release) 7.5 x 10^{-6} to 3.3 x 10^{-4} per year in maintenance and operation /161/. For development wells, the frequencies are in the range 3.8 x 10^{-5} to 6.6 x 10^{-3} per well /161/. As most reservoirs contain a mixture of oil and gas, the blow out may results in an oil spill and a gas release. Gas will ultimately be dispersed into the atmosphere, whereas the fate of the oil is more difficult to predict.

When the oil is spilled it goes through physical processes such as evaporation, spreading, dispersion in the water column and sedimentation to the seafloor. Eventually, the oil remaining in the sea will be eliminated from the marine environment through biodegradation. The rate and importance of these processes will depend on the type and quantity of the oil as well as the prevailing weather and hydrodynamic conditions. Models are used to predict the fate of oil spills and assess the potential impact on relevant environmental and social receptors.

Oils are classified following the ITOPF classification to allow a prediction of their likely behaviour /153/. Group 1 oils (API>45) tend to dissipate completely through evaporation, whereas group 2 (API: 35-45) and group 3 (API: 17.5-35) can lose up to 40% volume through evaporation but tend to form emulsion. Group 4 oils (API< 17.5) are highly viscous and do not tend to evaporate and disperse. Group 4 is the most persistent oil type. For the TYRA project, the oil is diverse, with relatively light oil with an API of 60 at Tyra East and Roar, 52 at Tyra West, 47 at Tyra South East (Group 1), intermediate API of 42 at Valdemar (Group 2) and 29 at Svend (Group 3).

The maximum expected initial blow out flow rates from existing producing wells at the TYRA project are 8,330 stbo/d (1,300 m^3/d) for Tyra South East, 2,400 (380 m^3/d) for Tyra West, 32,340 stbo/d (5,100 m^3/d) for Roar, 4,200 stbo/d (660 m^3/d) for Svend and 5,415 stbo/d(850 m^3/d) for Tyra East /161/.

The oil spill model was done using the Oil Spill Contingency and Response (OSCAR) model. OSCAR is a 3D modelling tool developed by SINTEF, able to predict the movement and fate of oil both on the surface and throughout the water column /5//25//26//27/. The model simulated more than 150 trajectories under a wide range of weather and hydrodynamic conditions representative of the TYRA area. The outputs of the model are statistical maps based on the simulations that define the areas most at risk to be impacted by an oil spill. Modelling is performed on the non-ignited spill without any oil spill response (e.g. mechanical recovery; section 0 and 0).

Three models were used to investigate the possible fate of an ITOPF Group1 (Xana-1X), ITOPF Group 2 (Siah NE-1X) and ITOPF group 3 (Svend) oil spill occurring at one of the wells for the TYRA existing or new development project. An oil spill from the TYRA project will be ITOPF Group 2. The modelled exploration scenarios correspond to a continuous release for 16 days with a flow rate of 8,534 stbo/d for ITOPF Group 3 oil (Xana-1X) and 40,432 stbo/d for ITOPF Group 2 oil (Siah NE-1X) respectively, and 4,200 stbo/d for ITOPF Group 1 (Svend). The duration of the modelled blowouts is based on the fact that most exploration wells such as Xana-1X and Siah NE-1X would collapse within a duration of 16 days /155/. The casing of a production well is designed to prevent the collapse of the well and a relief well may be necessary to stop the blow out. Such intervention may require about 90 days. Nevertheless, the total volume of the oil spill modelled for Siah NE-1X and Xana-1X (high flow rate and short duration) are higher or equivalent to the maximum volume that could be expected from a producing well over a longer time. Furthermore, it is expected that a high release rate over a short period would be a worse case than a lower rate (for a production scenario) over a longer period. Thus, the results for Siah NE-1X and Xana-1X can be used as representative of a worst credible well blow-out case at the TYRA project.

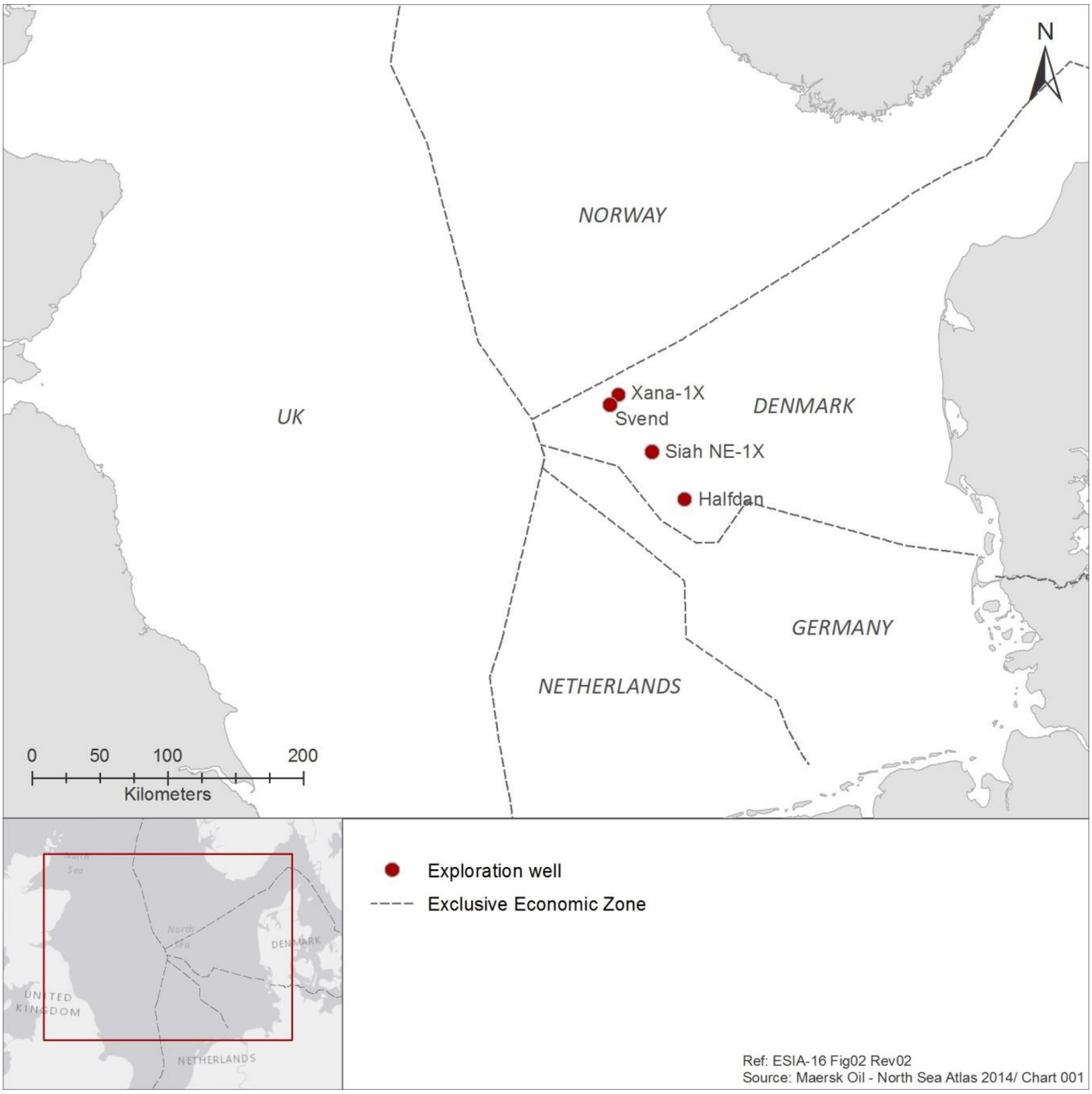


Figure 7-3 Location of four Maersk Oil wells, for which oil spill modelling has been undertaken. Siah NE-1X, Xana-1X and Svend are considered representative for the TYRA project

The oil spill modelling was used to determine how quickly the oil would reach shoreline and which countries could be affected. It is also used to determine the different oil spill fate and the relevant receptors at the TYRA project. The results are also used to assist in the development of an adapted oil spill response plan (section 9.5).

The trajectory resulting in the most oil onshore is extracted to illustrate the potential fate of an oil spill at the TYRA project in more details /151/. The model results are summarised in Table 7-3.

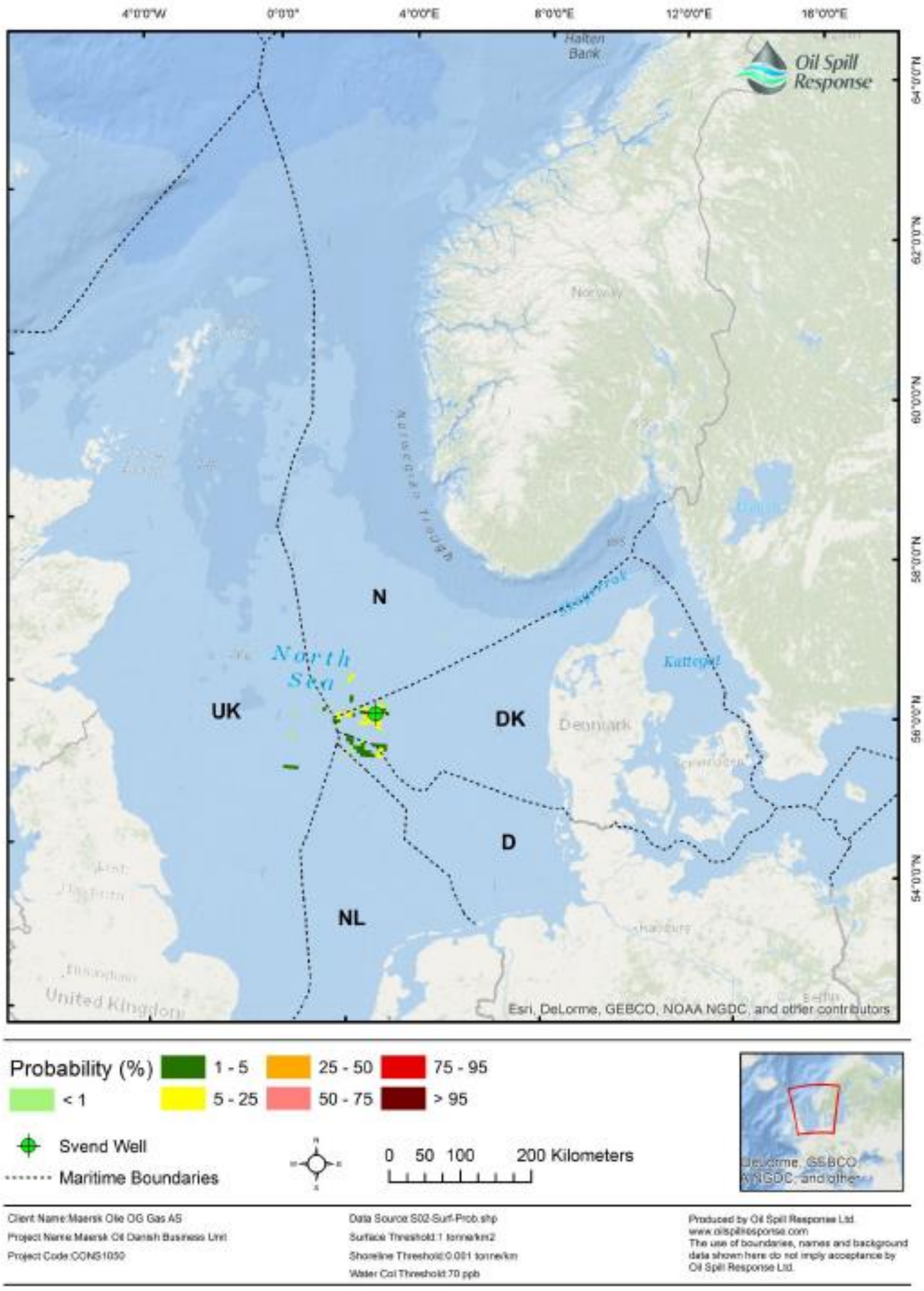
Table 7-3 Results from the worst credible case scenarios for a well blowout at the TYRA project: Svend, Siah NE-1X and Xana 1X /151//5//25//26//27/. Note that the modelling is performed without any oil recovery

Parameter	Svend	Siah NE-1X Scenario 1	Siah NE-1X Scenario 2	Xana 1X
Model set-up				
Time of year	All year	June-November	December-May	March-September
Release rate	4,200 stbo/d	40,432 stbo/d	40,432 stbo/d	8,534 stbo/d
Release period	90 days	16 days	16 days	16 days
Total mass spilled	53,400 MT (378,000 stbo)	90,004 MT (646,912 stbo)	90,004 MT (646,912 stbo)	19,016 MT (136,544 stbo)
Model run	118 days	44 days	44 days	44 days
ITOPF (API)	3 (API of 17.5-35)	2 (API of 35 - 45)	2 (API of 35 - 45)	1 (API of > 45)
Probability of reaching shore				
% of simulations reaching shore	98 %	100 %	96 %	21 %
Minimum arrival time to shore (days)				
Denmark	10 days	14 days	15 days	14 days
Sweden	60 days	n/a	n/a	n/a
Germany	17 days	n/a	n/a	n/a
Norway	71 days	37 days	37 days	24 days
UK	n/a	n/a	n/a	n/a
Fate of oil at end of simulation (MT/%)[1]				
Onshore	400 MT (<1 %)	10,450 MT (12%)	11,600 MT (13%)	<0.2 MT (<0.5%)
Surface	17 MT (<0.1 %)	14 MT (<1%)	15 MT (<1%)	<0.1 MT (<0.5%)
Water column	1,150 MT (2 %)	370 MT (<1%)	730 MT (<1%)	30 MT (<0.5%)
Evaporated	21,500 MT (40 %)	37,700 MT (39%)	35,400 MT (39%)	2,500 MT (13%)
Sedimentation	25,500 MT (48 %)	26,000 MT (29%)	26,900 MT (30%)	8,400 MT (44%)
Biodegraded	4,850 MT (9 %)	15,470 MT (17%)	15,359 MT (17%)	8,100 MT (42 %)

7.1.5.1 Svend spill (type 3) modelling

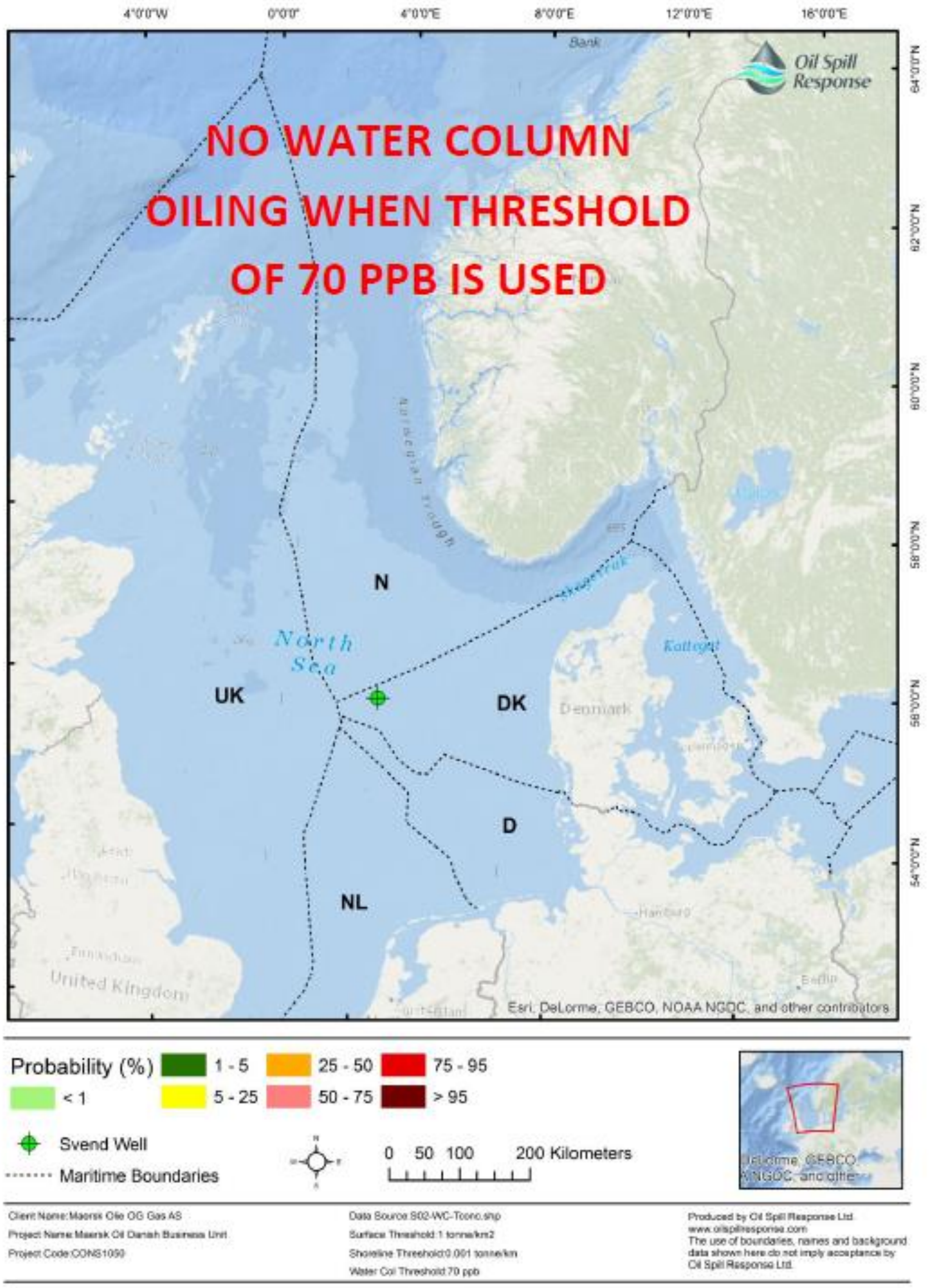
Selected results of the spill modelling for Svend are presented in the following /151/:

- Figure 7-4: Danish, German, UK and Norwegian surface waters could be impacted.
- Figure 7-5: No water column oiling is seen when a threshold of 70 ppb is applied.
- Figure 7-6: Danish, Swedish and Norwegian shorelines are most likely to be affected. The UK shoreline could also be affected.



Scenario	Threshold
S02	Thickness: 1 tonne / km^2

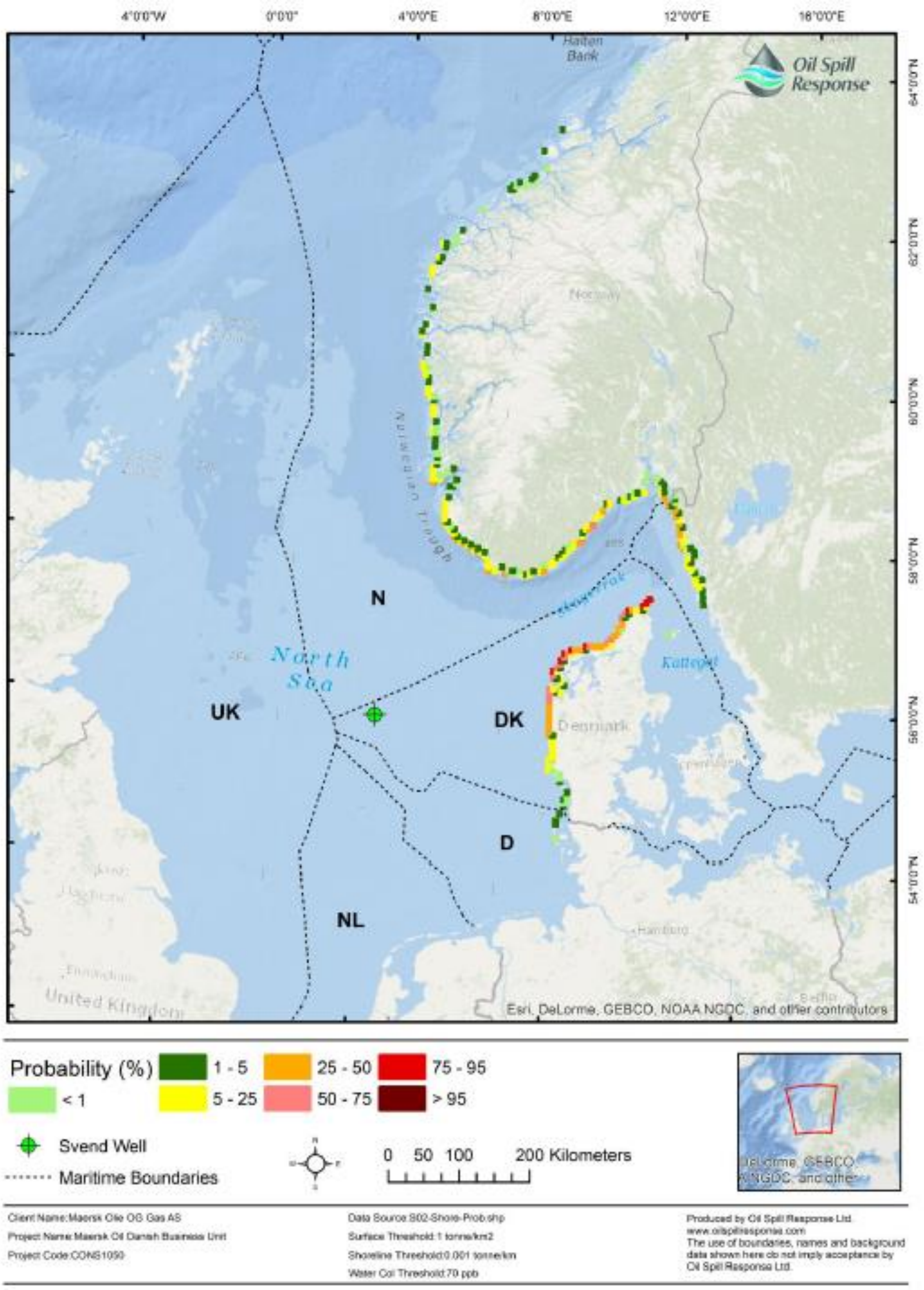
Figure 7-4 Probability that a surface cell could be impacted in a surface blowout at Svend well /151/. Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 159 independently simulated trajectories



Scenario	Threshold
S02	Concentration: 70 ppb

Figure 7-5 Probability that a water column cell could be impacted in a surface blowout at Svend well /151/

Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 159 independently simulated trajectories



Scenario	Threshold
S02	Thickness: 0.001 tonnes/km

Figure 7-6 Probability that a shoreline cell could be impacted in a surface blowout at Svend well /151/

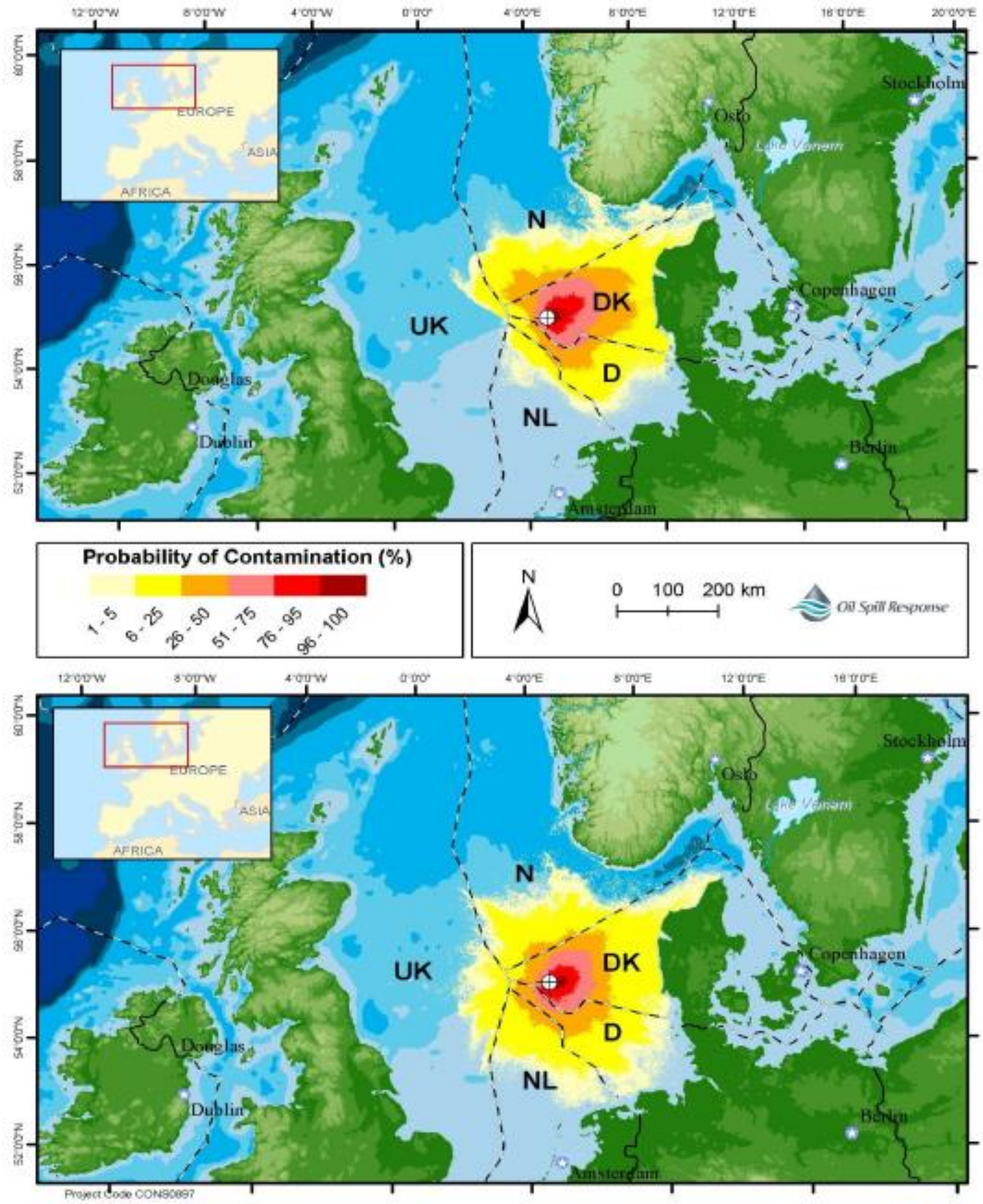
Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 159 independently simulated trajectories

7.1.5.2 Siah NE-1X spill (type 2) modelling

Selected results of the spill modelling for Siah NE-1X are presented in the following /5//25/:

- Figure 7-7. Norwegian, German and Dutch surface waters have up to 50 % risk of being oiled under these scenarios, while UK waters have at least a 6% risk of oiling. Danish waters (where the release site is located) have a 100 % risk of oiling.
- Figure 7-8. Norwegian, German, UK and Dutch surface waters have up to 25 % risk of being oiled in these scenarios. Danish waters (where the release site is located) have a 100% risk of oiling.
- Figure 7-9. Danish, Norwegian, German and Dutch shorelines could be affected during Scenario 1. The UK shoreline could also be affected during Scenario 2. The Danish shoreline is the most likely to be affected in both scenarios.
- Figure 7-10. In both scenarios, the total concentration of oil in water is generally less than 150 ppb, but could reach up to 300 ppb in Norwegian, Danish, German, Dutch and UK waters.

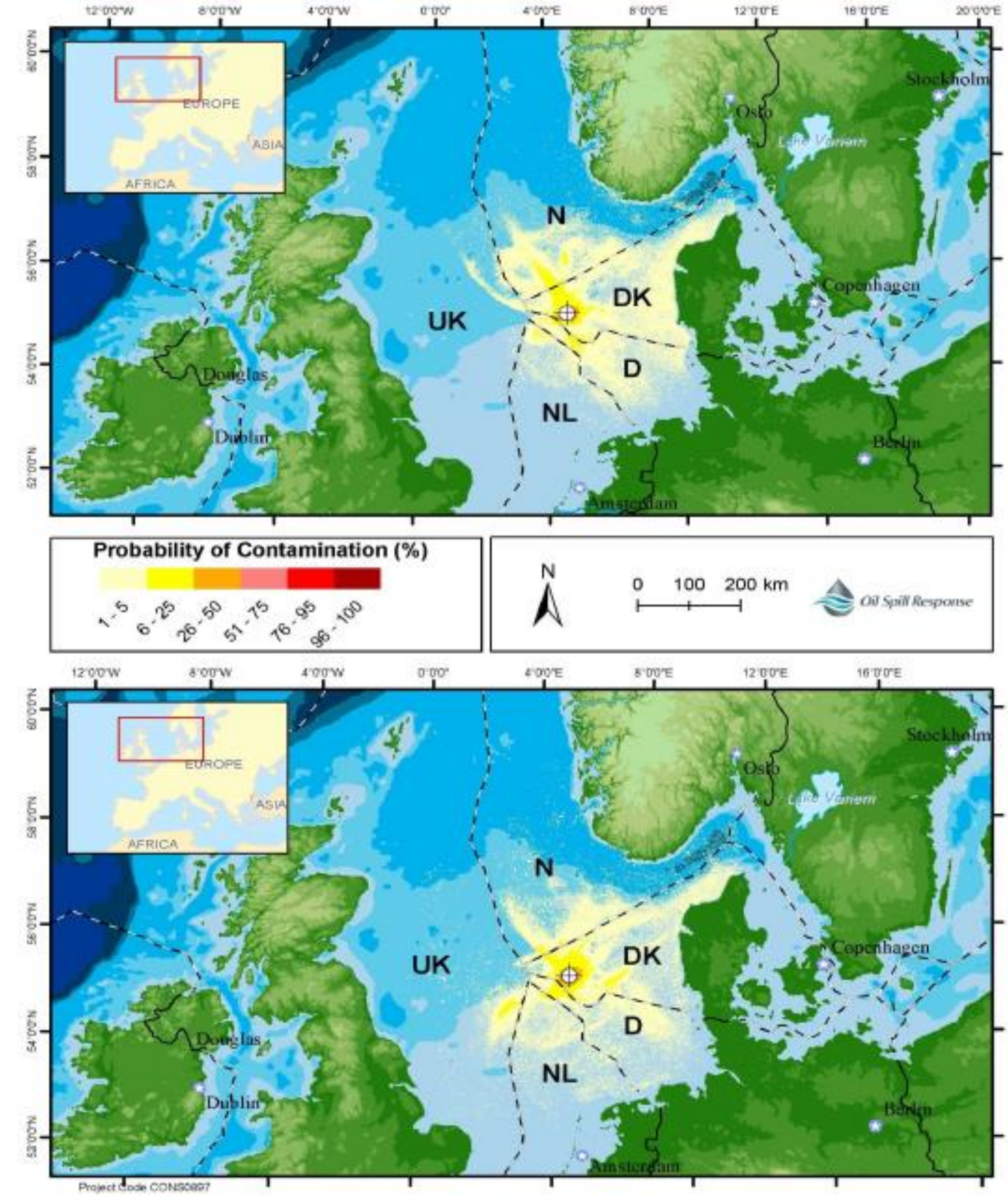
For the TYRA project, oil type 2 is found at Valdemar, with an API of 42.



Scenarios	Threshold
S01 (Jun-Nov), S02(Dec-May)	Thickness: 1 tonne / km^2

Figure 7-7 Probability that a surface of 1 km^2 cell could be impacted in Scenario 1 (sub-surface blowout between June and November, upper plot) and Scenario 2 (sub-surface blowout between December and May, lower plot) /5//25/

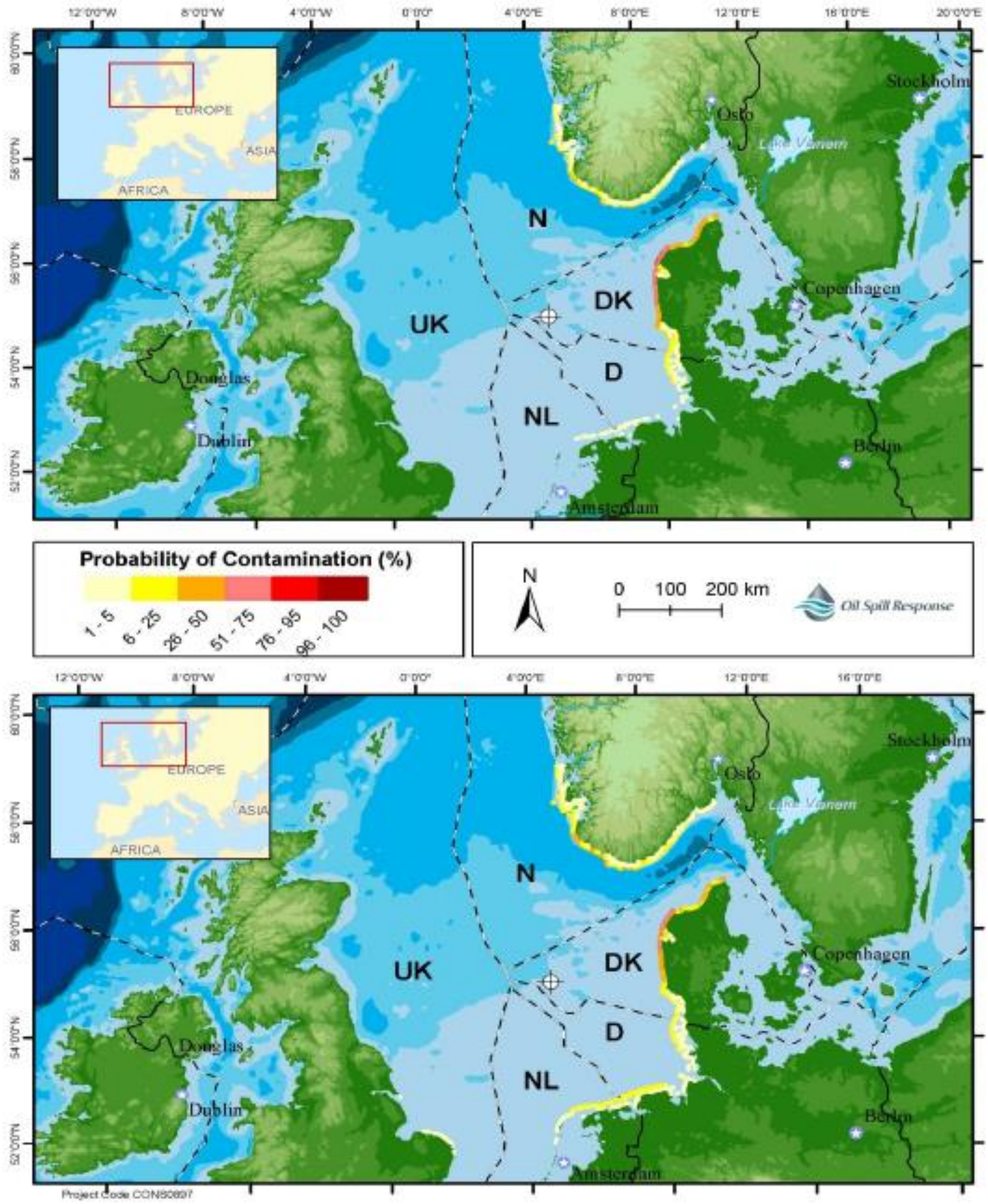
Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 168/167 independently simulated trajectories



Scenarios	Threshold
S01 (Jun-Nov), S02(Dec-May)	Total Concentration: 70 ppb

Figure 7-8 Probability that a water column cell could be impacted in Scenario 1 (sub-surface blowout between June and November, upper plot) and Scenario 2 (sub-surface blowout between December and May, lower plot) /5//25/

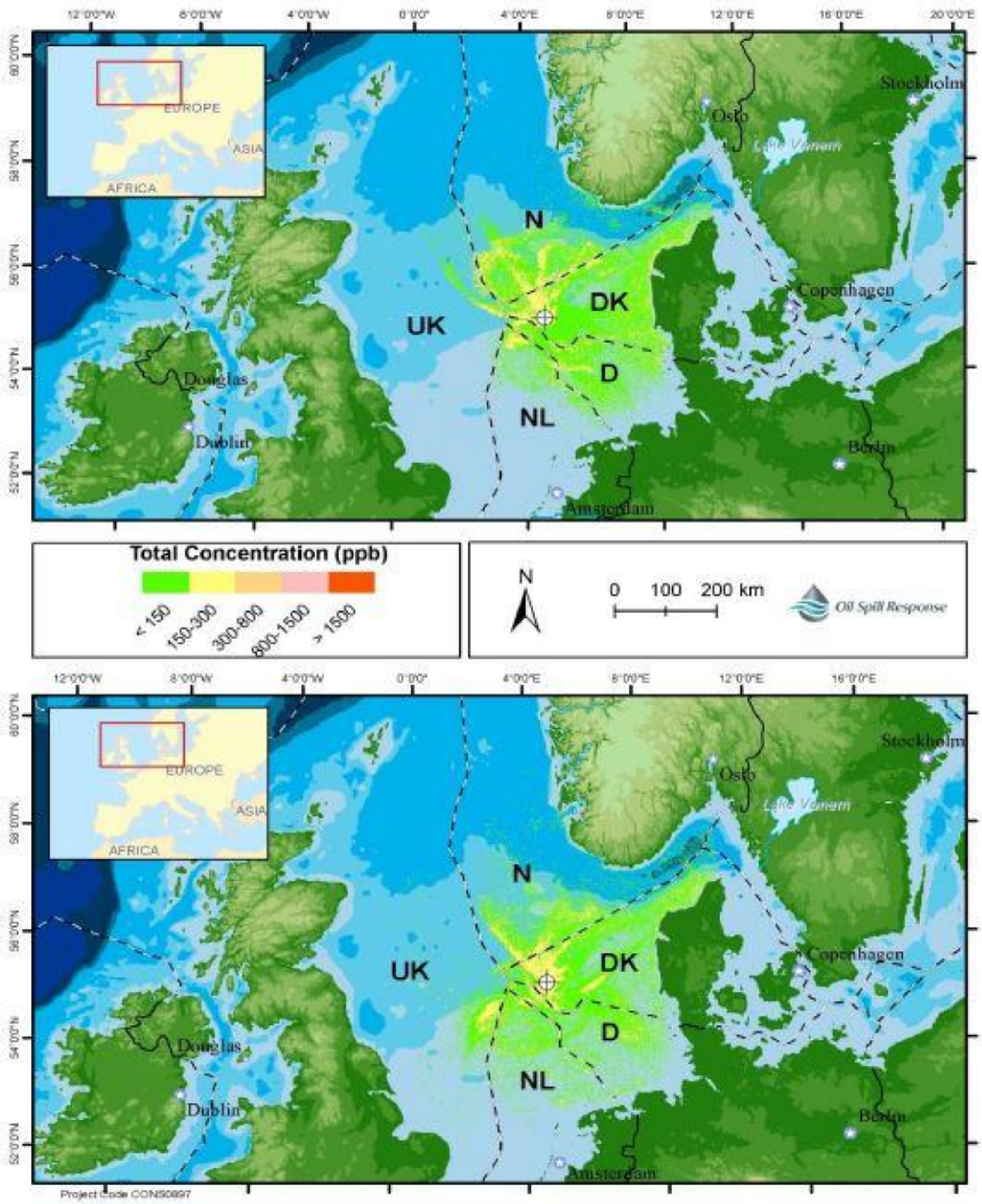
Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 168/167 independently simulated trajectories



Scenarios	Threshold
S01 (Jun-Nov),S02(Dec-May)	Thickness: 0.001 tonnes/km

Figure 7-9 Probability that a shoreline cell could be impacted in Scenario 1 (sub-surface blowout between June and November, upper plot) and Scenario 2 (sub-surface blowout between December and May, lower plot) /5//25/

Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 168/167 independently simulated trajectories



Scenarios	Threshold
S01 (Jun-Nov), S02(Dec-May)	Total Concentration: 70 ppb

Figure 7-10 Maximum time-averaged total oil concentration for the two scenarios. Upper plot: June-November, Lower plot: December May /5/. Note that the images does not show actual footprint of an oil spill but a statistical picture based on 168/167 independently simulated trajectories

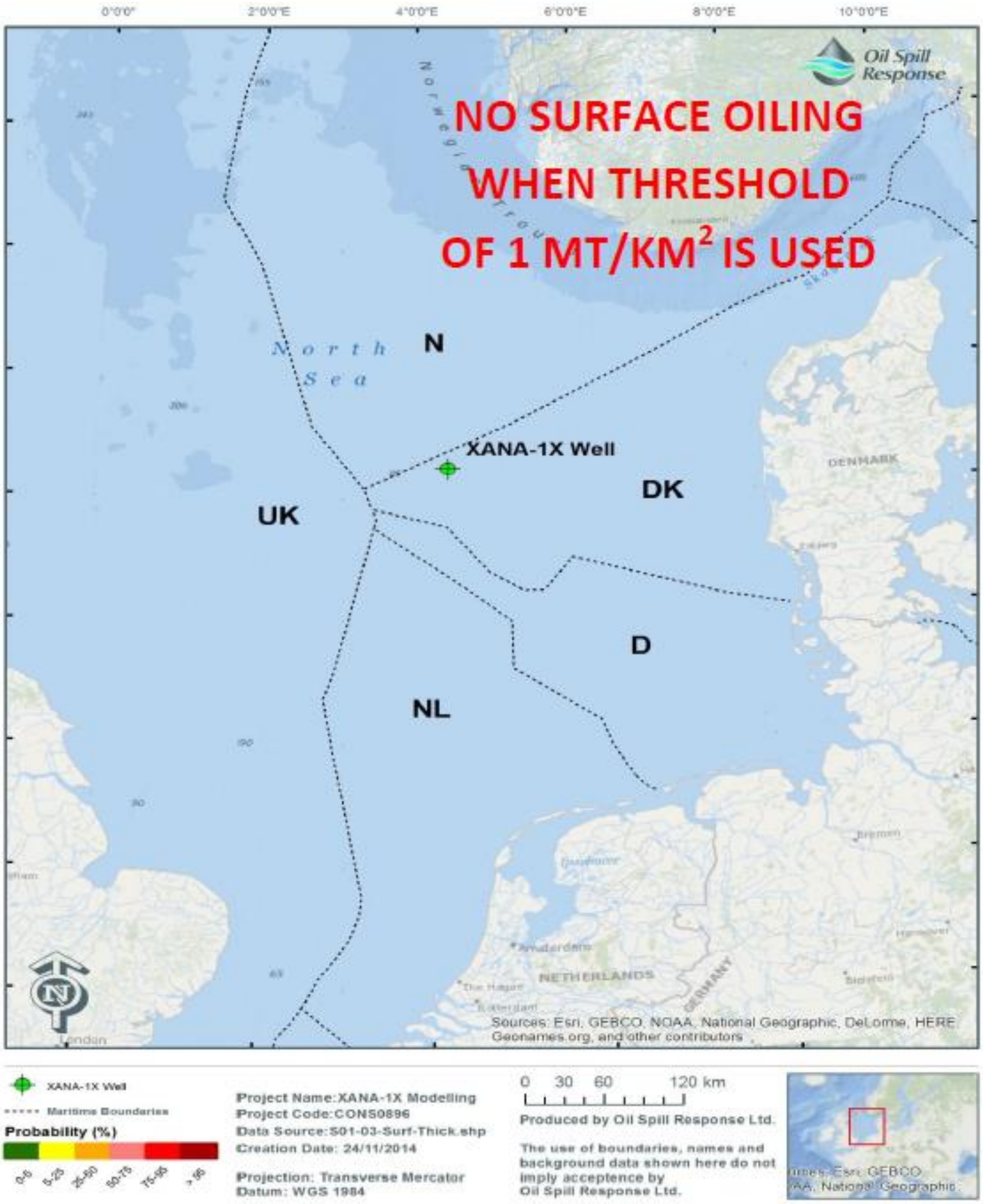
Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 168/167 independently simulated trajectories

7.1.5.3 Xana 1X spill (type 1 oil) modelling

One scenario has been modelled for a major oil spill at Xana. Selected results of the spill modelling for Xana 1X are presented in the following /26//27/:

- Figure 7-11: No surface oiling is probable anywhere, when threshold of 1 MT/km^2 is applied, though an oil sheen might be observed near the release location.
- Figure 7-12: Other than Denmark, Norway is the only country where the water column could be impacted by a spill.
- Figure 7-13: Only Danish and Norwegian shorelines could be affected in case of a spill.
- Figure 7-14: Concentrations can be over 1,500 ppb around the release site. The oil concentration decreases further away from the site. If Norwegian waters experience oiling, it is expected the concentrations will be less than 300 ppb.

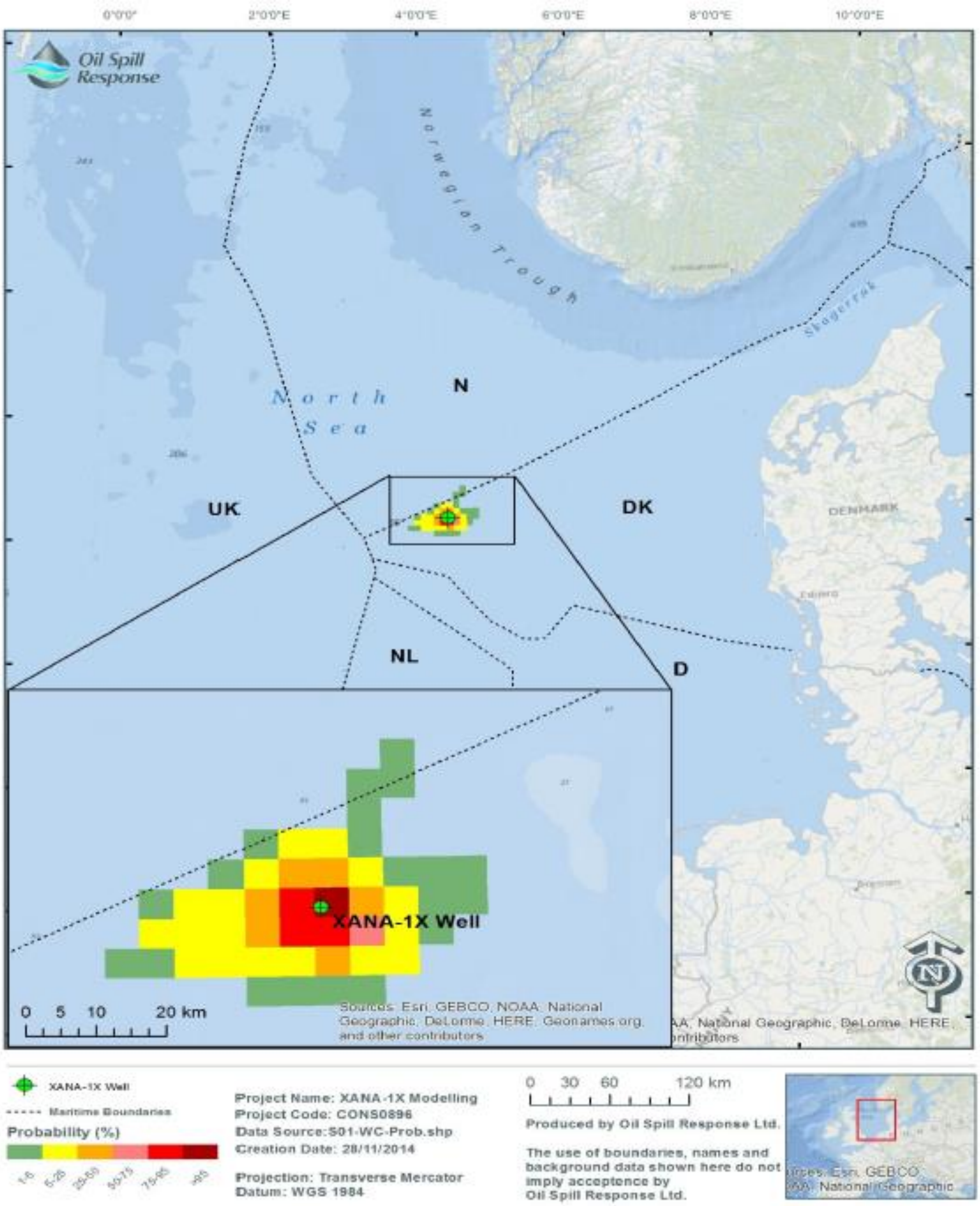
For the TYRA project, type 1 oil is found at Tyra East and Roar (API of 60), at Tyra West (API of 52) and at Tyra Southeast (API of 47).



Scenarios	Threshold
S01 (March-September)	Thickness: 1 tonne / km^2

Figure 7-11 Probability for a surface of 1km^2 cell could be impacted. Note than no surface oiling is probable, when threshold of 1 MT/km^2 is applied /26//27/

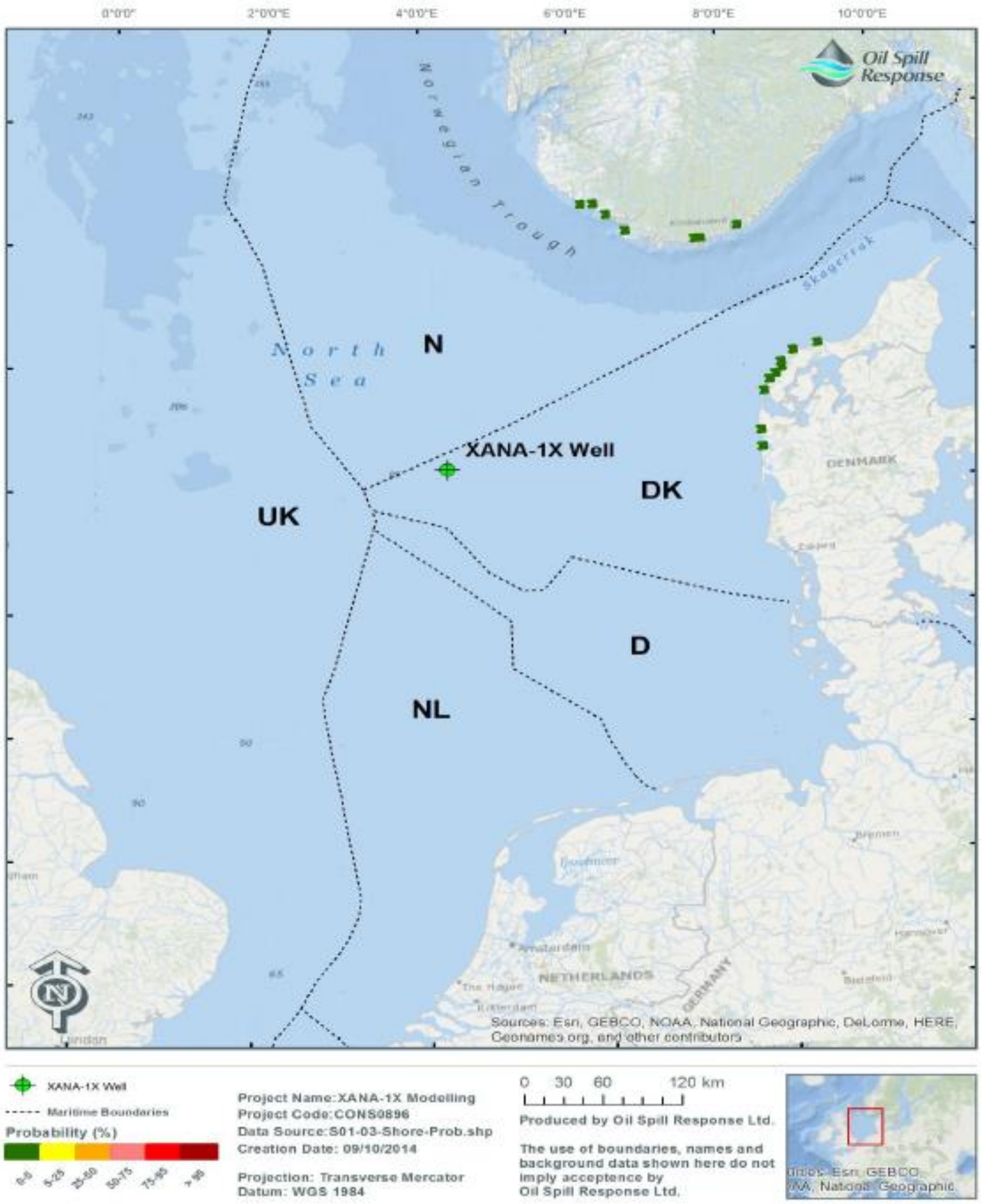
Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 400 independently simulated trajectories



Scenarios	Threshold
S01 (March-September)	Concentration: 70 ppb

Figure 7-12 Probability that a water column grid cell could be impacted /26//27/

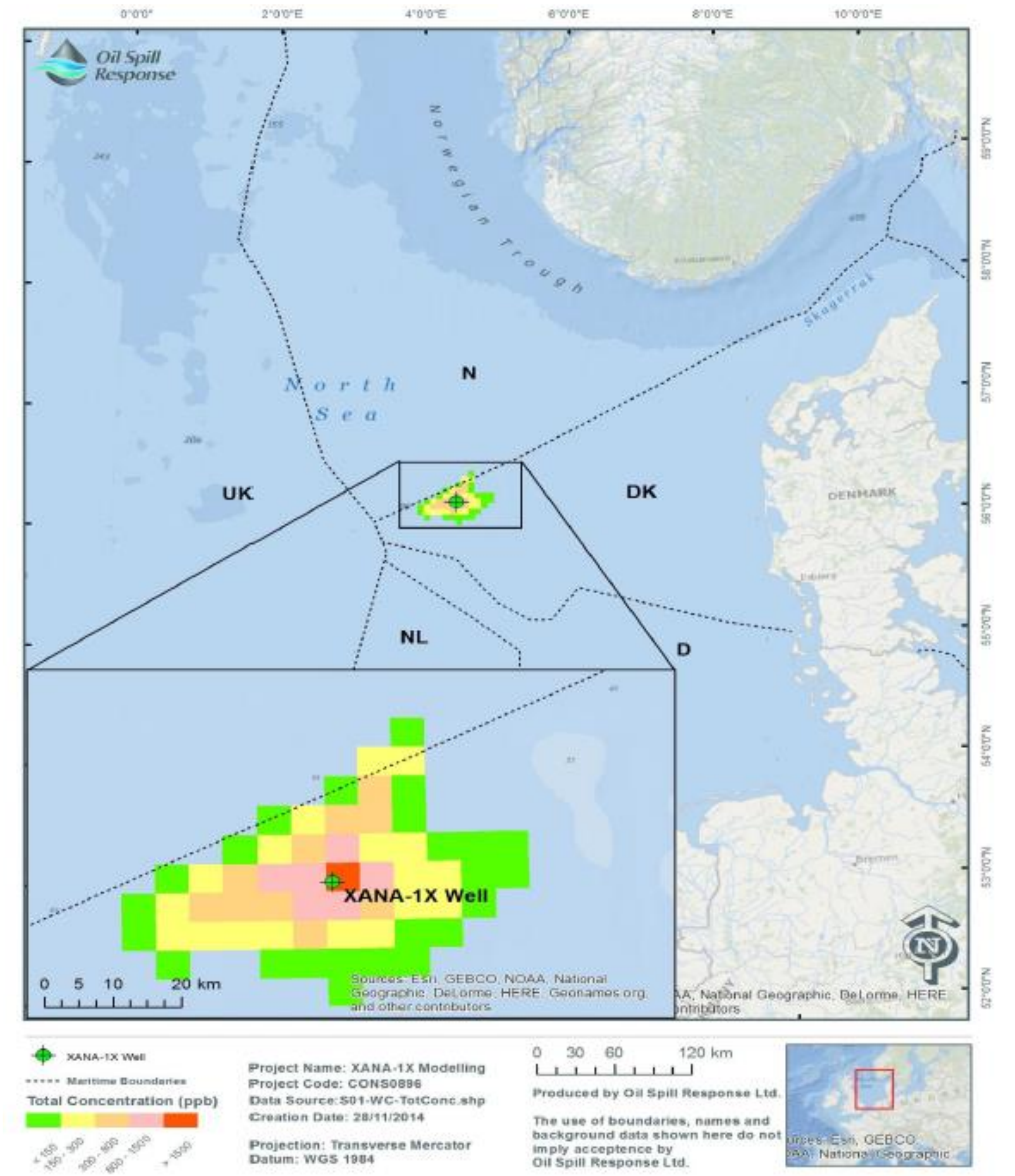
Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 400 independently simulated trajectories



Scenarios	Threshold
S01 (March-September)	Thickness: 0.001 tonnes/km

Figure 7-13 Probability of shoreline grid cells being impacted by oil /26//27/

Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 400 independently simulated trajectories



Scenarios	Threshold
S01 (March-September)	Concentration: 70 ppb

Figure 7-14 Maximum time-averaged total oil concentration in water column cells /26//27/

Note that these images DO NOT show the actual footprint of an oil spill, they present a statistical picture based on 400 independently simulated trajectories

7.2 Assessment of potential environmental impacts

Impact assessment for the relevant environmental receptors is presented in this section for accidental events. The assessment is based on modelling data to evaluate the extent, while literature data is applied to assess the intensity and duration of impact.

7.2.1 Climate and air quality

Potential impacts on climate and air quality from accidental events are related to gas release.

7.2.1.1 Major gas release

The gas release in case of a major leak is primarily composed of methane CH_4 or CO_2 if the gas is ignited. In case of an uncontrolled gas release, gas will be released to the atmosphere. CH_4 or CO_2 are greenhouse gas and a major gas release will contribute to the global pool of greenhouse gas (see section 6.2.1).

The impact to climate and air quality from an uncontrolled gas release at the TYRA project is assessed to be of medium intensity, with a transboundary extent and a long-term duration. The overall significance of the impact is assessed to be moderate negative.

7.2.1.2 Overall assessment

The potential impacts are summarised in Table 7-4.

Table 7-4 Potential impacts on climate and air quality related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Major gas release	Medium	Transboundary	Long-term	Moderate negative	Low

7.2.2 Water quality

Potential impact mechanisms to water quality from accidental spill are related to minor and major oil spill.

7.2.2.1 Minor oil spill

Modelling results for a marine diesel spill from a vessel show that after 20 days all of the released oil is no longer mobile; it has evaporated or biodegraded (section 7.1.4). Modelling results for a pipeline rupture show that the dispersion is local near the rupture.

The physical presence of a large oil slick will cause considerable changes to physical and chemical parameters of marine water quality, such as reduced light or oxygen levels. In addition, the increased concentration of oil substances (THC, PAH etc.) will alter the water quality.

Based on the modelling results the extent of the impact on the water quality is assessed to be local. The intensity is considered small with a short-term duration, as the oil will evaporate, settle or biodegrade. Overall, the impact on the water quality from a minor oil spill will be of minor negative significance.

7.2.2.2 Major oil spill

Based on the modelling of a major oil spill (section 7.1.5), oil components concentrations can be over 1500 ppb around the release site, while concentrations are generally below 150 ppb in the water column. At the end of the model simulation, most of the oil has either drifted onshore, evaporated, sedimented or is biodegraded (section 7.1.5).

The physical presence of a large oil slick will cause considerable changes to physical and chemical parameters of marine water quality, such as reduced light or oxygen levels. In addition, the increased concentration of oil substances (THC, PAH etc.) will alter the water quality. The extent of the impact depends to a large extent on the prevailing meteorological conditions.

Based on the modelling results the impact is assessed to be of medium intensity, transboundary extent and a medium duration. Overall, the impact on water quality from a major oil spill will be of moderate negative significance.

7.2.2.3 Overall assessment

The potential impacts are summarised in Table 7-5.

Table 7-5 Potential impacts on water quality related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Small	Regional	Short-term	Minor negative	Medium
Major oil spill	Medium	Transboundary	Medium-term	Moderate negative	Medium

7.2.3 Sediment type and quality

Potential impact mechanisms to sediment type and quality are related to minor and major oil spill.

7.2.3.1 Minor oil spill

Modelling results for a marine diesel spill from a vessel show that after 20 days all of the released oil is no longer mobile; it has evaporated or biodegraded (section 7.1.4).

Based on the modelling results the intensity of the impact is assessed to be small with a potential regional extent and a short-term duration. Overall, the impact on sediment type and quality from a minor oil spill will be of minor negative significance.

7.2.3.2 Major spill

Based on the modelling of a major oil spill, significant impacts on the sediment type and quality may occur. Modelling of five different scenarios (section 7.1.5) shows, that between 29-55 % of the oil will end up on the seabed, corresponding to up to approximately 159,000 MT over a large area in the North Sea. The rest will either drift onshore, evaporate or biodegrade.

Full recovery will require degradation or burial of contaminants in combination with naturally slow successional processes. Oil degradation in the marine environment is limited by temperature, nutrient availability (especially nitrogen and phosphorous), biodegradability of the petroleum hydrocarbons, presence of organic carbon, and the presence of microorganisms with oil degrading enzymes /123//124/.

Based on the modelling results the intensity of the impact from a major oil spill is assessed to be medium with a transboundary extent and a medium duration. Overall, the impact on the sediment type and quality will be of moderate negative significance.

7.2.3.3 Overall assessment

The potential impacts are summarised in Table 7-6.

Table 7-6 Potential impacts on sediment type and quality related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Small	Regional	Short-term	Minor negative	Medium
Major oil spill	Medium	Transboundary	Medium-term	Moderate negative	Medium

7.2.4 Plankton

Potential impact mechanisms to plankton are related to minor and major oil spill.

7.2.4.1 Minor oil spill

Based on the assessed impact to the water quality (section 7.2.2) a minor oil spill is assessed to have a limited impact on plankton community. Though planktonic organisms may be affected, the high reproductive potential of plankton is considered able to compensate.

The intensity of the impact is assessed to be small with a local extent and a short-term duration. Overall, the impact on plankton is assessed to be of minor negative significance.

7.2.4.2 Major oil spill

Laboratory toxicity studies have demonstrated great variation amongst planktonic organisms in response to the effects of spilled oil, with phytoplankton generally considered less sensitive than zooplankton /125/.

Tests in containers of naturally occurring algae and water soluble fraction of North Sea oil concentrations of 0.1 mg/l (=100 ppb) showed no significant effects on the total primary production /126/. Toxic effects including decreases in growth rate and inhibition of photosynthesis have been observed in phytoplankton exposed to water soluble fractions of oil concentrations ranging from 1,000 ppb to 10,000 ppb /127/.

Acute lethal effects to zooplankton have been observed from contact with water soluble fractions in concentrations greater than 200 ppb /125/. Sub-lethal effects to zooplankton, including physiological, biochemical and behavioural effects have been observed at one-tenth of lethal concentrations /125/. However, such laboratory toxicity studies have been shown to be of little relevance for predicting long-term effects on natural populations. Such studies are typically short-term and use robust, easily handled species not representative of the wide variety of planktonic organisms that exist naturally. Although such experiments demonstrate oil spill effects to plankton, field observations have typically shown minimal or transient effects /125/.

There are no examples of long-term effects on plankton stocks after oil spills. This is due to plankton reproductive capacity and the water circulation bringing new plankton from outside the affected area /128//129/. Plankton populations are thus not particularly vulnerable to oil spill, and may compensate for any impact through a high reproductive potential.

Based on the assessed impact to the water quality (section 7.2.2.2) the duration of the impact on plankton is short-term. The intensity of the impact is assessed to be medium with a transboundary extent and a short-term duration. Overall, the impact of major oil spill on the plankton community will be of minor negative significance.

7.2.4.3 Overall assessment

The potential impacts are summarised in Table 7-7.

Table 7-7 Potential impacts on plankton related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Small	Local	Short-term	Minor negative	Medium
Major oil spill	Small	Transboundary	Short-term	Minor negative	Medium

7.2.5 Benthic communities

Potential impact mechanisms on the benthic communities are related to minor and major oil spill.

7.2.5.1 Minor oil spill

Based on the assessed impact to the sediment type and quality (section 7.2.3) any significant impacts on the benthic communities are estimated to be limited. The intensity of the impact is assessed to be none/small with a regional extent and medium-term duration. Overall, the impact on sediment type and quality from a minor oil spill will be of minor negative significance.

7.2.5.2 Major oil spill

Lethal and sub-lethal effects to the benthos may include mortality, alterations in recruitment, growth and reproduction, as well as changes in community structure, including species richness. Nonselective deposit feeders such as polychaetes and nematodes have demonstrated resilience to the adverse effects of spilled oil /130/. Conversely, the density of crustaceans such as amphipods and copepods would be expected to decline due to their known sensitivity to the effects of oil /130/.

The biological effects of oil on the seabed and benthos depend largely on the fate of the spilled oil and the additive toxicity of aromatic hydrocarbons.

Model calculations have shown that up to half of the oil will end at the seafloor (section 7.1.5). It cannot be excluded that oil components could affect bottom fauna to some extent in the affected area. Recovery of soft-bottom benthos after previous shallow-water oil spills has been documented to take years to decades /123//124/.

The intensity of the impact is assessed to be medium with a transboundary extent and a long-term duration. In conclusion, the overall impact on the benthic community from a major oil spill will be of major negative significance.

7.2.5.3 Overall assessment

The potential impacts are summarised in Table 7-8.

Table 7-8 Potential impacts on benthic communities related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	None/Small	Regional	Medium-term	Minor negative	Medium
Major oil spill	Medium	Transboundary	Long-term	Major negative	Medium

7.2.6 Fish

Potential impact mechanisms on fish are related to minor and major oil spill. Note that eggs and larvae are assessed as part of plankton.

7.2.6.1 Minor oil spill

Based on the assessed impact to the water quality (section 7.2.2) and the sediment type and quality (section 7.2.3) a minor oil spill is assessed to have a limited impact on the fish communities. The impact of a minor oil spill is confined to impacts on individuals, and not populations. The intensity of the impact is assessed to be small with a regional extent and a short/medium-term duration. Overall, the impact on fish from a minor oil spill is assessed to be of minor negative significance.

7.2.6.2 Major oil spill

Although laboratory studies have shown a range of lethal and sub-lethal effects of oil on fish /131/ the hydrocarbon concentrations at which these have occurred have generally been considerably higher than those occurring during oil spills /125/. Fish appear to be more sensitive to short-term acute toxicity from the lighter aromatic components which are probably because they possess the enzymes necessary to metabolise sub-lethal concentrations of hydrocarbons /125//131/.

Laboratory studies have shown that adult fish are able to detect oil in water at very low concentrations, and large numbers of dead fish have rarely been reported after oil spills /132/ /133/. This suggests that juvenile and adult fish are capable of avoiding water contaminated with high concentrations of oil.

Fish are most susceptible to the effects of spilled oil in their early life stages, particularly during egg and planktonic larval stages, which can become entrained in spilled oil. Contact with oil droplets can mechanically damage feeding and breathing apparatus of embryos and larvae /134/. The toxic compounds of oil in water can result in genetic damage, physical deformities and altered developmental timing for larvae and eggs exposed to even low concentrations over prolonged timeframes (days to weeks) /134/. More subtle, chronic effects on the life history of fish as a result of exposure of early life stages to oil include disruption of complex behaviours such as predator avoidance, reproductive and social behaviour /132/. Prolonged exposure of eggs and larvae to weathered concentrations of oil in water has also been shown to cause immunosuppression and allows expression of viral diseases /132/. However, the effect of an oil spill on a population of fish in an area with fish larvae and/or eggs, and the extent to which any of the adverse impacts may occur, depends greatly on prevailing oceanographic and ecological conditions at the time of the spill and its contact with fish eggs or larvae.

Concentrations of 100 ppb THC (total hydrocarbons) has been found to cause acute death of fish eggs and larvae /135/. According to the model results there is a risk that concentrations of 70-150 ppb in the water column can be found out to a distance of a 200-300 kilometres. At this concentration, the eggs and larvae of fish are likely to be affected.

Based on the modelling results, and the above information, the impact is assessed to be of medium intensity with a transboundary extent and a short to medium-term duration. Overall, the impact on the fish community from a major oil spill will be of major negative significance.

7.2.6.3 Overall assessment

The potential impacts on fish are summarised in Table 7-9.

Table 7-9 Potential impacts on fish related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Small	Regional	Short/medium-term	Minor negative	Medium
Major oil spill	Medium	Transboundary	Short/medium-term	Major negative	Medium

7.2.7 Marine mammals

Potential impact mechanisms to marine mammals are related to minor and major oil spill.

7.2.7.1 Minor oil spill

Oil spill from collisions or pipeline rupture may impact marine mammals which come into contact with the spill. Marine mammals generally avoid oil slicks, but impacts on individuals may occur through ingestion, inhalation or consumption of contaminated organisms. The extent of a minor oil spill is local (section 7.1.4). The intensity of the impacts is assessed to be small with a short-term duration. The overall impacts on marine mammals at the TYRA project are assessed to be of minor negative significance.

7.2.7.2 Major oil spill

A major oil spill may impact marine mammals which come into contact with the spill. Impacts are related to direct contact with the oil, where smothering of seals may occur leading to inflammation, infection, suffocation, hypothermia and reduced buoyancy /25/. Whales and dolphins do not have hair, and are not susceptible to smothering. Both whales and seals may accumulate toxins through ingestion (which can lead to digestive complications), inhalation (which can lead to respiratory damage, paralysis, death) or consumption of contaminated marine organisms.

The sensitive months for marine mammals in relation to a major oil spill have been determined based on the months where the species are present in the North Sea /25/. Grey seal, harbour seal and harbour porpoise are sensitive year-round, while minke whale and white-beaked dolping are sensitive in summer (May-September).

Modelling results show that oil may impact Danish, Swedish, German, Dutch, UK or Norwegian sectors of the North Sea, and the extent is thus considered transboundary. The intensity of the impact is considered to be large, as there may be an impact to the individuals, and also to populations.

Seals can also lose their shoreline habitat if oil washes up on their haul-out sites. Oil spill modelling has identified Denmark, Sweden and Norway as most vulnerable to oil beaching, although Germany, UK and the Netherlands could also be affected.

The intensity of the impact from a major oil spill is large, and may affect the ecosystem structure of marine mammals in the North Sea. The duration of the impact is long-term, and the overall impact on marine mammals from a major oil spill is assessed to be of major negative significance.

7.2.7.3 Overall assessment

The potential impacts are summarised in Table 7-10.

Table 7-10 Potential impacts on marine mammals related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Small	Local	Short-tem	Minor negative	Medium
Major oil spill	Large	Transboundary	Long-term	Major negative	High

7.2.8 Seabirds

Potential impact mechanisms to seabirds are related to minor or major oil spill.

7.2.8.1 Minor oil spill

A minor oil spill may impact seabirds, if they come into contact with the oil (see description of vulnerability below). The extent of a minor oil spill is considered local, and of medium-term duration. The intensity is considered small, as the impact of a minor oil spill will affect individuals and not populations. The overall impact on seabirds from a minor oil spill is assessed to be of moderate negative significance.

7.2.8.2 Major oil spill

Seabirds are vulnerable to oil spills in the marine environment. Oil may impact the insulating and water-resistant properties and affecting the buoyancy of the plumage causing the bird to suffer from hypothermia, starvation or in severe cases drowning. In addition, birds may get intoxicated from ingestion or inhalation of fuels when they are cleaning their plumages or are feeding on contaminated food. Intoxication may cause irritation of the digestive organs, damages to liver, kidneys and salt glands and leading to anaemia. The intensity of the impacts is therefore assessed to be large /25/.

Birds tend to nest in late spring and summer, which means juveniles are most vulnerable to oil spills in the spring and summer months, although adults of many species may be found in the North Sea all year. The window of vulnerability for migratory birds depends on whether they spend summer or winter along the North Sea coasts.

A major oil spill is assessed to have a transboundary extent and long-term duration. The overall impact on seabirds from a major oil spill is assessed to be of major negative significance.

7.2.8.3 Overall assessment

The potential impacts are summarised in Table 7-11.

Table 7-11 Potential impacts on seabirds related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Large	Local-Regional	Medium-term	Moderate negative	Medium
Major oil spill	Large	Transboundary	Long-term	Major negative	High

7.3 Assessment of potential social impacts

Impact assessment for the relevant social receptors is presented in this section for accidental events. The assessment is based on modelling data to evaluate the extent, while literature data is applied to assess the intensity and duration of impact.

7.3.1 Cultural heritage

Potential impacts on cultural heritage are related to oil spill.

Cultural heritage as wrecks or submerged settlements can be impacted by smothering of oil in connection with minor or major oil spills.

The impact will depend on the type of cultural heritage, and the type of oil spilled. The intensity of potential impacts is assessed to be medium, with a transboundary extent and medium-term duration. The overall impact on cultural heritage from oil spill at the TYRA project is assessed to be moderate negative.

7.3.1.1 Overall assessment

The potential impacts are summarised in Table 7-12.

Table 7-12 Potential impacts on cultural heritage related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor or major oil spill	Medium	National	Medium-term	Moderate negative	Low

7.3.2 Protected areas

Potential impact mechanisms are related to minor or major spill. Potential impacts on protected areas concerns nature reserves along the west coast of Jutland, and the UNESCO reserve Wadden Sea.

7.3.2.1 Minor oil spill

A chemical spill and an oil spill following vessel collision or pipeline rupture are all events which are considered of local extent, based on the presented modelling (section 7.1). As the TYRA project is located offshore (200 km from shore), minor oil spills are assessed to have no impact on protected areas.

7.3.2.2 Major oil spill

Major oil spill has been modelled (section 7.1). The potentially impacted areas include the Wadden Sea and the nature reserves along the west coast of Jutland. As a precautionary approach, the intensity of the impacts is assessed to be large, with transboundary extent and long-term duration. The overall significance of impacts on protected areas from major oil spill is assessed to be major negative.

7.3.2.3 Overall assessment

The potential impacts are summarised in Table 7-13.

Table 7-13 Potential impacts on protected areas related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	None	Local	Short-term	Negligible negative	High
Major oil spill	Large	Transboundary	Long-term	Major negative	Medium

7.3.3 Marine spatial use

Potential impact mechanisms are related to minor and major oil spill and major gas release.

7.3.3.1 Minor spill

Minor oil spill from e.g. collisions will impact ship traffic in terms of risk of fire, contamination of vessels and restriction areas, where emergency handling is taken place. The intensity of the impacts is assessed to be small, with national extent and short-term duration. The overall significance of impacts on ship traffic from minor oil spill is assessed to be minor negative.

7.3.3.2 Major oil spill

A major oil spill is assessed to impact ship traffic as risk of fire and contamination of vessels and as restriction areas where ship traffic is prohibited due to emergency handling. The impact will have a medium intensity with transboundary extent and medium-term duration. The overall significance of impacts on ship traffic from minor oil spill is assessed to be moderate negative.

7.3.3.3 Major gas release

An uncontrolled gas release will likely impact the ship traffic indirectly as spatial restrictions in connection with safety distance to blow out point and danger of fire. The impact is assessed to be of medium intensity, transboundary extent and short term. The overall significance of impacts on ship traffic from major gas release at the TYRA project is assessed to be minor negative.

7.3.3.4 Overall assessment

The overall assessment of impacts on ship traffic from accidental events at the TYRA project is summarised in Table 7-14.

Table 7-14 Potential impacts on marine spatial use related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Minor oil spill	Small	National	Short-term	Minor negative	Medium
Major oil spill	Medium	Transboundary	Medium-term	Moderate negative	Medium
Major gas release	Medium	Transboundary	Short-term	Minor negative	Medium

7.3.4 Fishery

Potential impact mechanisms related to major oil spill and gas release.

7.3.4.1 Major gas release

An uncontrolled gas release will likely impact the ship traffic indirectly as spatial restrictions in connection with safety distance to blow out point and danger of fire. The impact is assessed to be of medium intensity, transboundary extent and short term. The overall significance of impacts on fishery from gas release at the TYRA project is assessed to be minor negative.

7.3.4.2 Major oil spill

A major oil spill may impact fishery in terms of risk of reduced amount of areas that are available for fishing, when emergency handling is taking place. The intensity of the impacts on areas available for fishing is assessed to be medium, with regional extent and short-term duration. The overall significance of impacts on fishery from major oil spill is assessed to be minor negative.

Physical effects to target species for fishery may have other consequences for fishery. As impacts on fish and marine invertebrates from an oil spill are expected to be major negative, it is assessed that impacts on fisheries will also occur. Further impacts on fisheries may arise due to market perceptions of poor product quality (no buyers or reduced prices, etc.). A major oil spill in the North Sea may significantly decrease buyer's interest in fish and shellfish from the area. This can lead to loss of business and affect local economy. Perceptions are difficult to predict, since the actual (physical) impacts of the spill might have little to do with these perceptions. As a precautionary approach, the intensity of the impacts is assessed to be large, with transboundary extent and long-term duration. The overall significance of impacts on fishery from major oil spill is assessed to be major.

7.3.4.3 Overall assessment

The potential impacts are summarised in Table 7-15.

Table 7-15 Potential impacts on fisheries related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Gas release	Medium	Transboundary	Short-term	Minor negative	Medium
Major oil spill Impacts on fishery areas	Medium	Regional	Short-term	Minor negative	Medium
Major oil spill Impacts on target species	Medium	Transboundary	Medium-term	Major negative	Low
Major oil spill Perception/reputation	Large	Transboundary	Long-term	Major negative	Low

7.3.5 Tourism

Potential impact mechanisms for tourism are related to major oil spill.

7.3.5.1 Major oil spill

Impacts on tourism from accidental events include oil contamination on the beaches of the west coast of Jutland and impacts on the Wadden Sea national parks and possible also the southern coast of Norway.

The oil spill modelling show, that Danish, Norwegian, German, Dutch and UK shorelines could be affected by oil, though the Danish shoreline is most likely to be affected. The reputation of this can stop tourists from returning for years and give loss of business and affect local economy. An oil spill can thus result in long term effects on tourist attraction.

The intensity of the impacts is assessed to be large, with transboundary extent and long-term duration. The overall significance of impacts on tourism from a major oil spill at the TYRA project is assessed to be major negative.

7.3.5.2 Overall assessment

The potential impacts are summarised in Table 7-16.

Table 7-16 Potential impacts on tourism related to accidental events at the TYRA project

Potential impact mechanism	Intensity of impact	Extent of impact	Duration of impact	Overall significance of impact	Level of confidence
Major oil spill	Large	Transboundary	Long-term	Major negative	Medium

7.4 Summary

The potential impacts on environmental and social receptors from accidental events at the TYRA project are summarised in Table 7-17. The impact with the largest overall significance is provided for each receptor. The likelihood for major accidental events is very low with frequencies of order of magnitude 10^{-4} per year, cf. section 7.1.5.

Table 7-17 Summary of potential impacts on environmental and social receptors for accidental events at the TYRA project. The impact with the largest overall significance is provided for each receptor

Receptor	Worst case potential impact
Climate and air quality	Moderate negative
Water quality	Moderate negative
Sediment type and quality	Moderate negative
Plankton	Minor negative
Benthic communities	Major negative
Fish	Major negative
Marine mammals	Major negative
Seabirds	Major negative
Cultural heritage	Moderate negative
Protected areas*	Major negative
Marine spatial use	Moderate negative
Fishery	Major negative
Tourism	Major negative

* a separate assessment for Natura 2000 is presented in section 10.

8. MITIGATING MEASURES

Maersk Oil has identified several mitigating measures for planned activities and accidental events with an environmental or social risk. The mitigating measures are in place to eliminate or reduce the risk as low as reasonably practicable (ALARP). In addition to the risk mitigating measures, several monitoring campaigns are conducted around Maersk Oil platforms (section 9.3).

8.1 Mitigating risks from planned activities

8.1.1 Measures to reduce emissions

Generally, Maersk Oil works continuously to reduce emissions to the environment and improve the energy efficiency offshore by keeping a sharp focus on fuel and flare gas consumption and including energy efficiency considerations early in the design phase for all major projects and modifications. The production has become more energy efficient over the years, and in 2013 the Energy Management System at Maersk Oil was ISO-14001 certified. Annual audits of performance are part of this and the system is to be re-certified every third year (See also BAT/BEP in chapter 9).

8.1.2 Underwater noise mitigating measures

The risks of underwater noise on marine mammals in geophysical acquisition and construction projects are generally mitigated by:

- In areas where impacts on marine mammals are anticipated, best available technology will be assessed
- Planning and efficient execution of the geophysical data acquisition and construction projects to minimise the overall duration of the operations and noise exposure of sensitive species.
- Monitoring the presence of marine mammals before the onset of noise creating activities, and throughout the geophysical data acquisition or construction.
- An exclusion zone is implemented and operations will be delayed when the presence of marine mammal is detected before start-up of the operations.
- Soft-start procedures, also called ramp-up, are to be used in areas of known marine mammal activity. This involves a gradual increase in sound signal level to full operational levels allowing the animal to move away from any adverse sounds thus reducing the risk of possible effects from the generated underwater noise.

8.1.3 Discharge mitigating measures

Maersk Oil uses chemicals in its operations, and is constantly examining the use and discharge of chemicals. Maersk Oil has a target of zero harmful discharges. Before any chemicals can be permitted for use and discharge offshore, an application must be submitted to the DEPA. Part of the application is an environmental classification of each chemical carried out in accordance with the OSPAR Recommendation 2010/4 on a harmonised pre-screening scheme for offshore chemicals. The classification applies a colour coding system used by Maersk Oil based on the criteria outlined in OSPAR, 2010 /44/:

- **Black**: Black chemicals contain one or more components registered in OSPAR's 'List of Chemicals for Priority Action'. The use of black chemicals is prohibited except in special circumstances. Maersk Oil has not used them since 2005 but has dispensation in 2015 to use black pipe dope in part of the casing in the drilling of a high-pressure, high temperature exploration well.
- **Red**: These are environmentally hazardous and contain one or more components that, for example, accumulate in living organisms or degrade slowly. OSPAR recommendation is that the discharge of these chemicals must end by 1 January 2017. Since 2008, Maersk Oil has been phasing out red chemicals, using them only if safety, technological and environmental arguments require use. Discharges have decreased sharply since 2010.

- **Green**: These contain environmentally acceptable components recorded on OSPAR's PLONOR list that 'pose little or no risk' to the environment. Chemicals included in OSPARs List of Substances / Preparations Used and Discharged Offshore which are Considered to Pose Little or No Risk to the Environment (PLONOR) or covered by REACH EC1907/2006 Annex IV or Annex V.
- **Yellow**: These are chemicals not covered by other classifications, which either degrade slowly, are toxic or bioaccumulate. Yellow chemicals are subject to ranking and can normally be discharged.

The environmental risks and impact of operational discharges associated with production are mitigated through management of produced water through Risk Based Approach (RBA) in accordance with the OSPAR Guidelines and Recommendation /4/.

The RBA is used to review management options, evaluate measures and develop and implement site-specific actions to reduce environmental risks of production chemicals discharges which are not adequately controlled. Risk reduction measures may comprise some of the following:

- Technical measures, such as abatement at the source by redesign of the applied processes (water shut off in the well);
- Substitution of chemicals;
- Application of closed systems (e.g. injection of produced water);
- End-of-pipe techniques such as separation or clarification techniques to treat produced water prior to discharge, and;
- Organisational measures such as management systems in place (training, instructions, procedures and reporting).

An important tool within the RBA is the use of hydrodynamic models to predict the dispersion of the produced water outflow with a substance based approach /154/. This allows identifying the most important contributors to the risk and evaluating chemical substitution options while ensuring the application of BAT/BEP.

Furthermore, BAT/BEP studies are carried out for existing and future facilities. The aim of the studies is to assess options and ultimate use of technology and operating practices that provide economically viable solution with greatest overall risk and impact reduction (see chapter 9).

8.2 Tyra Future specific measures

On an overall level, the Tyra Future project represents a step change, in rationalisation of the existing facilities.

The existing facilities have undergone stepwise expanding development phases for its first 25 years of operation, with a peak capacity of some 1.300 MMscfd of gas for sales and re-injection. Since 2006, the production has been declining and the capacity has been reduced, all at the same power consumption, due to the gradually reducing pressure in the reservoir. The existing facilities are characterised by many parallel trains, operating at reduced load.

The Tyra Future project in essence constitutes a rationalisation of many parallel trains into a process based on one single train, and a downsized tail-end production rate.

8.2.1 Emissions /Flare

The main sources of emissions are power generation and flaring.

Power generation for Tyra Future is based upon central lower generation by gas turbines. All main process drivers, small process drivers and utility drivers are electrical driven.

The advantage is twofold:

- The sum of power required for the entire plant is distributed on common turbines, enabling an optimised operating point, and thus better efficiency for the turbines, as compared to individual turbine drivers for process equipment.
- The dominating effect however, is that the configuration enables a choice of turbine models with significantly higher fuel efficiency than smaller models available for individual equipment drivers.

Flare emissions are reduced by several initiatives:

- Use of nitrogen for purge and blanket gas
- Recovery of most flash gas from produced water treatment into the flash gas compressors
- Recovery of most flash gas from glycol regeneration into the flash gas compressors.
- Potential use of hermetic sealed compressors avoiding seal gas emissions.
- Use of "cold finger" technology for glycol regeneration. The "cold Finger" shall be maximized, to reduce use of stripping gas.

8.2.2 Chemical use

Chemical use is optimised again by the rationalisation of many parallel trains into one, enabling more efficient optimisation.

Application of process heating for liquid/liquid separation is expected to reduce emulsion breaker chemicals.

Application of new produced water treatment technology is expected to reduce chemical consumption. Processing of reject and skimmed streams is based on "once trough and out", rather than recycling, which again by avoiding recycle of impurities and production chemicals improve the control of the process leading to optimisation of chemical use.

8.3 Mitigating risks from accidental events

Maersk Oil reports all accidental discharges of oil and chemicals, regardless of volume. Measures are introduced to reduce the volume and number of spillage through e.g. inspections and training. Maersk Oil follows industrial best practices for prevention of major accidents based on identification of major hazards assessed through risk assessment /136/.

Maersk Oil strives to reduce the risk of major accidents to as low as reasonably practicable (ALARP) through the identification of major hazards in risk analyses and the development of barriers (e.g. procedure, training, and design). For example, facilities are protected against collision by installing boat fenders to jackets. Processing facilities, wells and pipelines are protected against large release by safety valves. A safety zone around pipelines and platforms is implemented to prevent collisions from bottom trawling equipment or anchoring. Procedures are in place to restrict supply vessel traffic and hose handling in case of rough weather (see also Appendix 1).

The risk assessment and reduction measures are regularly updated in case of significant new knowledge or technology development.

As part of the licensing process, the Danish Working Environment Authority assesses the risk mitigation measures for new offshore platforms, in accordance with the ALARP principle.

Emergency response and contingency planning are also developed to limit the consequence in case of a major accident related to its projects. Maersk Oil's oil spill contingency plan is summarised in section 9.5.

9. ENVIROMENTAL STANDARDS AND PROCEDURES IN MAERSK OIL

9.1 Environmental management system

Maersk Oil operates with an ISO 14001 certified environmental management system /121/. The objective of the environmental management system is to minimise the impact on the environment by continually improving the environmental performance.

The objective shall be achieved by:

- Maintaining a complete and effective environmental management system
- Providing timely and effective innovative actions to reduce environmental impact
- Promoting the awareness of environmental matters at all organisational levels
- Minimising environmental impact through principles of best available technology (BAT) and best environmental practice (BEP).

9.2 Environmental and social impact in project maturation

An Environmental and Social Impact Assessment standard /159/ that lays out the process for managing environmental and social risk impacts of new large projects has recently been implemented in Maersk Oil. The standard provides a framework embedded within the Maersk Oil project maturation process which will be used from start and throughout the different development phases of future development projects.

For example, the standard has been used in early phase of the TYRA Future project. Several studies have been carried out during the design of the facilities. The aim of these studies was to reduce operational environmental impact of the new facilities as low as reasonably practical, see section 9.4.3. This included BAT studies for emissions and for produced water /185//186/, and an Environmental Aspect Register /187/.

9.3 Project-specific Environmental and Social Management Plan

A project-specific environmental and social management plan (ESMP) is developed for the Tyra Project /193/. The ESMP covers the construction, operation and decommissioning phases of the project. The ESPM builds on requirements stipulated in Maersk Oil Standard – Environmental and Social Impact Management in Projects /159/ in terms of environmental and social impact activities and deliverables, consultation with regulators and communities, option evaluation, baseline studies, Best Available Techniques studies, impact assessment, impact management planning and mitigation and monitoring.

The purpose of the ESMP is to establish a framework for ensuring that systems and processes are in place for facilitating the following during construction, operation and decommissioning:

- HSE Risks (accidents) are reduced to a level As Low As Reasonably Practicable (ALARP),
- Equipment and modes of operation are to be considered as Best Available Technology (BAT).

Both HSE risks and environmental impacts are minimised as an integral part of the design work.

The ESMP considers environmental and social risk management, environmental and social impact assessment, regulatory context and compliance, performance targets and improvement plan and monitoring and control mechanisms.

An environmental aspects register has been developed and reported as part of the Tyra Future Redevelopment FEED /187/. The scope of this aspects register entails all activities impacting the environment during the operation stage of the Tyra East, Tyra West, Wellhead and Riser

Platforms. Apart from normal operation phase, the environmental aspects register includes the effect of non-routine situations during operation phase such as maintenance, emergency conditions, start-up, and shutdown activities. Environmental aspects and impacts were identified for energy and natural resources consumption, discharges to sea, emissions to air, waste, noise and decommissioning.

The Technical Sections, appendix 1 to this Environmental and Social Impact Statement (ESIS), includes an environmental aspects register that covers the entire project and is therefore what has made the basis for the impact assessment as reported in the ESIS.

9.4 Demonstration of BAT/BEP

9.4.1 General philosophy

The OSPAR Convention of 1992 requires contracting parties to apply best available techniques (BAT) and best environmental practice (BEP) including, where appropriate, clean technology, in their efforts to prevent and eliminate marine pollution.

As defined the OSPAR convention BAT *means the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste*. BEP is defined as *the application of the most appropriate combination of environmental control measures and strategies*.

It follows that BAT and BEP for a particular source will change with time in the light of technological advances, economic and social factors, as well as changes in scientific knowledge and understanding.

BAT has also been implemented in the EU IPCC directive 96/61/EC, and the IE directive (2010/75/EU). The Danish Law on Environmental Protection of the Sea refers to BAT and BEP (§3). The BAT principle is illustrated in Figure 9-1.

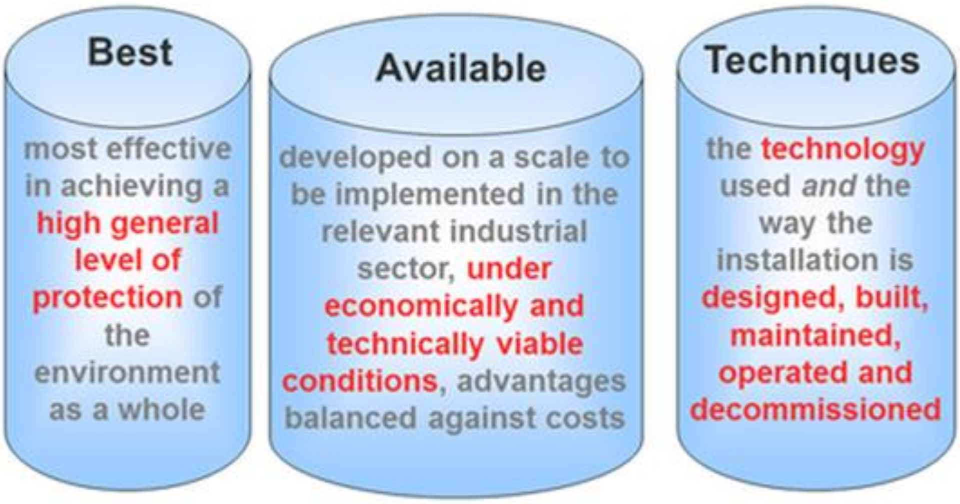


Figure 9-1 Illustration of best available technique /156/

It is a Maersk Oil objective to implement the principles of BAT and BEP in an effort to minimize the potential environmental impacts of activities in the North Sea. This entails that environmental concerns are addressed and encompassed in the planning phase. The BAT/BEP principle has been used in the design and operation of the installations and process equipment of Maersk Oil as well as for the selection of materials and substances.

Examples of how Maersk Oil applies BAT and BEP include measures to:

- Improving energy efficiency
- Monitoring and minimising emissions
- Optimising the use and discharge of chemicals, aiming towards zero discharge
- Supporting the development of chemicals with less environmental impact
- Use of efficient equipment during well test
- Continuous review and assessment of projects and applied equipment

9.4.2 Produced water treatment

9.4.2.1 Current system

TYRA facilities are equipped with technology such as hydrocyclones for treatment of produced water, which are included in the OSPAR, 2013, Background Document concerning Techniques for the Management of Produced Water from Offshore Installations, providing an overview of BAT for handling of produced water. Produced water system overview is shown for Tyra East and West in Figure 9-2 and Figure 9-3.

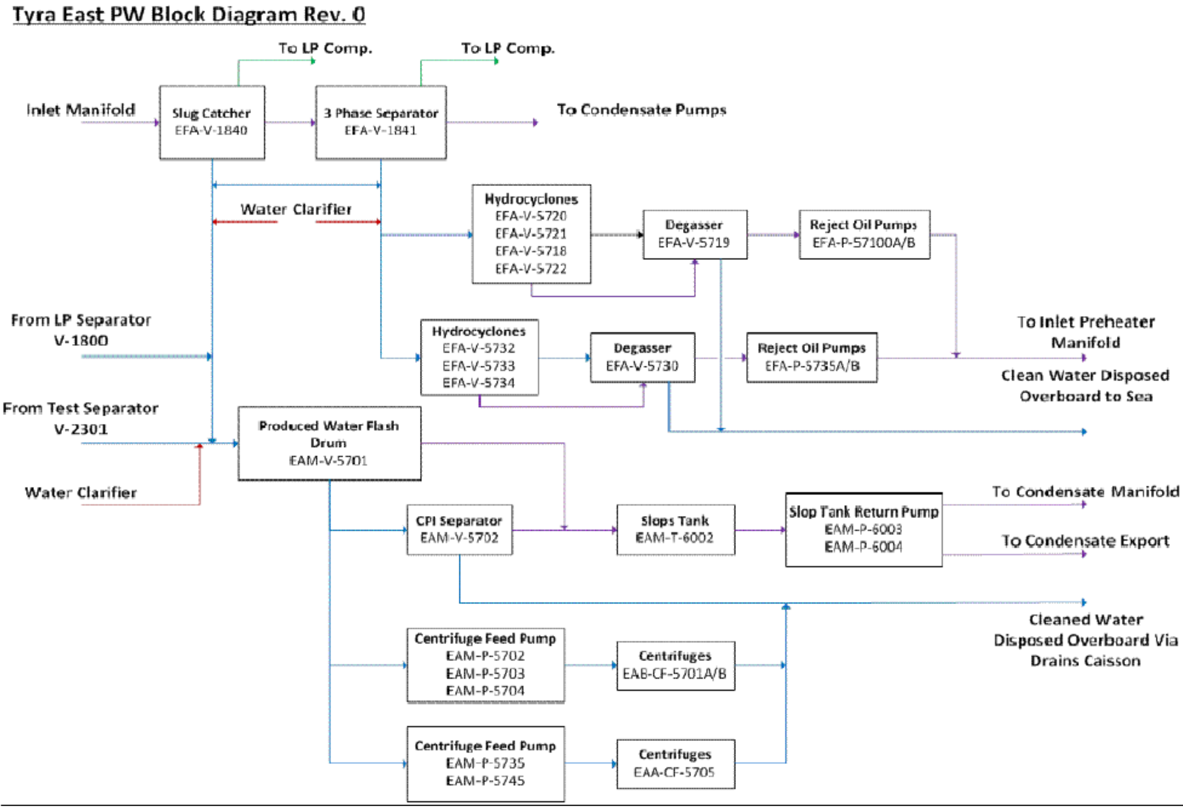


Figure 9-2 Tyra East produced water system overview

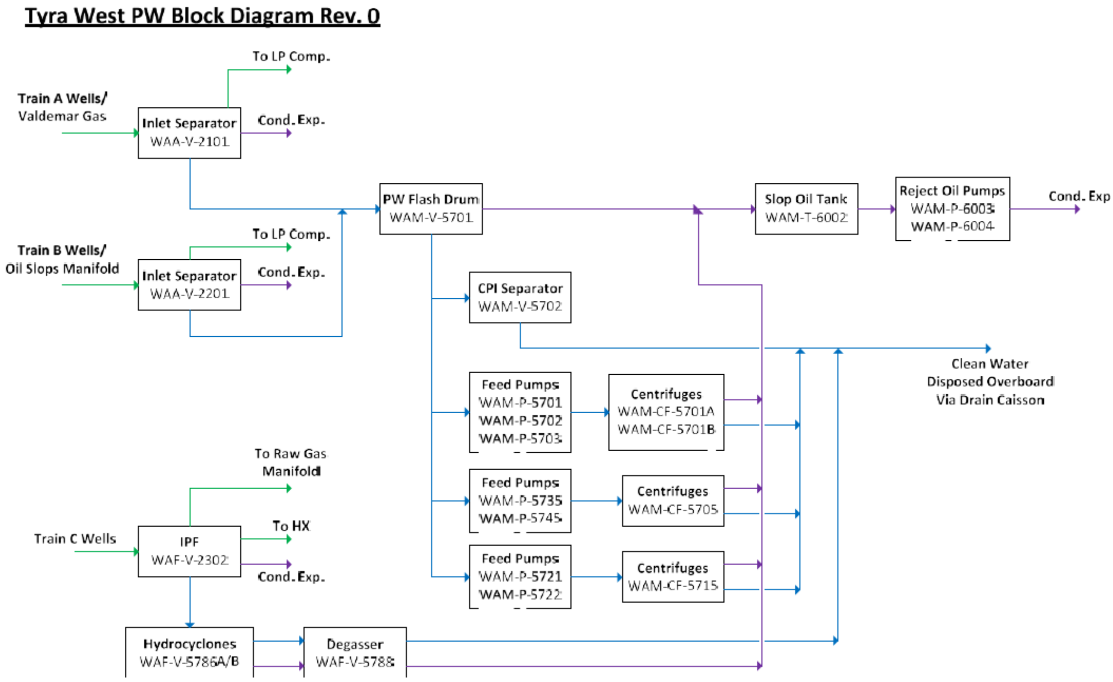


Figure 9-3 Tyra West produced water system overview

In the current discharge permit, Maersk Oil lists initiatives to improve its environmental performance at TYRA. These include the optimisation of procedures and equipment. It is also currently evaluated the possibility to change centrifuges at Tyra East and Tyra West to improve process performance. The latest discharge permit including the list of initiatives is available upon direct request to the DEPA.

9.4.2.2 Tyra Future redeveloped system

The produced water treatment technology for Tyra Future is identified to be based hydrocyclones and induced gas flotation. Depending upon choice of manufacturer, two options are identified for induced gas flotation:

- Large Hydraulic Induced Gas Flotation Unit
- Two stages, Compact Flotation Unit followed by Induced Gas Flotation Unit

Further, depending upon choice of manufacturer, pumps may be required upstream the hydrocyclones in late life, which is characterised by low pressure operation.

The Tyra Future redeveloped produced water system overview is shown in Figure 9-4.

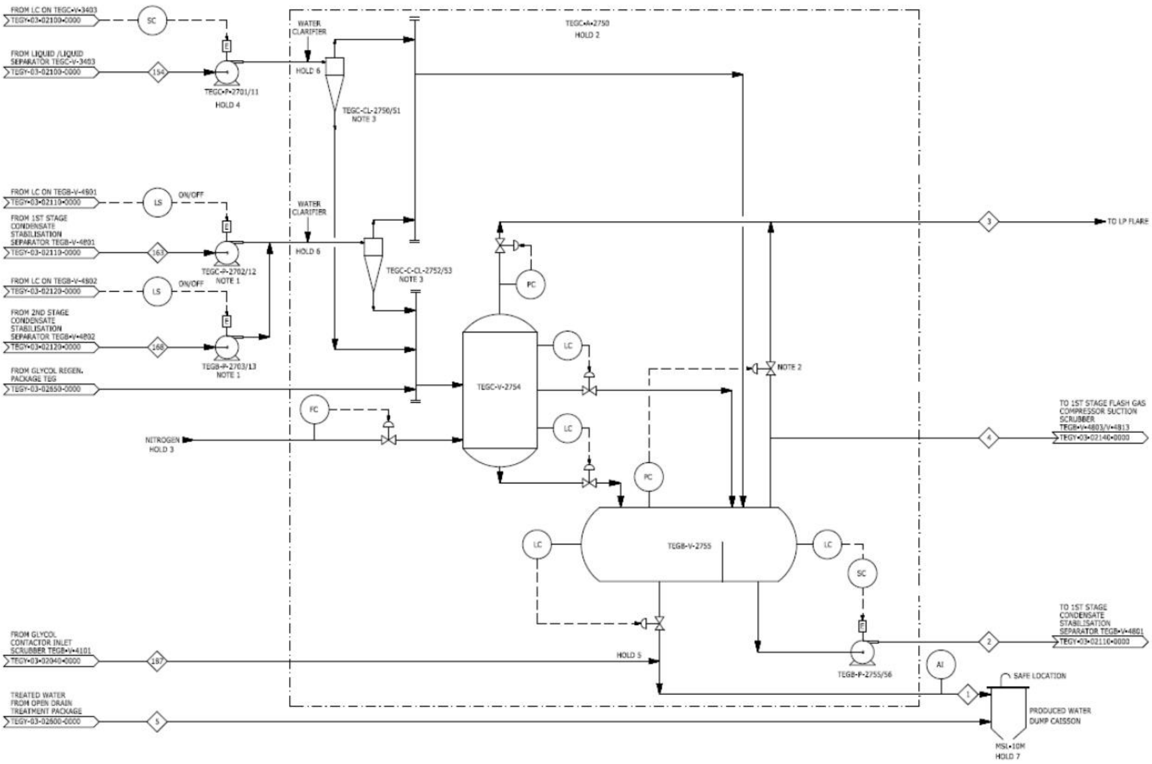


Figure 9-4 Tyra Future redeveloped produced water system overview

9.4.3 BAT studies related to Tyra Future redevelopment

BAT (Best Available Technology) studies have been carried out in connection with Tyra Future project planning and facilities design. The BAT studies aim to compare alternative design options and assess selected technologies and operating practises that provide the best environmental protection.

A BAT study for atmospheric emissions considers an overview of atmospheric emissions sources expected from the project, and a forecast of atmospheric emissions based on maximum operating capacity. The study aims at minimising emissions to air, via optimisation of energy utilisation and the energy generation process and minimisation of flaring and venting. BAT Reference Document on Large Combustion Plants update expected to be issued in 2017 need to be considered once officially published.

A BAT study for discharges to sea considers an overview of discharges of produced water and a forecast of discharges to sea based on the maximum operating capacity. Based on OSPAR agreement to reduce total discharge to sea, DUC has a 202 tonnes/year ceiling of oil with produced water. The produced water treatment package to be installed in the redeveloped Tyra process facilities shall be designed to reduce oil-in-water concentration down to a monthly average target of max. 6 mg/l. The study concludes on production chemicals required to operate the facilities to be reduced as possible and shall be replaced for more efficient and/or environmentally friendly products as available and applicable, and measures shall be considered to mitigate of prevent accidental spills during operation.

The BAT study considers technical proposals from different potential manufacturers, that all confirm 6 mg/l to be achievable under normal operation conditions, i.e. upstream separation functioning normally. In case of disturbance or upset of upstream separation the effect on oil-in water content, according to manufacturer specifications, is marginal, increasing to around 8 mg/l.

9.5 Oil spill contingency plan

Maersk Oil's emergency preparedness in connection with serious incidents offshore on and around Maersk Oil's installations and in Danish concession areas held by A.P. Møller-Mærsk is centred around and coordinated by permanently established emergency committees.

Maersk Oil has developed an oil spill contingency plan /121/, which describes how to combat possible oil spills. Oil spill scenarios up to and including the worst credible case discharge scenario for Maersk Oil facilities and wells have been considered to ensure an appropriate tiered capability is established.

- Tier 1 for small operational spills
  - Mobilise oil spill monitoring/surveillance vessel
  - Oil spill drift modelling
  - Use in-field vessel with boom/250 m^3 per hour skimmer equipment mobilised within 8 hours

- Tier 2 for medium spill volume
  - Tier 1 measures with additional measures
  - Use of additional resources (boom, several 200 m^3 per hour skimmer and transfer pump/hoses) mobilised from Esbjerg or from the Danish National stockpile within 20 hours to handle more than 1,500 tons per day
  - Waste removal is done by dedicated tanker

- Tier 3 for blow out
  - Tier 2 measures with additional measures
  - Mobilise trained personnel and additional equipment from Oil Spill Response Ltd (OSRL).
  - Mobilise relief well contractor
  - Consult NGOs regarding wildlife response

Maersk Oil has access to oil spill equipment offshore and in Esbjerg that can be mobilised to an oil spill location immediately. If necessary, additional equipment will be mobilised from the Danish stock pile and OSRL. Maersk Oil is a participant member of OSRL and has access to their world-wide pool of personnel and equipment. OSRL's main equipment stockpile in Europe is based in Southampton in the UK but additional equipment is also available in Stavanger.

The use of dispersant chemicals to increase oil dispersion, dilution and natural breakdown will be evaluated when relevant. The use of dispersant chemicals is regulated and dispersant may only be used after approval by DEPA.

Regular emergency exercises (oil spills) are carried out as a minimum every three years to train and motivate personnel, test the equipment and to ensure plans as described are effective. Relevant authorities participate in the exercise.

9.6 Ongoing monitoring

Maersk Oil has flowmeters that continuously measures the volume of discharged produced water, and water samples are regularly obtained for analysis of oil content. The nature, type and quantities of chemicals used and chemicals and oil discharged to sea are reported to the Environmental Protection Agency.

Monitoring of sediment quality and benthic fauna is undertaken at regular intervals around Maersk Oil platforms /6/.

- The physical and chemical analyses included grain size analysis, dry matter (DM), loss on ignition (LOI), total organic carbon (TOC), metals (barium (Ba), cadmium (Cd), chromium

(Cr), copper (Cu), lead (Pb), zinc (Zn), mercury (Hg) and aluminium (Al)), Total hydrocarbons (THC), Polycyclic aromatic hydrocarbons (PAH) and oil specific group of alkylated aromatic hydrocarbons (NPD).
- Samples obtained for identification and quantification of the benthic fauna

In addition, Maersk Oil monitors underwater noise and marine mammals through passive acoustic monitoring and an offshore sighting program in which offshore staff reports sightings of marine mammals near platforms.

Figure 9-5 Acoustic monitoring of marine mammals (Photo: Aarhus University, DCE)

Currently, emission monitoring is not installed at the gas turbines on Tyra. However, manual samples are taken once a year to measure the composition of the emissions. Manual sampling of the exhaust will be continued on new power generation. However a provision will be made to install automatic monitoring of exhaust composition.

10. NATURA 2000 SCREENING

10.1 Introduction

The Natura 2000 network comprises:

- Habitats Directive Sites (Sites of Community Importance and Special Areas of Conservation) designated by Member States for the conservation of habitat types and animal and plant species listed in the Habitats Directive
- Bird Directive Sites (Special Protection Areas) for the conservation of bird species listed in the Birds Directive as well as migratory birds

This section constitutes the Natura 2000 screening in accordance with the EC habits Directive and Order 408/2007, § 7.

10.2 Designated species and habitats

The designated Natura 2000 sites are shown in Figure 10-1.

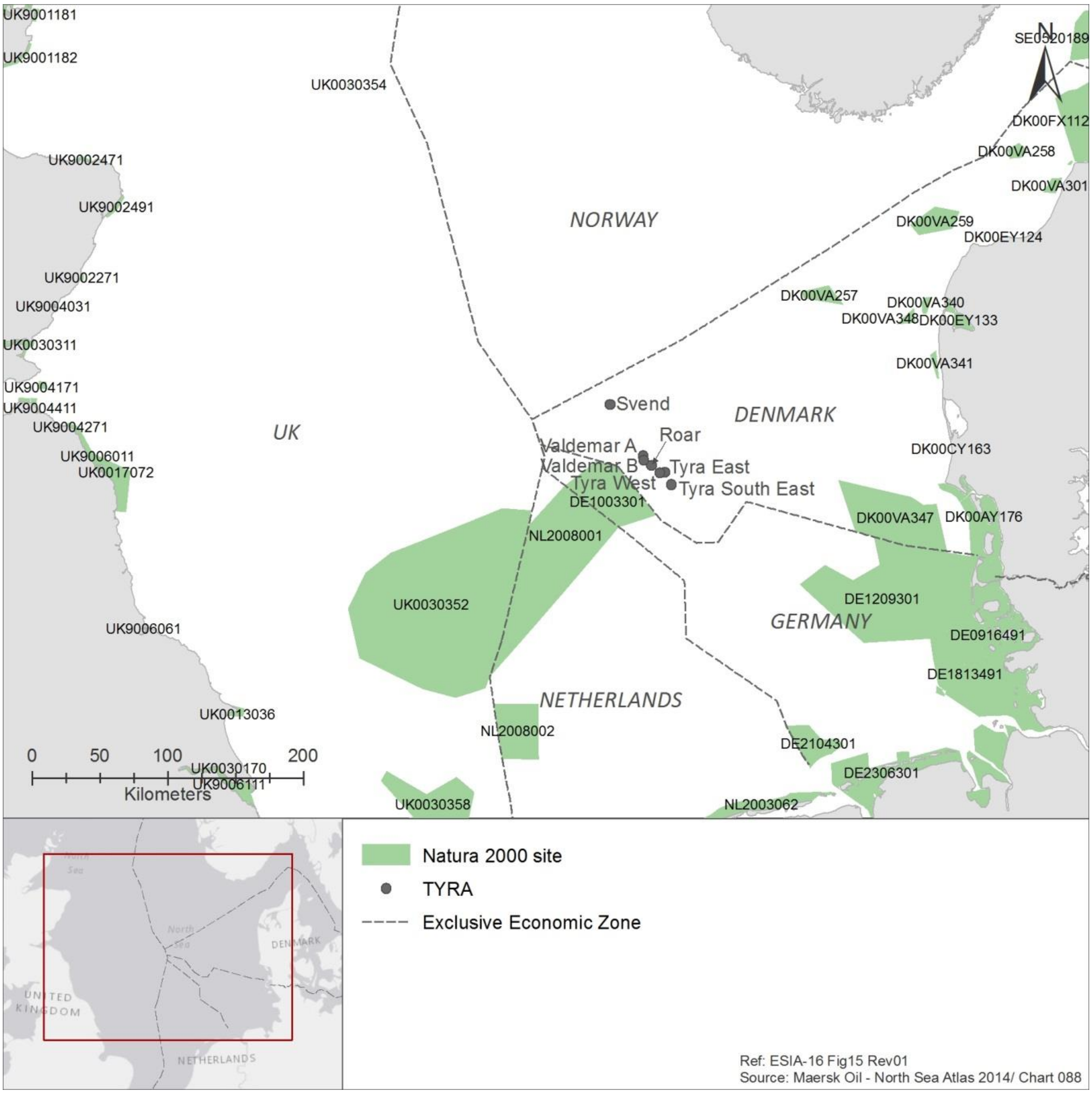


Figure 10-1 Natura 2000 sites in the North Sea

Natura 2000 sites in the central North Sea are detailed in Table 10-1.

Table 10-1 Natura 2000 sites in the central North Sea

Natura 2000 Site code	**Name**	**Designated marine species and habitattypes**
UK0030352	Dogger Bank	• 1110 Sandbanks which are slightly covered by sea water all the time • 1351 *Phocoena phocoena* • 1364 *Halichoerus grypus* • 1365 *Phoca vitulina*
NL2008002	Klaverbank	• 1170 Reefs • 1351 *Phocoena phocoena* • 1364 *Halichoerus grypus* • 1365 *Phoca vitulina*
NL2008001	Doggersbank	• 1110 Sandbanks which are slightly covered by sea water all the time • 1351 *Phocoena phocoena* • 1364 *Halichoerus grypus* • 1365 *Phoca vitulina*
DE1003301	Doggerbank	• 1110 Sandbanks which are slightly covered by seawater all the time • 1351 *Phocoena phocoena* • 1365 *Phoca vitulina* • *Fulmarus glacialis, Larus fuscus, Morus bassanus, Rissa tridactyla, Uria aalge*
DE1209301	Sylter Außenriff	• 1110 Sandbanks which are slightly covered by sea water all the time • 1170 Reefs • 1351 *Phocoena phocoena* • 1364 *Halichoerus grypus* • 1365 *Phoca vitulina* • 1103 *Alosa fallax* • *Gavia arctica, Gavia stellata, Lampetra fluviatilis, Larus canus, Larus fuscus, Larus marinus, Larus minutus, Morus bassanus, Rissa tridactyla, Sterna hirundo, Sterna paradisaea, Sterna sandvicensis, Uria aalge*
DK00VA347	Sydlige Nordsø	• 1110 Sandbanks which are slightly covered by sea water all the time • 1351 *Phocoena phocoena* • 1364 *Halichoerus grypus* • 1365 *Phoca vitulina* • *Gavia stellata, Gavia arctica, Larus minutus, Sula bassana, Somateria mollissima, Melanitta nigra, Stercorarius skua, Uria alge, Alca torda, Alle alle*
DK00VA257	Jyske Rev	• 1170 Reefs • 1351 *Phocoena phocoena*

Favourable conservation status for species is defined as when:

- Population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and;
- The natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and;
- There is, and will probably continue to be, a sufficiently large habitat to maintain its population on a long term basis.

Favourable conservation status of habitat types requires that:

- Its natural range and areas it covers within that range are stable or increasing, and;
- The specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and;
- The conservation status of its typical species is favourable.

10.3 Screening

The screening is carried out to identify all those elements of the project or plan, alone or in combination with other projects or plans that may have significant impacts on the Natura 2000 site.

No activities associated with the TYRA project are planned to occur within the designated Natura 2000 sites. The distance from the TYRA project to the nearest Natura 2000 site is 18 kilometres.

Planned activities at the TYRA project have been assessed in section 6. Potential impacts on Natura 2000 sites include underwater noise and discharges.

10.3.1 Underwater noise

A number of activities at TYRA may generate underwater noise, including seismic surveys, drilling, decommissioning and presence of production platforms and vessels. There is no geographical overlap between the TYRA area and Natura 2000 sites, but underwater noise propagate. The results from the modelling of underwater noise effects on marine mammals are described in section 6.2.8.1 and in /184/. Contour plots of the distribution of underwater noise for pile driving and conductor driving from the TYRA area (Figure 6-3 to Figure 6-10) show propagation of sound above defined sound levels (TTS or PTS) /184/.

The modelling results on effects of underwater sound from piling on seals show no propagation of sounds above TTS levels into nearby Natura 2000 sites. Figure 6-3 and Figure 6-4 shows results from jacket piling, while Figure 6-7 and Figure 6-8 shows results from conductor driving.

Based on the modelling results on underwater sound from jacket piling in the Tyra area there is an overlap of up to 0.6 km during summer and 4 km during winter between the TTS zone for harbour porpoise and the Natura 2000 site DE1003301 Dogger Bank (Figure 6-5 and Figure 6-6) when looking at the cumulative underwater noise during the whole piling period. Underwater noise from conductor driving on harbour porpoise has a lower impact than jacket piling and does not propagate into Natura 2000 sites (Figure 6-9 and Figure 6-10).

The potential risk of marine mammals to be affected by noise levels above their TTS level varies in geographical distribution and numbers depending on species (Table 6-17). Time of year is also important due to effects of water temperature on sound propagation and due to higher numbers of harbour porpoises being present during winter. Based on worst case scenario (winter conditions) harbour porpoises within a distance of 30 kilometres are at risk of experiencing noise levels above the TTS limit. Potential effects of noise levels above TTS will disappear again after a short time (minutes) or longer (hours) depending on time of exposure /138/. The potential risk of TTS is therefore not considered critical for the population of harbour porpoises in the North Sea as the duration of the pile driving is limited to a short period. Given the modelling result for piling is based on worst case scenario and the short duration time of jacket piling, it is assessed that underwater noise will not have significant environmental effects on the conservation objectives of the habitat types or species in the Natura 2000 sites.

10.3.2 Discharges

The main discharges are related to production and drilling, though other minor negative discharges may also occur (e.g. from vessels).

- Discharges of water based mud and cuttings during planned drilling activities are expected to occur from a drilling rig (at the existing and new wellhead platforms). The distance to which impacts on pelagic environment may occur has previously been modelled for a typical well, and is up to 7 km from the discharge (section 6). The area where impacts may occur will depend on the currents, and will likely follow the prevailing northward currents. The distance to which impacts on sediment quality has also been modelled, and is assessed to be within a few hundred metres for the drilling rig (section 6.2.4). The distance from the point of discharge (Tyra East and West) to the nearest Natura 2000 site it approximately 18 km. Based on the distance, it is therefore assessed that production activities will not have significant environmental effects on the conservation objectives of the habitat types or species in the Natura 2000 sites.
- Discharges from production are expected to continue until 2042, and will occur at Tyra East and West. The distance to which potential risk of impacts on the pelagic environment may occur has been modelled, and is up to 14 km from the point of discharge (section 6). The area will depend on the currents, and will likely follow the prevailing northward currents. The distance from the point of discharge (Tyra East and West) to the nearest Natura 2000 site is 18 km. Based on the distance, it is therefore assessed that production activities will not have significant environmental impacts on the conservation objectives of the habitat types or species in the Natura 2000 sites.
- Discharges from decommissioning activities are expected to be minor (section 6.2.3.2). Structures (jacket and topside) will be cleaned, before transport to shore. The minor discharges during decommissioning (e.g. cooling water, grey wastewater from vessels) are assessed to have no significant environmental effects on the conservation objectives of the habitat types or species in the Natura 2000 sites.

10.4 Conclusion

It is assessed that planned activities at the TYRA project will not have significant environmental impacts on the conservation objectives of the habitat types or species in the Natura 2000 sites.

11. TRANSBOUNDARY IMPACTS

11.1 Introduction

The TYRA project refers to the project that covers activities for the remaining lifetime of operation at the Tyra facilities, until 2042. It covers existing and planned projects for the Tyra East and West facilities and their satellite platforms Tyra Southeast, Valdemar (A and B), Roar and Svend, including all pipelines that are departing from any of those platforms. Tyra Future refers to the redevelopment project of the existing Tyra East and Tyra West facilities, planned for execution in the period 2018-2022.

This Maersk Oil DBU ESIS TYRA shall replace the ESIS prepared in 2016 (ESIA-16) for TYRA. It is an update of the ESIA-16 ESIS TYRA incorporating the Tyra Future redevelopment project.

In this section, a summary of the TYRA project and its likely significant transboundary impacts is provided. The section is focused on providing sufficient information to facilitate the identification of possible transboundary impacts. The rationale and support for the attributed level of significance and spatial extent can be found in detail in the relevant sections of the ESIS (section 6 and 7).

11.2 ESPOO convention

The ESPOO convention states that the concerned parties likely to be affected by transboundary adverse significant impacts are to be informed of and provided with possibilities for making comments or objections on the proposed activity.

The TYRA project can be found as item 15 (offshore hydrocarbon production) on the list of activities in appendix I to the convention, that are likely to cause a significant adverse transboundary impact.

11.3 The TYRA project

11.3.1 Existing production and processing facilities

Production was initiated at Tyra East and West in 1984, then later Tyra South East (2002), Valdemar (1993), Roar (1996) and Svend (1996). The total production peaked in 2005 and has been on a natural decline since. Maersk Oil has the license to explore for and produce oil and gas was extended until 8 July 2042.

Tyra East and West are primarily oil and gas producing and processing platforms that receives, processes and sends to shore the entire gas production. Treated produced water is discharged to sea at Tyra East and West

Valdemar (A and B) consist of three unmanned wellhead platform, while Tyra South East, Roar and Svend each comprise one unmanned wellhead platform.

The processing facilities include hydrocarbon processing equipment (oil stabilisation, gas processing and processing of production water), auxiliary safety systems such as an emergency shutdown system, emergency blow-down system, fire and gas detection system, firewater system, etc.

11.3.2 Planned development activities

The following main activities are planned to continue and optimise the production for the TYRA project and potentially access new hydrocarbon resources:

- Seismic investigations provide information to interpret the geological structure of the subsurface and to identify the location and volume of remaining and potential new hydrocarbon reserves. Seismic data is also acquired as part of drilling hazard site surveys to map and identify potential hazards to the installation of drilling rigs and to the drilling operation. Seismic data are also acquired as part of seabed and shallow geophysical surveys to map seabed and shallow soil conditions for the design and installation of pipelines, platforms and other structures.

- New structures and pipelines are expected as a consequence of development projects planned within the remaining lifetime of the facilities. Establishment of up to six new wellhead platforms, with connecting pipelines.
- Drilling of up to 24 wells in free well slots and 32 wells at the new structures may be done under the TYRA project. Slot recovery or re-drilling from existing wells is not expected. Drilling is performed from a drilling rig, which is placed on the seabed. Different types of drilling mud will be used based on the well and reservoir properties. Water-based mud and cuttings will be discharged to the sea, whereas oil-based mud and cuttings will be brought onshore to be dried and incinerated.
- Well stimulation will be performed to facilitate hydrocarbon extraction (for a production well) or water injection (for an injection well).

11.3.3 Accidental events

As part of the production, accidental spills of oil, gas or chemical may occur. There is a risk of accidents that could lead to major significant environmental and social impacts, such as vessels collisions or a well blow out. The risk of a well blowout is very unlikely.

11.3.4 Alternatives

The offshore oil and gas production is important to Danish security of supply and Danish economy. Tyra has an estimated production reserve equivalent to 250 million barrels of oil equivalent. About 500 people are employed with and on the Tyra facilities and another 4,000 Danish jobs are dependent on Tyra. Tax revenue to the state of Denmark is significant. The state’s total revenue is estimated to DKK 20 billion per year.

The Danish government has set a target of 30 % of the Danish energy use is provided from renewable energy by 2020. As part of a long-term Danish energy strategy, the oil and gas production is considered instrumental in maintaining high security of supply. Denmark is expected to continue being a net exporter of natural gas up to and including 2025 and Maersk Oil has a license to operate until 2042 /35/.

At the time of issue of this ESIS the project is subject to clarification of the economic framework for continued production of oil and gas from TYRA. Should the project prove non-viable, a number of options will be pursued, but for the project at hand no alternatives exist for provision of a similar redevelopment.

Technical alternatives

Best environmental practice for the different type of activities planned for the TYRA project (seismic, pipelines and structures, production, drilling, well stimulation, transport and decommissioning) is frequently monitored and applied when feasible.

Alternative location

The TYRA project is a continuation of production and activities at existing facilities. As such, there is no alternative location for the project.

11.4 Identified impacts – planned activities

Potential impacts to environmental and social receptors during planned activities at the TYRA project have been assessed in section 6. A summary of the potential worst case impacts is presented in Table 11-1.

Table 11-1 Summary of potential impacts on environmental and social receptors from planned activities at the TYRA project. The impact with the largest overall significance is provided for each receptor (without mitigating measures).

Receptor	Worst case potential impact	
	Extent	Overall significance of impact
Climate and air quality	Transboundary	Moderate negative
Hydrography	Local	Minor negative
Water quality	Local	Minor negative
Sediment type and quality	Local	Minor negative
Plankton	Local	Minor negative
Benthic communities	Local	Minor negative
Fish	Local	Minor negative
Marine mammals	Local or regional	Moderate negative
Seabirds	Local	Minor negative
Cultural heritage	None	None
Protected areas (UNESCO, nature reserve)	None	None
Natura 2000	No significant environmental effects	
Marine spatial use	Local	Negligible negative
Fishery	Local	Negligible negative
Tourism	None	None
Employment and tax revenue	Local or national	Positive
Oil and gas dependency	Local or national	Positive

Transboundary adverse impacts have been identified for climate and air quality, where the emissions from the TYRA project may contribute to climate change and air pollution. Maersk Oil has implemented a structured energy efficiency process and conduct a comprehensive review to identify ways to improve energy efficiency offshore. The production has become more energy efficient over the years, and in 2010 the environmental management system at Maersk Oil was ISO-14001 certified.

No other significant adverse transboundary impacts have been identified for the planned activities at the TYRA project.

A Natura 2000 screening is presented for the planned activities. It is assessed that the planned activities will have no significant environmental effects on the conservation objectives of the habitat types or species in the national and international Natura 2000 sites (section 10).

11.5 Identified impacts – accidental events

Potential impacts to environmental and social receptors during accidental events from the TYRA project have been assessed in section 7. A summary of the worst case potential impacts (without mitigating measures) is presented in Table 11-2.

Table 11-2 Summary of potential impacts on environmental and social receptors for accidental events at the TYRA project. The impact with the largest overall significance is provided for each receptor (without mitigating measures).

Receptor	Worst case potential impact	
	Extent	Overall significance of impact
Climate and air quality	Transboundary	Moderate negative
Water quality	Transboundary	Moderate negative
Sediment type and quality	Transboundary	Moderate negative
Plankton	Transboundary	Minor negative
Benthic communities	Transboundary	Major negative
Fish	Transboundary	Major negative
Marine mammals	Transboundary	Major negative
Seabirds	Transboundary	Major negative
Cultural heritage	National	Moderate negative
Protected areas (UNESCO, nature reserve)	Transboundary	Major negative
Marine spatial use	Transboundary	Moderate negative
Fishery	Transboundary	Major negative
Tourism	Transboundary	Major negative

If a major oil spill occurs, there is a risk of major negative transboundary impacts. The risk of a major oil spill is very unlikely, but could potentially have significant, adverse transboundary impacts. Oil released could cross maritime boundaries with Norway, Germany, the Netherlands and the UK. The oil spill modelling identified the north and west of Denmark and south Norway as most vulnerable to oil beaching, although Germany, UK and the Netherlands could also be affected.

Maersk Oil follows industrial best practices for prevention of accidents based on identification of major hazards assessed through risk assessment. Emergency response and contingency planning are also developed to limit the consequences of a major accident related to its projects.

12. LACK OF INFORMATION AND UNCERTAINTIES

Uncertainty may be viewed as an inescapable part of assessment of impacts of plans, programmes or projects.

12.1 Project description

The project description has been based on input from Maersk Oil. The project description is based on a scenario with maximum activity, emissions and discharges.

For some activities, the location and/or timing has not been decided. This will be done as part of the preparation of the detailed planning of the activities. The ESIS is undertaken using a worst case approach, and therefore alterations to location and/or timing is assessed to be of minor influence to the assessments.

The understanding of the contribution of the TYRA project to the employment and tax revenue has not been described specifically and in details. The assessment is based on the overall DUC contribution.

12.2 Environmental and social baseline

The central North Sea is relatively well known, and the environmental and social baseline is generally considered sufficient for the ESIS.

However, a few receptors are less well understood:

- The distribution and biology of non-commercial fish species is scarce, and knowledge of spawning areas is limited.
- The variability of distribution of marine mammals within and between years is not well known, and the breeding and moulting periods and locations are not certain.
- Fishery is mapped based on the North Sea Atlas which is based on the ICES data. However, the variability between years is not detailed for this ESIS.

12.3 Impact assessment

Impact predictions can be made using in different ways, ranging from qualitative assessment and expert judgement to quantitative techniques like modelling. Use of these quantitative techniques allows a reasonable degree of accuracy in predicting changes to the existing environmental and social conditions. However, not all of the assessed impacts are easily quantified or modelled, and expert judgement may be required.

Uncertainty has been addressed in this ESIS by presenting a level of confidence for each of the assessments in section 6 and 7. The level of confidence includes interactions between impact mechanisms and receptors, available baseline data as well as modelling (section 4).

Overall, impacts are assessed based on today’s technological capabilities. Maersk Oil expects that technological development will lead to a reduction in emissions and discharges, which will reduce the impact assessed here.

12.3.1 Planned activities

The potential environmental impacts have been assessed for each relevant environmental and social receptor (e.g. water quality, marine mammal, fisheries, employment). The impact assessment is based on empirical studies, best available scientific literature, modelling results as well as previous environmental impact assessments.

Previous and recent modelling results have been applied in this ESIS that relate to Maersk oil and gas exploration in the North Sea in the same area, including modelling of e.g. dispersion of drill mud and cuttings, dilution of produced water and underwater noise propagation. In addition, Maersk Oil prepared EIF and the PEC/PNEC calculations, using the Chemical Hazard Assessment and Risk Management model (CHARM) developed by authorities and offshore industry. The calculations have some weaknesses (as reviewed in /1/), but are considered valid for the impact assessment.

The project which is assessed is at or near existing platforms, where monitoring of chemical and biological conditions have been undertaken for many years. These surveys have contributed to a solid knowledge of the baseline /3/, as well as an understanding of the environmental impacts.

Impacts of underwater noise are not well understood, and there is ongoing debate regarding thresholds for potential impact.

12.3.2 Accidental events

Oil spill modelling has been undertaken for a number of selected spill scenarios. However, the spill rates for blowouts are not directly comparable, but considered applicable as a worst case scenario.

12.3.3 Cumulative impacts

Within the geographical scales of this project it is concluded that there is no immediate evidence of substantial cumulative pressures that entails a worsening of the receptors identified. There may be some serious consequence in the case of simultaneously accidental oil spill, but such scenario is considered to be unlikely.

These assessments embrace direct effects on the receptors identified while more indirect effects are difficult to unravel in detail. No clear elaborated and standardised methods exist for describing the severity of environmental impact on the functioning of the ecosystem. The lack of knowledge about the population status of species, the range and ecological status of habitat types, and the combined impacts of environmental pressures add to the ambiguity of assessments of cumulative impacts. Environmental monitoring can provide information on some impacts and decrease some uncertainty, but cumulative effects will not be possible to deduce in detail alone from looking at the status of the receptors.

The marine strategy frameworks directive (MSFD – see section 6.3) embraces both the nature of sources and the receptors for identifying human impact on marine ecosystems. The descriptors presented in the MSFD are meant as general criteria used to define environmental status. As described above more detailed understanding on how system react on different external impacts is however needed for an appropriate assessment of different cumulative impacts on system level. We still have an insufficient knowledge of the precise ecological effects from different human activities taking place in this part of the North Sea region and thus extract the possible cumulative impacts on adjacent habitats to Tyra.

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APPENDIX 1
TECHNICAL SECTIONS