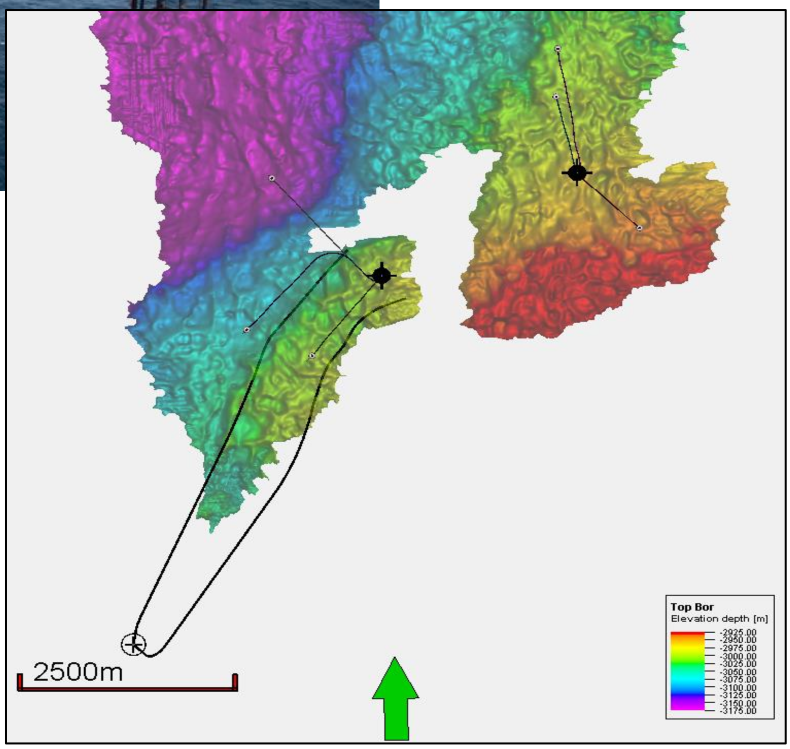
INEOS

December 2021

SOLSORT UNIT
(LICENSE 4/98, 3/09 & 7/89)
NORTH SEA – DENMARK
ENVIRONMENTAL IMPACT ASSESSMENT
SOLSORT WEST LOBE



Top photo shows Syd Arne Main with bridgelinked East Well-head Platform and North Well-head Platform in the distance
Bottom picture shows the two Solsort wells to be drilled from North Well-head Platform.

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1. Non-technical summary

INEOS Oil & Gas Denmark (hereafter called INEOS) plans to develop the Solsort field by drilling two wells from the South Arne Well Head Platform North into the Solsort West Lobe reservoir including modifications at the South Arne installations to allow for receiving, transporting, processing and exporting the Solsort West Lobe fluids.

This report provides an assessment of potential environmental and socioeconomic impacts of the development.

The report includes a screening of potential impacts of the development on Natura 2000 sites and Annex IV species.

An assessment according to the Marine Strategy Act implementing the Marine Framework Strategy Directive (MFSD) is carried out to evaluate if impacts from the activities will prevent achievement of the environmental targets set under Danish Marine Strategy II.

1.1 The Project

The Solsort West Lobe will be developed with one production well and one water injection well.

The two wells will be drilled from the SA WHPN platform, located approximately 250 km west of Esbjerg, at a water depth of 61 meters. The wells will end in the Solsort West Lobe reservoir, see Figure 1-1.

Solsort West Lobe production is metered prior to being commingled with South Arne production at the South Arne WHPN. Solsort production relies on commercially available processing capacity in the South Arne facilities.

Licence Partners in the Solsort Unit are:

- INEOS E&P A/S (Operator)
- INEOS E&P (Petroleum Denmark) Aps
- INEOS Energy (Syd Arne) Aps
- Nordsøfonden (Danish North Sea Fund)
- Danoil II Aps
- Danoil Exploration A/S

The project includes:

- Drilling of two wells from the South Arne North platform into the Solsort West Lobe reservoir, one producer and one injector. New flowlines including in-line metering on South Arne North platform and lift gas flowline for later use. Modifications of the South Arne central including installation of a new water filter package for water injection pump. New wax inhibitor on South Arne East platform.
- Decommissioning at end of field life including plug and abandonment of wells.

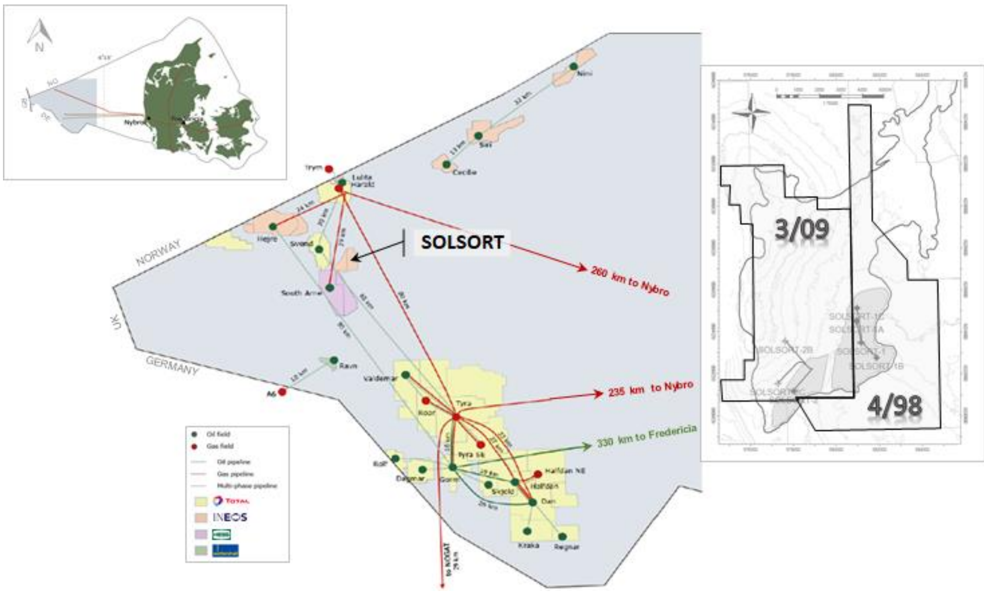


Figure 1-1 Solsort field location and surrounding infrastructure in the Danish sector of the North Sea

1.2 Alternatives

The following non-exhaustive list of alternatives for the unphased development of Solsort West and East Lobe have been considered but screened out:

Unmanned Solsort WHP. Unmanned WHP at the Solsort field. The well fluid to be transferred to the South Arne East platform, via a multiphase pipeline, and receive and inject water via a water injection pipeline. Production fluids will be processed on the South Arne platform.

Mobile Production Unit (MPU). Converted jack-up drilling rig with process module located at the Solsort field for processing of the Solsort fluids. Wellhead support structure with jacket located at Solsort. New export pipelines to be established.

FPSO. Floating, Production, Storage and Offloading (FPSO) vessel located at Solsort field for processing of Solsort fluids and unmanned WHP at Solsort. New gas export pipeline to be established to tie-in to existing infrastructure. Oil export through tanker off-loading.

Harald tie-back. Solsort tie-back to Harald through a new module to be placed on the existing Harald platform. New min. manned WHP at Solsort for local water injection.

Harald bridge linked platform (BLP). Tie-back to Harald through a new BLP at Harald. Processing of Solsort fluids at Harald. New unmanned WHP at Solsort.

South Arne bridge-linked platform (BLP). Tie-back to South Arne through a new BLP at South Arne. Processing of Solsort fluids at South Arne. New unmanned WHP at Solsort.

1.3 Existing environment

1.3.1 Biological environment

1.3.1.1 Biological production and water quality

The Solsort and South Arne fields are located centrally in the North Sea in an area with low biological productivity. As a result, the area is not an important nursery area for fish larvae and juvenile fish (although fish spawning takes place in the area) and the abundance of seabirds is low.

The water quality is comparable to other areas in the central North Sea, which are defined as "problem areas" based on their chemical status.

1.3.1.2 Environmental status of the seabed

The seabed sediment in the project area consists of fine sand with a very low content of organic material. Based on measurements of sediment concentrations of Polycyclic Aromatic Hydrocarbons (PAH's) and heavy metals: Barium (Ba), Cadmium (Cd), Chromium (Cr), Copper (Cu), Mercury (Hg), Lead (Pb) and Zinc (Zn) the sediments around the South Arne Field and a reference station are classified as having a "*good environmental status*" according to the criteria defined in the EU Marine Strategy Framework Directive (MSFD). It is expected that the Solsort field is comparable to this general picture for the area.

The benthic infauna that lives in and on the surface of the seabed in the area is characterized by the following dominant and characteristic species: The bristle worms *Myriochele oculate* (=*Galathowenia oculata*), *Spiophanes bombyx* and *Paramphius jeffreysii* as well as the echinoderm *Amphiura filiformis.*

1.3.1.3 Fish

Herring, sprat and mackerel are the dominating pelagic fish species around South Arne and Solsort. The dominating demersal (bottom dwelling species) are whiting, haddock, dab, long rough dab, plaice and grey gurnard.

Most of the commercially exploited fish stocks in the project area are in good condition and are fished at a sustainable level. However, the cod stock in the North Sea is in a poor condition. Spawning stock biomass is below the sustainable level and the fishing mortality is too high

Cod, plaice, dab, long rough dab, lemon sole, mackerel, sandeel and probably also whiting spawn in the South Arne/Solsort area. Eggs and larvae are carried with the prevailing east, north-east and north going currents to areas with high plankton production close to the coasts of the eastern North Sea and Skagerrak where they feed and develop.

1.3.1.4 Seabirds

Due to the relatively low biological production, the waters around South Arne and Solsort are not important for sea birds. During winter some seabirds may however be encountered in the area. The predominant species are northern fulmar and kittiwake. Additionally, gannet, razorbill and common guillemot occur in low densities. These species are mainly associated with cliffs and offshore islands and only occur in the open sea outside the breeding season.

1.3.1.5 Marine mammals

Harbour porpoise is the most common cetacean in the North Sea followed by white-beaked dolphin, and minke whale. All cetaceans are listed in Annex IV of the EU-Habitats Directive and is therefore strictly protected. The harbour porpoise is regularly occurring in the waters around the South Arne and Solsort field.

1.3.1.6 Protected areas

South Arne and Solsort are situated far from Danish designated Natura 2000 areas. However, ca. 45 km south of South Arne is a German designated Natura 2000 area: DE 1003-301 *Doggerbank.* As an extension of this area is the Dutch NL 2008-001 *Doggerbank* and the UK0030352 *Dogger Bank* in the UK sector. The basis for the designations of these areas are grey seal and harbour seal.

Valuable and vulnerable areas (SVO-areas) is the management framework for marine protected areas in Norway. The closest SVO to Solsort and South Arne is the Sandeel field South. The Sandeel field South is designated as SVO to protect valuable spawning areas for sandeel. The SVO is located ca. 59 km from Solsort. The area is also designated to protect the two seabird species, common guillemot and northern fulmar. North West of the Sandeel field South is the Mackerel field SVO, designated as important spawning area for mackerel.

1.3.2 Human environment

Commercial activities in the western part of the Danish sector of the North Sea include:

- Oil and gas extraction
- Shipping
- Fishery

There is ongoing oil and gas activities in the central North Sea. The closest existing oil and gas facilities in operation to Solsort/South Arne field is the Total operated fields Svend and Harald.

South Arne and Solsort are situated outside shipping routes of merchant vessels.

South Arne and Solsort are also situated in an area with low fishery intensity compared to other areas in the North Sea. Although the fishing intensity is relatively low the area is nonetheless of some significance for the Danish fishery for sandeel. The mean annual value of the total catch of sandeel is approximately 11 million DKK in this area corresponding to ca. 0.6% of the value of the total fish catch in the North Sea. The value of the catch of sandeel in the area around South Arne and Solsort is 95% of the total value. The waters around South Arne and Solsort are without significance for the fishery of other countries.

1.4 Assessment of impact and environmental risks

1.4.1 Impacts that have been assessed

Figure 1-2, Figure 1-3 and Figure 1-4 provide overviews of operations and conditions that potentially may affect organisms and other environmental features that have been assessed in the EIA during the three phases: construction, production and decommissioning.

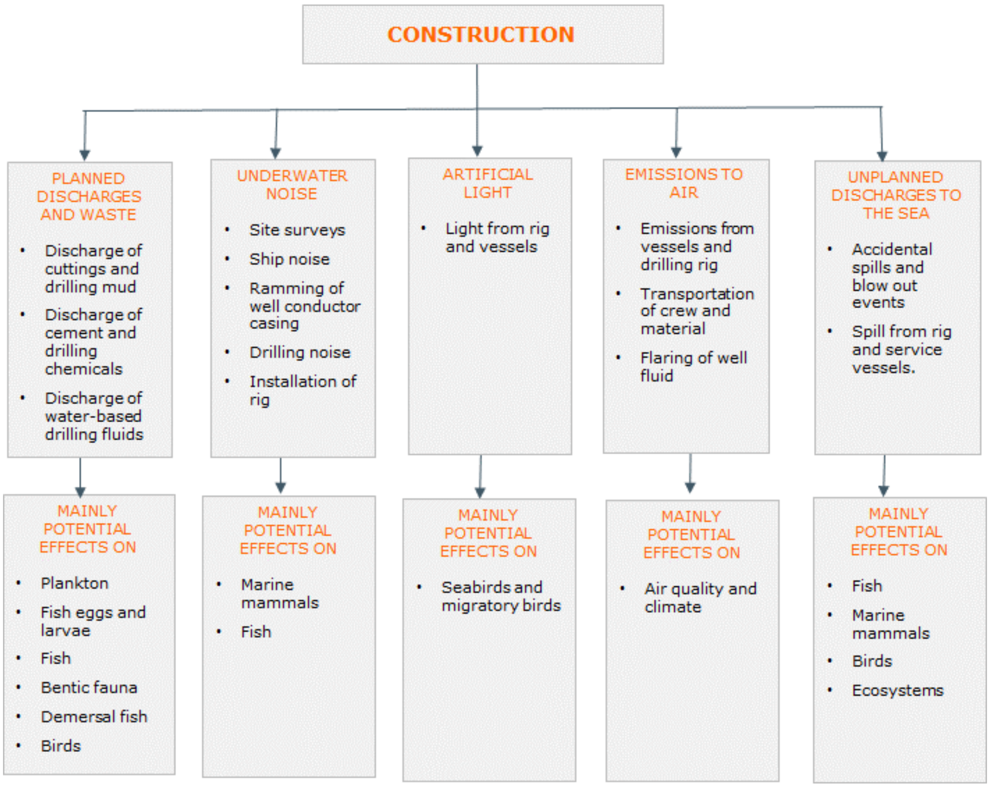


Figure 1-2 Overview of operations during construction and the receptors that may primarily be affected by the different operations which has been assessed in the EIA.

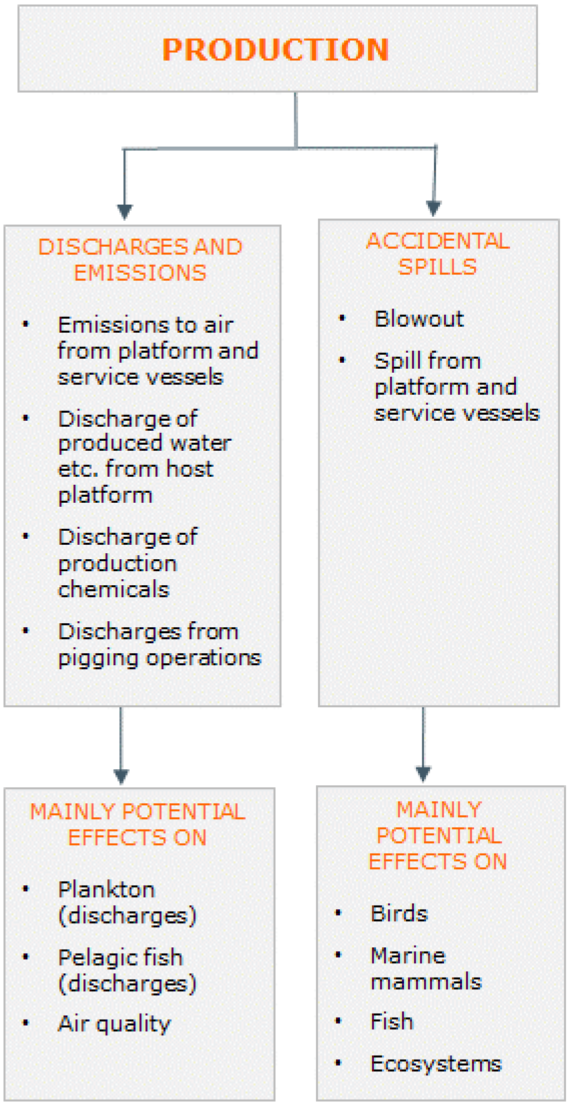


Figure 1-3 Overview of operations during production and the receptors that may primarily be affected by the different operations which has been assessed in the EIA.

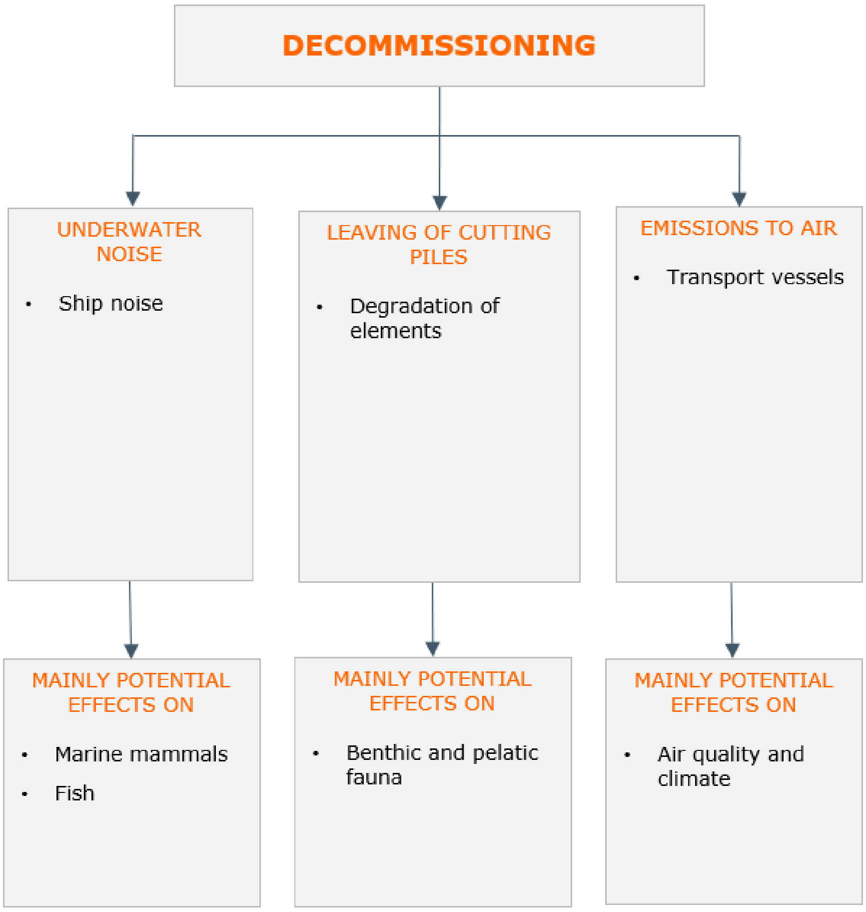


Figure 1-4 Overview of operations during decommissioning and the receptors that may primarily be affected by the different operations which has been assessed in the EIA.

1.4.2 Severity and risk of impacts

Environmental severity and risks of different project activities and incidences have been assessed. Environmental risk is defined as the combination of the severity of and impact of an activity/incidence and the probability that the impact will occur.

The severity of an impact has been defined by combining criteria for:

- The nature of the impact (Positive or negative)
- Extension of the impact (Local, regional, national, or international)
- Duration of the impact (Short-term, medium-term, or long-term)
- Magnitude of the impact (Small, medium, or large).

By combining these criteria in a predefined manner, the following severity categories have been used: Positive impact, no impact, minor impact, moderate impact or major impact.

The probability that an impact will occur has been defined as very low, low, probable, highly probable or definite.

1.4.3 Impacts during construction phase

1.4.3.1 Discharge from drilling

Discharges leading to potential impact distances of more than 500 metres can occur in connection with the short-term activities completion and rig washing (durations of 1-4 hours/event), which, based on PNEC values for long term effects, imply a risk of effects up to 4,700 m away from the discharge point (completion, use of bactericide). However, the duration of these activities is very short (few hours per event), and, in the case of completion, will occur only once during the lifetime of the field.

It is therefore assessed that toxic effects on any eggs or larvae of fish that may be spawning in the area (such as, cod, plaice, dab, long rough dab, lemon sole, mackerel, sandeel and probably also for whiting are encountered) and other plankton organisms around Solsort and SA-WHPN will be local, marginal and without measurable impacts on the stocks.

1.4.3.2 Impact of underwater noise

Possible ramming of well conductor and noise from machinery, propellers and thrusters of ships will generate underwater noise. The impact of noise producing activities are temporary and local. Based on this, it is assessed that underwater noise will have negligible impacts on marine life such as cetaceans and fish.

1.4.3.3 Impacts of artificial light

As the drilling rig operates 24 hours per day, it will be illuminated during the dark hours. Artificial light may affect seabirds and migrating land birds both positively and negatively. Light may improve foraging during night for seabirds, but there may also be an increased risk of bird collision, since they may be attracted by the light.

The risk of bird collision due to light attraction is considered to be minor and the negative impact on bird population due to light is negligible.

1.4.3.4 Emissions during construction

In relations to the site survey, construction of the wells, emissions to air will be generated from the fuel gas and diesel combustion for power generation, machinery and transport of supplies, equipment and crew. The emissions relation to site survey and drilling are expected to be approx. 21,800 ton CO_2-eq and 250 ton NO_X/year.

1.4.3.5 Impacts of waste during the construction phase

All waste from South Arne and Solsort will be transported to Esbjerg by vessel. The waste will be sorted and sent to approved waste treatment plants. The environmental risk is assessed to be negligible.

1.4.3.6 Impacts of drilling on cultural heritage

Drilling and discharge of cuttings during drilling may potentially burry and damage ship and plane wrecks. There are no registered findings of wrecks in the vicinity of the project area and the environmental risk is assessed to be negligible. Potential findings of wrecks or other historical artifacts will be reported to Slots- og Kulturstyrelsen.

1.4.3.7 Impacts on hydrography

The substructure of the rig will be temporary located in the water column. The structure consists of 3 legs with a total cross section area of 2013 m^2. The legs are placed in an open structure and are considered too small to have any impact on the hydrography of the North Sea. In addition to that the rig will placed in the location temporary.

1.4.4 Impacts during production phase

1.4.4.1 Impacts of planned discharges during the production phase

Produced water will be discharged from the host platform after pre-treatment with the primary objective of keeping the content of oil in the produced water below the OSPAR requirement of 30 mg/l. The content of natural occurring substances is available through water samples of the produced water.

Impacts during the production phase from tie-in of the Solsort West Lobe wells will be limited and is expected to result in no additional impacts compared to the impacts from planned activities at the South Arne installations already covered by existing EIA.

1.4.4.2 Emissions during production

In comparison with the overall national emissions of CO_2 from the oil and gas industry, the production of oil originated from Solsort West Lobe wells will equal 5.7% of the CO_2 emissions of 2013 (Danmarks olie- og gasproduction, 2013).

The emissions to air related to production and maintenance of the two Solsort West Lobe wells are covered within the emissions to air from planned production and maintenance for the South Arne field as the well are utilising the most appropriate slots on the SA-WHPN platform already covered by the South Arne EIA.

1.4.5 Impacts during decommissioning

The expected lifetime of the wells is approximately 25 years. Decommissioning of the project include pull out of production strings as well as plug and abandonment of wells. It is assessed that the environmental risk of the decommissioning of the production and water injection wells will be negligible and included in the decommissioning activities related to the South Arne field.

1.4.6 Impacts of accidental spills

Blowout is an extremely rare event and extensive preventative/control measures are implemented to reduce the likelihood of such events.

Experience from previous blowouts and oil spills at sea have shown that it is mainly birds, marine mammals, fish and coastal ecosystems that may be affected by large oil spills.

The assessment of the environmental impacts of accidental blowout is based on modelling results representing a worst-case scenario in which no mitigating oil spill response measures are taken.

The modelling shows that the risk of oil stranding on coasts is negligible, even in case of a blowout. However, Norwegian SVOs may be hit by oil in case of an unmitigated blowout.

Impacts on the conservation status of the nearest Natura 2000 areas (German and Dutch Natura 2000 areas 45 km south of Solsort) is assessed to be limited. There may however be a risk of sedimentation of oil on the habitat type 1110 Sandbanks, especially in the German area, thereby affecting the benthic infauna community at Dogger Bank.

Harbour porpoises, harbour seals and grey seals may be affected by oil, but it is assessed that only a tiny fraction of the populations is likely to be affected.

The risk of environmental impacts during a blowout is generally assessed to be low. This is mainly due to the risk that a blowout is extremely low since all safety systems and measures are in place on the platform or during drilling.

In case of a blowout, the South Arne oil spill contingency plan will be activated, and oil spill combat will be carried out, which will reduce the spreading of oil and mitigate impacts of any spill.

1.4.7 Summary of environmental impacts

The tables below summarize the assessed environmental severities and risks of planned activities during the construction (Table 1-1), production, decommissioning and accidental spills (Table 1-2).

*Table 1-1 Environmental severity and risk of **planned activities** during the **construction** phase.*

Impact	Severity of impact	Probability of impact	Environmental Risk
Impacts of discharges from the drilling rig			
Impacts of the discharge of cuttings and drilling mud (WBM)	Minor Impact	Definite	Low risk
Impacts of the discharge of drilling chemicals	Insignificant impact	Probable	Negligible risk
Impacts of underwater noise			
Impacts of underwater noise during site survey	Insignificant impact	Probable	Negligible risk
Impacts of underwater noise during ramming of well conductor casing	Insignificant impact	Probable	Negligible risk
Impacts of drilling noise from rig	Insignificant impact	Probable	Negligible risk
Impacts of underwater noise from support vessels	Insignificant impact	Probable	Negligible risk
Impacts of artificial light			
Improvement of night foraging opportunities for seabirds	-	Probable	Positive effect
Risk of bird collision due to light attraction	Minor impact	Low	Negligible risk
Air emissions during construction			
Impacts of air emissions (VOC)	Insignificant impact	Low	Negligible risk
Impacts of air emissions (NO_X, SO_X)	Minor impact	Low	Negligible risk
Impacts of air emissions (CO_2-eq)	Minor impact	Low	Negligible risk
Impacts from waste			
Impacts of waste	Minor impact	Low	Negligible risk

Impact	Severity of impact	Probability of impact	Environmental Risk
Impacts of cultural heritage			
Risk of damage of wrecks	Minor impact	Very low	Negligible risk
Impact on hydrography			
Impacts on seabed	Insignificant impact	Low	Negligible risk
Impacts on water column	Insignificant impact	Low	Negligible risk
Impacts on benthic fauna	Insignificant impact	Low	Negligible risk
Impacts of accidental spills			
Impacts of oil release during blow-out	Major impact	Very low	Low risk
Impacts of gas release during blow-out	Moderate impact	Very low	Negligible risk
Impacts of accidental spills of chemicals	Insignificant impact	Low	Negligible risk

*Table 1-2 Environmental severity and risk of impacts of **planned activities** during the **operation** phase, of **accidental spills** and **decommissioning.***

Impact	Severity of impact	Probability of impact	Environmental Risk
Impacts of planned discharges and emissions from host platform			
Discharge of produced water	Insignificant impact	Probable	Negligible risk
Impacts of air emissions	Insignificant impact	Low	Negligible risk
Impacts of accidental spills			
Impacts of oil release during blow-out	Major impact	Very low	Low risk
Impacts of gas release during blow-out	Moderate impact	Very low	Negligible risk
Impacts of accidental spills of chemicals	Insignificant impact	Low	Negligible risk
Impacts of decommissioning of production wells			
Impacts from leaving cutting piles	Insignificant impact	Highly probable	Negligible risk
Emissions to air	Insignificant impact	Low	Negligible risk

1.5 Socio-economic impact

The following socio-economic issues have been assessed:

- Changes in employment
- Changes in fishing industry and tourism due to accidental oil spill and gas escape
- Consequences due to potential discharges and atmospheric emissions.

The impact from the project is considered to be negligible or positive:

- It is unlikely that a potential oil spill will affect the commercial fishery or the tourism sector due to the low probability of the accident to occur.

1.6 Cumulative effects

Potential cumulative effects from tie-in of the Solsort West Lobe wells fall in two categories:

- impacts from other oil and gas activities, and
- impacts from other activities such as wind farms, cable and pipeline installation and fishery and shipping in the region.

Potential cumulative effects from the project have a low likelihood to occur during the production phase with emission to air and discharges from the platform as closest platform Svend operated by DUC is more than 8 km from Solsort/South Arne.

At the South Arne platform, discharges of produced water are not likely to have potential cumulative effects as the distance to other platforms with similar discharges are too far to influence each other and the discharge from South Arne is very limited due to high produced water reinjection.

Cumulative impacts from other activities are not expected.

1.7 Cross border impact

Mainly local effects from the project are expected during normal operation but in relation to accidental situations as blowouts and spills transboundary effects can occur.

Cross border impacts will be described in detail in a specific Espoo document.

1.8 Marine strategy framework directive

Good Environmental Status in the marine environment is described by 11 descriptors defined in the Marine Strategy Framework Directive (MSFD). MSFD is implemented in Danish marine strategy act, which is setting the framework for the management of the marine areas in Denmark.

The potential impacts from the Solsort project activities are compared with the targets for the 11 descriptors as described in section 19.2 to 19.12.

The environmental impacts of the environmental components of the descriptors are assessed in chapter 10 to 15 .

The main impact from the oil and gas activities are as described in the Danish Marine Strategy II on D1, D6, D8 and D11. The impact on these four indicators is summarized below in Table 1-3.

Table 1-3 Potential impacts on the environmental targets in the Danish Marine Strategy II which implements EU's Marine Strategy Framework Directive (MSFD).

Descriptor	Environmental subject (Danish Marine Strategy II)	Assessment of potential impact
D1 **Biodiversity**	Birds	Population identified in the project area, which are covered by the Danish Marine Strategy I - monitoring programme: Kittiwake (Rissa tridactyla) and Guillemot (Uri aalge) The trend for the population is unknown according to table 22.4 in the Danish Marine Strategy II.
	Marine mammals	Information is included about the population of harbour porpoise, harbour seal and grey seal in the projects area covered by the Danish Marine Strategy I - monitoring programme. The project area is although not a core area for these species. The impact is temporary and will not influence on the population.
	Fish (plankton)	The primary production of plankton is generally higher in the coastal regions compared to offshore areas. Solsort and South Arne are in an area with low plankton production
D6 Sea floor integrity	Losses and physical impacts	The only impact from the Solsort project on the seafloor will be during the location of the spud cans of the rig on the seafloor. The project will give input on physical disturbance as required. The physical disturbance is temporary.
	Habitat types and seafloor	The habitat in the area is offshore circalittoral mud, which total area in the North Sea is 18,170 km². The area of the spud cans is very small compared to the area of the habitat and is considered to have no impact on the habitat in the area.
D8 Contaminants (concentrations and species health)	Contaminants	According to the Danish Marine Strategy Directive II threshold values are decided for PFOS, PBDE, Benz(A)pyrene and mercury. Only Benz(A)pyrene and mercury are present around the installations in very small concentrations.

Descriptor	Environmental subject (Danish Marine Strategy II)	Assessment of potential impact
		The values can although not directly be compared as the thresholds are defined by concentrations in fish or mussels.
	Acute pollution events	Acute pollution events are extremely rare events. The risk of accidental spill and blow-out is further-more prevented through several mitigating measures
D11 Underwater noise	Adverse effects	During site survey and construction of wells marine mammals will be disturbed due to underwater noise from seismic survey, ramming of well con-ductor casing, noise from drilling, noise from instal-lation of rig and ship noise. However, noise levels will not exceed the thresholds for PTS.

Based on the assessment above it is concluded that the Solsort West Lobe wells will not prevent or delay the achievements of good environmental status for each descriptor as defined in the Danish Marine Strategy II

1.9 Mitigating measures

Mitigating measures are applied through INEOS's general environmental management system including proper working procedures to minimize the environmental impact from operation, using BAT and BEP (best available technology and best environmental practice) in the process of selecting the technical solutions and to have proper contingency plans in place with established working procedures to minimize the effects of incidents or to effectively collect spills, should an incident happen. INEOS also systematically register and analyse incidents and near-miss events to prevent unintended environmental impact in the future

Several more project specific mitigating measures will be considered to use for the specific installations sum-marized below:

- Minimizing the use of chemicals and mainly selecting chemicals classified as green or yellow
- To reduce the negative impact on underwater noise on marine mammals from drilling activities an experienced mammal observer can look after marine mammals and pause the conductor ramming (if ramming is needed). In addition, standard soft-start procedures and use of acoustic sounders can be applied before ramming to scare marine mammals to safe distances.
- Limiting impact on marine mammals in relation to underwater noise from decommissioning activities by evaluating noise impact from equipment to be used, by use of passive acoustic monitoring equip-ment and marine mammal observer where noise will be encountered.
- At any time, a minimum of two barriers are in place to prevent any uncontrolled hydrocarbon discharge.
- Oil spill contingency plan in place and implemented. The plans are forwarded to Authorities for ap-proval.

- Limiting the risk of introducing non-indigenous species from vessels by exchange of ballast water in open waters, by implementing a ballast water treatment system or by regular removal of marine fouling from the vessels sides prior to departure.

- Operational excellence: Minimizing the environmental impact by focusing on stable production, reduction of slugging and limiting number of unplanned shutdowns

- Improve the water injection system at South Arne by adding a booster pump to one of the water injection trains to keep up the high amount of produced water reinjected

- Reducing emissions to air as part of the energy efficiency management system. Potential savings in energy consumption and emissions to air evaluated on a yearly basis.

1.10 Monitoring programme

A monitoring programme for the site survey and the drilling of the 2 Solsort West Lobe Wells are to be agreed with the relevant authorities during the permitting process.

A monitoring programme is already in place for South Arne including continuous monitoring in relation to discharges to sea and emissions to air.

For the South Arne area, a risk-based approach for produced water management in alignment with OSPAR and Danish authority guidelines is already in place.

A monitoring programme covering the Danish part of the North Sea takes place every three years. This has traditionally included seabed sampling for monitoring the environmental status of the seabed around the oil and gas installations. Water column monitoring to characterize the impact of discharge of produced water on the marine ecosystem will be added to the programme from 2021.

2. Introduction

Several development concepts have been considered for a combined development of the Solsort East and West lobes. In May 2020, the Solsort Unit decided to discontinue the unphased development of the East and West Lobes through tie-back of the Solsort discovery to South Arne. The decision was taken based on comprehensive and thorough investigations of development concepts since 2015.

Following the decision to halt the combined Solsort East and West development, the Solsort Unit partnership continued to investigate the attractiveness of a separate Solsort West lobe development.

On this basis, INEOS now intends to develop the West Lobe of the Solsort oil and gas field in the Danish Sector of the North Sea. The East Lobe development may take place at a later point and will instigate an EIA to be developed for the East Lobe development.

The development involves drilling of two wells from the South Arne North platform into the Solsort West Lobe reservoir, one producer and one injector. The project also includes associated modifications at the South Arne installations to allow for receiving, transporting, processing and exporting the Solsort West Lobe fluids.

The Solsort produced fluids will be commingled with South Arne production at South Arne WHP North, transported to the South Arne main platform for processing and export.

The location of the Solsort field in relation to South Arne is shown in Figure 2-1 below.

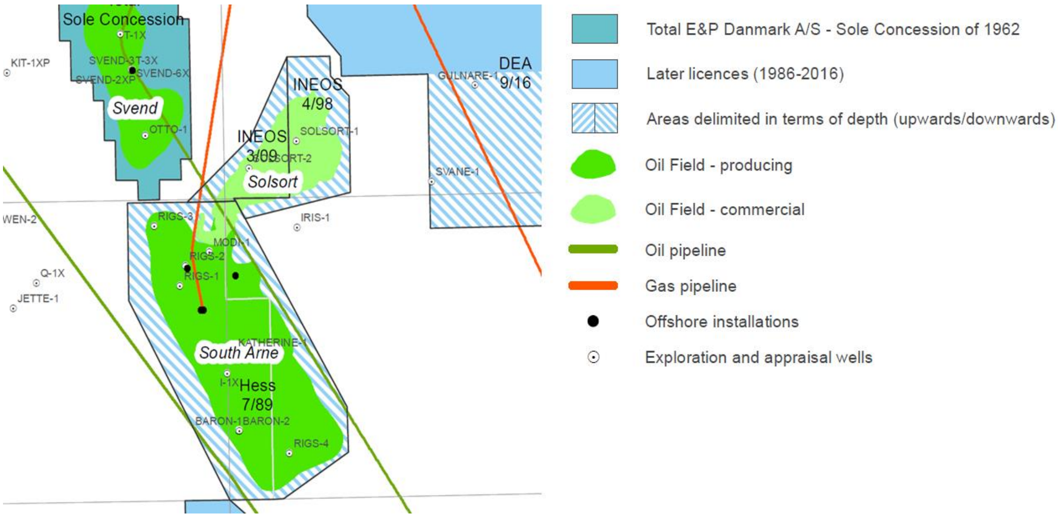


Figure 2-1 Location of the Solsort field in relation to South Arne

INEOS has commissioned COWI to carry out an environmental impact assessment (EIA) for the site survey, construction, operation and decommissioning of the West Lobe of the Solsort field.

The present report documents the EIA process, findings and conclusions. The EIA has been carried out in compliance with the Danish EIA regulation (Consolidation Act No. 1976/2021).

The present EIA report assesses the environmental impacts of the Solsort West Lobe elements.

The report also includes a screening of potential impacts of the development on Natura 2000 sites and Annex IV species.

Finally, an assessment according to the Marine Strategy Act, implementing the Marine Framework Strategy Directive (MFSD) is carried out to evaluate if impacts from the activities will prevent achievement of the environmental targets set under Danish Marine Strategy II.

2.1 The Solsort field

The Solsort West Lobe discovery is an oil field. The discovery of the field was confirmed by the Solsort-1 exploration well drilled in the East Lobe in 2010. Solsort-1 was followed by the Solsort-2 appraisal well in the West Lobe in 2013. Solsort-2 proved the presence of 17 meters hydrocarbon bearing reservoir at a depth of 3008 - 3025 meters.

The Solsort West Lobe is a Bor Sandstone reservoir compared to South Arne being a Chalk reservoir, Figure 2-2.

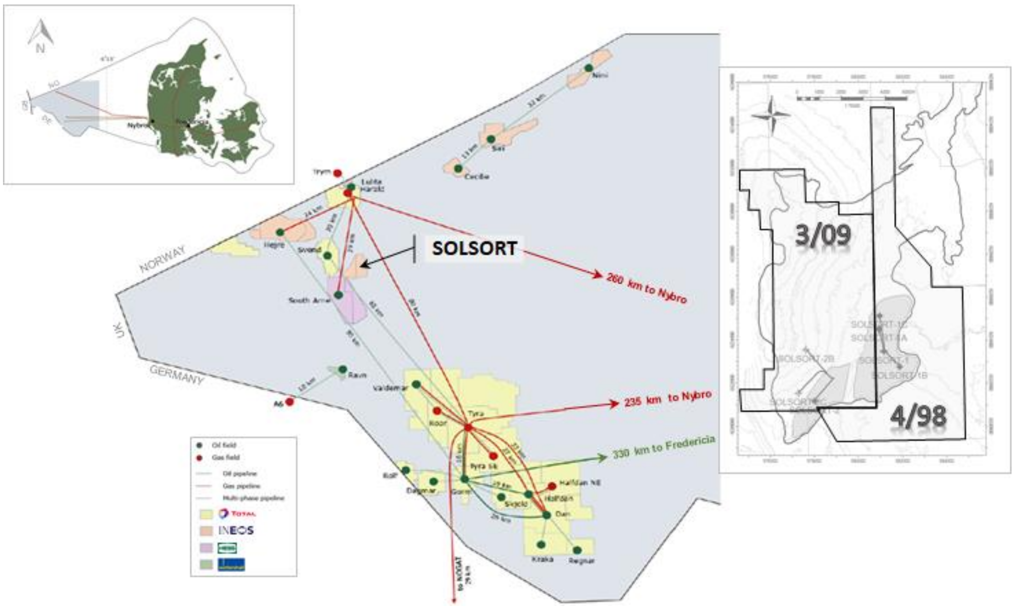


Figure 2-2 Location of the Solsort field along with oil and gas installations in the Danish sector of the North Sea.

2.2 Scope of EIA

This EIA provides a technical description of the project, a presentation of the environmental impacts from the construction, operation and decommissioning phases and a set of mitigating measures.

In short, the EIA covers the following processes:

- Drilling of up to a total of 2 wells into the Solsort West lobe drilled from South Arne Wellhead Platform North (SA-WHPN)
- Site survey for a relief well
- Modifications of the SA-WHPN platform including installation of some equipment as for example a Solsort multi-phase meter and a scale inhibitor injection pump. No structural changes are planned for.
- A new wax inhibitor injection pump at South Arne Wellhead Platform East (SA-WHPE).
- Modifications at South Arne Main water injection package.
- Plugging and abandonment of Solsort West Lobe wells.

It is emphasised that the focus in this EIA report is on the additional environmental impacts resulting from the Solsort West Lobe project as described above.

Other emissions and discharges from South Arne are expected to remain unchanged.

2.3 Abbreviations

The following abbreviations are used in the document:

BAT	Best Available Technique
BEP	Best Environmental Practice
BLP	Bridge Linked Platform
BRL	Background Reference Level
CO	Carbon Oxides
CRI	Cutting Re-Injection
Cs/K	Caesium/Potassium
DCE	Danish Centre for Environment and Energy
DEA	Danish Energy Agency
DEPA	Danish Environmental Protection Agency
EC	European Council
EIA	Environmental Impact Assessment
EnS	Environmental Status
ERL	Effect Range Low
EU	European Union
FPSO	Floating Production Storage and Offloading
HOCNF	Harmonised Offshore Chemical Notification Form
IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Seas
IMO	International Maritime Organization
IOPP	International Oil Pollution Prevention
JNCC	Joint Nature Conservation Committee
MPU	Mobile Production Unit
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning
MSY	Maximum Sustainable Yield
NH4+	Ammonia
NORM	Naturally Occurring Radioactive Materials
NOx	Nitrogene Oxides
OBM	Oil Based Mud
OSCAR	Oil Spill Contingency And Response
OSPAR	OSlo PARis convention
OSRL	Oil Spill Response Limited
PAH	Polycyclic Aromatic Hydrocarbons
PCB	PolyChlorinated Biphenyls
PEC	Predicted Environmental Concentration
PLONOR	Pose Little Or NO Risk
PNEC	Predicted No-Effect Concentration
PPB	Parts Per Billion
PPM	Parts Per Million
PTS	Permanent Threshold Shift
RBA	Risk Based Approach

ROV	Remotely Operated underwater Vehicle
SA	South Arne
SAC	Special Areas of Conservation
SA-WHPE	South Arne Wellhead Platform East
SA-WHPN	South Arne Wellhead Platform North
SCANS	Small Cetacean Abundance in the North Sea
SEL	Sound Exposure Levels
SINTEF	Stiftelsen for INdustriell og TEknisk Forskning
SO2	Sulphur diOxides
SPL	Sound Pressure Level
TD	Total Depth
TL	Transmission Losses
TTS	Temporary Threshold Shift
VOC	Volatile Organic Compounds
WBM	Water Based Mud
WHP	Well Head Platform
WHPE	Well Head Platform East
WHPN	Well Head Platform North

3. National and international legislation

3.1 Environmental impact assessment

An Environmental Impact Assessment (EIA) is required to obtain an approval for offshore exploration and production of oil and gas and certain industrial plants. This requirement is set forth in Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment. The directive is implemented in Danish legislation through the:

Subsoil act (Consolidation act no. 1533 of 16/12/2019)

- The act on environmental impact assessment of plans and programs and on specific projects – The EIA act (Consolidation act no. 1976 of 27/10/2021)
- Regulation on EIA, impact assessment regarding international nature conservation areas and protection of certain species during offshore exploration and production of hydrocarbons, subsoil storage, pipelines, etc. (Executive Order no. 434 of 02/05/2017).

The present EIA is compliant with the above-mentioned legislation.

The public hearing process for offshore projects is as follows:

- The project owners' application, the environmental impact assessment report and a draft permit from the authority will be available on the website of the Danish Energy Agency, and the public will have the opportunity to comment on the EIA through an eight-week public hearing phase. After the hearing period the DEA will decide if a permit for the project will be granted.
- Decisions regarding the project and the EIA will be published on the DEA website, and any party with relevant and individual interests in the decision may file a written complaint on environmental issues to the Energy Board of Appeal within four weeks of the publication. No activities will take place in the public hearing period.

3.2 Protection of the marine environment

The Marine Environment Act (Consolidation act no. 1165 of 25/11/2019) regulates discharges and emissions from platforms.

3.2.1 Discharges to sea

The associated regulation on discharges to the sea of compounds and materials from certain marine facilities (Executive order no. 394 of 17/7/1984) defines the information needed to obtain a permission for discharges.

Danish Environmental Protection Agency (DEPA) is the permitting authority.

The discharge permit regulates discharge of oil and chemicals to the sea and, among others, define requirements on:

- Maximum oil concentration in discharged produced water
- Limitations for total amount of oil to be discharged
- Monitoring program for oil concentration in discharge water

- Continuous control of total oil discharge
- Classification of offshore chemicals
- Use and discharge of offshore chemicals depending on classification (explained below).
- Regularly reporting on discharge of oil and chemicals.

Classification of offshore chemicals

Chemicals are classified according to the DEPA colour coding system, which follows the OSPAR classification (substitution, ranking and PLONOR) and relates to the environmental hazard of offshore chemicals. The codes are:

Black chemicals are the most critical and not acceptable to be used offshore.

Red chemicals are environmentally hazardous to such an extent that they should generally be avoided and be substituted where possible. Substances that are inorganic and highly toxic and/or have a low biodegradation are classified as red.

Green chemicals are considered not to be of environmental concern (so-called PLONOR-substances that "Pose Little Or NO Risk" to the environment) and includes organic substances with EC_{50}/LC_{50} > 1 mg/l, acids and bases categorized as green chemicals.

Yellow chemicals are those that do not fall into any of the above categories, i.e., substances exhibiting some degree of environmental hazard, which in case of significant discharges can give rise to concern. Substances that meet one of three criteria of low biodegradation, high bioaccumulation or toxicity are classified as yellow. If substances meet two or three criteria it will be classified as red.

3.2.2 Regulation of non-indigenous species

Regulation to prevent introduction of non-indigenous species through ballast water regulated through Executive order no. 1000 of 1818/09/2019 about handling of ballast water and sediments from ship ballast tanks. In addition, introduction of non-indigenous though ballast water species is regulated through the following international conventions and declarations:

IMO's Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter (known as the London Convention 1972) including the 1996 Protocol which became effective in 2006.

3.2.3 Emissions

In addition, air emissions from platforms and ships are regulated in the regulation on certain air polluting emissions from combustion installations on offshore platforms (Executive order no. 1449 of 20/12/2012) and in the regulation on prevention of air pollution from ships (Notification no. 9840 of 12/04/2007).

3.3 Offshore safety

To prevent and mitigate pollution from major accidents, the Offshore Safety Act (Consolidation act no. 125 of 06/02/2018) requires response contingency plans for offshore platforms carrying out exploration, production and transport of petroleum hydrocarbons. The required content of such plans is specified in the associated regulation on contingency plans in case of pollution of the marine environment from oil and gas pipelines and other platforms (Executive order no. 909 of 10/07/2015 because of protection of the marine environment act no. 1165 of 25/11/2019 § 34 a.).

3.4 Naturally Occurring Radioactive Material (NORM)

Offshore oil production in the North Sea is associated with contamination of certain parts of the processing equipment by low-level radioactivity substances, known as NORM (Naturally Occurring Radioactive Material).

NORM naturally occurs in the reservoirs in the North Sea; hence NORM may occur in drill cores and cuttings in drilling mud. The radioactive elements occur in chemical compounds in the produced water (formation water) either dissolved in the water or as small particles in the multiphase flow from the wells. NORM also occurs in systems where formation water and sea water are mixed. The radioactive particles or NORM can be accumulated and concentrated in separators (sludge) or deposited as scale in pipes and process equipment due to changes in pressure and temperature. NORM can also occur in the production liner of the wells.

The use (handling, storage, discharge, and disposal etc.) of radioactive substances such as NORM is regulated through The Radiation Protection Act (Act no. 23 from 23 of January 2018 on Ionizing Radiation and Radiation Protection No. 23 of 15/01/2018) and its underlying orders:

- Executive Order No. 669 of 1 July 2019 on ionizing Radiation and Radiation Protection.
- Executive Order No. 670 of 1 July 2019 on Use of Radioactive Substances.

The above legislation also regulates the use of sealed radioactive sources.

3.5 Natura 2000 sites

Natura 2000 is a network of nature protection areas established under the EU Habitats Directive and the Birds Directive. The network consists of Special Areas of Conservation (SACs) designated by the member states under the Habitats Directive 92/43/EEC of the Council of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. The network also consists of Special Protection Areas (SPAs) designated under the Birds Directive 2009/147/EC of the European Parliament and by the Council of 30 November 2009 on the conservation of wild birds. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats.

The directives are implemented in Danish legislation through:

- The Environmental Goal Act: Consolidation Act no. 119 of 26/01/2017
- The Subsoil Act: Consolidation Act no. 1533 of 16/12/2019
- The EIA Act: Consolidation Act no. 1976 of 27/10/2021
- The Habitat Act: Executive Order no. 1595 of 06/12/2018
- Executive Order no. 434 of 02/05/2017 on impact assessment regarding international nature conservation areas and the protection of certain species in connection with offshore exploration and production of hydrocarbons, storage in the subsoil, pipelines, etc.

Prior to any decision on projects with potential impact on a Natura 2000 area, documentation must be presented that the activity will not lead to negative effects on the favourable conservation status of species or habitats that are part of the selection basis or affect the integrity of the area negatively.

3.6 Espoo Convention

Convention on Environmental Impact Assessment in a Cross-border Context, the Espoo Convention from 1991, sets out obligations of parties to assess the environmental impact of certain activities at an early stage of the planning. The convention also lays down a general obligation on the Member states to notify and consult each other on all major projects that are likely to have a significant adverse environmental impact across boundaries.

The Danish Environmental Protection Agency is the Danish Point of Contact for notifications regarding to the Espoo Convention and thus also takes care of the notifications and consultation of other countries according to the Espoo convention for projects where the Danish Energy Agency is the competent authority.

3.7 OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic or OSPAR Convention is the main legislative instrument regulating international cooperation regarding the marine environment in the North Sea. The Convention regulates international cooperation in the North-East Atlantic and sets European standards for the offshore oil and gas industry, marine biodiversity and baseline monitoring of environmental conditions. The focus of the convention is on BAT, BEP and clean technologies.

The OSPAR Convention has implemented several strategies on environmental issues such as hazardous substances, biodiversity and radioactive compounds. The strategies include prohibition of the discharge of oil-based mud (OBM), and how drill cuttings are managed in the construction phase. In addition, hazardous substances are regulated after principles of substitution, where less hazardous substances or preferably non-hazardous substances substitute these substances if possible. The Convention requires a HOCNF (Harmonised Offshore Chemical Notification Format) and a pre-screening of substances in relation to their toxicity, persistence and biodegradability. Compounds that cannot be substituted must be ranked if not listed on the PLONOR (Pose Little Or No Risk) list, which contains the substances with no or little environmental effect.

The OSPAR Commission recommends an elimination of discharges of produced water, so that by 2020 the discharge of produced water will not result in unwanted effects in the marine environment. Discharged produced water should not contain more than 30 mg dissolved oil per litre calculated as a monthly average. The Commission has established a risk-based approach (RBA) to assess the discharge of produced water. The RBA recommendation 2012/5 and the associated RBA guideline 2012-07 were adopted in 2012, and all contracting parties finalised their implementation plans in 2013 which is followed by full implementation in 2020.

OSPAR agreement 2017-02 recommends procedures for monitoring of environmental impacts of discharges from offshore installations including monitoring of sediment and water column characteristics. The monitoring programme should comprise both baseline surveys prior to any petroleum development and follow-up surveys during exploration, production and decommissioning.

In OSPAR decision 98/3 on the disposal of disused offshore installations, OSPAR sets up the rules for leaving disused installations offshore. A disused offshore installation is defined as an offshore installation that no longer serves the purpose it was originally placed in the area for, or not serving another legitim purpose. Offshore pipelines are not covered by the decision.

The general rule is that offshore installations are not allowed to be left in a maritime area. Derogation from decision 98/3 may be considered for parts of an installation if certain conditions are met.

3.8 Energy and climate

The Danish Government has decided that the emission of CO_2 in Denmark shall be reduced with 70% in 2030 compared to the emissions in 1990.

The Government has invited Danish companies to participate in Climate Partnership to develop ideas to meet the goal for 2030. The oil and gas sector are included in the Confederation of Danish Industry and takes part in the Partnership related to the Danish Energy Industries.

The oil and gas industry have given input to the Partnership agreement within the areas of:

- Energy efficiency
- Electrification of the installations using common power infrastructure in the North Sea for example from wind power plants
- Carbon Capture and Storage (CCS)
- Hydrogen production, transportation, and storage.

The final climate partnership agreement has been finalized in March 2020 and published by the Danish Council on Climate Change in the report “Known paths and new tracks to 70 percent reduction”.

Some of the initiatives have been initiated in the first Danish oil and gas energy efficiency action plan 2008-2011 agreed between the Minister of Energy and Climate and the Danish Operators in April 2009. The focus areas were the operators' commitment to implement energy management as part of their existing environmental management system, to improve energy efficiency, to lower the energy consumption and to lower the flaring. The action plan included analysis of additional possibilities to reduce energy consumption. The second energy efficiency action plan covering the period 2012-2014 was agreed April 2012. After 2014, a new plan has not been agreed but the operators still have energy managements systems, which require setting goals for energy efficiency and power consumption and to yearly consider possibilities for improvements for the coming year.

3.9 Marine Strategy Act

The EU has a marine strategy that aims to maintain or establish a 'Good Environmental Status' (GES) in all European marine areas by 2020. This strategy is set forth in Directive of the European Parliament and by the Council of 17 June 2008 on establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive - MSFD). The directive is implemented in Danish legislation through Marine Strategy Act (Consolidation act no. 1161 of 25/11/2019).

The marine strategy act sets up the content of a marine strategy to include:

1. Basis analysis
2. Description of good environmental status
3. Stipulate environmental targets and indicators
4. Monitoring programme
5. Performance programmes

3.9.1 Danish Marine Strategy II

The Danish Ministry of Environment defines what is regarded as 'Good Environmental Status' of the marine environment using 11 different descriptors. For each descriptor a set of qualitative environmental targets and preliminary indicators are set in the Danish Marine Strategy II – part 1. The 11 descriptors are listed below:

- D1 Biodiversity
- D2 Non-indigenous species
- D3 Commercially exploited fish stocks
- D4 Marine food webs
- D5 Eutrophication
- D6 Sea floor integrity
- D7 Alteration of hydrographical conditions
- D8 Contaminants
- D9 Contaminants in fish and other seafood for human consumption
- D10 Marine litter
- D11 Underwater noise

OSPAR is currently working on a common framework of indicators and assessment values to be used in the North East Atlantic. In this EIA, of the targets and indicators from the Danish Marine Strategy II has been used to assess the impact of the project on the objectives of the Marine Strategy. The Danish strategy has been prepared based on the 2017 EU criteria for good environmental status (GES).

It should be noted that targets are not defined for all descriptors. The remaining targets are defined as trends that describe a positive development or descriptive target.

3.9.2 Marine Strategy – Monitoring programme

The Danish Ministry of Environment has prepared a monitoring programme as part of the Danish Marine Strategy II covering the period 2021-2026. The monitoring programme includes activities related to all the 11 descriptors and covers both existing monitoring programmes and new initiatives. The monitoring programme serves as input to the performance programme planned to be finalized in 2021.

3.10 Maritime spatial plan (MSP)

Maritime spatial planning is regulated through the Danish legislation in the Act on Maritime spatial planning (Consolidation act no. 400 of 06/04/2020).

The Danish Maritime Authority has made a draft to the first maritime spatial plan (MSP) in Denmark. The maritime spatial plan points out areas to a number of different purposes and concrete projects according to the regulation on maritime physical planning.

When the national maritime spatial plan has been drawn up, it will not be permitted to carry out development activities at sea if they conflict with the plan. The project area is located within the MSP's development zone for oil and gas exploitation. The MSP is currently in public hearing and is expected to be finally approved by the end of 2021.

3.11 Regulation of decommissioning

Decommissioning is regulated through Danish legislation in the Subsoil Act (Consolidation act no. 1533 of 16/12/2019) and the Marine Environment Act (Consolidation act no. 1165 of 25/11/2019).

According to the Subsoil Act decommissioning plans for offshore oil and gas installations shall be prepared, submitted and approved by the DEA before the installations can be removed. DEA has prepared a guideline for these decommissioning plans called “Guideline on decommissioning plans for offshore oil and gas facilities or installations” dated August 2018. The guideline explains the legal framework and the required contents of the plans.

In addition, decommissioning is regulated through the following international conventions and declarations:

- IMO's Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter (known as the London Convention 1972) including the 1996 Protocol which became effective in 2006.

  The London Convention is a global convention that aims at protecting the marine environment from human activities by promoting control of sources of marine pollution and by taking steps to prevent pollution of the ocean. Under the convention all dumping of waste is prohibited except certain types of waste listed on the convention's 'reverse list'.

- Ministerial Declaration of the Ninth Trilateral Governmental Conference on the Protection of the Wadden Sea (known as the Esbjerg Declaration 2001).

- OSPAR Commission's OSPAR Convention (1992 and 1998), Annex III on Prevention and elimination of pollution from offshore sources, Decision 98/3 on Disposal of disused offshore installations, and recommendation 77/1 on Disposal of pipes, metal shavings and other material resulting from offshore petroleum hydrocarbon exploration and exploration operations.

- Regarding decommissioning, the Esbjerg Declaration states that more environmentally acceptable and controllable land-based solutions are preferred, and that decommissioned offshore installations therefore shall either be reused or be disposed on land.

The OSPAR Commission establishes the framework for decommissioning including guidelines and procedures. Recommendation 77/1 states that dumping of bulky waste such as pipes and containers is prohibited without special permission excluding inter-field pipelines. All dumping or leaving wholly or partly in place of offshore installations in the North Sea is prohibited according to Decision 98/3. However, derogation from this regulation is possible when there are significant reasons why an alternative disposal is preferred. Decision 98/3 does not include decommissioning of pipelines.

4. Alternatives

A few alternative concepts to the main concept for the unphased development of both Solsort West and East Lobe have been considered and investigated for Solsort Unit, either in the past or in the feasibility phase. These are listed in the below Table 4-1, that is non-exhaustive and presented more in detail in following sections.

Table 4-1 Overview of alternative concepts.

Concept	Description	Type	Status	Comment
Unmanned Solsort WHP	Unmanned WHP at the Solsort field. The well fluid to be transferred to the South Arne East platform, via a multiphase pipeline, and receive and inject water via and water injection pipeline. Production fluids will be processed on the South Arne platform.	Stand-alone	Screened out	Not economical viable
Mobile Production Unit (MPU)	Converted jack-up drilling rig with process module located at the Solsort field for processing of the Solsort fluids. Wellhead support structure with jacket located at Solsort. New export pipelines to be established.	Stand-alone	Screened out	Not economical viable
FPSO	FPSO located at Solsort field for processing of Solsort fluids and unmanned WHP at Solsort. New gas export pipeline to be established to tie-in to existing infrastructure. Oil export through tanker off-loading.	Stand-alone	Screened out	Not considered economically viable based on current business case evaluation and technically challenging
Harald tie-back	Solsort tie-back to Harald through a new module to be placed on the existing Harald platform. New min. manned WHP at Solsort for local water injection.	Tie-back	Screened out	Not economical or environmental competitive
Harald bridge linked platform (BLP)	Tie-back to Harald through a new BLP at Harald. Processing of Solsort fluids at Harald. New unmanned WHP at Solsort.	Tie-back	Screened out	Not economical viable
South Arne bridge-linked platform (BLP)	Tie-back to South Arne through a new BLP at South Arne. Processing of Solsort fluids at South Arne. New unmanned WHP at Solsort.	Tie-back	Screened out	Not economical viable

4.1 Status quo alternative (0 alternative)

A situation in which the present project is abandoned is interpreted as a status quo alternative, where no production will take place from the Solsort field. Consequently, no drilling will take place and no additional impact on the environment.

The offshore oil and gas production are important for the Danish economy. According to Oil and Gas Denmark's report "The green transition – our shared responsibility" from 2019 thousands of people are employed in full-time jobs related to the offshore extraction industry and the state benefits from the tax contribution from the oil and gas business around 5 billion DKK with an expected increase for the coming years to around 10-15 billion until 2037.

The Danish government have set a target stating that 30 % of the energy supply will be supplied from renewable energy sources by 2020. At present, Denmark cannot rely on renewable energy alone and the political decided transition to renewable energy and reduction of carbon emissions whilst ensuring secure energy supplies means that the need for fossil fuels remains. Fossil fuels are still an integral part of a diverse energy mix for a number of years and as such, the development of the Solsort field is very much in line with the current Danish energy policy.

The consequences of a scenario where the Solsort field is not developed will be a lower tax income from the oil and gas activities in the North Sea, no positive socioeconomic effects (employment, financial benefits) and a lower level of energy supply security. On the other hand, if the 0 alternative is to be chosen and the field will not be developed for production, the consequences may involve less direct environmental impact on the North Sea.

4.2 Main concept – Solsort West Lobe development

The Solsort West Lobe concept is drilling of two wells, one producer and one injector, from the South Arne Well Head Platform North (WHPN) into the Solsort West Lobe (WL) reservoir and the associated modifications to the South Arne installations to allow receiving, transporting, processing and exporting of the Solsort fluids.

4.3 Unmanned Solsort WHP

The project concept is tie-back to the South Arne Wellhead Platform East (WHP-East) for further processing at the main South Arne platform.

After processing, the stabilized oil will be exported to tankers via the existing offshore loading system.

Gas will be exported through the existing gas export pipeline to the Danish onshore gas treatment plant in Nybro.

Utilities for the Solsort WHP will be transferred from South Arne facilities through a new ca. 10 km umbilical tied-in on the WHP-East. A pipeline for water injection from the South Arne platform to the Solsort WHP is also planned.

- From an environmental perspective the unmanned Solsort WHP would be of a worse impact compared to the main concept due to following considerations:
- A jacket and a topside are required for the unmanned Solsort WHP case and thus the environmental impact from vessels used during installation, production and decommissioning are worse.
- Only 2 wells are drilled for the Solsort West lobe project compared to the 5 wells planned for the unmanned Solsort WHP, which results in higher energy consumption and discharge of chemicals and cuttings compared to the main concept.
- The use of energy and resources for the unmanned Solsort WHP both during production and decommissioning is worse compared to the main concept
- Pipelines to transfer fluid is needed for this concept and not for the main concept.

4.4 Mobile Production Unit (MPU)

The concept consists of a Solsort wellhead platform (WHP) to support the Solsort wells interfacing an MPU (Jack-Up rig type) for processing the fluids coming from the Solsort wells. Export pipelines would be installed from Solsort to the “Hejre to Gorm E WYE” for the live oil crude and Solsort to the WYE at Harald for the gas export.

The concept is comprised of two different variations, one exporting Sales Gas and one exporting Rich Gas. In both cases nitrogen injection would be required onshore at Nybro. For the Rich Gas export concept further modifications onshore at Nybro would be required to treat the Rich gas.

From an environmental perspective the MPU at Solsort concept would be of a worse impact compared to the main concept, due to some of the same considerations as described in section 4.3.

Based on above, no environmental benefits are seen from the MPU at Solsort concept when compared to the base case.

4.5 Floating, Production, Storage and Offloading (FPSO) vessel at Solsort

The concept consists of a Solsort WHP to support the Solsort wells and a FPSO for processing the fluids coming from the Solsort wells. Pipelines will be installed between the Solsort WHP and the FPSO and from Solsort WHP to the WYE at Harald for the gas export. The stable oil will be exported by a DP tanker.

The concept is comprised of two different variations, one exporting sales gas and one exporting rich gas. In both cases nitrogen injection would be required onshore at Nybro. For the rich gas export concept further modifications onshore at Nybro would be required to treat the rich gas.

From an environmental perspective the FPSO would be of a worse impact compared to the main concept, due to some of the same considerations as described in section 4.3.

Based on above, no environmental benefits are seen from the FPSO at Solsort concept when compared to the base case. In addition, the FPSO concept would introduce technical and legal complexity, such as the fact that a FPSO have never been operated in the Danish North Sea sector.

4.6 Tie-back to Harald

The concept consists of a Solsort unmanned WHP with a multiphase pipeline to connect to the Harald platform for processing of Solsort fluids. Oil and gas export will be through existing Harald export routes. A new, large module would be installed on Harald to provide power, utilities, and water injection to Solsort.

From an environmental perspective the Harald tie-back concept would be of a worse impact compared to the main concept, due to some of the same considerations as described in section 4.3.

Based on above, no environmental benefits are seen from the Harald tie-back concept when compared to the base case.

4.7 Tie-Back to new bridge linked platform at Harald or South Arne

This concept would be like the unmanned Solsort WHP or similar to the Harald tie-back as described above.

From an environmental perspective the difference would be the addition of a BLP at the HOST platform, which would increase the need for offshore vessels for the transportation and installation of the new BLP. No environmental benefits are seen from the BLP concept when compared to the base case.

5. Technical description of project - Construction phase

5.1 Field description

The Solsort field is located within License 7/89, 3/09 and 4/98 in Denmark, approximately 250 km west of the Danish Coast, see Figure 5-1. The field is an oil field.

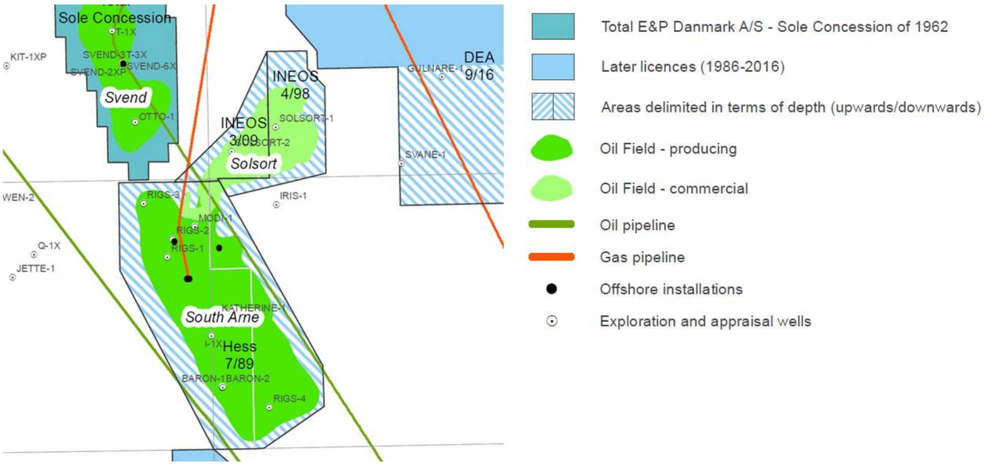


Figure 5-1 Location of Solsort field in relation to South Arne, Map of Danish oil and gas fields

An overview of surrounding infrastructures in the vicinity of the Solsort field is shown in Figure 5-2.

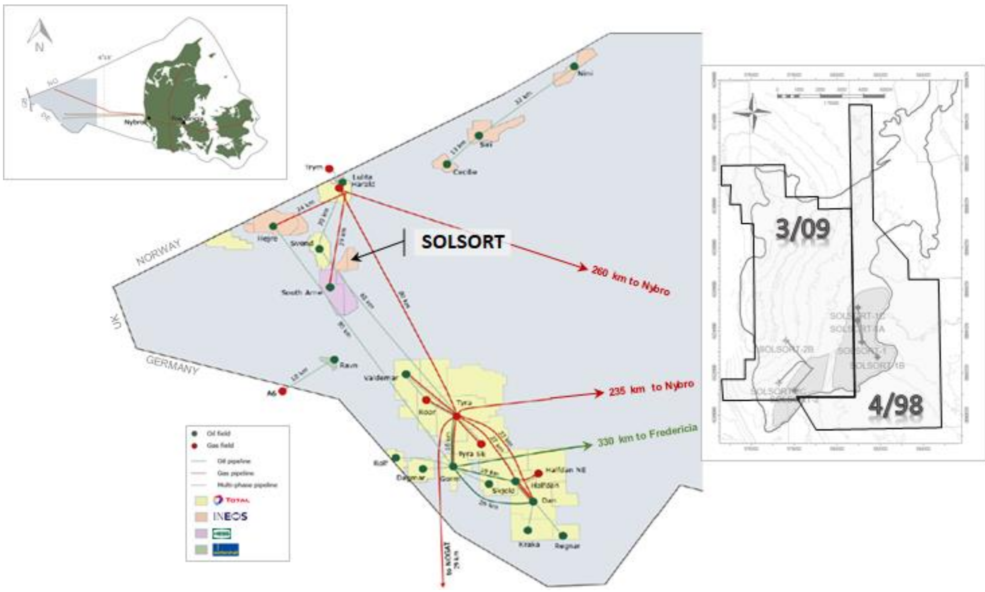


Figure 5-2 Solsort field location and surrounding infrastructure in the Danish sector of the North Sea.

The Solsort field reservoir sand is a basin floor fan system deposited in a ponded basin. The Bor Member is the oldest of the Palaeogene sand members of the North Sea. These sands are all fine grained and rich in glauconite. The sand was shed from the Stavanger Platform and transported by density flows through the Siri Canyon to their current position in the Tail End Graben to form the Solsort lobe complex. Sediment transport in the Tail End Graben was towards the South through a feeder channel system oriented parallel to the Coffee Soil Fault. Just south of the Amalie area, the transport was diverted in a south-westerly direction towards a small basin located along the evolving rim syncline east of Svend and Syd Arne salt structures and delimited to the south by the Iris inversion structure.

The field was discovered by the Solsort-1 exploration well drilled in the East Lobe in 2010 (see Figure 5-3). The Solsort-1 exploration well was drilled as a vertical well with 3 deviated appraisals side-tracks Solsort-1A, Solsort-1B and Solsort-1C that outlined the oil accumulation in the East Lobe.

Solsort-1 was followed by the Solsort-2 appraisal well in the West Lobe in 2013 as a deviated well with two deviated side-tracks appraising the Solsort-2 discovery. Solsort-2 proved the presence of 17 meter TVD hydrocarbon bearing reservoir in the West Lobe at a depth of 3008 - 3025 meters. The two appraisals side-tracks both drilled water filled reservoir.

In Figure 5-3 is indicated the outline of the 2 planned development wells in the West Lobe. One horizontal producer well and one horizontal water injection well. The horizontal sections are around 2000 meter long. Both wells are drilled from the South Arne North Well Head platform.

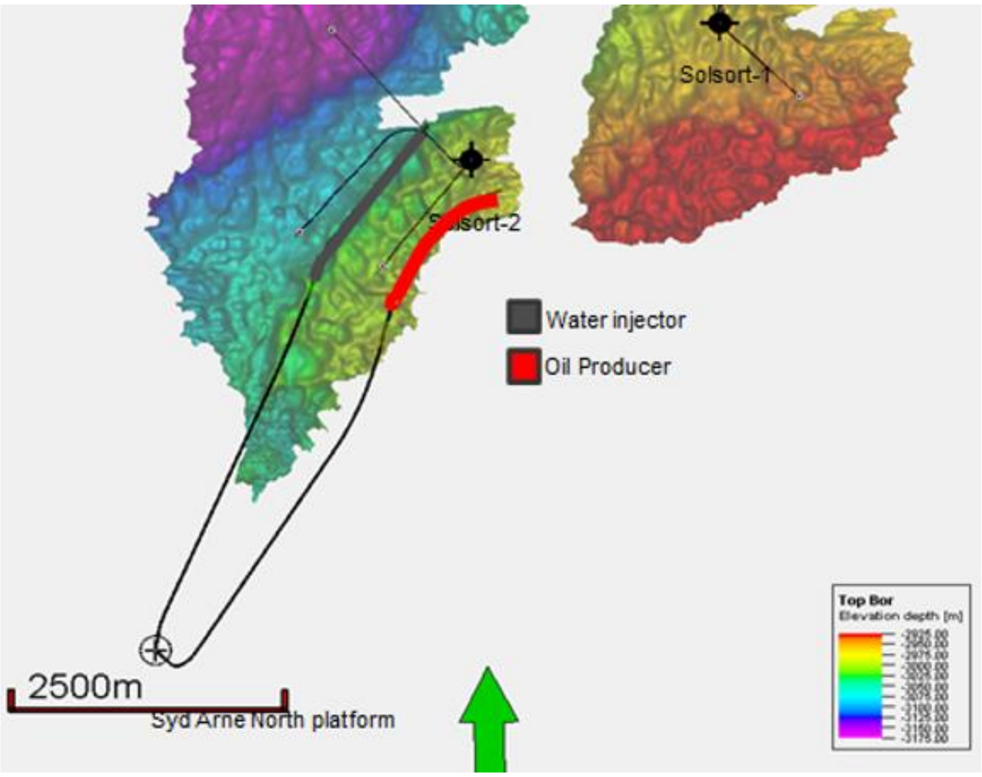


Figure 5-3 Depth map of the Solsort field East and West lobes indicating the existing exploration and appraisal wells Solsort-1, 1A, 1B, 1C and Solsort-2, 2B, 2C and the 2 new wells.

The position of the South Arne and the Solsort West Lobe wells are shown in Table 5-1.

Table 5-1 Position of South Arne and the Solsort West Lobe wells

Projection ED 50 – UTM31	**South Arne North Platform** **Block: 5604/29,30** **Licence: 7/89**		**Solsort** **Block: 5604/26,30** **Licence: 4/98** **Block: 5604/25,26,29,30** **Licence: 3/09**		
	SA Surface Location (RT 62m):		Reservoir Entry and TD:		
	East (X)	North (Y)	East (X)	North (Y)	Z m TVDSS
Producer *(WL-P-01)*	575.947,46 m	6.217.612,91 m	578.040,00	6.220.510,00	2.992,0
			579.154,00	6.221.963,00	2.992,0
Injector *(WL-WI-01)*	575.943,57	6.217.620,68	577.420,00	6.221.080,00	3.040,0
			578.503,00	6.222.606,00	3.048,0

The fluid characteristics for the Solsort West Lobe are shown in Table 5-2.

Table 5-2 Solsort West Lobe reservoir and fluid characteristics.

Parameter (unit)	Value
Reservoir depth (m)	2,900 – 3,050
Reservoir pressure (bar)	416 - 417
Saturation pressure (bar)	265 - 315
Reservoir temperature (°C)	108-109
Oil °API	35-36

5.2 Project overview

The Solsort West Lobe project involves 2 new wells - 1 producer incl. optional gas lift and 1 water injector that optional will be initial producer and afterward permanent water injector - from the Solsort West Lobe drilled from South Arne Wellhead Platform North (SA-WHPN) using South Arne (SA) as host.

The project includes:

- Drilling of up to a total of 2 wells into the Solsort West Lobe drilled from South Arne Wellhead Platform North (SA-WHPN)
- Modifications of the SA-WHPN platform including installation of some equipment as for example a Solsort multi-phase meter and a scale inhibitor injection pump. No structural changes are planned for.
- A new wax inhibitor injection pump at South Arne Wellhead Platform East (SA-WHPE).
- Modifications at South Arne main including modification of existing water injection pump, a new produced water filter and optional a new produced water injection booster pump for mixed seawater and produced water.
- Plugging and abandonment of Solsort West Lobe wells.

5.2.1 South Arne host platform

The facilities at South Arne main, see Figure 5-4 consist of a combined wellhead, processing and accommodation platform, connected by a bridge to a wellhead platform, SA-WHPE, and an unmanned satellite platform, SA-WHPN. SA-WHPE is placed about 80 m east of the existing South Arne platform and connected to the platform by a combined foot and pipe bridge while SA-WHPN is an unmanned platform with a helideck about 2.5 km north of the existing South Arne platform. A bundle pipeline has been established between SA-WHPN and SA-WHPE, which incorporates a production pipeline, lift gas and water-injection pipelines and power supply cables. South Arne main has accommodation facilities for 75 persons.

The processing facilities at South Arne consist of a plant that separates the hydrocarbons produced and an 87,000 m^3 oil storage tank on the seabed from which the oil is exported to shore by tanker. The treated gas is exported by a pipeline to Nybro. All the produced water is processed and treated, after which as much as possible is reinjected and the rest is discharged to sea.

Figure 5-4 South Arne and well head platform East.

The amounts of oil, gas and water produced at South Arne in 2020 are listed in Table 5-3, together with amounts of gas for fuel and flared gas.

Table 5-3 Key activity figures from South Arne 2020 (South Arne OSPAR report 2021).

Activity	Unit	Value
Oil production	thousand Sm^3	479
Gas production*	million Sm^3	82
Produced water, discharged	thousand Sm^3	290
Displacement water discharged	thousand Sm^3	481
Injected water	thousand Sm^3	2,218

* Including for flaring and used locally as fuel

5.3 Drilling activities

5.3.1 Site Survey for relief well

A new site survey might be required to ensure a safe position for a relief well and drilling rig in case of a well control situation and if a safe location cannot be found within current survey areas.

A site survey will collect data to determine the risk level of shallow gas down to surface hole True Depth (TD), as this section is drilled with an open drilling fluid system and a diverter system. The survey will also ensure a safe seabed for rig positioning.

The site survey to be conducted with the following equipment:

- Sparker System (surface-towed Low-frequency)
- Sub-bottom profiler (Chirp) system
- Multibeam sounder

- Dual Channel side scan sonar
- Underwater positioning system
- Magnetometer

The exact equipment that is to be used is not known by now, as the contractor performing the survey has not been chosen yet. The above equipment is what is normally used during geophysical site surveys like the planned survey for the location of a rig.

Emissions

The duration of the site survey for relief well are estimated to be approximately 21 days. The conduction of the survey itself will take between 2 and 4 days, but due to potential standby in case of weather conditions and transport onshore/offshore the activities regarding the survey are set to be operational for 21 days. Emissions to air from survey activities are related to:

- Supply vessel fitted with needed equipment

The needed crew and fitted equipment are transported to and from the area by the same vessel. Thus, the whole duration of the operation including transport is accounted for regarding the associated emissions.

Underwater noise

Equipment expected to be used during the survey is listed above. Most of the equipment has been assessed as having no significant impact inside the Natura 2000, based on the frequency range, which is either too high or too low for marine mammals to hear, compared to their hearing threshold according to the report ”Environmental assessment of pipeline route survey” prepared by RAMBØLL on behalf of INEOS. Noise propagation has been calculated for three of the listed instruments, which has been assessed as having the largest noise impact. The three instruments are:

- Surface-towed Low-frequency SBP GeoSpark 200TIP. Source level is estimated to be 188 dB re 1 µPa2s at 1 meter SEL.
- High Res. Sub-bottom profiler (CHIRP, Innomar SES2000 Medium). Source level is estimated to be 243 dB re 1 µPa2s at 1 meter SEL, corrected for beam directivity.
- Singlebeam Echosounder (Kongsberg EA 400). Source level is estimated to be 147 dB re 1 µPa2s at 1 meter SEL

Potential impacts from the geophysical survey have been assessed and described in section 10.3.

5.3.2 Location assessment

Before rig arrival a site survey in form of a basic Remote Operated Vehicle (ROV) will inspect the area for setting the spud cans to ensure no obstacles can intervene with the jack-up process. The ROV inspection will be carried out from a simple fishing- or supply vessel.

The area next to the South Arne North platform have had a rig standing next to it relatively recently. However, it might be required to perform new geophysical drilling activities to confirm the soil integrity for supporting another type of rig.

5.3.3 Well design and drilling

Two wells are envisaged to be drilled from the South Arne WHPN, one production well and one water injection well, into the Solsort West Lobe (WL) reservoir.

The wells are expected to be drilled by a three-legged jack-up rig from the South Arne WHPN. The drilling of the wells is planned to take place in 2022 at the earliest. The planned drilling period is estimated to last 240 days, with 120 days per well. The expected depth of reservoir drilling is around 2,900 - 3,100- meters True Vertical Depth (TVD). Additionally, there is a possibility of drilling a technical side-tracks or geological side-tracks (to be decided later).

The well design considered consists of five sections: a 26" conductor pipe, an 18-5/8" surface casing, a 13-3/8" intermediate casing, a 9-5/8" production casing, and an 8-½" open hole section.

When drilling the wells, first the conductor is drilled and cemented into the seabed or hammered in position. Installation of the conductor typically takes between 24 and 86 hours. Soft start procedures will be applied if hammering of the conductor.

5.3.4 Drilling rig

INEOS plan to use a jack-up rig for drilling the wells. The drilling rig is designed to minimize discharges during drilling operations.

The jack-up rig will be towed to the South Arne WHPN. When the rig is in position, the rig's legs with spud cans will be lowered into the seabed to ensure that the rig will stay stabilized during drilling operations. A spud can is a flat conical shaped foot attached to the leg of the rig, which ensures that the rig will not sink too deep into the seabed. The spud cans will typically penetrate 0.5-3 m into the seabed, depending on the underlying sediment. If necessary, the spud cans can be supported by rock dumps. Each spud can will have a size of 201 m^2, which is 603 m^2 (0.000603 km^2) in total. The substructure of the leg will be an open construction with 3 rig legs each having a size of around 671 m^2, which results in 2013 m^2 (0,002013 km^2) in total.

The jack-up rig will be positioned alongside the South Arne WHPN. The drilling derrick will then be positioned over the platform so that the wells can be drilled through the selected slots on the platform.

5.3.5 Use of chemicals in the construction phase

Chemicals will be used for a variety of purposes in the construction phase of Solsort West Lobe wells. Thus, a few chemicals are added to the drilling muds to optimise the drilling process and subsequently for cementing and completion of the wells prior to initiation of the production. Also, chemicals are needed on the rig itself (utility chemicals).

The processes and the associated use of chemicals are described in more detail in the following sections, which include tables providing an overview of the expected amounts of chemicals with different functionalities to be used in the different construction sub-phases. Each chemical is assigned to an environmental category by use of colour codes.

It should be noted that many of the chemicals mentioned in the following tables are not or only to some extent being discharged to the sea after use. Some will remain completely or partially in the formation, while others are brought onshore e.g., along with cuttings/mud for treatment and disposal.

5.3.6 Drilling muds

Offshore drilling typically applies two types of drilling mud: water-based mud (WBM or Formate fluid) and low toxicity oil-based mud (OBM). Both types of drilling mud will be applied during drilling of the Solsort West Lobe wells (see Table 5-4).

For the Solsort West Lobe wells, WBM is applied in the 26" and 21-1/2" (18-5/8" casing) sections, and OBM is applied in the sections below 17-1/2" (13-3/8" casing) and 12-1/4" (9-5/8" casing). It has been assessed that drilling of a 13-1/2" underreamed hole will be needed due to hole stability issues. In addition, specifically for the horizontal reservoir drilling section (8-½"), Cs/K formate brine (WBM) drilling fluid will be used. Table 5-5 and Table 5-6 show the planned usage of chemicals for the drilling of the two wells.

Table 5-4 Types of drilling mud for Solsort West Lobe wells. Water-based mud (WBM), low toxicity oil-based mud (OBM) and Cs/K formate mud (horizontal sections).

Section	Drilling mud
26"	WBM
21-1/2" (18-5/8" casing)	WBM
17-1/2" (13-3/8" casing)	OBM
13-½"	OBM
9-½"	Cs-K Formate

Drilling muds have six primary purposes:

- Moving the cuttings (produced by the drill bit) from the well to the surface.
- Lubricating and cooling the drill bit during operation.
- Maintaining hydrostatic pressure in the well so that gas and fluids in the surrounding environment do not enter the well, thereby minimizing the risk of a kickout or a blowout.
- Building a protective layer on the well wall to prevent loss of fluids.
- Supporting and preventing collapse of the wellbore.
- Inhibiting wellbore and cuttings

The drilling rig circulates the mud by pumping it through the drill string to the drill bit. From there it travels back up the annulus space between the drill string and the walls of the hole being drilled and the last casing installed. During drilling of the lower part of the well using OBM and drilling the reservoir section with Cs/K formate, the rig switches to total containment mode to obtain zero discharge, in accordance with OSPAR Decision 2000/3. It is a closed circulating system where the mud is recycled throughout the drilling period for the well.

All WBM and the associated chemicals and cuttings are discharged to the sea a few meters below the sea surface. All OBM and Cs/K formate fluids used to drill the reservoir section and associated drill cuttings are contained and shipped for onshore disposal or recycling, alternatively they are injected into one of the cutting reinjection (CRI) wells on the WHPN. Hence, neither OBM or Cs/K formate, nor associated chemicals or cuttings, are discharged to the sea.

Table 5-5 Estimated usage of WBM chemicals at Solsort West Lobe (per well). All the usage figures include 50% for contingencies.

Estimated use for WBM drilling	Planned use per well [tons]	Colour code
Barite	147	Green
Bentonite	71	Green
Soda ash	2.3	Green
Viscosifier	5.4	Green
pH lower	17.6	Green
pH control	18	Green
Lost circulation material (total)	242	Green
Defoamer	1.1	Yellow

Table 5-6 Estimated usage of OBM and Cs/K formate chemicals at Solsort West Lobe (per well). All the usage figures include 50% for contingencies.

Estimated use for OBM and Cs/K formate drilling	Planned use per well [tons]	Colour code
Chemicals for vertical OBM drilling		
Barite	1540	Green
Synthetic paraffin fluid	1365	Yellow
Emulsifier	56	Yellow
Filtration control	15	Red
Viscosifier	15	Yellow
Viscosifier	33	Green
Calcium chloride	84	Green
Lime	15	Green
Calcium carbonate	75	Green
Lost circulation material (total)	300	Green
pH lower	26	Green
pH control	25	Green
Defoamer	2.2	Yellow
Chemicals for horizontal Cs/K formate drilling		
Potassium formate	1350	Green

Estimated use for OBM and Cs/K formate drilling	Planned use per well [tons]	Colour code
Caesium formate	165	
Potassium bicarbonate	5.3	
Potassium carbonate	5.9	
Polymer	3.6	
Filtration control	2.9	
Calcium carbonate	38	
Friction reducer	42	
Lost circulation material (total)	155	
H_2S scavenger	7.4	
Defoamer	0.7	
pH lower	12	
pH control	11	

5.3.7 Cementing

Casing is cemented into place in all the sections of the well. When drilling of each section is completed, sections of metal casing, slightly smaller than the well diameter, are placed in the hole to provide structural integrity. These are fixed into place by pumping cement into the annulus space between the casing and the well wall.

The cement fluids are pre-mixed in pits on the drilling rig before being pumped into the well. To minimize the quantities of chemicals used, a cement liquid additive system is used to calculate the volumes of pre-mixed fluids required. Possible dead volumes may remain in the pit after the operation and excess cement may return from the well. In both cases, the cement will be discharged to sea.

Table 5-7 gives an overview of the estimated usage of cementing chemicals at Solsort.

Table 5-7 Estimated usage of cementing chemicals at Solsort (per well). All the usage figures include 25% for contingencies.

Estimated use for cementing	Planned use per well [tons]	Colour code
Cement	814	
Barite	180	
Retarder 1	18	
Sodium silicate	5.8	
Stabilizer/gas migration control	36	
Spacer	5.6	
Friction reducer	9.2	

Estimated use for cementing	Planned use per well [tons]	Colour code
Emulsifier	2.8	
Mutual-solvent	2.8	
Retarder 2 (only contingency)	2.0	
Fluid loss control additive	24	
Defoamer	1.0	

5.3.8 Completion and borehole clean-up

When reaching the reservoir, the completion process begins. A sand control completion is installed in the reservoir section. Then, the top completion takes place installing the production tubing, safety valves, sensor for pressure and temperature measurements and valves for injection required downhole chemicals.

Completion of a well consists of a few processes that start after the well has reached TD. The well must first be circulated clean for drill cuttings and the fluid conditioned to ensure the reservoir completion can be run to TD. The reservoir completion is run in weighted and cleaned drilling fluids. An inner string might be run inside the lower completion for optional annulus displacement to a Breaker system capable of dissolving established filter cakes or other material on the outside of the sand screen, that could plug up the sand screens during clean-up production. Then the top completion is installed and prior to setting the production packer the upper part of the well is displaced to a clean and inhibited completion fluid as the fluid could be static for a longer period between the production casing and the production tubing.

Table 5-8 provides an overview of the estimated amounts of completion chemicals to be used at Solsort WL. Possible amounts for contingencies are included in the figures.

Table 5-8 Estimated usage of completion chemicals at Solsort West Lobe (per well). All the usage figures include 50% for contingencies.

Estimated use for completion	Planned use per well [tons]	Colour code
Hydrate inhibitor (MEG + methanol)	57	
Base oil	27	
Viscosifier	0.3	
Surfactant	1.8	
Weight control	530	
Bactericide	0.9	
Oxygen scavenger	1.8	

The wellbore displacement to completion fluid will displace the Cs/K formate drilling fluid out of the well and up to the rig, where it will be treated and contained, or if not useable possible reinjected into a CRI well. In this process, a spacer train containing viscous and detergent pills is pumped into the well ahead of the completion fluid to maintain a good interface between the two type of fluids.

As much as possible of the returned drilling fluid from the borehole clean-up will be collected for reuse, recycling, reinjection or disposal onshore.

5.3.9 General clean-up

After completing and preparing the wells for production, a well clean-up process will be performed.

The wells are opened on the tree and the weighted drilling and completion fluid is initially removed/flowed from the wells. Once the completion fluid is produced back reservoir fluids will come to surface. As much as possible of the returned drilling and completion fluid from the well will be reinjected or shipped to shore for reuse or disposal. The wells will be cleaned-up via rig-based equipment from which the well fluids are directed to the rig-based burners and burned. Minor droplets of oil can reach the sea surface creating a thin sheen at surface, which cannot be collected with the measures in place. In case of serious oil drop-out to sea surface creating more than a sheen the oil spill response set-up will be mobilized as per normal procedure. Drilling fluid remaining after well clean-up and completion fluid below the completion tubing will be produced with the formation fluid to the clean-up surface package.

A well clean-up period is typically 24-48 hours during which flaring will take place. The well is cleaned up until the returned fluid has a quality acceptable to be handled by production facilities.

5.3.10 Well intervention / Well service

Over the lifetime of the Solsort field, there will be some visits due to well intervention activities (wireline, coil tubing, workovers). Some of these will be planned maintenance activities, while others are contingency activities that will only take place if something is wrong with the wells.

In total, up to 6 to 8 months of rig visits to Solsort West Lobe wells are expected over the lifetime of the field. The rig type is assumed to be like that used for the drilling activities. It is not given that the full number and duration of rig visits will be needed.

5.3.11 Utilities

A limited number of chemicals will be used at the rig during the construction and testing of the Solsort West Lobe wells (utility chemicals), mainly for cleaning, sealing and lubricating purposes.

Table 5-9 lists the estimated amounts of utility chemicals planned to be used at Solsort West Lobe.

Table 5-9 Estimated usage of utility chemicals at Solsort West Lobe (per well).

Estimated use for utility	Planned use per well [tons]	Colour code
Rig wash	48	Yellow
Pipe dope	0.5	Yellow
Jacking grease	0.3	Yellow
Casing grease	0.3	Yellow
POB control line fluid	0.3	Yellow

About 50% of the rig wash chemical is expected to be discharged to sea while only about 10% of the other rig chemicals will be discharged.

5.4 Overview of usage of chemicals during drilling

In summary, the expected usage of chemicals in the different stages of the construction are listed in Table 5-10 segregated into the main hazard categories (DEPA colour classification black, red, yellow and green). All hazard categories have been included in the table although chemicals in the category black are not planned to be used. Possible amounts for contingencies are included in the figures (50% for drilling chemicals and 25% for cementing chemicals).

Table 5-10 Overview of expected usage (in tons) per well of chemicals classified as black, red, yellow and green for the main construction activities at Solsort. No chemicals classified as black is planned to be used. All the usage figures include amounts for contingency

Activity	Black chemicals (tons)	Red chemicals (tons)	Yellow chemicals (tons)	Green chemicals (tons)
Drilling, WBM	0	0	1.1	503
Drilling, OBM + Cs/K formate	0	15	1656	3679
Cementing	0	0	42	1059
Completion	0	0	32	587
Utility	0	0	49	0

5.5 Discharges to the sea during drilling

During the construction of a well, a number of the materials or chemicals being used or generated will be discharged to the sea. In terms of tonnage, the discharge of cuttings and water-based drilling mud, WBM, are the most significant. WBM consists mainly of a brine with added bentonite and barite and a number of agents aimed at regulating viscosity and stabilising clay. OBM and cuttings from the reservoir sections will not be discharged to sea.

Table 5-11 provides an overview of the amounts of cuttings and muds from different drilling sections (per well) and their fate.

Table 5-11 Estimated generation and discharge of cuttings and drilling mud at Solsort West Lobe (per well).

Section	Amount of cuttings [MT]	Drilling mud [m^3]	Discharge to sea
26''	269	858 (WBM)	Cuttings: 1392 MT WBM: 858 m^3
23''	1123		
17 ½''	1322	1299 (OBM)	0 (OBM, not discharged)
13 ½''	697		
9 ½''	386	563 (Cs/K formate)	0 (Cs/K formate, not discharged)

As can be seen in the table, all OBM and Cs/K formate cuttings with adhered mud will be reinjected or shipped onshore for further treatment and disposal, and, thus, there will be no discharge from the sections drilled with OBM and/or Cs/K formate.

The construction of a well at Solsort includes drilling, cementing and completion. Stimulation or fracking will not be necessary. In addition to these, the operation of the rig itself requires a few utility chemicals for e.g., rig wash etc. Some of the chemicals will be discharged to sea. The amounts of chemicals estimated to be discharged from the different activities are shown in Table 5-12 according to colour coding. The largest amount of chemicals discharged will be from the green category. The figures include amounts for contingencies set conservatively at 50% for all drilling chemicals and 25% for all cementing chemicals.

Table 5-12 Overview of estimated discharge of black, red, yellow and green chemicals per well for the main construction activities at Solsort. No chemicals classified as black is planned to be used.

Main activity	Black chemicals per well [tons]	Red chemicals per well [tons]	Yellow chemicals per well [tons]	Green chemicals per well [tons]
Drilling, WBM	0	0	1.2	470
Drilling, OBM and Cs/K formate	0	0	0	0
Cementing	0	0	13	294
Completion	0	0	2.3	338
Utility	0	0	24	0

5.6 Emissions during drilling

Emissions to air in relation to drilling activities are related to:

- Energy production at the rig
- Crew transport activities by helicopter, standby boat, and supply boat
- Flaring during well clean-up
- Volatile Organic Compound (VOC) emissions from the oil-based mud

The vessel types in Table 5-13 will be used for transport.

Table 5-13 Type of transport related to drilling activities for 2 wells (provided by INEOS).

	Numbers	Days	Fuel consumption [m³/day]
Drilling			
Rig	1	280[1]	11.4
Supply vessel	3	128[2]	4.8
Standby boat	1	280[3]	4.8
Tugs	2	15[4]	20
Helicopters (kerosene)		36[5]	1.2

[1] The rig is operating 140 days per well.
[2] 3 supply vessels operating 11 hours/day in 280 days equivalent to 43 days per vessel per well.
[3] Standby boat is available 24 hours/day while rig is operating.
[4] Operation of tugs for transportation of the rig
[5] Helicopters are operating 3 hours/day equivalent to 10 days per well.

An estimation of the emissions related to drilling activities can be seen in section 10.5.

5.7 Modification at South Arne Installations

The wells will be drilled utilising the most appropriate slots on South Arne North platform. The production and injection flowlines will be installed within the existing allocated future flowline space envelope and utilise existing future slot control provisions on WHPN and in the well head control panel. Production fluids will be metered by a new dedicated multiphase flow meter (MPFM). Post metering, the Solsort West Lobe produced fluids will be routed to the existing production header and comingled with native South Arne production at WHPN and then transported onto South Arne main platform via the existing multiphase subsea production pipeline via WHPE. The West Lobe produced water will be reinjected as part of the South Arne produced water reinjection.

5.7.1 Water injection

Mixed water (Sulphur Removal Package (SRP) plus produced water (PW)) will be supplied from the existing WHPN water injection manifold for injection into the West Lobe reservoir. A new produced water filter is anticipated to be required within the existing produced water pump train at the South Arne main platform to achieve the Solsort mixed water suspended solids specification. An additional Produced Water booster pump might be installed later, either for capacity reasons or for improving uptime.

5.7.2 Gas Lift

Gas lift of the West Lobe production well is only required as a contingency if the reservoir pressure is depleted or the well productivity is very poor, i.e., the gas lift is a risk mitigator rather than a production optimisation. In this case the gas lift pressure system available on South Arne WHPN will be used.

5.7.3 Chemicals

All West Lobe chemical injection requirements will be supplied from South Arne. It is expected that new dedicated scale inhibitor pumps are required at WHPN to accommodate Solsort injection rates. Chemicals in use at South Arne for the same services are assumed to be suitable for Solsort.

South Arne currently does not carry Wax Dissolver chemical for intermittent start-up. Base case assumption is supply from a temporary system mobilised as required to South Arne WHPN rather than provide permanent facilities.

Continuous wax inhibition injection via the existing umbilical from WHPE to the WHPN subsea pipeline is done for mitigating against wax formation in the South Arne crude oil coolers, storage and export systems. For this purpose, a new wax inhibitor pump will be installed at the SA-WHPE.

Use of chemicals during production is described in 6.3.1.

5.7.4 Emissions

Emissions to air during modification of the South Arne installations are related to:

- Supply boat
- Standby boat.
- Crane operations

The South Arne supply boat will be utilised also for the South Arne modifications, thus no additional emissions related to this activity is expected. It is expected that lift of equipment can be handled by the lifting equipment on board the South Arne installations.

Based on the above no additional emissions are expected due to the modifications required due to tie-in of the Solsort West Lobe wells.

6. Technical description of project, production phase

In the following a description of production activities related to the Solsort West Lobe wells are presented.

6.1 Production from the Solsort West Lobe wells

The current project development plan with South Arne as host platform anticipates first oil exported from Solsort West Lobe wells in 2023.

The production profile during the expected lifetime of Solsort is shown in Figure 6-1.

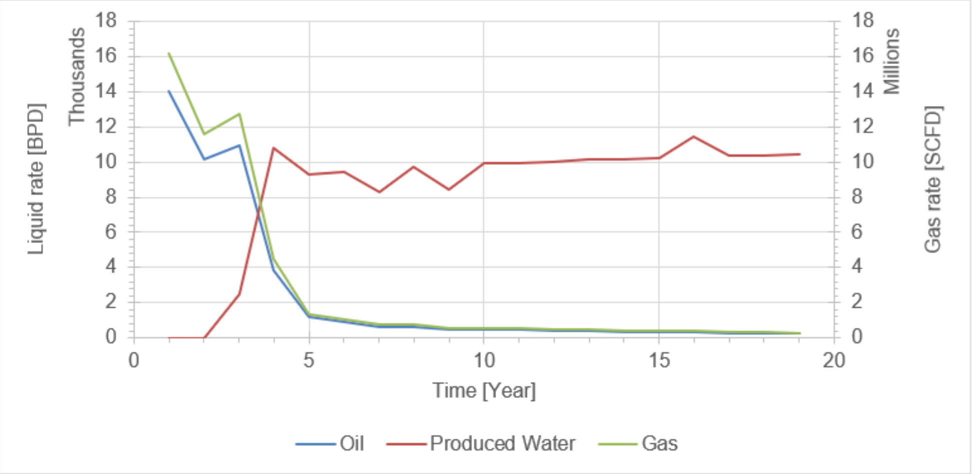


Figure 6-1 Indicative production profile from the Solsort West Lobe, over the life-time of the field with a maximum allowable oil rate of 14000 BPD. Production of oil and gas is expected to reach a maximum within the first 3 years of production, after which it will gradually decline. Water production is expected to increase gradually during the lifetime of the field.

The multiphase production will be transported from South Arne wellhead platform North to the South Arne wellhead platform East and from there commingled with other South Arne production to the processing facilities on South Arne main Platform. Processing will take place on the South Arne platform.

The stabilized oil will be stored at a sub-sea tank and exported via loading to tankers. Gas will be exported through the existing gas export pipeline to the Danish onshore gas treatment plant in Nybro. Any excess natural gas liquids will be utilized offshore as fuel.

The production profile after tie-in of Solsort West Lobe wells is shown in

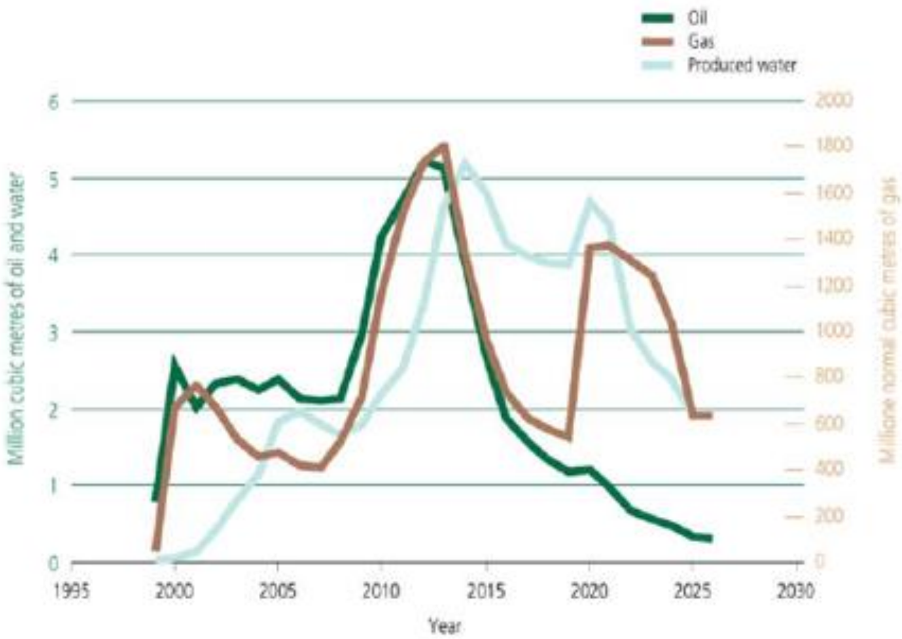


Figure 6-2 Total production for both South Arne and Solsort West lobe wells.

6.2 Maintenance

6.2.1 Wells

Solsort West Lobe wells will require regular intervention over the field life like the other South Arne wells at the South Arne wellhead platform North.

It is expected that the maintenance of the Solsort West Lobe wells is covered by the planned maintenance of wells for the South Arne wells.

6.3 Discharge of produced water

During the processing at the host platform, where oil and gas is extracted from the multiphase production, the remaining produced water mixed with treated seawater is transported back to South Arne North Well Head platform for injected into the reservoir at the Solsort injection well to maintain a high pressure in the reservoir and thereby ensuring a high oil recovery.

Discharge of produced water is not expected to increase due to the tie-in of the Solsort West Lobe production well.

The discharge of produced water is expected to be limited due to high produced water reinjection above 80% at South Arne supported by the improvement of the water injection system.

6.3.1 Production phase chemicals

The use of chemicals is evaluated continuously balancing technology, economy and impacts on environment and work environment.

All Solsort West Lobe chemical injection requirements are supplied from South Arne. It is expected that new dedicated scale inhibitor pumps are required at WHPN to accommodate Solsort West Lobe injection rates. Indicative chemical injection requirements are summarised below. Chemicals in use at South Arne for the same service are assumed to be suitable for Solsort:

- Scale inhibitors to prevent mineral coating on steel surfaces.
- Corrosion inhibitors to protect the steel in the processing equipment from corrosion.
- H_2S and oxygen scavengers to remove H_2S from the produced gas, to meet the specifications. Not clarified yet whether this product will be relevant to use.
- Biocides
- Wax inhibitors and dissolvers to prevent precipitation of wax on cold surfaces
- Sodium hypochlorite as a bactericide.
- Antifoam to secure separation of oil and water.
- Demulsifier to enhance the separation of oil and water in the separators.
- Flocculant to enhance the processing.

Estimated use of chemicals for production	**Planned use after tie-in of Solsort wells [ton/year]**	**Planned discharge after tie-in of Solsort wells [ton/year]**	**Colour code**
Biocide (Process + deaerator)	6	1	Y
Corrosion inhibitor	65	8	Y
Demulsifier	1	**0**	Y
PW treatment	5	0,3	Y
H_2S scavenger (Batch treatment)	195	23	Y
Sodium hypo-chlorite	165	165	R
TEG	3	0,15	Y
Scale inhibitor	44	5	Y
Scale inhibitor (WI)	58	7	Y
Wax inhibitor	0,3	0	R
Wax treatment	0,01	0	R
Total after tie-in of Solsort wells tie-in	542	209	
Red	165	165	
Yellow	377	44	
Green	0	0	
Total South Arne (2007)	647	336	
Red	82	82	
Yellow	495	188	
Green	70	66	

As can be seen in the table above the amounts of expected used and discharged chemicals will be lower compared to the amounts from South Arne EIA (2007). The discharge of red chemicals will increase with a factor 2 not due to the Solsort tie-in but due to the changes classification of sodium hypochlorite.

Hydraulic oil will be used in a closed system for wellhead control panel and actuated valves. As this is a closed loop system, there will be no discharge to sea. The expected volume is <100 litre in total and this is installed onshore as part of the equipment purchase. No replacement of oil hydraulic oil is expected over the lifetime of field.

6.4 Emissions

The multiphase is transported to the South Arne wellhead platform East and further to the South Arne main platform, where the processing of the oil gas and water takes place. In relation to the production emissions to air will be generated from fuel gas, flare gas and diesel combustion. A temporary higher amount of flaring may be expected during tie-in of the Solsort West Lobe wells compared to normal production flaring.

The tie-in of Solsort West Lobe wells will be within the existing production capacity on South Arne. It is assumed that the emissions to air are proportional to the production volume for diesel and fuel gas and is within the existing approvals for South Arne.

6.5 NORM

It is a general experience and well-known that offshore oil production in the North Sea is associated with contamination of certain parts of the processing equipment by small amounts of natural radioactive constituents in the reservoir, which are transported to the surface along with the extracted oil and/or particles. This material with low-level radioactivity is known as NORM (Naturally Occurring Radioactive Material).

NORM will most likely also be present at the Solsort West Lobe field and will have to be handled, stored and disposed of in accordance with the Radiation Protection Act administered by Sundhedsstyrelsen, Strålebeskyttelse, SIS (see section 3.4)

6.6 Human Health

Establishment of large structures can have direct or indirect impact on human health and their possibilities for use of recreational areas.

The typical impacts would be noise, visual effects, impacts on the humans possibilities for use of culture, nature etc.

The offshore oil and gas installation are too far from shore to result in impact on human health from the activities taking place both during construction, operation and decommissioning.

7. Technical project description, decommissioning phase

7.1 Decommissioning of the Solsort West Lobe Wells

The lifetime of the Solsort West Lobe Wells will be approximately 25 years depending on the lifetime of the South Arne installations. The decommissioning of the Solsort West Lobe wells will be conducted in accordance with Danish legislation and international agreements in force at the end of the installation lifetime.

7.1.1 Decommissioning procedure

The following is a general description of how production wells may be decommissioned:

- Production strings and casings are pulled out of the well and transported to shore for reuse or recycling.

- The reservoir will be secured by plugging and sealing the wells with concrete fillings in predetermined depths of the wells. The concrete fillings prevent the gasses and fluids from escaping from the wells into the marine environment or into other layers in the underground.

The procedure for abandonment of wells will follow the same logic as for a South Arne wells and to a great extent as possible reuse or recycling of equipment will be preferred.

NORM may occur in relation to decommissioning. Procedures are prepared and implemented for safe handling of equipment contaminated with NORM and reviewed by Authorities.

7.2 Possible impacts

The plugging and sealing of the abandoned wells will prevent contamination of the surrounding waters and sediments with oil components and other chemicals.

7.2.1 Cutting piles

When a field on deeper waters is abandoned, cuttings piles from the drilling operations are often encountered beneath platforms. Such piles are sometimes removed during decommission but not expected for the Solsort project. However, Cuttings piles are, however, not likely to develop in the relatively shallow waters (60 m) at Solsort with relatively strong currents on the seabed that will disperse the cuttings.

7.2.2 Emission to air

Air emissions can be expected from the operating fleet to execute and support the decommissioning activities as jack-up rig, standby-boat and supply boats almost like the construction fleet. These emissions are covered by the South Arne EIA description of the decommissioning and the decommissioning plan to be prepared for these installations.

8. Existing environment

This chapter describes the physical, biological, ecological and human use features and conditions in the North Sea, which are relevant for the assessment of impacts during the construction, production and decommissioning phases of the development of the Solsort West Lobe field and associated modifications to the South Arne installations.

Table 8-1 provides a list of the potential receptors that are described in this chapter.

Table 8-1 Relevant receptors for the assessment of impact during construction, production and decommissioning of the Solsort West Lobe.

Environmental receptors	Social receptors
• Bathymetry • Hydrography • Air quality and climate • Plankton • Primary production • Water quality • Sediment composition and quality • Benthic fauna • Non-indigenous species • Sea floor integrity • Contaminants in sediments • Birds • Marine mammals • Fish	• Protected areas (Natura 2000) • Fisheries • Maritime traffic

As far as possible the existing environment is described according to the descriptors as defined in the Marine Strategy Framework Directive (see section 3.9). The relevant descriptor is indicated as D1, D2.. etc. in the titles of each of the following sections where relevant.

8.1 Bathymetry

The Solsort and South Arne fields are located centrally in the North Sea. The North Sea is relatively shallow with a maximum depth of 800 m in the north down to 20 m at the Dutch and German coasts (average depth 80 m). The Solsort field is situated Northeast of the Dogger Bank on water depths around 61 m.

8.2 Hydrography

The North Sea is a semi-enclosed area, and the currents are mainly driven by the topography and determined by the water inflow from the North Atlantic through the English Channel, river outflow and the out-going currents from the Baltic Sea. The general circulation of the tidal currents in the North Sea are characterised by a strong north going current along the continental coast and an east going current in the central North Sea (Otto et al. 1990). The prevailing currents at South Arne/Solsort area are east-going (Figure 8-1).

Hydrographical fronts are created where the different water masses meet and include upwelling, tidal fronts, and saline fronts. Hydrographical fronts are generally highly productive areas since nutrients are brought from the seabed to the surface waters. The Solsort and South Arne fields are located outside areas with the potential to develop hydrographical fronts and is consequently low productive areas (Edelvang et al. 2017, OSPAR 2000). Areas with hydrographical fronts are shown on Figure 8-1.

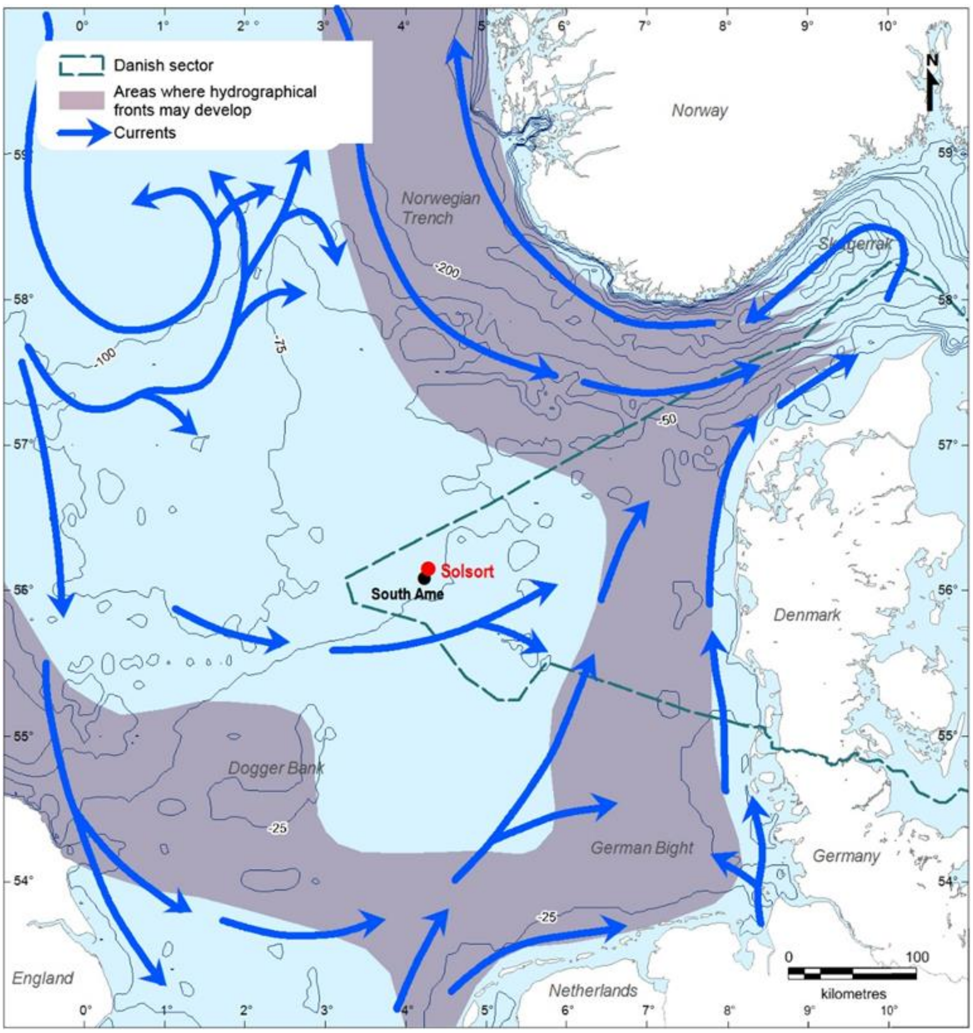


Figure 8-1 General circulation of surface currents in the North Sea and the location of areas in the North Sea where hydrographical fronts may develop (OSPAR 2000).

8.3 Air quality and climate

The air quality in the project area is affected by global and local emissions of CO_2, NO_X and SO_X. Most of the emissions of NO_X and SO_X in the North Sea area are emitted from cargo ships and the concentration of anthropogenic emissions falls with distance from the coast. Despite this, platforms contribute to air pollution.

In Table 8-2 below the emission from the South Arne installations during production for 2020 is shown. No drilling activities took place in 2020.

Table 8-2 Emissions from the South Arne installations for 2020 based on the South Arne OSPAR report 2020.

CO_2	NO_x	nmVOCs	CH_4	SO_2
(10^3 tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)
165	243	394	107	7

8.4 Plankton

Plankton constitutes the main biomass in marine ecosystems and plays a fundamental role in marine food webs. Plankton includes phytoplankton (pelagic microscopic algae) and zooplankton (pelagic microscopic animals) drifting passively with currents. Zooplankton includes both organisms that stay planktonic during the entire life cycle (holoplankton) and organisms that are only planktonic in the earliest life stages (meroplankton) such as larvae of fish, sea urchins, starfish, mussels, bristle worms, shrimps, crabs and lobsters.

8.4.1 Phytoplankton

Diatoms and autotrophic dinoflagellates dominate the phytoplankton in the North Sea. Solsort and South Arne are in an area of the North Sea, where the water is stratified during the summer. Algal blooms typically occur during spring as the light intensity increases when the water masses are mixed and there are available nutrients. During summer, the biomass of plankton decreases due to the stratification and the depletion of nutrients in the surface waters. A minor bloom is often observed during the autumn, when the waters are mixed, and nutrients are again available in the surface waters.

8.4.2 Zooplankton

Copepods dominate the zooplankton in the North Sea. Copepods are food for fish and other organisms, including larvae, juveniles and mature individuals of many commercially important fish species such as herring and sprat.

The composition of the copepod populations in the North Sea has changed markedly. The biomass of the previously dominant "cold-water" copepod *Calanus finmarchicus* has declined by 70% since the 1960s and is now primarily encountered in colder waters north and north-west of the North Sea. On the other hand, species with warmer water affinities e.g., *C. helgolandicus* has moved northwards into the North Sea from the south to replace *C. finmarchicus*. The displacement of cold- and warm water species to the north has been related to global warming and the observed increase in the water temperature in the North Sea (ICES 2016, Planque and Fromentin 1996).

8.5 Primary production

ın the North Sea, primary production is generally higher in the coastal regions compared to offshore areas. This is due to inputs of nutrients from rivers, the fact that hydrographical fronts may develop and that the water column is mixed during the productive seasons in coastal areas. The primary production has decreased since the 1980s because of reductions in discharge of nutrients from land (ICES 2016). Solsort and South Arne are in an area with low plankton production (Figure 8-2).

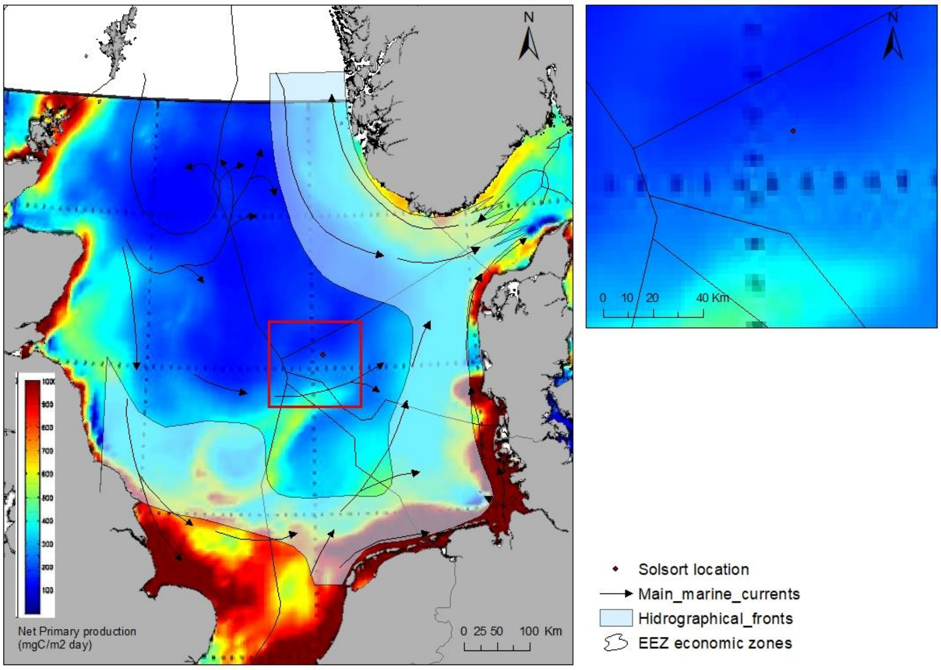


Figure 8-2 Net primary Production (mg m-2d-1), modelled yearly average for a representative year. The location of Solsort is indicated with a red dot. (OSPAR 2000).

8.6 Water quality (D8)

Most parts of the North Sea are classified as 'problem areas' (95%) based on their Chemical Status (EEA 2018). Metals, other organohalogens, PCBs and PAHs are the triggering substances.

Contaminants in seawater can enter the food web through ingestion by animals and bioaccumulation. 93% of the units assessed for the North Sea have been classified as problem areas according to their Chemical Status (EEA 2018). Organ bromines, organohalogens and metals are identified as the triggering substances. The concentration of cadmium, lead, mercury, PCBs, and PAHs has decreased radically since the 1990s. The concentration of PAHs is still above background levels, but below the Environmental Assessment Criteria and thus unlikely to cause any adverse effects (OSPAR 2017).

Seabed monitoring has regularly been conducted around the offshore installations in the North Sea. The results from the survey around South Arne are further described in 8.7. Water column monitoring planned to take place in the near future, which can give input about the water quality around the installations.

8.7 Environmental status of the seabed (D1, D2, D6 and D8)

The baseline of the chemical and biological conditions of the seabed is based on the monitoring data collected in 2015 at the Solsort field and at the South Arne field in 2018.

The monitoring program for the sediment followed the program based on the following MSFD descriptors. Descriptor 1: Biodiversity, Descriptor 2: Non-indigenous species, Descriptor 6: Seafloor integrity, Descriptor 8: Contaminants, each described by indicators. The assessment in the following sections included a valuation of the Environmental Status (EnS) of each Descriptor listed above following the assessment approach outlined in the Danish Marine Strategy II, section 5.

Assessment of the EnS requires that selected indicators are compared to reference conditions and to target values (Effects Range Low, ERL) that define good environmental status. To estimate the Background Reference Level (BRL) a local and a regional reference station was used for both fields.

In general, it has been found that the benthic fauna is not affected beyond 1500 meters from the platforms and that the local reference stations have good environmental status according to the Danish Marine Strategy II (Oil & Gas Denmark 2017). Based on this, the local reference station is considered as appropriate back-ground reference.

8.7.1 Sediment composition and quality

8.7.1.1 Solsort

The sediment around the Solsort field was monitored in 2015 (DHI 2015). A total of 20 sampling stations were monitored located within a distance of 2500 m from Solsort.

The investigations revealed a sediment consisting of fine sand with a very low content of organic material. The colour of the sediment at Solsort was brown or grey. No smell of dissolved hydrogen sulphide (H_2S) was detected confirming generally oxidic conditions.

The sediment was mostly comprised of sand with an average grain size of 206 ±13 µm (Hess Denmark, 2015).

8.7.1.2 South Arne

The sediment around South Arne has been monitored lately in 2015 and 2018 (Hess Denmark 2015, 2018).

The sediment is characterised by fine to medium sand with a very low content of organic material. The colour of the surface sand was brown and grey, with a lower layer of grey to black sand, with some shells included. No H_2S smell was detected.

The sediment was mostly comprised of sand with an average grain size of 173 ±6 µm (Hess Denmark, 2018).

8.7.2 Benthic fauna and biodiversity (D1)

The benthic fauna includes invertebrates living in and on the surface of the seabed. The benthic fauna mainly includes species of bristle worms, mussels, snails, echinoderms and crustaceans.

The benthic fauna was monitored during 2012, 2015 and 2018 in the area around the South Arne field together with reference station N located 32 km northeast of South Arne (Hess Denmark 2012, 2015, 2018).

During the 2018 sampling program the average number of individuals at the reference station was estimated to 193 individuals per 0.1 m^2. The abundance was within the historical range estimated at the reference station. The species richness was during the same sampling program estimated to 30 species per 0.1 m^2 (Hess Denmark 2018).

Reiss et al. (2010) carried out a comprehensive study of the spatial patterns of benthic infauna communities in the North Sea. According to this study, the benthic infauna community in the Solsort area is characterised by the following dominant and characteristic species:

- The bristle worms Myriochele oculate (=Galathowenia oculata), Spiophanes bombyx and Paramphius jeffreysii and
- The echinoderm Amphiura filiformis.

- The species distribution was not determined in 2018. However, a baseline study of the benthic fauna was carried out in 2015 at South Arne field and reference station N (Hess Denmark 2015). The findings are in accordance with historical data from the reference station (Hess Denmark 2012) and confirms the findings of Reiss et al 2010 (Figure 8-3, Table 8-2 and Table 8-3).

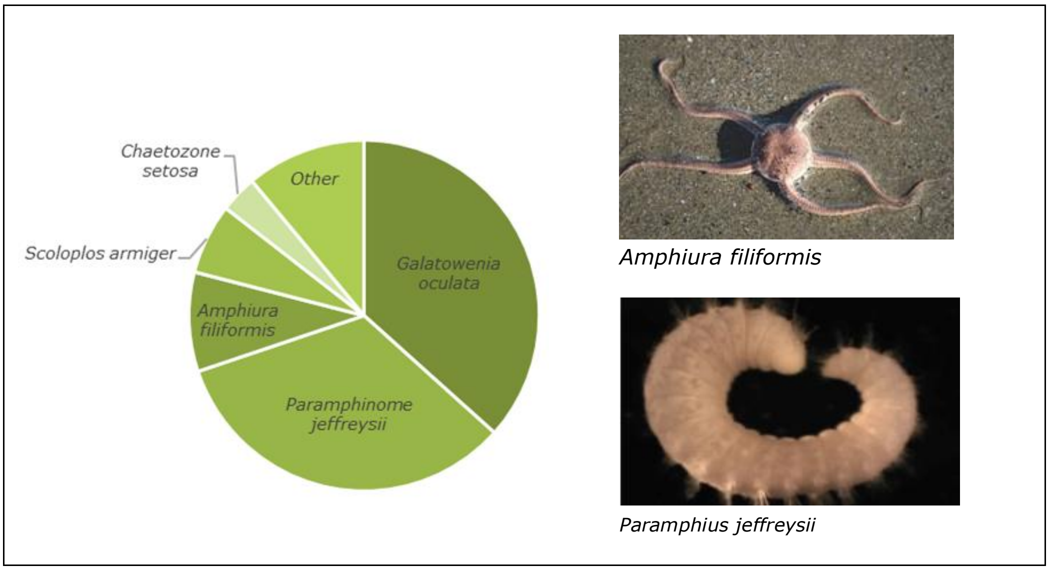


Figure 8-3 Relative abundance of benthic infauna species encountered at the reference station N north-east of Syd Arne. The figure is based on data from 2015 (Hess Denmark 2016).

Table 8-3 Average abundance of the ten most abundant species at Reference station North platform in 2015 (Hess Denmark 2016)) Pol=Polychaetes; Ech=Echinoderms; Biv=Bivalves, Pho= Phoronids and Apla=Aplachophora

Species	Average abundance (Number of individuals per 0.1 m²)	% of total abundance
Galathowenia oculata (Pol)	96	35.3
Paramphinome jeffreysii (Pol)	87	32.0
Amphiura filiformis (Ech)	24	8.8
Scoloplos (Scoloplos) armiger (Pol)	17	6.3
Chaetozone setosa (Pol)	9	3.3
Apistobranchus tullbergi (Pol)	5	1.8
Phoronis sp. (Pho)	5	1,8
Chaetoderma nitidulum (Apla)	4	1.5
Goniada maculata (Pol)	2	0.7
Pholoe inornata (Pol)	2	0.7
Sum	251	92.3

Table 8-4 Average abundance of the ten most abundant species at site of future South Arne N platform in 2015 (Hess Denmark 2016) Pol=Polychaetes; Ech=Echinoderms; Biv=Bivalves and Pho= Phoronids.

Species	Average abundance (Number of individuals per 0.1 m²)	% of total abundance
Galatowenia oculata (Pol)	200	73.5
Spiophanes bombyx (Pol)	88	32.4
Paramphinome jeffreysii	58	21.3
Scoloplos armiger (Pol)	17	6.3
Chaetozone setosa (Pol)	9	3.3
Chaetoderma nitidulum	6	2.2
Owenia fusiformis (Pol)	6	2.2
Apistobranchus tullbergi	5	1.8
Phoronis sp. (Pho)	5	1.8
Magelona filiformis (Pol)	5	1.8
Sum	399	92,1

8.7.3 Non-indigenous species (NIS) (D2)

Information on non-indigenous species (NIS) were derived from two sources, AquaNIS Information system on aquatic non-indigenous and cryptogenic species) and EASIN (European Alien Species Information Network). It should be noted that there is not identified a target for Good Environmental Status for D2 Non-indigenous species but an EnS score going from 0-100 is used to compare the relative EnS, where 100 is no NIS.

Comparing the species identified at South Arne with the AquaNIS database from the North Sea, resulted in 8 individuals of 2 species identified as a non-indigenous species *Aphelochaeta marioni* and *Glycera celtica*. There is limited information on the distribution pathways of these species.

D2 has been evaluated by calculating the index as shown in Table 8-5. The closer the score is to 100 the less impact from NIS.

Table 8-5 Index for D2 – The higher the score is the less impact of NIS

If $S_{NIS} = 0$, then score = 100

If $S_{NIS}/S_{NS} \geq 1$, then score = 0

If $1 > S_{NIS}/S_{NS} > 0$, then score = $100(1- S_{NIS}/S_{NS})$

where

S_{NIS} is the number of Non-Indigenous Species

and S_{NS} is the number of native species

The results at different stations from the seabed monitoring is shown in Figure 8-4. All the indexes are above 95 except for one, which is 89, which is to be considered as high score showing insignificant impact from NIS.

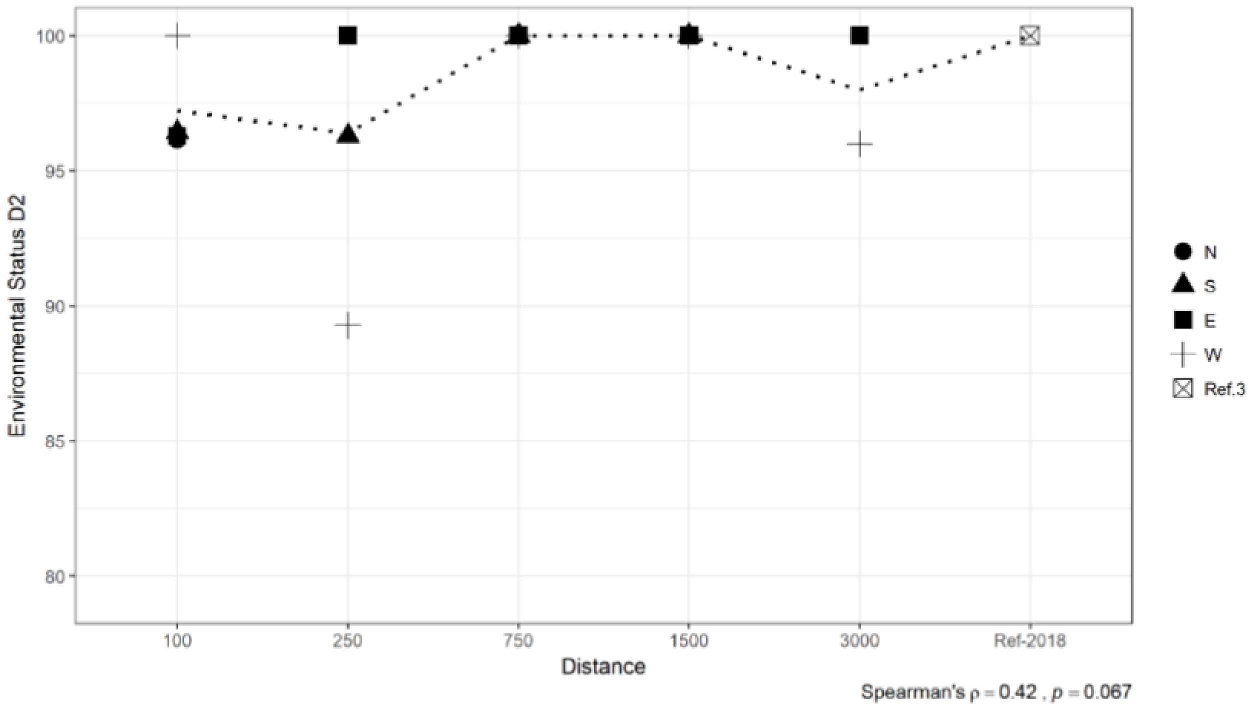


Figure 8-4 Environmental index for MSFD descriptor D2. Dotted line represents the mean index across stations at same distance. Reference South Arne seabed monitoring, 2018.

Information on NIS around Solsort has not been obtained during the Solsort baseline seabed monitoring in 2015. However, similar occurrence of NIS is expected for the Solsort field as for South Arne.

8.7.4 Eutrophication (D5)

The targets set for descriptor D5 are related to discharge of nutritional substances as phosphor and nitrogen and are mainly related to near coast activities. The installations are located far from the coast and are assessed to have no or insignificant impact on D5.

8.7.5 Seafloor integrity (D6)

The impact on seabed integrity is based on two indicators:

Grain size, D_{50}; which give an indication of how vulnerable the seabed will be in relation to physical impacts

AMBI; which gives an indication of how vulnerable the benthic fauna is in relation to physical disturbance.

The seafloor integrity (estimated as AMBI1-values) can range between 0 and 7, being 7 when the sediment is azoic, i.e., without macrobenthic organisms present. A target for Good Environmental Status has not been defined.

[1]AMBI (AZTI's Marine Biotic Index) value is an index developed by the software company AZTI for assessment of the quality of benthic macroinvertebrates assemblages.

8.7.5.1 Solsort

D50 for Solsort stations are shown in the Figure 8-5.

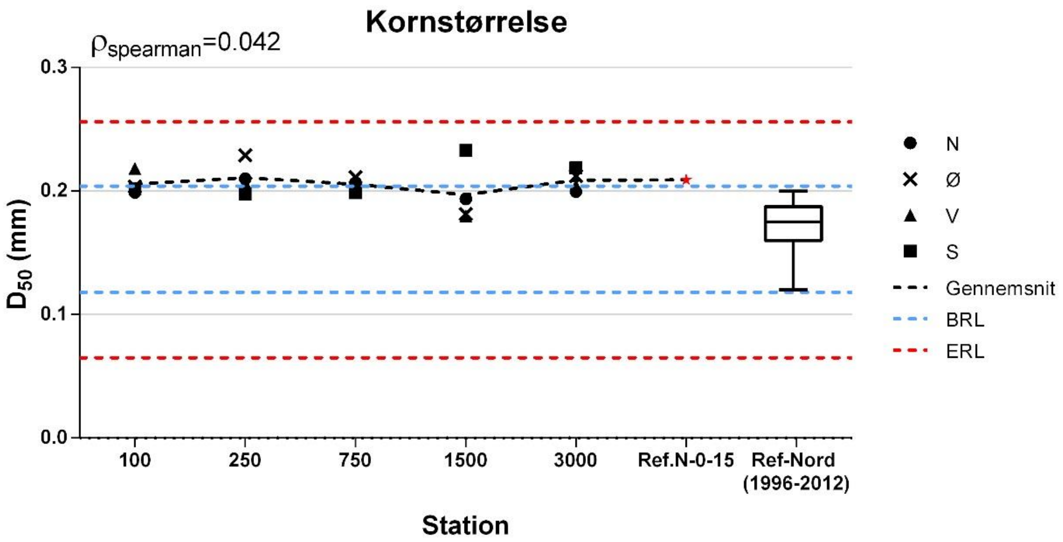


Figure 8-5 D_{50} at the top sediment (0-1 cm). Reference station North N-0-15 is represented by (★). BRL indicates the background level. The Box-plot, represent the historical date from the reference stations in North and shows 2,5, 25, 50, 75 og 97,5 percentiles.

On all stations, inclusive the local reference station, all AMBI values were around BRL and within the natural variation represented by historical data. On 13 station AMBI exceeded BRL and on 8 stations AMBI was below BRL (including the reference station). At the Solsort stations the variation was between 2,61 og 2,87. AMBI above 1.2 and below 3.3 is classified at moderately disturbed. AMBI was not related to distance from Solsort.

The combined impact for D_{50} and AMBI is calculated to define the impact in D6 and is shown in Figure 8-6

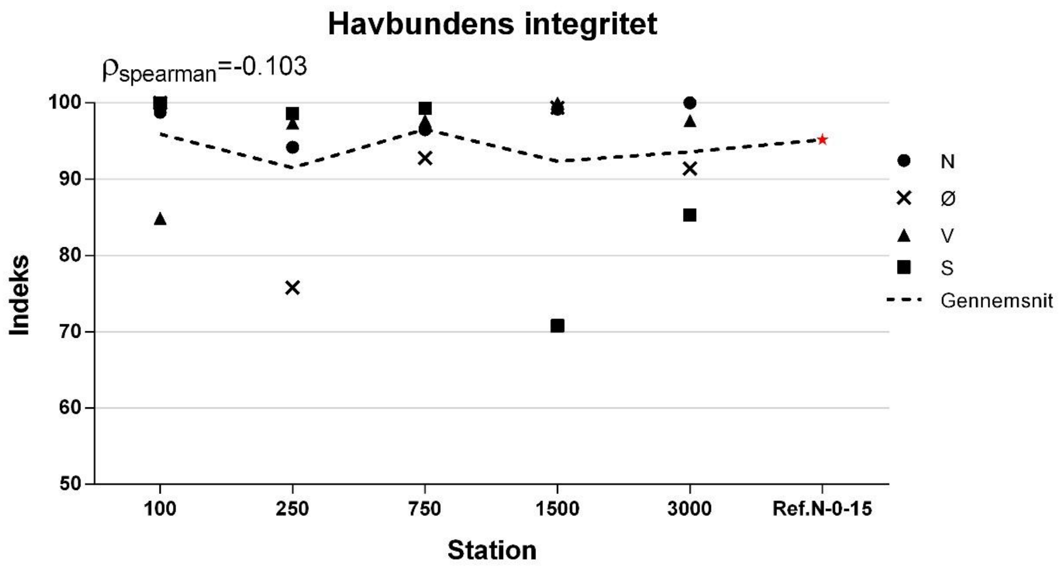


Figure 8-6 Index for D6 as a combination between D50 and AMBI. Reference station North N-0-15 is represented by (★).

The index for the different stations is between 70,8 and 100. The great variation is mainly due to the large variations in grain size (D50).

8.7.5.2 South Arne

The AMBI value at the South Arne platform stations and both local reference station and the regional reference station were within the same range. At the South Arne stations the variation was between 2,1 og 2,9. AMBI above 1.2 and below 3.3 is classified at moderately disturbed. There was a negative correlation between distance from platform and AMBI (Spearman correlation: $\rho = -0.7$, p). At some stations close to the platform, AMBI was close or above BRL. The two reference stations were 2.7 and 2.5.

8.7.5.3 Summary seafloor integrity (D6)

The only impact from the Solsort project on the seafloor will be during the construction during the location of the spud cans of the rig on the seafloor. Each spud can will have a size of 201 m^2, which is 603 m^2 (0.000603 km^2) in total.

The types of habitats in the area of Solsort are shown in the figure 6.4 in Danish Marine Strategy II, first part. The habitat in the area is offshore circalittoral mud, which total area in the North Sea is 18,170 km^2. The area of the spud cans is very small compared to the area of the habitat and is considered to have no impact on the habitat in the area.

In general loss of seabed in relation to the presence of oil and gas installations in the North Sea are calculated to be below 0,1 % according to the Danish Marine Strategy II, first part.

8.7.6 Contaminants in sediments (D8)

8.7.6.1 Solsort

An assessment of contaminants in the sediment around Solsort was conducted in 2015 (DHI, 2015). The contaminant included Polycyclic Aromatic Hydrocarbons (PAH's) and heavy metals: Barium (Ba), Cadmium (Cd), Chromium (Cr), Copper (Cu), Mercury (Hg), Lead (Pb) and Zinc (Zn).

The detection limits for the contaminant are shown in Table 8-6.

Table 8-6 Detection limits for contaminants

Contaminant	Detection limit (mg/kg DW)
Ba	1
Cd	0.01
Cr	0.1
Cu	0.5
Hg	0.05
Pb	0.1
Zn	1
THC	1
PAH (All individual PAHs)	0.0005

The results from the seabed monitoring for heavy metals and hydrocarbons are shown in Table 8-7.

Table 8-7 Concentration of heavy metals. Reference figure 4.6 in Solsort seabed monitoring report 2015. The black dotted line is the average concentration in the sediment

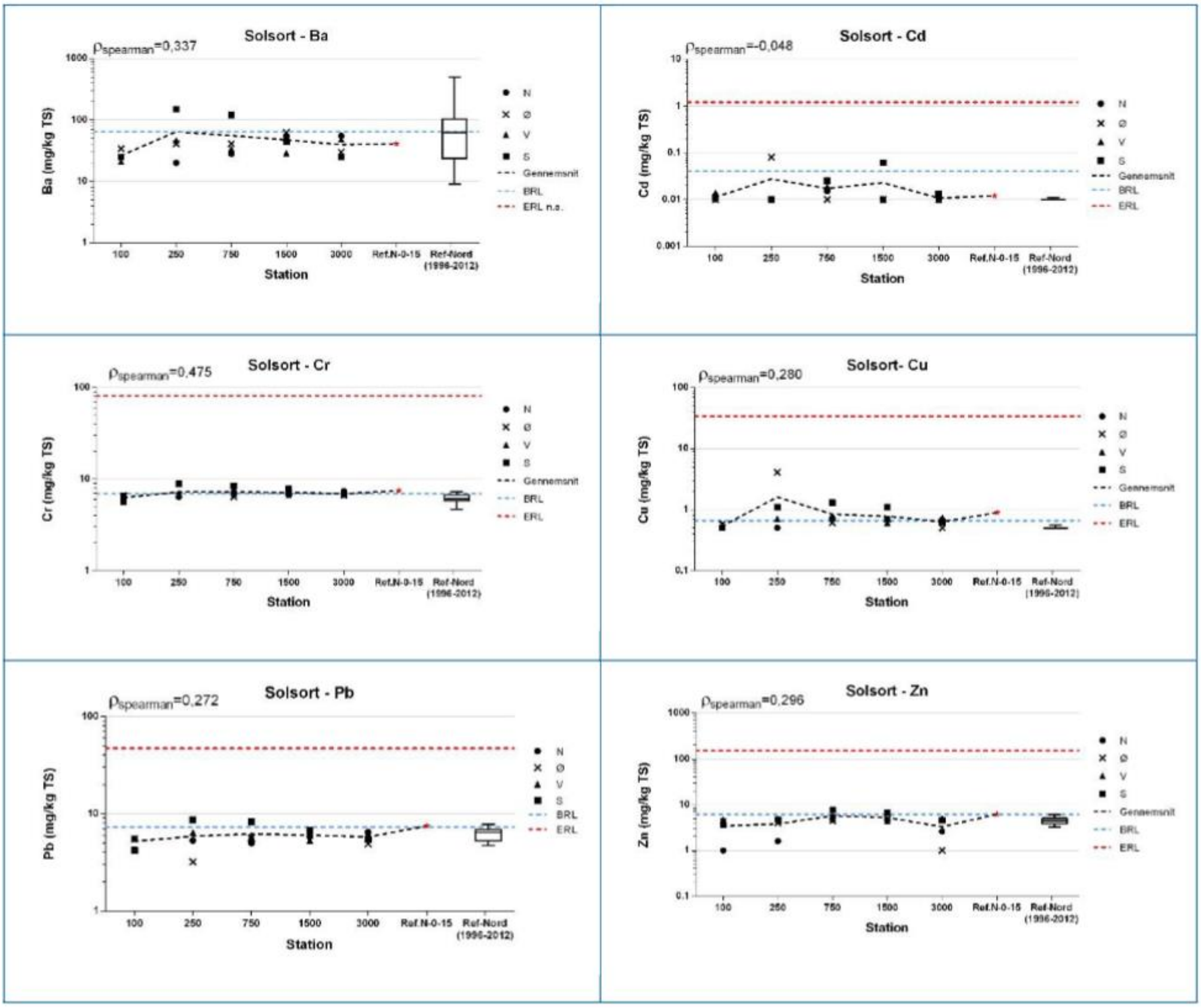
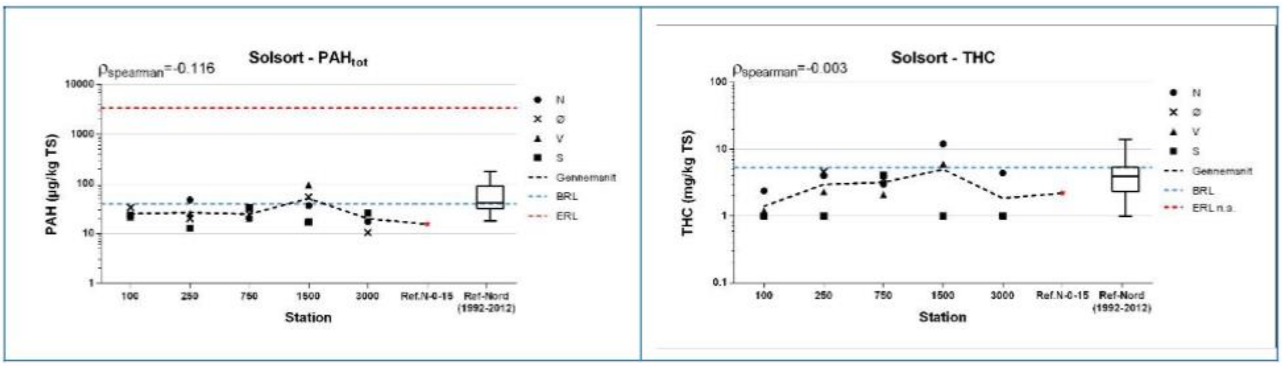


Table 8-8 Concentration of hydrocarbons. Reference figure 4.7 in Solsort seabed monitoring report 2015. The black dotted line is the average concentration in the sediment.



The concentration of heavy metals and PAHs were well below the corresponding ERL values. Furthermore, Ba, Cd, Zn and Hg were well below detection level. All measured heavy metals were below or close to BRL. The concentration of PAHs was many times lower than the ERL provided by OSPAR. PAHs was below BRL in 17 out of 20 Solsort sampling stations, The combined index for all contaminants are shown in Figure 8-7.

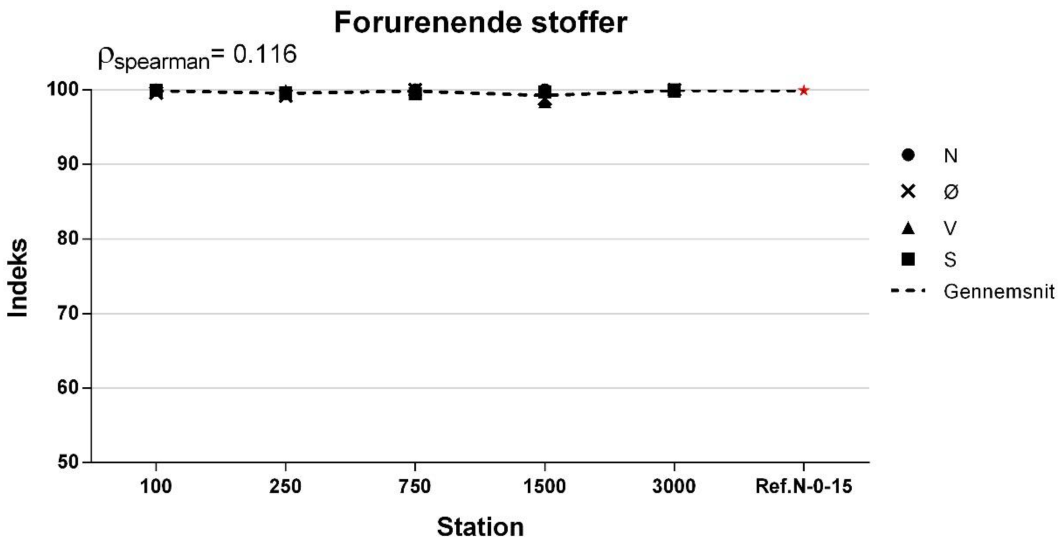


Figure 8-7 Descriptor index at all stations calculated as a combination of all indicators for all contaminants including Reference station North N-0-15 (★) .

Index 100 defines insignificant impact from contaminants. As shown in Figure 8-7 the descriptor indexes were generally high at Solsort (above 98,4) and thus classified as "good environmental status" according to Danish Marine Strategy. It is expected that the Solsort field is comparable to this general picture for the area.

NORM is not a part of the seabed monitoring as there is no discharge of produced water from South Arne WHP North. The cuttings from the top holes where water based drilling mud and cutting discharged to sea will not contain NORM.

8.7.6.2 South Arne

At all stations around South Arne the concentration of heavy metals and PAHs were well below the corresponding ERL values. Furthermore, Cd and Hg were below detection level. Only few stations had contaminant loads over BRL and only for contaminants Cu, Zn and total PAH.

The combined index for all contaminants were generally high at South Arne as shown in Figure 8-8 and thus generally classified as "good environmental status" according to Danish Marine Strategy II. The contaminant index at South Arne was on average 93,5 (SD = 3.66) and 99.5 at the regional reference station. Scores did not significantly change with distance from platform.

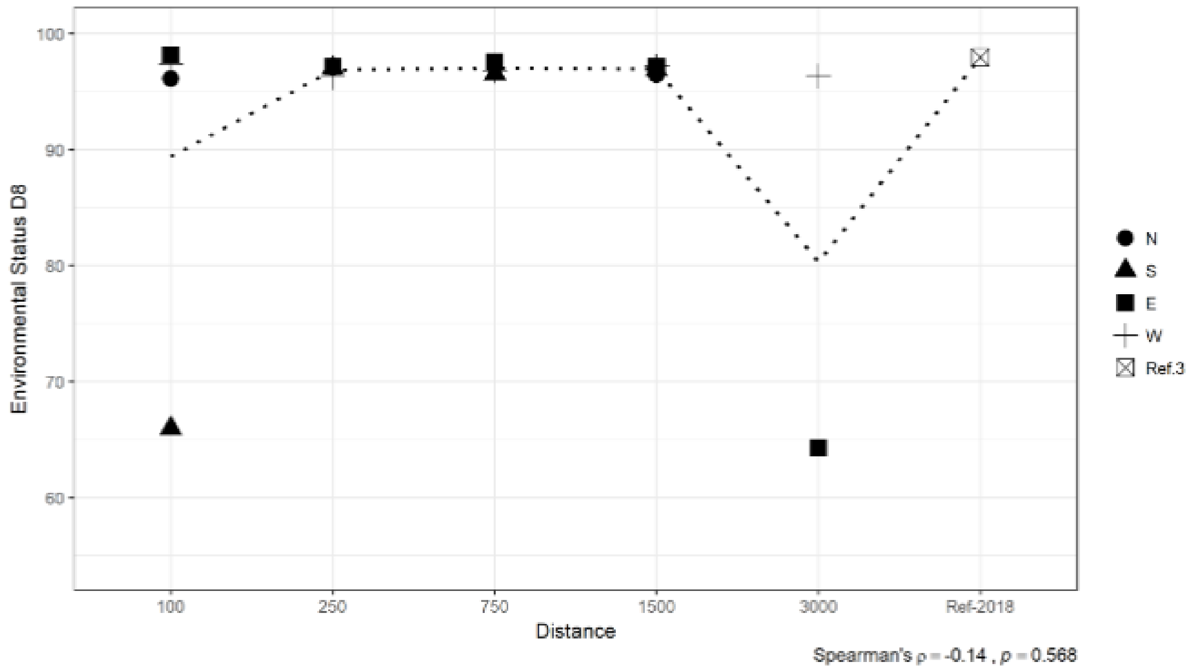


Figure 8-8 Index for descriptor D8. The dotted line represents the mean index across stations at the same distance. Reference South Arne seabed monitoring report 2018.

8.7.6.3 Summary contaminants (D8)

According to the Danish Marine Strategy II the threshold values to define GES are PFOS, PBDE, Benz(a)pyrene and mercury (kviksølv) as shown in Table 8-9.

These threshold values are defined by concentration in fish. Similar values are not a part of the monitoring programme agreed with the Authorities.

Table 8-9 Threshold values according to Danish Marine Strategy II

Tabel 15.2: Tærskelværdier for god miljøtilstand i Havstrategi II.

Stof	Tærskelværdi
PFOS (Perfluorerede forbindelser)	9,1 µg kg^{-1} vådvægt fisk[1]
PBDE (Bromerede diphenyletere)	8,5 ng kg^{-1} vådvægt fisk
Benz(a)pyren	5 µg kg^{-1} vådvægt muslinger
Kviksølv	20 µg kg^{-1} vådvægt fisk

[1] Ifølge bek. 1625 af 19. december 2018 om fastlæggelse af miljømål for vandløb, søer, overgangsvande, kystvande og grundvand træder denne EQS-værdi i kraft 22. december 2018.

Concentrations of Benz(a)pyrene and mercury in the sediment at Solsort and South Arne shown in Table 8-10. The values are although not comparable with the threshold values.

Table 8-10 Content of Benz(a)pyrene and mercury in sediment samples

Contaminant	Solsort	South Arne
Benz(a)pyrene (µg/kg DW)	0,69-6,5	0,001-0,006

Mercury (µg /kg DW)	< 0,5 (Set to the detection limit. Could not be measured)	49,6-84,4

8.8 Birds (D1)

The North Sea is a very important area for sea and coastal birds due to the high biological production, which provide excellent feeding conditions. More than 10 million birds make use of the North Sea for breeding, feeding, or migratory stopovers every year and important breeding colonies fringe the coastlines. (Skov et al. 1995).

8.8.1 Seabirds

Seabirds include those species of bird that depend wholly or mainly on the marine environment for their survival. They spend most of their lives at sea, exploiting its surface and the water column to varying depths for food. Most of these species come ashore only to breed. Many of the seabird species are encountered in internationally important numbers including:

- Internationally important breeding populations of auks, gannets, and cormorants.
- Internationally important pathway for numerous species of migratory seabirds.
- Internationally important wintering areas of auks, divers and duck

8.8.1.1 Seabirds at South Arne and Solsort

The waters around South Arne and Solsort are not important for sea birds. Areas of international importance for seabird in the North Sea coincide with the highly productive areas where hydrographic fronts can be formed, producing an abundance of food for sea birds (Figure 8-9, Figure 8-10).

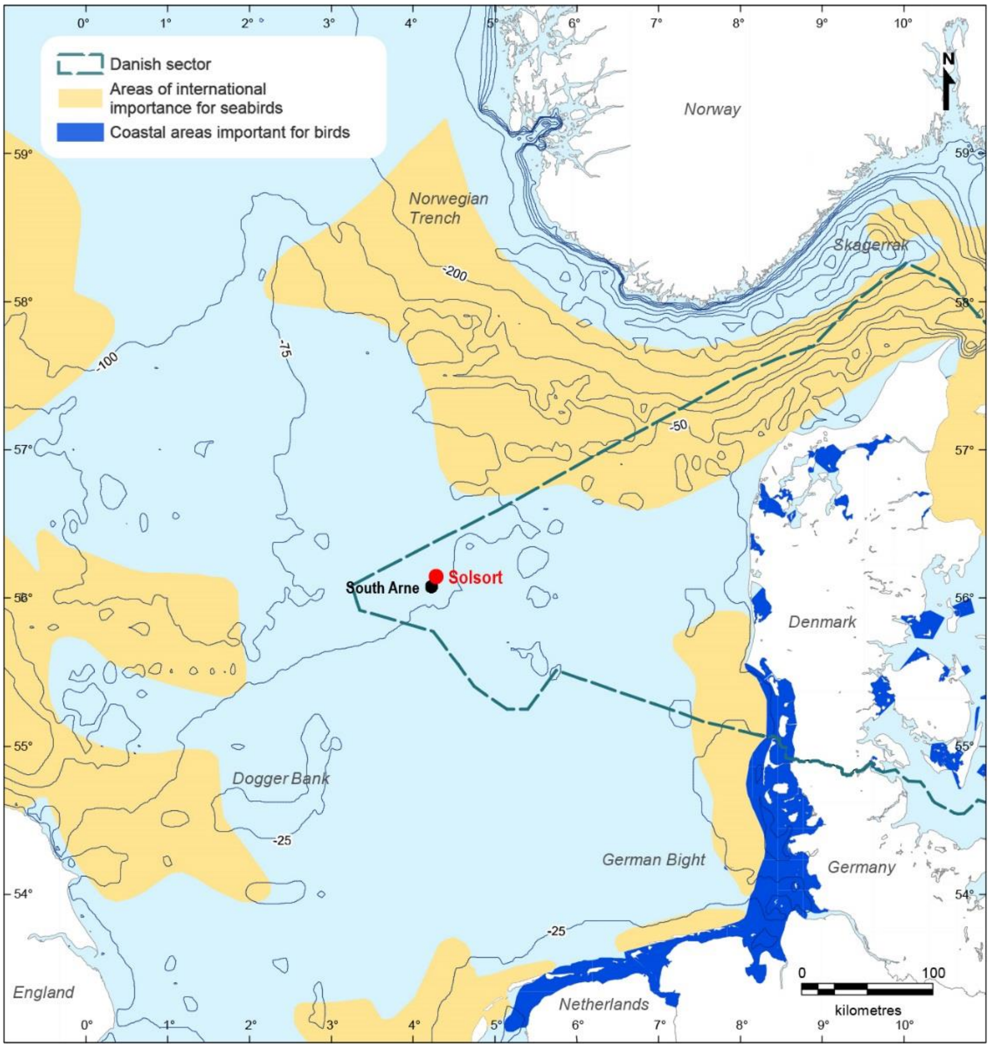


Figure 8-9 Areas of international importance for sea birds (light brown shading) and coastal areas important for birds (blue shading). (Data: Skov et al. 1995, Falk & Brøgger Jensen 1995).

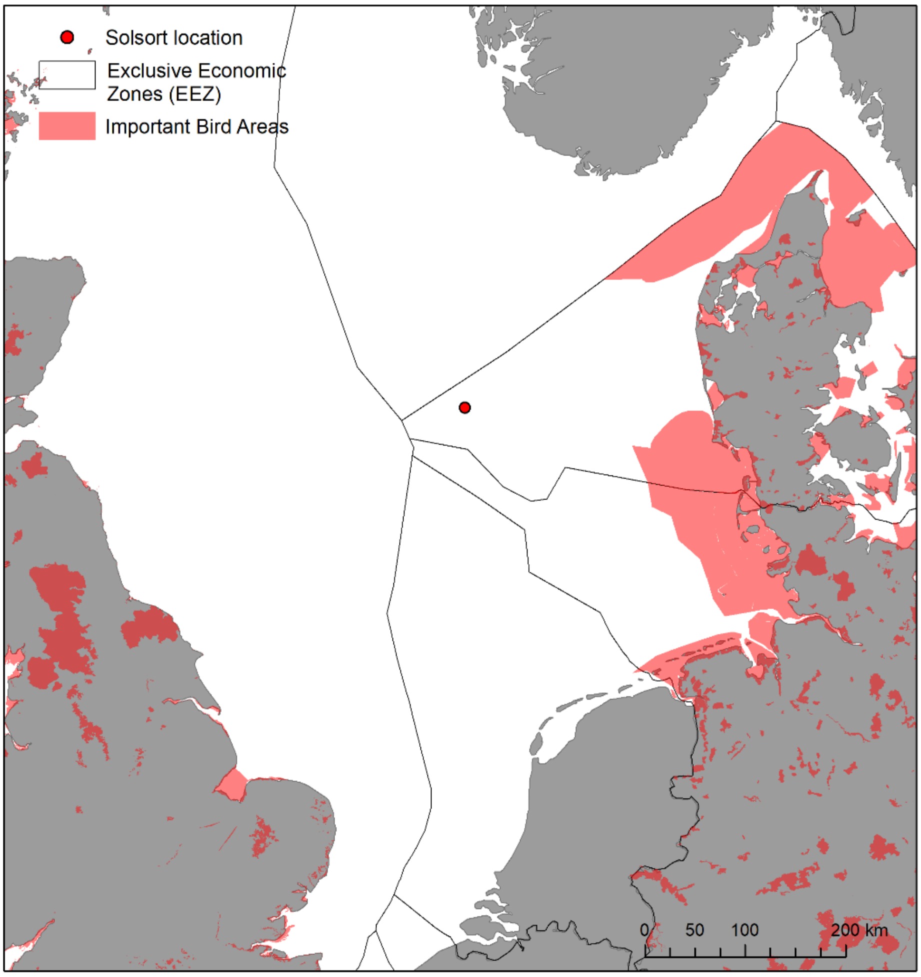


Figure 8-10 Important Bird Areas (IBAs) (Birdlife, 2021).

During winter some seabirds may be encountered at South Arne and Solsort, not because the area is of importance for the species, but because these species are distributed over the entire North Sea during winter. The predominant species are fulmar (*Fulmarus glacialis*) and kittiwake (*Rissa tridactyla*) (Figure 8-11 and Figure 8-12) (Waggit et al. 2019). Additionally, Gannet (*Sula bassanus*), razorbill (*Alca torda*) and common guillemot (*Uria aalge*) occur in low densities. These species are mainly associated with cliffs and offshore islands and only occur in the open sea outside the breeding season. They occur in larger densities in other areas of the North Sea with more favourable feeding opportunities that the central parts (COWI 2006, Skov et al., 1995). The biology of these species is described in Table 8-11.

Table 8-11 Biology of birds that may be encountered at South Arne and Solsort during winter (Source: Birdlife International 2014). Images from www.rsbp.org

Fulmar (*Fulmarus glacialis*)

The fulmar typically breeds on cliffs and rock faces, occasionally on flatter ground and up to 1km inland, nesting within colonies on narrow ledges or in hollows. The most important breeding colonies in the North Sea are found in Scotland, the Orkneys, and the Shetlands and at Flamborough head. Fulmars have a potentially large offshore foraging range from their colonies, as birds regularly depart for more than 4-5 days on foraging trips, both before egg-laying and during incubation. Fulmars prey on a wide variety of fish such as, sandeels, sprat, and small gadoids. Large zooplankton species (especially amphipods and copepods) and squid are also important food items. They will also scavenge offal including fishery waste, entrails, and whole fish discarded by fishing vessels.

Kittiwake (*Rissa tridactyla*)

The kittiwake breeds from mid-May to mid-June in very large single- or mixed-species colonies. The most important breeding colonies in the North Sea are found in Scotland, the Orkneys, Shetlands and at Flamborough head. The kittiwake nest on high, steep coastal cliffs with narrow ledges. The nest is a compacted mass of mud, grass and feathers. During the breeding season, it generally feeds within 50 km of the breeding colony. After breeding, it disperses from coastal areas to the open ocean. The species begins to disperse from the breeding colonies between July and August, often moulting in large flocks of several thousand individuals on beaches between the breeding grounds and the open sea. During the winter, the species is highly pelagic, usually remaining on the wing out of sight of land. Its diet mainly consists of small pelagic shoaling fish such as sandeel, sprat and young herring, but squid shrimps or other invertebrates may also be included in the diet

Gannet (*Sula bassanus*)

The gannet is strictly marine, with movements largely confined to the continental shelf. Individuals nest on cliffs and offshore islands and occasionally on the mainland. Its diet consists primarily of shoaling pelagic fish, mostly caught by plunge diving. Birds can also be seen attending trawlers in large numbers. This is a ground nesting species, usually within large colonies. The nest is built with seaweed, grass and earth stuck together with excreta.

Guillemot (*Uri aalge*)

The guillemot breeds in colonies primarily on steep cliff faces or low, flat islands. The most important breeding colonies in the North Sea are found in Scotland, the Orkneys, Shetlands and at Flamborough head It does not construct a nest but lays on broad or narrow cliff ledges and low, flat islands. Individuals mostly occur offshore during winter usually within the breeding range, but the species may be encountered in low to moderate density all over the North Sea. Most individuals return to the colony in March-April. Its diet consists mostly of schooling pelagic fish, mostly sandeel, herring and sprat with small gadoids important at some colonies. Crustaceans can also be the dominant food source. The food is usually obtained within 10-20 km of the colony (Birdlife International 2014)

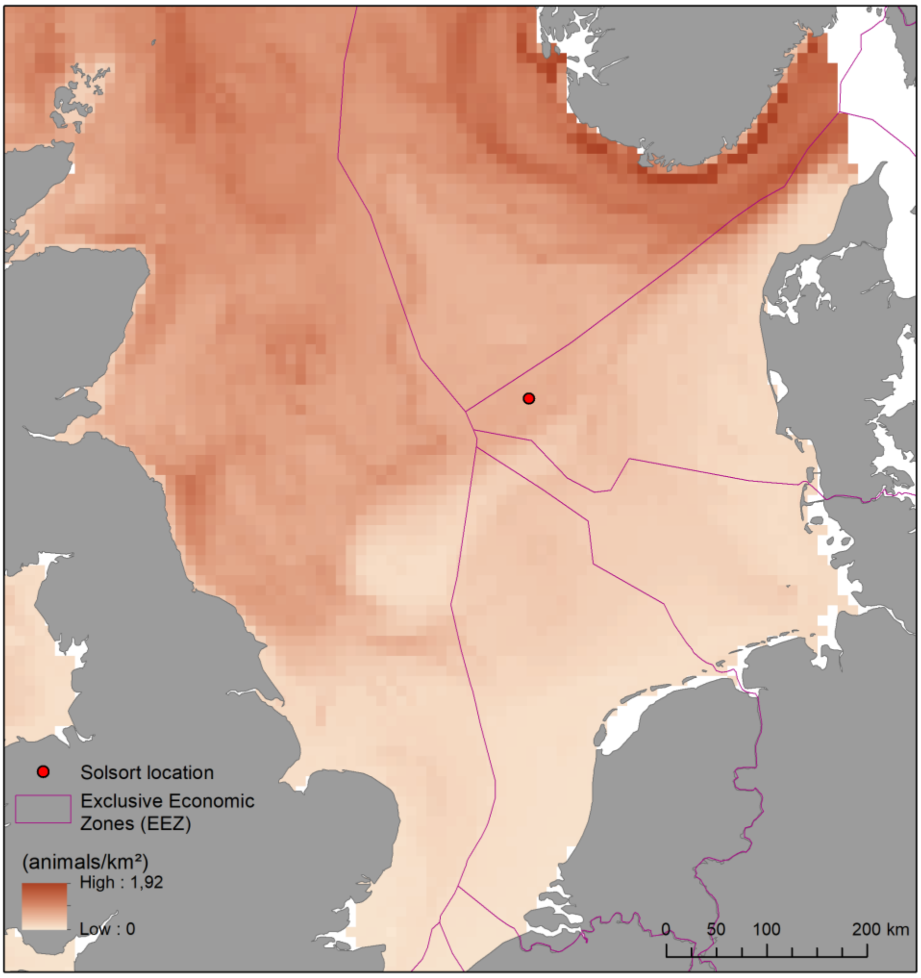


Figure 8-11 Relative abundance of Northern Fulmar (Fulmarus glacialis) in the North Sea. (Waggit et al. 2019).

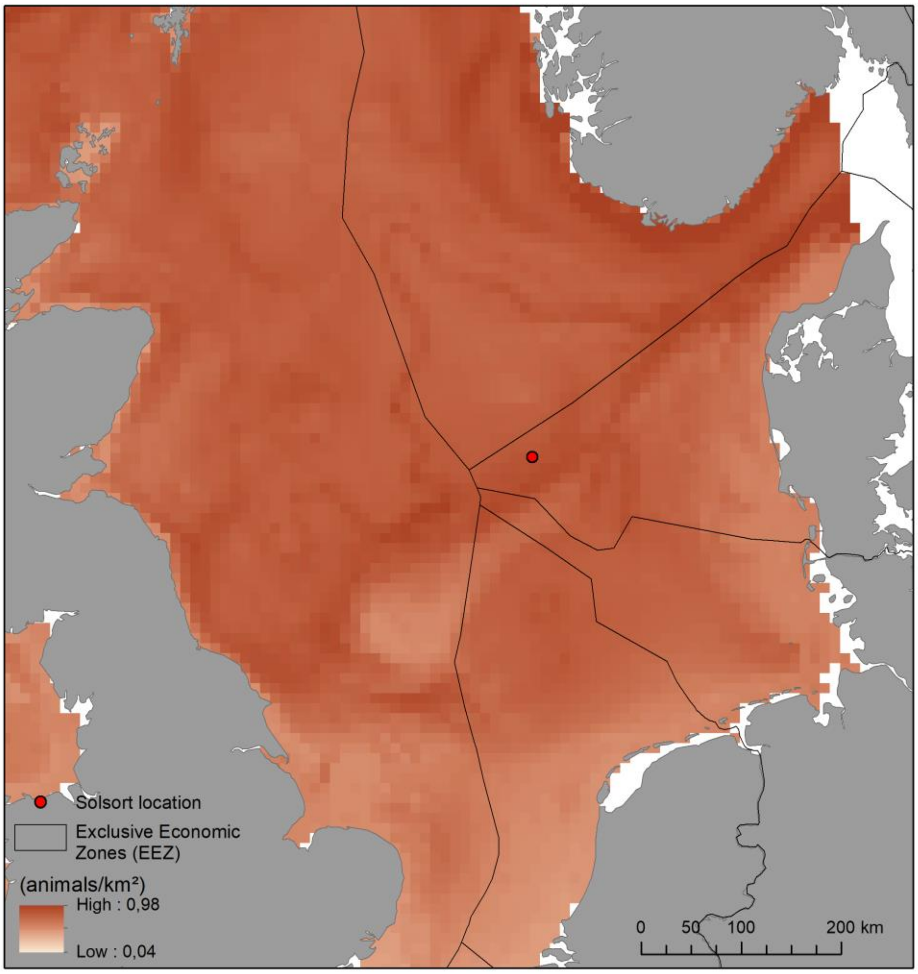


Figure 8-12 Relative abundance of Kittiwake (Rissa tridactyla) in the North Sea (Wag-git et al. 2019).

8.8.2 Coastal birds

Costal birds are birds commonly found along sandy or rocky shorelines, mudflats and shallow waters. They mainly include gulls, terns, waders, ducks, geese, and swans.

8.8.2.1 Migrating land birds

Large numbers of land birds migrate across the North Sea between the UK and Western Europe including waders and species of thrushes, chats, warblers and finches (Baptist 2000, Lack 1959, 1960, 1963). Several of these species may sporadically be encountered at South Arne and Solsort.

8.9 Marine mammals (D1)

8.9.1 Cetaceans (Annex IV species)

All species of cetaceans (whales, dolphins and porpoise) are listed in Annex IV in the Habitats Directive and are therefore strictly protected. In addition, harbour porpoises are included in the basis for the designation of the German, Dutch and UK Nature 2000 areas *DE 1003-301 Doggerbank*, *NL 2008-001 Doggerbank* and *UK0030352 Doggerbank* (see section 8.11 - Natura 2000).

Harbour porpoise (*Phocoena phocoena*) is the most common cetacean in the North Sea followed by white-beaked dolphin (*Lagenorhynchus albirostris)* and minke whale *(Balaenoptera acutorostrata*) (Waggit et al.

2019). However, the Solsort field and the South Arne field is not a core area for the species (Sveegaard et al. 2018, *Gilles et al. 2016).*

The biology of the three cetacean species is briefly described in Table 8-12. Other cetacean species are rare and do only occasionally migrate into in the North Sea from the Atlantic.

The population characteristics of harbour porpoise is described in more detail below.

8.9.1.1 Harbour porpoises

The North Sea population of harbour porpoise is estimated to include 300,000-350,000 individuals (Gilles et al. 2016). Gilles et al. (2016) has modelled the distribution of harbour porpoise in the North Sea based on three marine mammal surveys (the so-called SCANS surveys). The model has recently been updated by Waggit et al. (2019) to include the entire East Atlantic. The model by Waggit et al. (2019) shows that harbour porpoise is concentrated in the most Eastern part of the North Sea during winter and distributed over a larger area during summer (Figure 8-13). This conflicts with the observations by Gilles et al. (2016) and Delefosse et al. (2018) who found higher occurrence of harbour porpoises in the central North Sea during summer. The most important area for harbour porpoise in the North Sea is the waters between the western part of the Dogger Bank and the UK. The waters along the Danish, German and Dutch coasts, especially the German Bight/Horns Rev areas, are also important (Waggit et al. 2019, Gilles et al. 2016, Sveegaard et al. 2018). It appears from the model that the project area is located within an area of some importance for harbour porpoises.

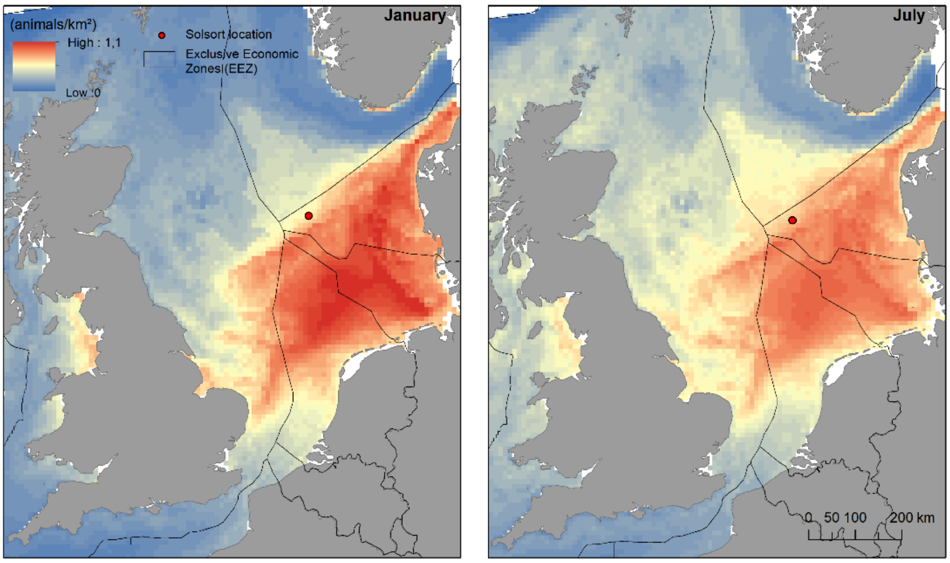


Figure 8-13 Distribution of harbour porpoise (Phocoena phocoena) in the North Sea. South Arne/Solsort are indicated with red dots (Waggit et al. 2019).

Table 8-12 Biology of species of the three most common cetaceans that may be encountered at South Arne and Solsort.

Harbour porpoise (*Phocoena phocoena*)

The harbour porpoise (*Phocoena phocoena*) is the most abundant whale species in the North Sea and occur regularly in the Solsort area. The population in the North Sea has been estimated to 300.000-350.000 (Sveegaard et al. 2018, Gilles et al. 2016).

Harbour porpoises feed mostly on fish such as cod, whiting, mackerel, herring and sprat. Harbour porpoises tend to be solitary foragers, but they do sometimes hunt in packs. However, they are generally seen as a solitary species. The mating season is July-August. The gestation period typically lasts 10–11 months and most births occur in late spring and summer. Calves are weaned after 8–12 months.

White-beaked dolphin (*Lagenorhynchus albirostris*)

White beaked dolphin (Lagenorhynchus albirostris) is relatively common in the northern part of the North Sea and may be encountered in the Solsort area (Geelhoed et al 2014, Hammond et al 2013, Reid, et al. 2003). In Danish waters, however, the species is mainly observed in Skagerrak, the northern part of the Danish sector of the North Sea and parts of the Central North Sea (Kinze 2007). White beaked dolphin is much less abundant than harbour porpoise. The total population in the North Sea is only about 16,500 individuals (Hammond et al. 2013). White-beaked dolphins are acrobatic and social animals that are typically found in pods of 4-6 animals. They will frequently ride on the bow wave of fast-moving vessels and jump clear of the sea's surface. White beaked dolphin mates from May to August and the delivery occur the following summer after a gestation period of 11 months. They primarily feed on fish such as herring, cod, haddock, whiting and hake but may also prey on squid, octopus and benthic crustaceans.

Minke whale (*Balaenoptera acutorostrata*)

Minke whale (*Balaenoptera acutorostrata*) may also be observed at the Solsort field (Geelhoed et al. 2014, Hammond et al. 2013, Kinze 2007, Reid et al. 2003). Minke whale is the only species of baleen whale that occurs regularly in the North Sea. The population in the North Sea has been estimated to about 19.000 individuals (Hammond et al. 2013). Mating and delivery take place from late winter to early spring. The female minke whale gives birth to a calf every year or every second year. The gestation period is 10 months and nursing of the calf takes place for 3-6 months. Minke whales primarily feed on pelagic fish such as herring and sprat and small crustaceans.

8.9.2 Seals

Harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) are regularly sighted around oil and gas fields in the Danish sector of the North Sea (Delefosse et al. 2018). However, the area is not in any way a core area for these species (Tougaard et al. 2008). Seals are generally coastal which is seen from Figure 8-14.

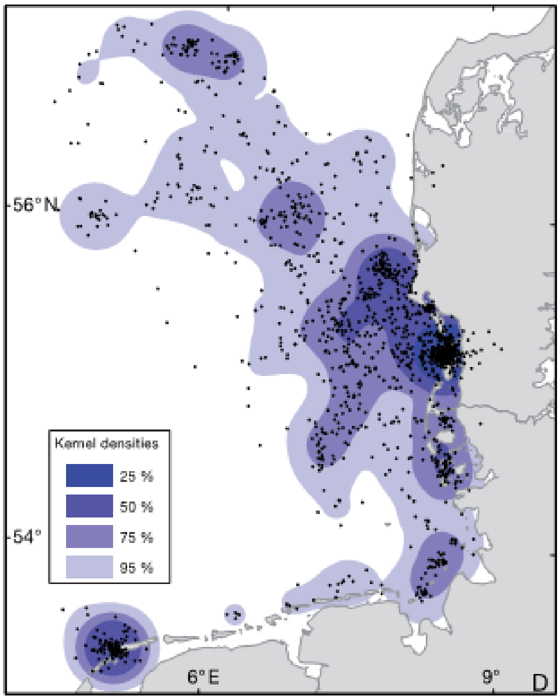


Figure 8-14 Modelled distribution of seals in the central North Sea. The densities are estimated from satellite marking. Tougaard et al. 2008.

Harbour seal is the only seal species that has been observed regularly in the Danish sector of the central part of the North Sea. Harbour seals are primarily coastal and so do not generally venture more than 20 kilometres offshore (Herr et al. 2009). However, radio-tagging experiments using satellite tracing have indicated that harbour seals may undertake foraging migrations far out into the North Sea from their core areas along the coast (Tougaard et al. 2003, Tougaard 2007).

The grey seal breeds in several colonies on islands along the east coasts of Great Britain. In the German Bight, colonies exist off the islands Sylt, Amrum and on Helgoland. Tagging experiments have indicated that grey seals breeding in Great Britain migrate long distances into the North Sea from their breeding colonies (McConnell et al. 1999) and have also been observed around Danish oil and gas fields in the North Sea (Delefosse et al. 2018). The basic biology of grey seal and harbour seal is described in Table 8-13.

Harbour seal is included in the basis for the designation of the German, Dutch and UK Nature 2000 areas *DE 1003-301 Doggerbank*, *NL 2008-001 Doggerbank* and *UK0030352 Dogger Bank*. Grey seal is also listed in the basis for the designation of *NL 2008-001 Doggerbank* and *UK0030352 Dogger Bank* areas (see section 8.11).

Table 8-13 Biology of seal species that may be encountered at South Arne/Solsort.

Harbour seal (*Phoca vitulina*)

Harbour seal (*Phoca vitulina*) is the only species of seal that has been observed regularly in the Danish sector of the central part of the North Sea. Harbour seals are primarily coastal, depending on isolated and undisturbed land areas for resting, breeding and moulting (such as undisturbed islands, islets sandy beaches, reefs, skerries and sandbanks). They are gregarious animals and when not actively feeding, they will haul onto a terrestrial resting site. The harbour seal does not generally venture more than 20 kilometres offshore. However, radio-tagging experiments using satellite tracing have indicated that harbour seals may undertake foraging migrations far out into the North Sea from their core areas along the coast (Tougaard et al. 2003, Tougaard 2007). They are known to prey primarily on fish such as herring, mackerel, cod, whiting and flatfish, and occasionally upon shrimp, crabs, molluscs and squid. Females give birth once a year, with a gestation period of approximately nine months. Harbour seal breed in large numbers in the Wadden Sea. It is less common along the British coast.

Grey seal (*Halichoerus grypus*)

The grey seal (*Halichoerus grypus*) breeds in several colonies on islands on the east coasts of Great Britain. Notably large colonies are at Donna Nook (Lincolnshire), the Farne Islands off the Northumberland Coast Orkney and North Rona off the north coast of Scotland. In the German Bight, colonies exist off the islands Sylt and Amrum and on Helgoland. The pups are born in the period September-November. Within a month or so, they shed the pup fur and grow the dense waterproof adult fur, and soon leave for the sea to learn to fish for themselves. Tagging experiments have indicated that grey seals breeding in Great Britain migrate long distances into the North Sea from their breeding colonies (McConnell et al. 1999) but they have not actually been observed in the offshore parts of the Danish sector of the North Sea (Tougaard 2007). 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.

8.10 Fish (D3)

Approximately 230 fish species are found in the North Sea. Compared to other areas in the North Sea, the diversity is low in the South Arne and Solsort area but increases towards the coast. The fish species in the North Sea can be grouped in pelagic species (species living in the free water masses) and demersal (bottom dwelling) species. Biology and distribution patterns of common species are described below.

8.10.1 Pelagic species encountered in the project area

Pelagic species commonly found in the Danish sector of the North Sea include Herring (*Clupea harangues*), sprat (*Sprattus sprattus*) and mackerel (*Scomber sombrous*). The biology of these species is described in Table 8-4.

Table 8-14 Biology of the dominating pelagic fish species that may be encountered at South Arne and Solsort.

Species	Distribution and biology	References
Herring *(Clupea harengus)* 	Herring is numerically one of the most important pelagic schooling species in the North Sea and is an important commercial species. Herring may be found all over the North Sea. They form large shoals, which tend to remain close to the seabed during the day. At dusk, the herring follow their prey (zooplankton), move towards the surface, and disperse over a wider area during the night. There are several different stocks of herring in the North Sea of which, the Orkney-Shetland, Bucan, Bank and Downs stocks represent the bulk of the stocks. During the spawning season the different stocks migrate to specific spawning grounds. Peak: December-January). Herring deposits its sticky eggs on coarse sand, gravel, shells, rocks or stones on the seabed. After hatching larvae drift with the currents south and eastwards towards nursery areas in the Skagerrak and along the Danish coast to Southern Bight.	ICES 2019a, Sundby et al. 2017, Warnar et al 2012, Schmidt et al. 2010, Worsøe et al. 2002
Sprat *(Sprattus sprattus)* 	Sprat is a small-bodied pelagic schooling species that is mainly landed for industrial processing. Sprat is most abundant in the eastern part of the central North Sea, in the southern North Sea and in the Kattegat. Sprat spawning areas extent through the southern North Sea, the German Bight, the west coast of Jutland and in Kattegat. Spawning also occurs northwards along the English and Scottish coast. The main spawning areas are found in the German Bight, in the Southern Bight and in the English Channel. Spawning occurs during spring and late summer, with peak spawning during the period May - August. Sprats are multiple batch spawners with females spawning repeatedly throughout the spawning season (up to 10 times in some areas). The eggs and larvae are pelagic.	ICES 2019a, Sundby et al. 2017.
Mackerel (*Scomber scombrus*) 	Mackerel are widespread throughout the North Sea. During winter, both immature and mature mackerel tend to be more abundant along the edges of the continental shelf and the Norwegian Deeps, as well as the central parts of the North Sea. Abundance increases during the summer, when mackerel enter the Southern Bight through the Channel and the northern North Sea around Scotland. Mackerel make extensive annual migrations between feeding, wintering and spawning areas. Spawning occurs in the	ICES 2019a, Sundby et al. 2017 and Worsøe et al. 2002.

Species	Distribution and biology	References
	central and northern North Sea between May and July with peak spawning in June. Eggs and larvae are pelagic.	

8.10.2 Demersal species encountered in the project area

The abundance of demersal (bottom dwelling) fish species in the project area is relatively low compared to other areas in the North Sea (ICES International Bottom Survey database, Reiss et al. 2010). The typical demersal species found at 50-100 m depth in the central North Sea include whiting (*Merlangius merlangus*), haddock (*Melanogrammus aeglefinus*) , dab (*Limanda limanda*), long rough dab (*Hippoglossus platessoides*), plaice (*Pleuronectes platessa*) and grey gurnard (*Eutrigla gurnardus*). It should, however, be noted that the abundance of haddock is larger in the northern North Sea, compared to the central North Sea. Cod (*Gadus morhua*), lemon sole (*Microstomus kitt*) and sandeel (*Ammodytes*/*Hyperoplus* sp.) are also relatively common.

The basic biology of these species is described in Table 8-15, Table 8-16 and Table 8-17.

Table 8-15 Biology of demersal cod fish species that may be encountered at South Arne/Solsort.

Species	Distribution and biology	References
Cod *(Gadus morhua)* 	Cod may be encountered at the South Arne and Solsort although the area is not a core area for cod. South Arne and Solsort is situated in a spawning area for cod (Figure 8-17). The spawning season is from the beginning of January to May and peaking in January – February. -After spawning, the eggs are found floating near the water surface over large areas. The eggs hatch within 2-3 weeks, depending on water temperature. The pelagic eggs drift with the prevailing east, northeast and north going currents to nursery areas for larvae, which are mainly found in German Bight, north of German Bight, Jutland Bank, Great- and Little Fishing Bank and along the Norwegian Trench into Skagerrak. These areas are characterised by the formation of hydrographical fronts with high concentrations of zooplankton on which the larvae feed.	ICES 2019a, Sundby et al. 2017, Knutsen et al. 2004, Munk et al. 1999, Munk et al. 1995.
Haddock *(Melanogrammus aeglefinus)* 	Haddock is widespread throughout the deeper waters of the temperate northern Atlantic, shoaling loosely at depths from around 40 to 300 m with a preference for depths between 75 and 125 m. In the Norths Sea the bulk of haddock is found in the northern parts. Haddock may be encountered at South Arne and Solsort, but this area is not a core area for the species. Spawning takes place, at depths of 100 to 150 m in the northern part of the North Sea. Spawning period is from February to May, with peak spawning in March – April. Eggs and larvae are pelagic.	ICES 2019a, Sundby et al. 2017, Worsøe et al. 2002.
Whiting	Whiting is widely distributed throughout the North Sea, Skagerrak and Kattegat. High	ICES 2019a, Sundby et al. 2017.

Species	Distribution and biology	References
(Merlangius merlangus) 	densities of whiting are found along the UK east Coast, the southern and central North Sea (except the Doggerbank) and Kattegat Skagerrak The spawning areas of whiting are wide ranging and are distributed over much of the North Sea from Viking Bank-Shetland in the North to the English Channel in the south. South Arne/Solsort is located very close to the mapped spawning area. As spawning areas for fish are not static and fixed delimited areas, it is very likely that whiting in fact spawns at South Arne/Solsort. Spawning takes place from March to June. Eggs and larvae are pelagic.	

Table 8-16 Biology of flatfish species that may be encountered at South Arne/Solsort.

Species	Distribution and biology	Reference
Plaice (*Pleuronectes platessa*) 	Plaice generally inhabits relatively soft sub-strata and are most abundant on water depths between 10 and 50 m. In the North Sea plaice is most abundant in the central and southern parts. South Arne and Solsort are situated in a plaice spawning area (Figure 8-18). Spawning takes place from December until March (peak: January and February). The pelagic eggs and larvae are transported by the currents, mainly in the eastern and north-eastern directions. During the transport larvae gradually metamorphose and obtain the typical flatfish form. The juveniles settle on the seabed in in nursery areas in shallow inshore waters. The nursery areas in the Wadden Sea are of especially importance.	ICES 2019a, Sundby et al 2017 and Bromley 2000.
Dab *(Limanda limanda)* 	Dab is the most abundant flatfish species in the North Sea and is distributed over the whole of the North Sea in waters down to a depth of about 100 m. Dab spawn in the Central and Southern North Sea. South Arne/Solsort is located very close to high abundance areas for Dab. As spawning areas for fish are not static and fixed delimited areas, it is very likely that dab in fact spawns at South Arne/Solsort.The spawning takes place from April to June.	ICES 2019a, Sundby et al 2017.
Long rough dab *(Hippoglossus platessoides)* 	Long rough dab lives over clean, muddy and sandy bottoms usually at deeper waters. It is not of commercial value. South Arne/Solsort is located very close to the mapped spawning area. As spawning areas for fish are not static and fixed delimited areas, it is very likely that long rough dab in fact spawns at South Arne/Solsort. Spawning takes place from February to May (Peak: April).	ICES 2019a, Sundby et al 2017.

Species	Distribution and biology	Reference
Lemon sole (*Microstomus kitt*) 	Lemon sole is a medium sized flatfish. It mostly occurs on rocky or sandy bottoms at depths between 20 to 150 m. Solsort and South Arne are situated in a spawning area for lemon sole. Spawning takes place from January to October.	References: ICES 2019a, Sundby et al 2017.

Table 8-17 Biology of sandeel and grey gurnard that may be encountered at South Arne/Solsort.

Species	Distribution and biology	Reference
Sandeel (*Ammodytes/Hyperoplus* sp.) 	Four different species of sandeels are encountered in the North Sea. They are an important food source for many predatory species, including other fish, marine mammals and seabirds. Sandeels are burrowing species that spend most of their time in sandy sediments, although during the spring and summer they enter the water column to feed. The spawning areas correspond to the sandeel banks shown on Figure 8-19. After hatching the juveniles, spend approximately 3-4 months in the plankton before settling on a suitable sandy substrate.	References: ICES 2019a.
Grey gurnard *(Eutrigla gurnardus)* 	Grey gurnard is one of the main demersal species in the North Sea. It occurs throughout the North Sea but there is a marked seasonal northwest-southeast migration pattern. During winter the population is concentrated in the central western North Sea to the northwest of the Dogger Bank at depths of 50-100 m. During spring there is a mass migration to the south-east. Spawning takes place in this area from April to August. The eggs are pelagic.	References: ICES 2019a.

8.10.3 The state of fish stocks in the project area

Most of the commercially exploited North Sea stocks of the typical fish species encountered in the South Arne/Solsort area are in good condition and are fished at a sustainable level.

However, the cod stock in the North Sea is in a poor condition. Spawning stock biomass is below the sustainable level and the fishing mortality is too high (Table 8-18).

Table 8-18 State of the North Sea stocks of the commercially exploited typical fish species encountered in the South Arne/Solsort area.

Species	State of stock
Herring	The condition of the herring stock is good. The stock is fished at a sustainable level and the spawning stock biomass has shown a fluctuating but increasing trend since 1987 (ICES 2019b).
Sprat	The spawning stock of sprat has full reproductive capacity (ICES 2019c)
Mackerel	The condition of the mackerel stock is good. The spawning biomass is estimated to have increased in the late 2000s, reaching a maximum in 2014. It has declined since but has still full reproductive capacity. The Fishing mortality has declined from high levels in the mid-2000s, and the stock is harvested sustainably (ICES 2019d)
Cod	The cod stock in the North Sea is in a poor condition. However, the state of the stock is gradually improving. Spawning stock biomass has increased from the historic low in 2006 but is still below sustainable level and the fishing mortality is still too high (ICES 2019e).
Haddock	The condition of the haddock stock is good. Spawning stock biomass has full reproductive capacity, and the stock is harvested sustainably ICES (2019f)
Whiting	The condition of the whiting stock is good. Spawning stock biomass has full reproductive capacity, and the stock is harvested sustainably ICES (2019g)
Plaice	The plaice stock is in excellent condition. The spawning stock biomass is at a record high and has increased almost fivefold during the last 15 years. The stock is harvested in a sustainable manner (ICES 2019h).
Dab	Sustainable levels for dab have not been defined. The ICES assessment of the dab stock is indicative only. The spawning stock biomass has been increasing since 2006 and total mortality has decreased since 2009. ICES (2019i).
Long rough dab	The condition of the long rough dab is unknown, as the species has no or little commercial value, and no ICES advice is made on the stock.
Lemon sole	Lemon sole is managed under a combined species TAC, and this prevents effective control of the species, and could lead to overexploitation of the species. ICES advises that management should be implemented at the species level in the entire stock distribution area (ICES 2020a).
Sandeel	The condition of the sandeel stock is good (Miljø- og Fødevareministeriet 2019). However, the spawning stock biomass has a reduced reproductive capacity (ICES 2019j).
Grey gurnard	ICES has not been requested to provide advice on fishing opportunities for this stock from 2019 and onwards to 2022 (2020b).

8.10.4 Fish spawning in the project area

There are two main ways fish spawn: demersal and pelagic spawning. Demersal spawners lay their eggs on the seabed, pelagic spawners lay their eggs in the free water masses where they remain free flowing for fertilization.

Cod, plaice, dab, long rough dab, lemon sole, mackerel and whiting are pelagic spawners. All are encountered at Solsort and South Arne (Sundby et al. 2017, Warnar et al. 2012). Sandeel is demersal spawner (lay egg on the seabed) and is dependent on sandbanks. However, sandeel banks are not identified in the Solsort/South Arne area (Figure 8-19).

Solsort is located inside the spawning area for lemon sole (Figure 8-15) and mackerel (Figure 8-16), and close to spawning areas for cod (Figure 8-17) and plaice (Figure 8-18). As spawning areas for fish are not static and fixed delimited areas, these species may be spawning at the project area.

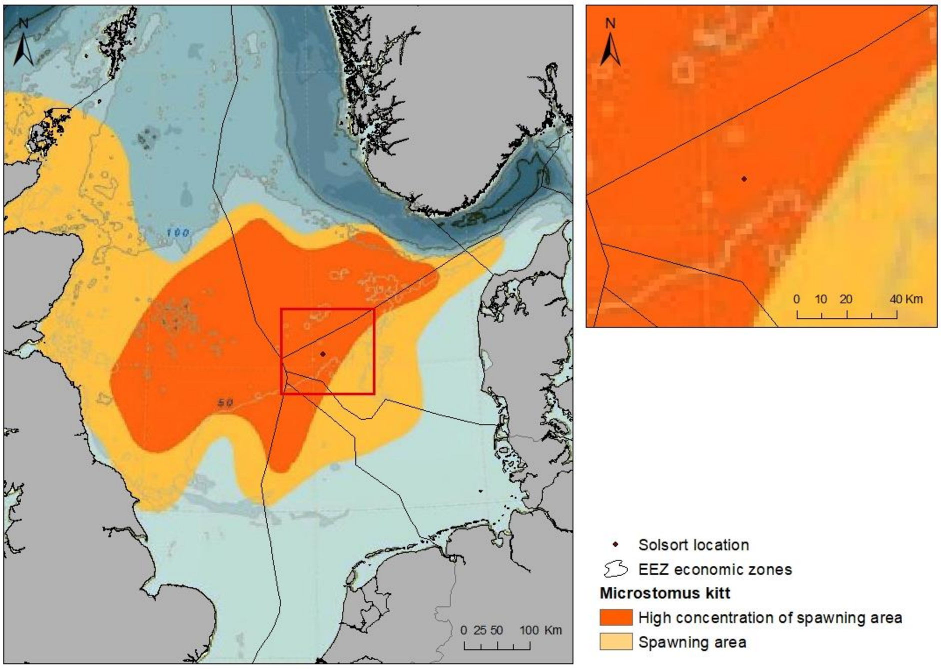


Figure 8-15 Spawning areas for lemon sole in the North Sea. (Based on Sundby et al 2017).

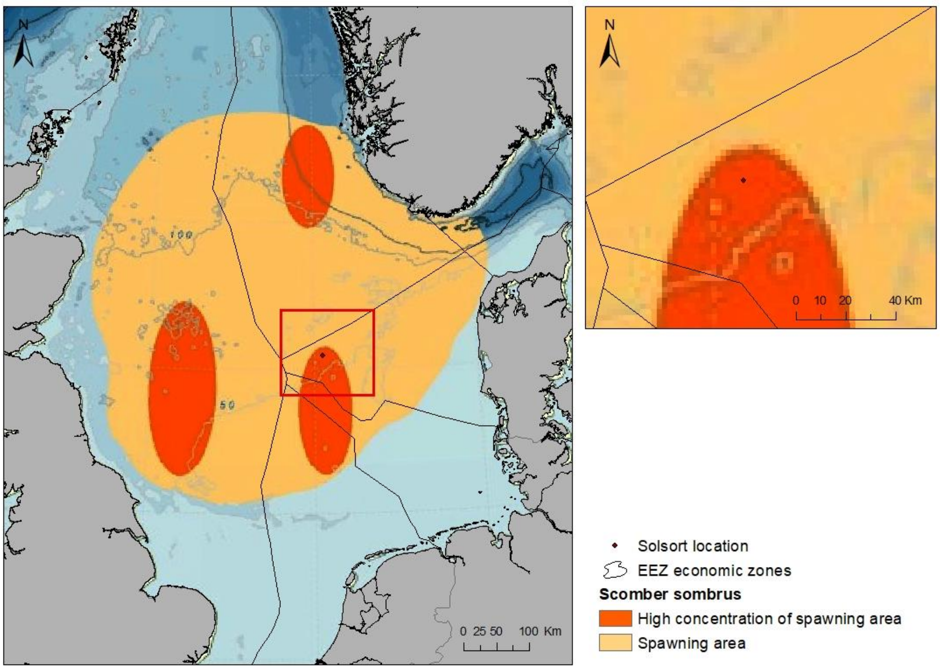


Figure 8-16 Spawning areas for mackerel (Scomber sombrus) in the North Sea (Based on Sundby et al. 2017).

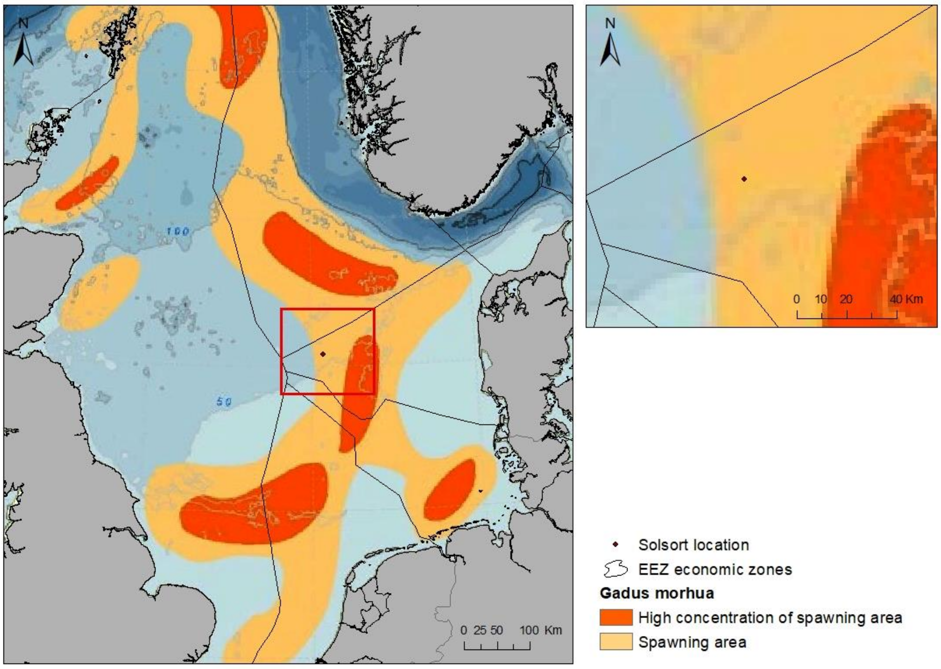


Figure 8-17 Spawning areas for cod (Gadus morhua) in the North Sea. (Based on Sundby et al 2017).

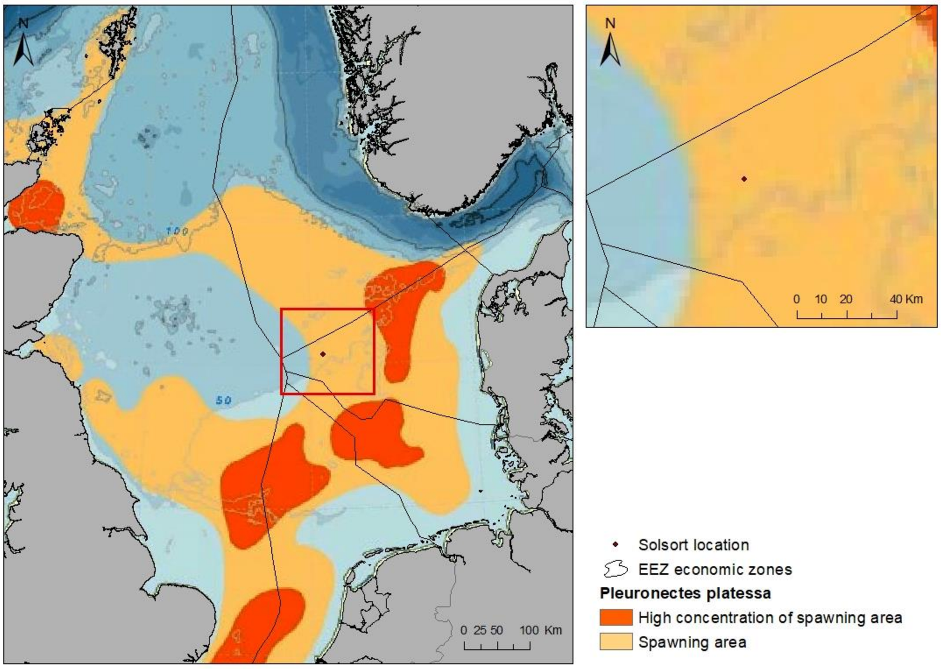


Figure 8-18 Spawning areas for plaice (Pleuronectes platessa) in the North Sea. (Based on Sundby et al. 2017).

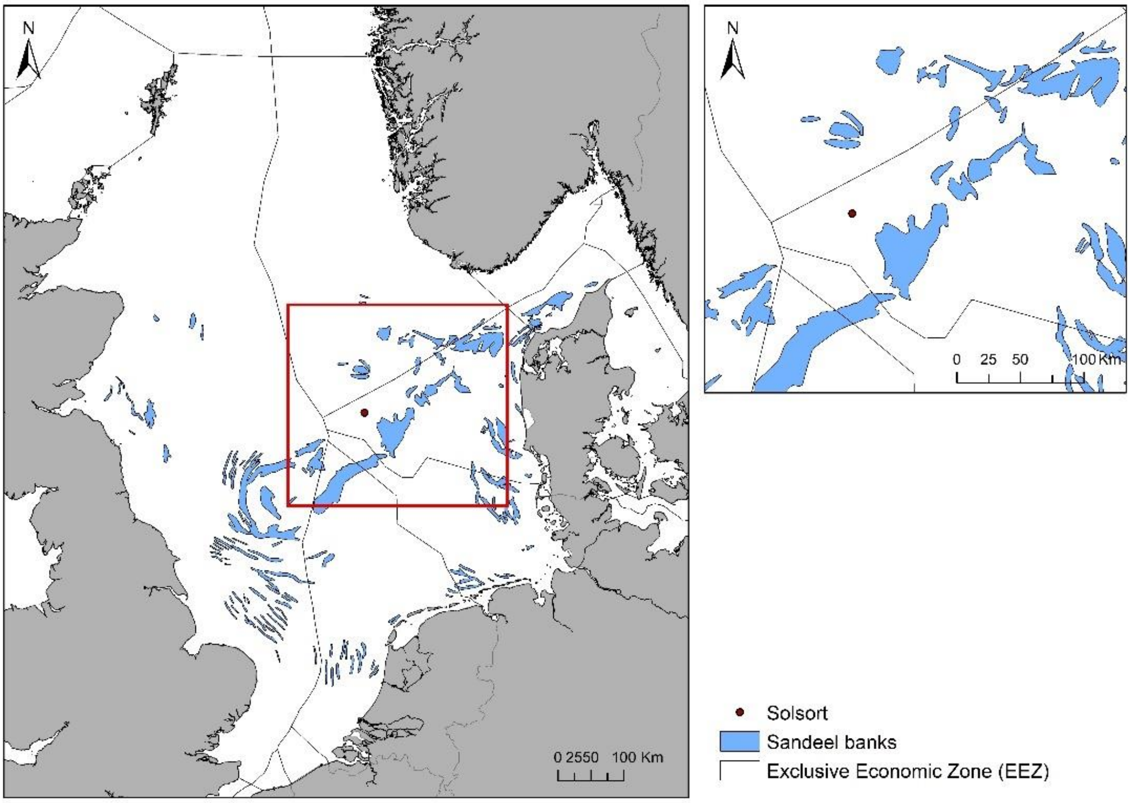


Figure 8-19 Spawning areas (banks) for sand eel (Ammodytes spp.) in the North Sea. (van Deurs 2019).

The spawning seasons for the species that are likely to spawn are shown in Table 8-19. It is seen that most spawning takes place during winter, spring and early summer.

Table 8-19 Spawning seasons for fish that may spawn in the project area (Sundby et al. 2017). Light grey: Total spawning period. Dark grey: Peak spawning.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cod	dark grey	dark grey	light grey	light grey	light grey							
Whiting			light grey	light grey	light grey	light grey						
Plaice	dark grey	dark grey	light grey									light grey
Dab				light grey	light grey	light grey						
Long rough dab		light grey	light grey	dark grey	light grey							
Lemon sole	light grey	light grey	light grey	light grey	light grey	light grey	light grey	light grey	light grey	light grey		
Mackerel					light grey	dark grey	light grey					
Sandeel	light grey	light grey	light grey	light grey	light grey	light grey	light grey					light grey

Eggs and larvae are carried with the prevailing east, north-east and north going currents to the front areas close to the coasts of the eastern North Sea and Skagerrak, where they can benefit from the high plankton production at the hydrographical fronts. Several field surveys have demonstrated that high concentrations of larvae of cod, whiting and sandeel are encountered in the front areas of Skagerrak and north-eastern North Sea south of Norway. Other surveys have shown that the front area along the Danish west coast and in the German Bight houses large concentrations of larvae of sandeel, plaice, cod and whiting (Knutsen et al. 2004, Munk et al 2002, Munk et al. 1999, Munk et al 1995).

8.11 Protected areas

8.11.1 Natura 2000 sites

EU-habitats directive (Council Directive 92/43/EEC of 21 May 1992) specifies natural habitats and wild fauna and flora for which the member states must ensure protection. The species and natural habitats to be protected are specified in the Annexes of the directive:

- Annexes I and II to the Directive contain the types of habitats (Annex I) and species (Annex II) whose conservation requires the designation of Special Areas of Conservation (SACs) (Natura 2000 areas).
- Annex IV lists species of animal and plants in need of particularly strict protection. Of the marine mammals encountered in the North Sea, all species of cetaceans are listed in Annex IV.

South Arne and Solsort is situated far from Danish designated Natura 2000 areas. However, ca. 45 km south of the field is a German designated Natura 2000 area: *DE 1003-301 Doggerbank*. As an extension of this area is the Dutch *NL 2008-001 Doggerbank* and the *UK0030352 Dogger Bank* in the UK sector (Figure 8-20).

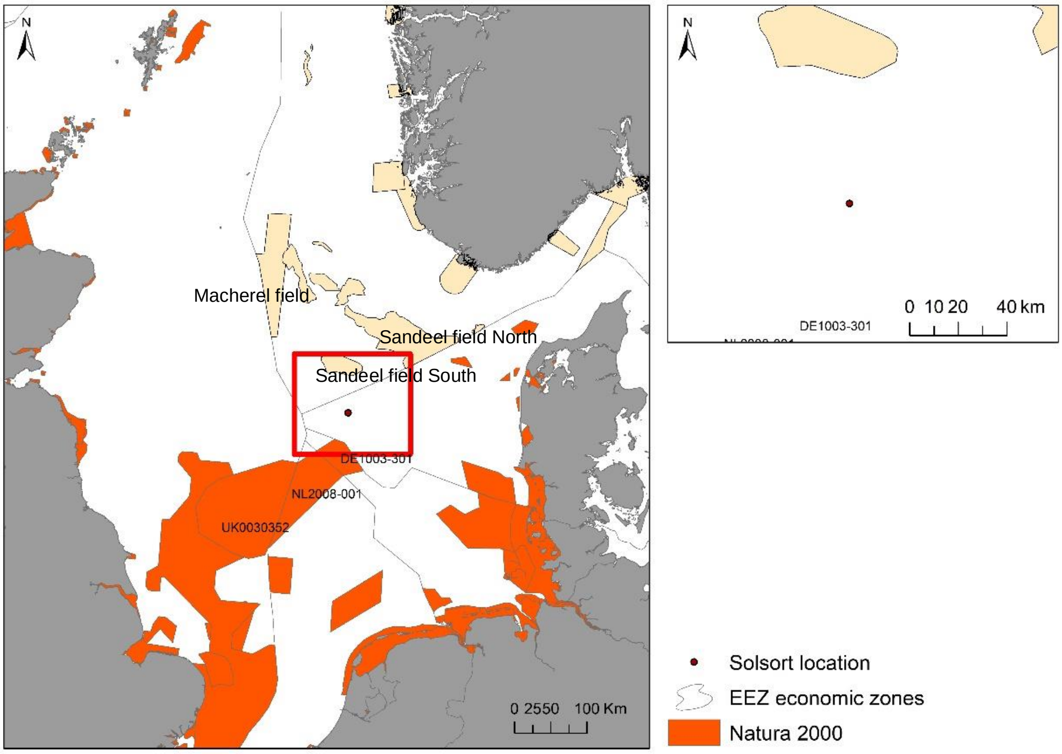


Figure 8-20 Location of Natura 2000-areas (SAC) in the North Sea. The red dot indicates the project area.

The basis for the designation of these three SACs are listed in Table 8-20.

Table 8-20 Basis for the designation of the closest Natura 2000 areas.

Natura 2000 areas (SACs)	Basis for the designation
DE 1003-301 Doggerbank	Annex I habitat type 1110 Sandbanks which are slightly covered by sea water all the time and Annex II species 1351 Harbour porpoise and 1365 Harbour seal.
NL 2008-001 Doggerbank	Annex I habitat type 1110 Sandbanks which are slightly covered by sea water all the time and The Annex II species 1351 Harbour porpoise, 1365 Harbour seal and 1364 Grey seal
UK0030352 Doggerbank	Annex I habitat type 1110 Sandbanks which are slightly covered by sea water all the time and The Annex II species 1351 Harbour porpoise, 1365 Harbour seal and 1364 Grey seal

8.11.2 RAMSAR

RAMSAR sites are designated through the RAMSAR convention. It is an intergovernmental treaty that provides the framework for national action and international management of wetlands. RAMSAR sites are of importance for birds. In Denmark they overlap with SPA (Natura 2000-areas) for birds.

8.11.3 Valuable and vulnerable areas (SVO-areas)

Valuable and vulnerable areas (SVO-areas) is the management framework for marine protected areas in Norway. The SVO-areas include protected areas for red listed species and bird protection areas such as RAMSAR-sites (international conservation of wetlands). The SVO-areas have integrated management plans with criteria for protection.

The closest SVO's are in the Norwegian sector of the North Sea and include the Sandeel field North (Vikingebanken) and South, Table 8-21.

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The Sandeel field North and South are designated as SVO to protect valuable spawning areas for sandeel. The SVO is located 59 km north of Solsort. The area is also designated to protect the two seabird species common guillemot (*Uria aalge)* and northern fulmar (*Fulmaris glacialis*).

North West of the Sandeel field South is the Mackerel field SVO, designated as important spawning area for mackerel. There are existing oil and gas activities in the SVO. The basis for the designation of the Sandeel fields SVO and the Mackerel field SVO area listed in Table 8-21.

Table 8-21 Basis for the designation of the closest SVO areas.

SVO/SPVO	Basis for the designation
Sandeel field north (Vikingebanken) and sandeel field south **(SVO10 and SVO 11)**	The sandeel fields north and south are spawning and foraging area for sandeel. Furthermore, the sandeel fields are a valuable habitat for common guillemot (*Uria aalge)* and northern fulmar (*Fulmaris glacialis*) from April to December. Common guillemot overwinters in the North Western part of the area from December to March.
Mackerel field (Makrellfeltet) (SVO12)	The SPVO 12 Makrellfelt is a spawning area for mackerel from May to July. It is vulnerable towards fisheries and oil spill.

8.12 Human Environment

Commercial activities in the western part of the Danish sector of the North Sea include:

- Oil and gas extraction
- Shipping and
- Fishery

8.12.1 Oil and gas extraction

There is ongoing oil and gas activity in the central North Sea. The closest existing oil and gas facilities in operation to the Solsort field is the INEOS operated South Arne platform, the Total operated Svend and Harald. Other installations in the vicinity include the INEOS operated Hejre field (still under development) (Figure 8-21).

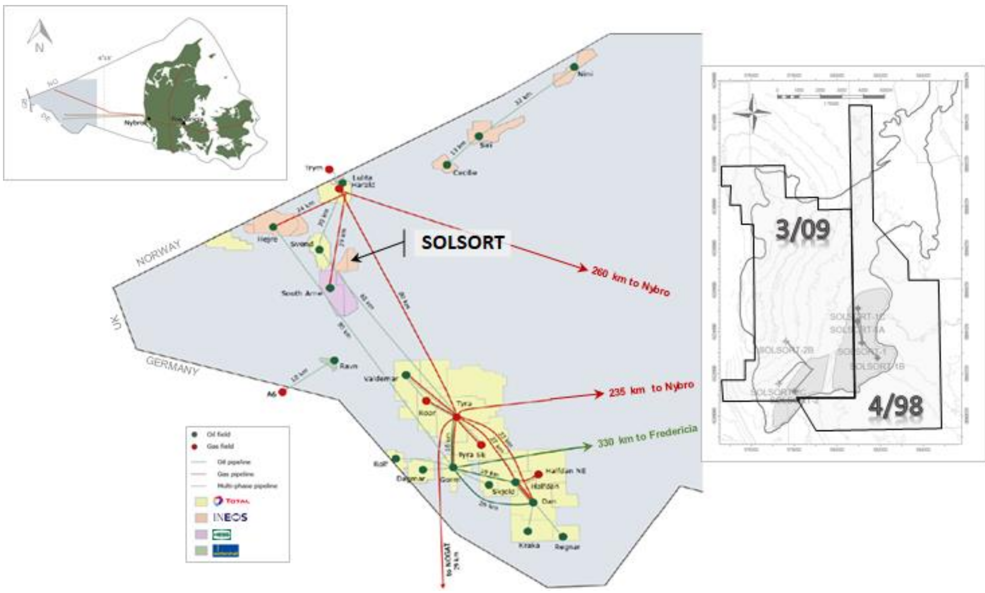

Figure 8-21 Location of Solsort West Lobe wells at the SA-WHPN and surrounding infra-structure in the Danish sector of the North Sea.

8.12.2 Shipping

COWI (2020) carried out a vessel traffic study based on data from the AIS system (Automatic Identification System). In the analysis, the North Sea was divided in cells of 500 m x 500 m, and the traffic intensity of merchant vessels in each cell was estimated.

Figure 8-22 shows the traffic intensity of merchant shipping for the year 2018 in the western part of the Danish sector of the North Sea. South Arne and Solsort is situated outside shipping routes of merchant vessels.

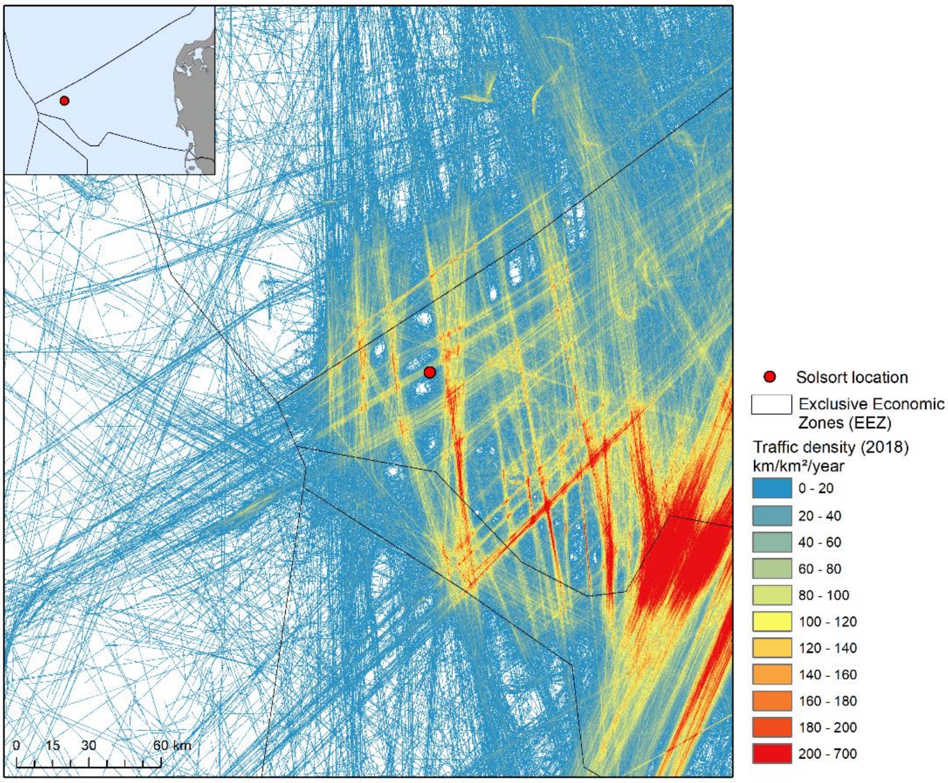

Figure 8-22 Ship traffic in the North Sea based in AIS data from all ships in 2018, except fishing, military and offshore related traffic (COWI 2020).

8.12.3 Wind Power

There is currently no offshore wind power production in the neighbouring area to the Solsort field and the South Arne installations. However, Norway has opened an area (Sørlige Nordsjø II) for offshore windfarms in the Southern Sector of the Norwegian North Sea bordering the Danish sector of the North Sea (ca. 20 km from Solsort). The closest established windfarms are located near Horns Rev more than 200 km from Solsort. The offshore windfarms at Horns Rev include Horns Rev I, Horns Rev II and Horns Rev III with a total of 200 wind turbines.

8.12.4 Fisheries

Fisheries and Danish fishing effort in the eastern North Sea

Figure 8-23 shows the fishing effort of Danish vessels using active gear (dredgers, beam trawl, pelagic trawl, otter trawl or demersal seiners) in the eastern North Sea during the period 2007-2015. Figure 8-24 shows the fishing effort using passive gear (i.e., mainly gill nets) in the same area during the same period.

It is seen that South Arne installations are situated in an area with low fishery intensity.

It appears that the fishery is concentrated in the following areas:

- Along the edge of the Norwegian trench and the Skagerrak.
- Along the Danish west coast.

The main fishing, which takes place in the Danish sector of the North Sea (COWI 2015) are:

- Fishery for Norway lobster, using otter trawls.
- Industrial fishery for sandeel by trawlers using small meshed demersal trawl in industrial fisheries (i.e., for fishmeal).
- Industrial fisheries for sprat for fish oil and fish meal using small, meshed trawls; and
- Mixed fishery for flatfish using primarily otter trawl and gill nets.

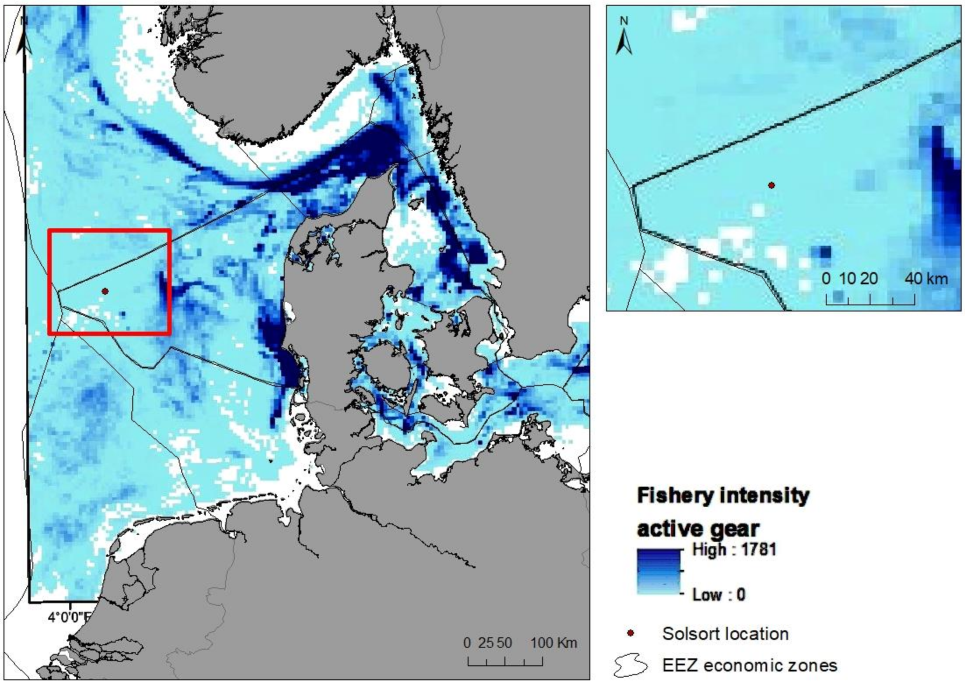

Figure 8-23 The distribution of active fishing intensity based on VMS and AIS data from the period 2007-2015 (Based on Egekvist et al 2018). Active fishing includes the use of dredgers, beam trawl, pelagic trawl, otter trawl or demersal seiners.

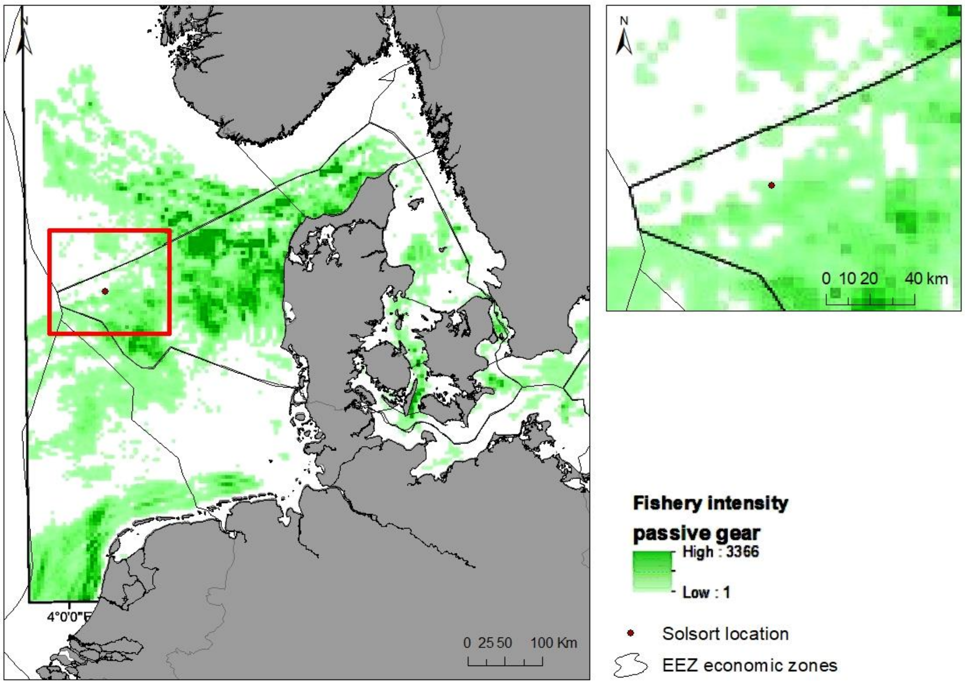

Figure 8-24 The distribution of passive fishing intensity based on VMS and AIS data from the period 2007-2015 (Based on Egekvist et al. 2018). In the area passive gear used is primarily gill nets.

Danish catches in the South Arne/Solsort area

Although the waters around the South Arne/Solsort field have a low fishing intensity it is nonetheless of some significance for the fishing industry with a mean annual value of fish catch of approximately 11 million DKK in this area corresponding to 0,6 % of the value of the total fish catch in the central North Sea (Figure 8-25).

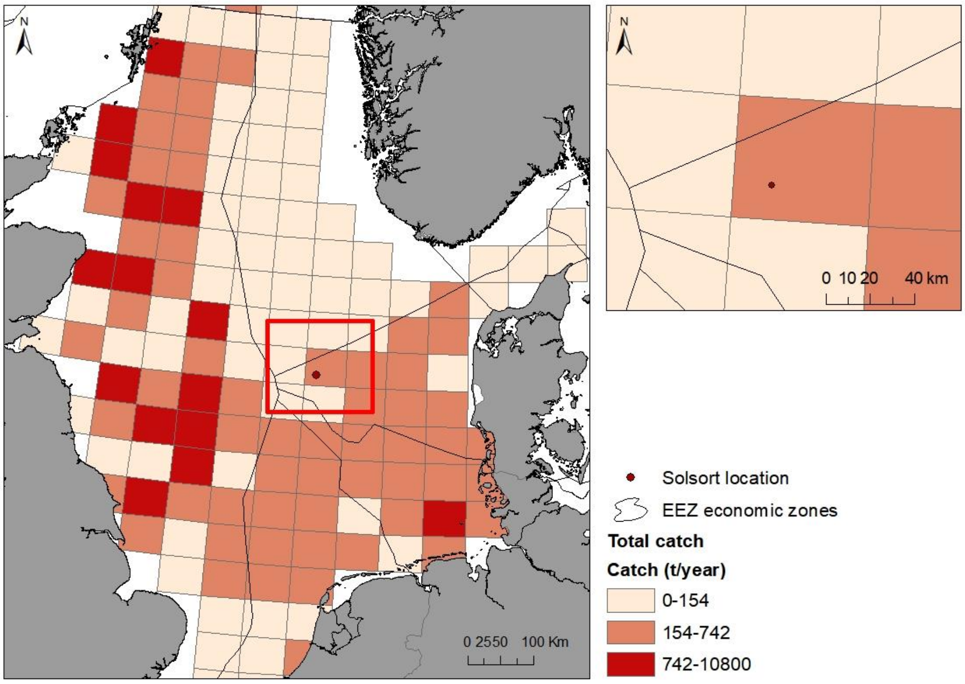

Figure 8-25 An average of approximately 7,600 tons fish are caught per year.

In terms of value, the most important fish species around the South Arne/Solsort field are sand eel, plaice, turbot, lemon sole, cod and monkfish. Sand eel alone makes up 95% of the value of fish caught in this area (Figure 8-26). The distribution of the Danish total fishery catches is shown in Figure 8-27. Compared to the fish catch in the North Sea in the area around Solsort (ICES square 41F4), sand eel fishery is of some significance has been carried out around the South Arne/Solsort field in 2014-2018; however, the remaining fish species are of less importance. The distribution of catches of the most important fish species (sandeel, plaice, turbot, lemon sole, cod and witch flounder) are shown in Figure 8-28 to Figure 8-33.

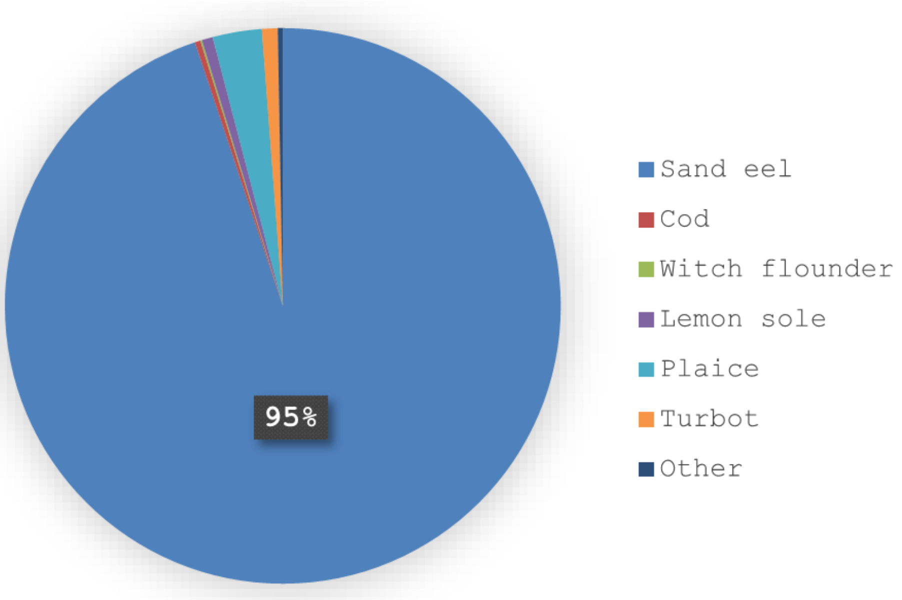

Figure 8-26 The value of key fish species caught in the Solsort area in percentage. Values represent an average during the period 2014-2018. Source: Fiskeristyrelsen 2019

The waters around South Arne/Solsort field are without significance for the fishery of other countries (MMO 2012, Van Oostenbrugge et al. 2010, Agenda 1999, Rogers & Stocks 2001).

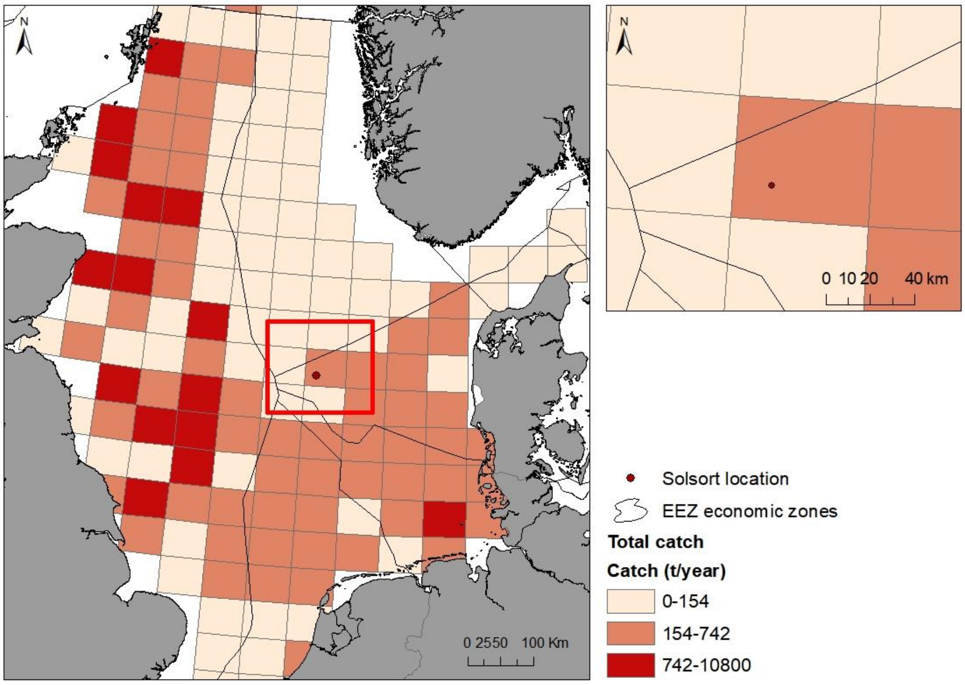

Figure 8-27 Mean catches of all fisheries in the period 2014-2018. Based on data from the Danish AgriFish Agency (2019).

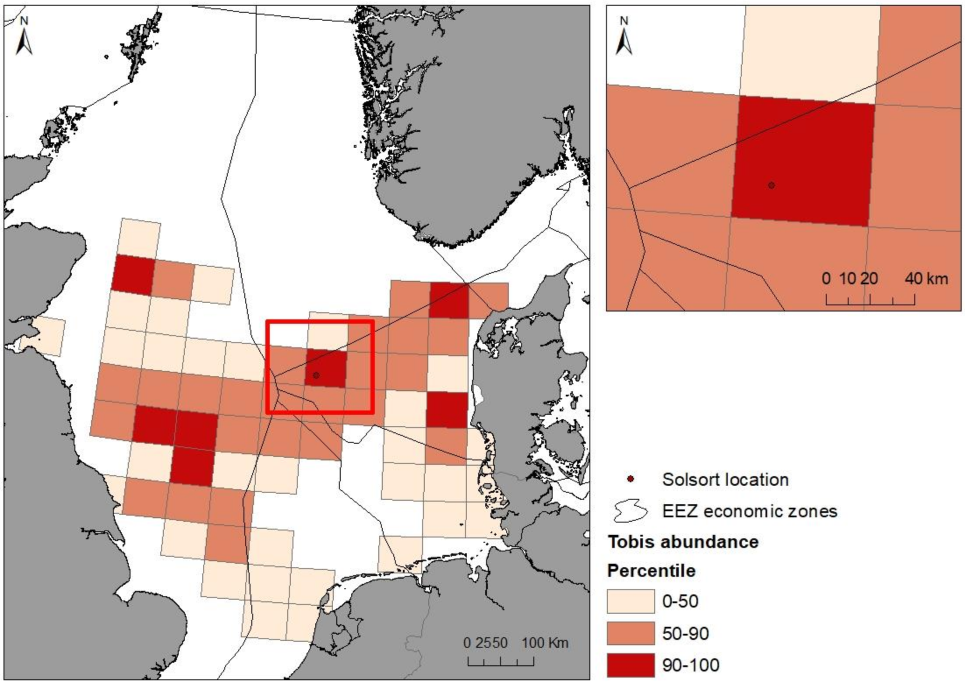

Figure 8-28 Mean Danish catches of sand eel (Ammodytes spp.), during the period 2014-2018. Based on data from the Danish AgriFish Agency (2019).

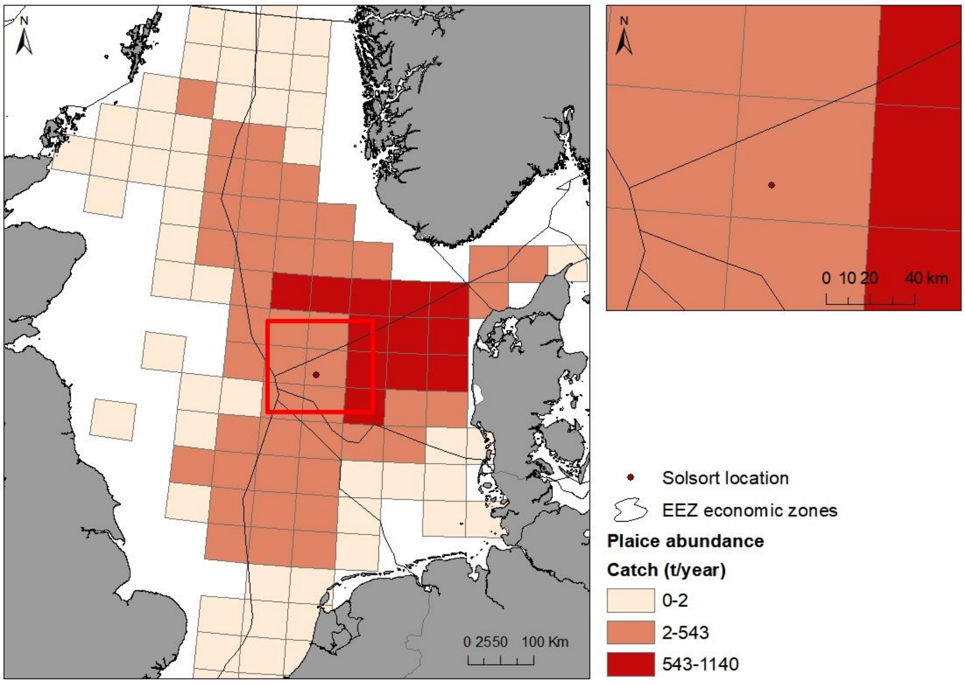

Figure 8-29 Mean Danish catches of plaice, during the period 2014-2018. Based on data from the Danish AgriFish Agency (2019).

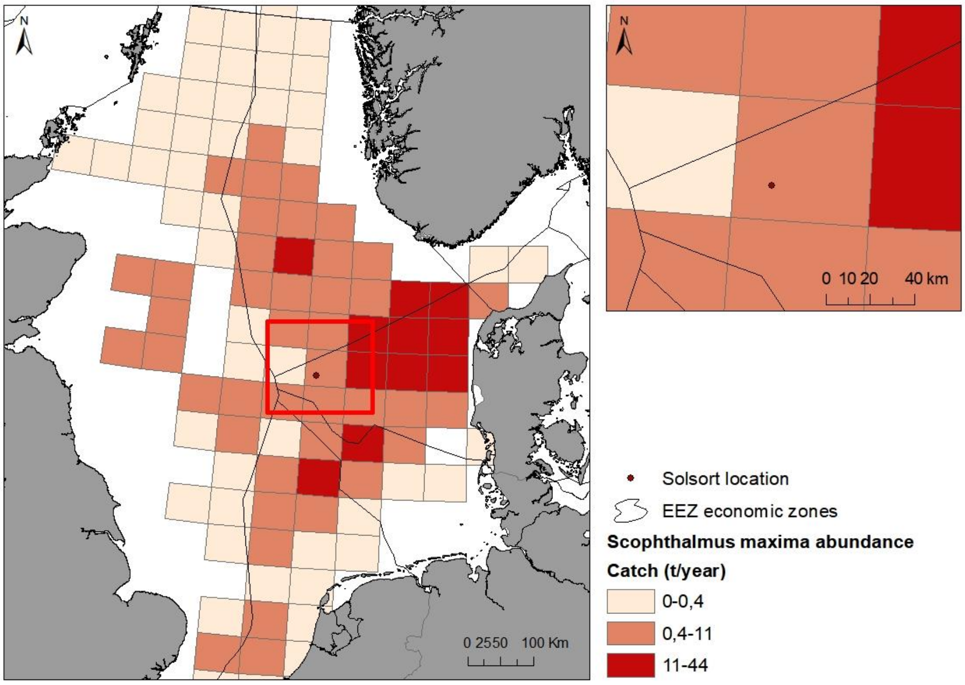

Figure 8-30 Mean Danish catches of turbot (Scophthalmus maxima) in the period 2014-2018. Based on data from the Danish AgriFish Agency (2019).

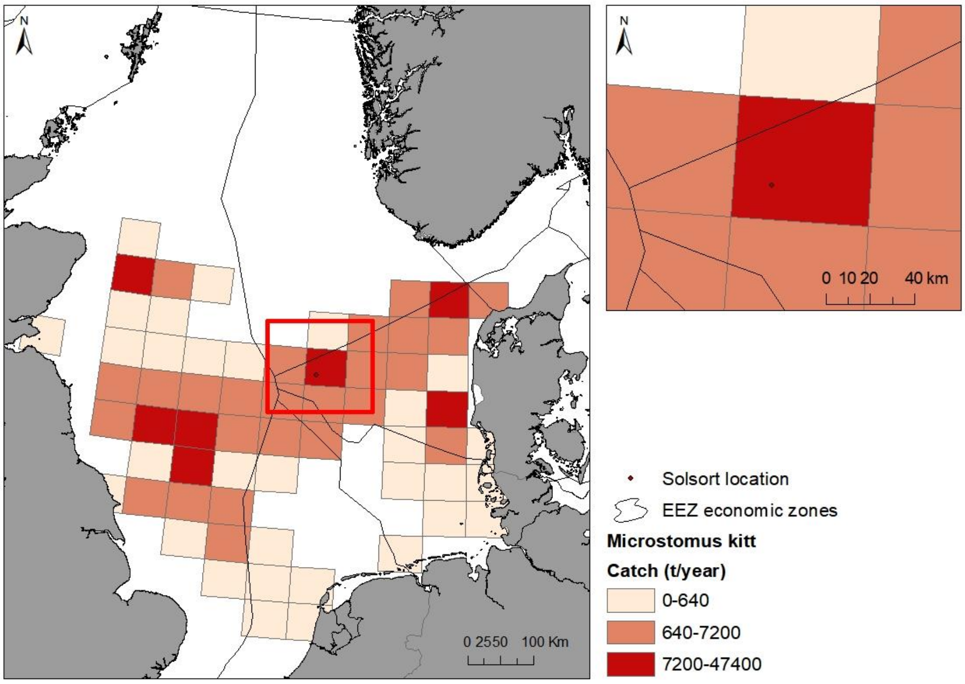

Figure 8-31 Mean Danish catches of lemon sole (Microstomus kitt) during the period 2014-2018. Based on data from the Danish AgriFish Agency (2019).

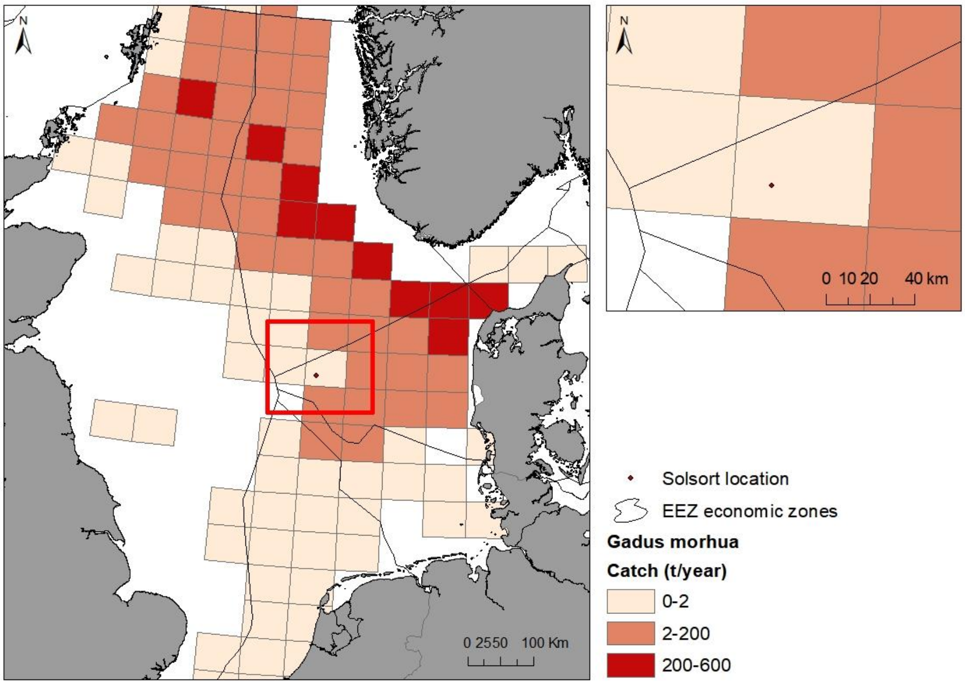

Figure 8-32 Mean Danish catches of cod (Gaudus morhua) during the period 2014-2018. B based on data from the Danish AgriFish Agency (2019).

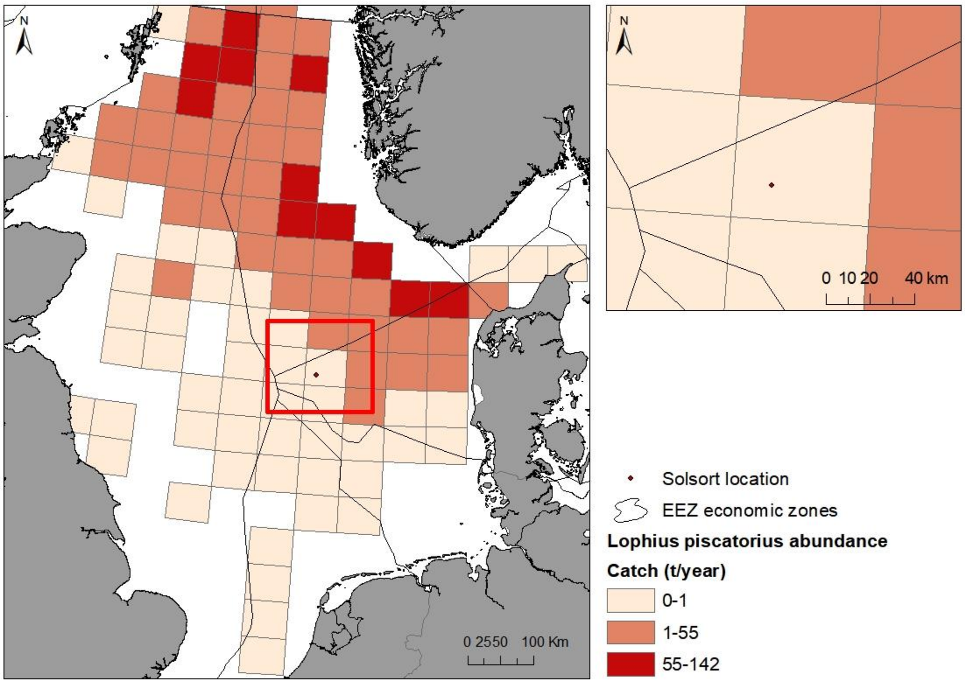

Figure 8-33 Mean Danish catches of monkfish (Lophius piscatorius) during the period 2014-2018 based on data from the Danish AgriFish Agency (2019).

8.12.5 Cultural heritage

The only cultural heritage that potentially could exist in the project area is ship and plane wrecks. There are no registered wrecks in the project area (Slots- og Kulturstyrelsen, 2021). The closest registered wreck is located ca. 20 km south of Solsort. The wreck is not protected.

9. Methodology for Evaluation of Environmental Severity and Risk

The environmental significance (severity) and risk of impacts of the project on environmental and socioeconomic receptors has been evaluated using the following methodology.

9.1 Procedure for risk assessment

Environmental risk is the combination of the significance (severity) of an impact and the probability that an impact may arise. This implies for instance that an incidence that may cause severe impacts but is not very likely to occur has a low environmental risk.

For each operation or incidence, the assessment of environmental risk includes three steps:

- Assessment of environmental significance (severity) of an impact.
- Assessment of the probability that an impact will occur.
- Assessment of risk by combining severity and probability.

9.1.1 Assessment of environmental significance (severity) of an impact

Qualitative assessments of environmental severity of impacts of different operations and events will be carried out for both the EIA screening and the Natura 2000 screening. The assessment of severity includes the following steps:

- Assessments of nature, extension, duration, and magnitude of impacts using the criteria shown in Table 9-1, including whether the impact is positive or negative, temporary, or permanent.
- Assessment of the severity of impacts combining the assessments of extension, duration and magnitude of the impacts using the criteria shown in Table 9-2.

Table 9-1 Criteria for assessment of nature, extension, duration and magnitude of impacts.

Criterion	Description
Nature	***Nature of the environmental change***
Positive	Beneficial environmental change
Negative	Adverse environmental change
Extension	***The geographical area that may affected by the impact***
Local	Only the place where the activities directly related to construction and drilling operations may occur - within 500 meters of the activity
Regional	Effects may occur in the Central North Sea (Beyond 500 meters)
National	Effects may occur in Danish waters
International	Effects may occur in the entire North Sea
Duration	***Period along which the impact is expected to occur***
Short-term	Less than 8 (eight) months
Medium-term	Between 8 (eight) months and 5 (five) years
Long-term	More than 5 (five) years
Magnitude	***The magnitude of impacts on environmental and social processes***
Small Medium Large	If possible, the magnitude of an effect is assessed from results of environmental modelling. Otherwise, the magnitude of an effect is based on an expert assessment based on previous experience from other projects. The following factors are taken into consideration: › The extent to which potentially affected habitats and organisms are unaffected by human activity › The numbers/areas of an environmental feature that will be potentially affected › The uniqueness/rarity of potentially affected organism and habitats › The conservation status of habitats or organism (Natura 2000 areas, Annex IV species etc. › The sensitivity of the habitat/organism › The robustness of the organism/habitats against impacts, i.e., and evaluation of the ability to adapt to the impact without affecting the conservation status, uniqueness or rarity › The potential for replacement i.e., an assessment of to what extent the loss of habitats or populations of organisms can be replaced by other.

Table 9-2 Criteria for assessment of severity of potential impacts of the project.

Severity rating	Relation with the criteria on nature-, extension-, duration- and magnitude that describe the impact
Positive impact	The assessed ecological or socioeconomic feature or issue is improved compared to existing conditions
No impact	The assessed ecological or socioeconomic feature or issue is not affected
Insignificant impact	Small magnitude, with local extension and short-term duration.
Minor impact	1) Small magnitude, with any combination of other criteria (except for local extension and short-term duration, and long-term duration and national or international extension) or 2) Medium magnitude, with local extension and short-term duration.
Moderate impact	1) Small magnitude, with national or international extension and long-term duration; or 2) Medium magnitude, with any combination of other criteria (except for local extension and short-term duration; and national extension and long-term duration 3) Large magnitude, with local extension and short-term duration;
Major impact	1) Medium magnitude, with national or international extension and long-term duration. 2) Large magnitude, with any combination of other criteria (except for local extension and short-term duration)

9.1.2 Assessment of the probability that an impact will occur

The probability that an impact will occur will be assessed using the criteria shown in Table 9-3.

Table 9-3 Criteria for assessment of the probability and if the impact will occur.

Probability criterion	Degree of possibility of impact occurrence
Very low	The possibility of occurrence is very low, either due to the project design or due to the project nature, or due to the characteristics of the project area
Low	The possibility of occurrence is low, either due to the project design or due to the project nature, or due to the characteristics of the project area
Probable	There is possibility of impact occurrence
Highly Probable	Possibility of impact occurrence is almost certain
Definite	There is certainty that the impact will occur

9.1.3 Risk assessment

The environmental risk of different operations and incidences will be assessed combining significance (severity) and probability of an impact according to a risk matrix as outlined below (Table 9-4).

Table 9-4 Qualitative risk assessment matrix.

	Significance /severity of impact			
Probability	**Insignificant Impact**	**Minor impact**	**Moderate impact**	**Major impact**
Definite	Negligible risk	Low risk	Significant risk	High risk
Highly probable	Negligible risk	Low risk	Significant risk	High risk
Probable	Negligible risk	Negligible risk	Low risk	Significant risk
Low	Negligible risk	Negligible risk	Low risk	Low risk
Very low	Negligible risk	Negligible risk	Negligible risk	Low risk

10. Environmental impacts during construction

10.1 Potential impacts

The potential environmental impacts of the following operations during the construction phase assessed in this EIA comprise of:

Impacts during establishment of wells including:

- Underwater noise impact on fish and marine mammals during site survey
- Discharge of cuttings, drilling and cement chemicals and water-based drilling fluids
- Underwater noise impact on fish and marine mammals during drilling
- Emissions from vessels during site survey and drilling
- Impacts of blowout and chemical spills
- Waste
- Consumption of natural resources
- Impacts from modifications at South Arne North, East and Main platform

Figure 10-1 and Table 10-1 provide overviews of potential effects during the construction phase assessed in the EIA. This chapter deals with environmental impacts of planned activities. Environmental impacts of accidental spills are dealt with in chapter 13 and socioeconomic impacts are described and assessed in chapter 16.

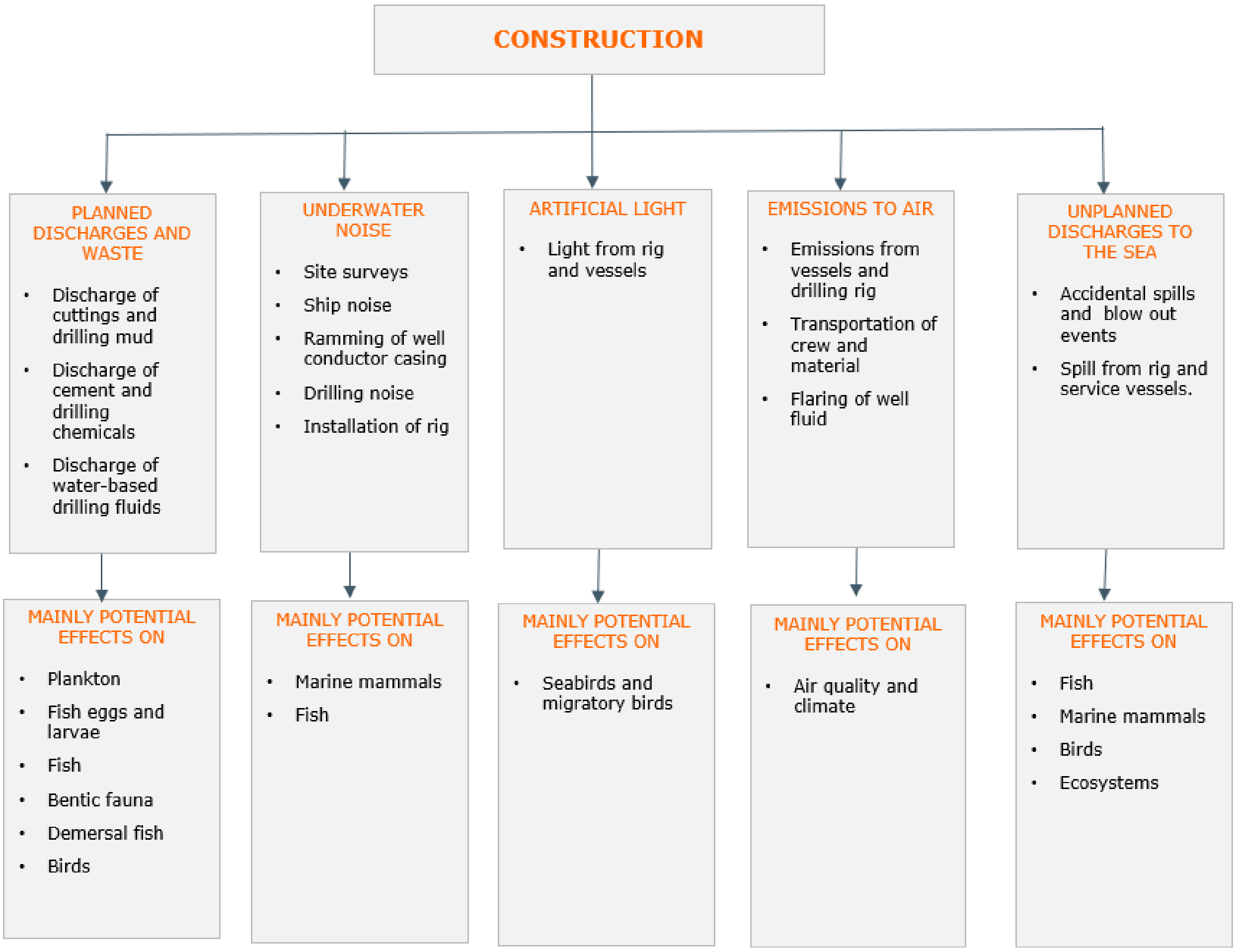

Figure 10-1 Overview of operations during construction that may have an impact on the environment and organisms that may primarily be affected by the different operations which will be assessed in the EIA.

Table 10-1 Overview of potential environmental and socioeconomic impacts of planned activities during construction which is assessed in the EIA.

	Potential Impacts
Drilling/establishment of wells	
Discharge of drill cuttings, drilling mud components and cementing chemicals	› Physical smothering of seabed mainly affecting benthic fauna › Water contamination from suspended cuttings, solids and drilling chemicals and impact on pelagic organisms › Sediment contamination from drilling chemicals affecting benthic fauna
Well completion	› Discharges of completion fluids can impact on water quality and marine fauna. However, only green and yellow chemicals are discharged.
Flaring during well clean-up and other operations causing emissions to the air	› Release of particles (PM_{10}) and gaseous emissions (SO_x, NO_x, VOC,) with potential mainly local effects on air quality › Release of gaseous emissions (CO, CO_2, CH_4) with potential effects on global climate
Noise from site survey, drilling operation and potential ramming of well conductor casing	› Noise disturbance to marine mammals resulting in behavioural avoidance
Accidental spills and blowout	› Mainly birds, marine mammals, fish, coastal ecosystems, fisheries, aquaculture and tourism may be affected. Blowouts are extremely rare events › Economic loss to fisheries, aquaculture and tourism due to oiling

10.2 Impacts of discharges from the drilling rig

10.2.1 Introduction

During the construction phase, the following planned discharges to the sea may take place:

- Discharge of cuttings and drilling mud solids (water-based mud)
- Discharge of chemicals (chemicals used in drilling mud, cementing, completion, rig utility and pressure testing)
- Discharge of treated sewage from the drilling rig.

10.2.2 Impacts of the discharge of cuttings and drilling mud

10.2.2.1 Discharge of cuttings and drilling mud (WBM)

The use of drilling mud and discharge of cuttings during drilling is described in Chapter 5.3.5 og 5.3.6. During drilling, the mixture of cuttings and WBM is returned to the rig and treated in the rigs solids control system as follows:

- On the rig, drilling waste materials are placed on shale shakers, which are a series of vibrating screens that separates cuttings from drilling mud components. Each successive shale shaker uses finer mesh screen, so the size of the collected particles is successively smaller. The solid cuttings coated with a film of mud remain on top of the shale shakers and are collected at the opposite end of the shakers and discharged if the cuttings meet the discharge standards at this point.

- The liquid mud passes through the shale shaker screens. If the recycled mud contains fine particles that would interfere with drilling performance, the muds are treated using hydro cyclones and decanting centrifuge to remove very fine particles and is sent back to mud pits on the platform for reuse.

- After treatment, the cleaned WBM is returned to the mud tanks for recycling down-hole.

- Cuttings and mud components adhered to the cuttings will be discharged from the rig approximately 10 meters below the sea surface. After completion of drilling with WBM, the spent mud will be reused or discharged to sea.

The Solsort West Lobe wells will be longer than the normal South Arne wells and an extra casing string run for the Solsort West Lobe wells. The surface hole will increase from 16" to 23" and the equivalent casing from 13-3/8" to 18-5/8" and consequently more WBM and cuttings will be discharged. A longer 17-1/2" and 13-1/2" hole will be drilled with OBM or Formate drilling fluid. The Solsort West Lobe reservoir section is planned to be drilled with a Formate drilling fluid system compared to a normal South Arne reservoir, which is usually drilled with WBM.

An estimated total of about 580 m³ (1,392 MT) of cuttings and 858 m³ of WBM will be discharged per well i.e., 1i.e., m³ (2,784 MT) of cuttings and 1,716 m³ of WBM, respectively for the two wells. The wells will be drilled without intermission.

Low toxic oil-based mud (OBM) and low solid-based formate mud is applied in the lower and more complicated part of the well. The volume of cuttings is estimated to 1002 m³ per well (1,902 m³ in total) while the volume of OBM and Formate drilling fluid is 1,862 m³ per well (3,620 m³ in total). In accordance with OSPAR Decision 2000/3, OBM fluids and associated cuttings will not be discharged, but contained and shipped for onshore disposal or recycling or re-injected into a CRI well.

10.2.2.2 Fate of cuttings and WBM solids

When WBM solids and drill cuttings are discharged to the sea they form plumes that dilute rapidly as they drift away from the discharge point with the prevailing currents. Two separate plumes are generally formed (Sanzone et al 2016) (Figure 10-2):

- A plume of heavier larger particles and flocculated small particles that constitutes about 90% of the mass of the mud and cuttings solids. This plume settles quickly on the seafloor in close vicinity of the rig

- A plume formed in the upper water column, which constitutes the remaining 10% of the mass of the mud solids that consists of fine-grained clay-sized particles and soluble components. This plume drifts away from the platform with prevailing currents and is diluted downstream.

Several field studies have confirmed this pattern and have consistently shown that drilling waste solids are diluted by up to 30-fold in the discharge pipe and by an additional 1.000-3.000 fold within 30 meters from the rig, dependent on current speed (Neff 2010).

On the seabed material may be subject to erosion, dissolution, bioturbation as well as re-suspension and bed transport. Oxygen depletion may occur if the material contains large amounts of organic material especially in areas with low current speed on the seabed (Figure 10-2).

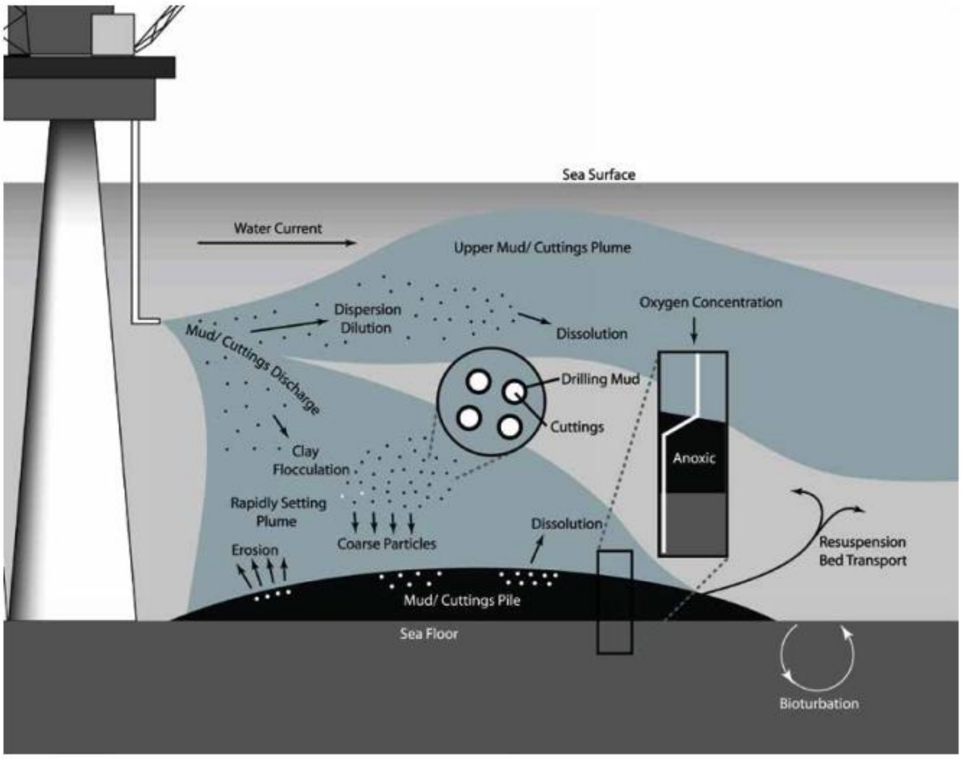

Figure 10-2 Dispersion and fates of cuttings and WBM components following discharge to the ocean (From Sanzone et al 2016).

10.2.2.3 Impacts of discharge

Ecological impacts of the discharge of WBM solids and cuttings, when detected, are predominantly physical effects of particles. Ecotoxicological studies, microcosms and mesocosm studies, as well as field surveys have consistently shown that WBM and WBM cuttings are non-toxic or practically non-toxic to marine plants and animals. Metals in WBM are associated almost exclusively with barite and bentonite and do not affect the environment because of their low bioavailability (Grant and Briggs 2002, Schaaning et al. 2002, Neff 2008). The metals have a low bioavailability because they are present as insoluble minerals in the nearly insoluble barite.

Once on the seabed, they do not dissolve in sediment pore water or overlying water even under anoxic conditions (Neff 2010). When toxicity of drilling muds and cuttings was identified in the past it was attributed to petroleum hydrocarbons or chrome lignosulfate in the mud, both now strictly limited in WBM destined for ocean disposal (Neff 2010).

10.2.2.4 Impacts in the water column

Modelling studies combined with data from laboratory tests as well as field studies have shown that offshore discharges of WBM and associated cuttings will cause little or no harmful effects on organisms in the water column (Sanzone et al 2016, Neff 2010).

A study in which measurements of the concentrations of suspended solids in the plume of drill cuttings showed a marked decrease in concentrations from 1,430,000 mg/l in the discharge point to 7-24 mg/l at distances of 250-375 m from the rig depending on rate of discharge (Ayers et al. 1980 Neff 2005). Smith et al. 2004 found that the concentration of bentonite clay in the discharge plume from a drilling rig was below 1000 mg/l at about 25 m down current from the discharge. Comparing these concentration levels with effect levels determined in the laboratory (cf. Table 10-2) it is assessed that impacts on plankton organisms, may only be expected in the immediate vicinity of the drilling rig i.e., within less than 100–200 meters from the rig.

This is substantiated by zooplankton monitoring around a rig drilling an exploratory well in the Canadian Beaufort Sea in December 2005 through March 2006. It was concluded that the discharge of water-based drilling mud had little or no effect on zooplankton communities dominated by copepods at and beyond 100 m from the rig (KAVIK-AXIS 2007, referred in Sanzone et al 2016) (samples were not collected closer to the rig than 100 m).

Local impact on plankton, including fish larvae in the immediate vicinity of the rig will not detectably affect the plankton populations and fish stocks in the Central North Sea. This is explained by the high abundance of plankton which naturally suffer very high levels of mortality and has an enormous regeneration capacity. Moreover, most fish species have extensive spawning grounds and produce vast numbers of eggs and larvae.

Fish may flee the plume of drilling mud and cuttings at larger distances. Laboratory experiments have shown that a sensitive specie like herring, may avoid concentrations of suspended matter ≥ 10 mg/l (Wildish & Power 1985, Johnston & Wildish 1981, Wildish et al. 1977).

Table 10-2 Lethal and sublethal effects of elevated concentration of WBM solids in the water column observed in the laboratory.

Observed effect	Effect concentrations	References
Average median lethal concentration of suspended barite to 12 to 15 species of pelagic animals (zooplankton and larvae of invertebrates and fish)	3010 mg/l	Smit et al. (2008)
Average median lethal concentration of suspended bentonite to 12 to 15 species of pelagic animals (zooplankton and larvae of invertebrates and fish).	1830 mg/l	Smit et al. (2008)
Barium (as barite) affected embryos of the crab *Cancer anthonyi* at concentrations greater than 1000 mg/l	> 1000 mg/l	MacDonald et al. 1988
Marine phytoplankton were adversely affected by exposure to more than about 1000 mg/l barite in suspension. Primary production was reduced due to shading	1000 mg/l	Smit et al. 2008

Observed effect	Effect concentrations	References
effect of the suspended matter.		
No observed effect concentration (NOEC) for marine phytoplankton exposed to bentonite for 72 hours was 1000 mg/l	1000 mg/l	Garcia et al. 2014
Early life stages of sea scallops *Placopecten magellanicus* exposed to 100 mg/l of used water-based drilling fluids for 96 hours were not affected in terms of fertilization success of eggs, survival of larvae and growth of the larvae	100 mg/l	Cranford et al. 1988
Early life stages of lobsters *Homarus americanus* to 100 mg/l of used water-based drilling fluids for 96 hours had reduced survival	100 mg/l	Cranford et al. 1988
Early life stages of haddock *Melanogrammus aeglefinus* exposed to 100 mg/l of used water-based drilling fluids for 96 hours showed a slight reduction in survival of two of the four early life stages	100 mg/l	Cranford et al. 1988

10.2.2.5 Impacts on the seabed

Several monitoring studies have shown that the bulk of discharged cuttings and WBM components deposit in the immediate vicinity of the wellhead. Alterations to benthic infauna communities following the discharge of cuttings and WBM are generally restricted to within 100-200 m from the platform, if at all detected (Cf. Table 10-3). Effects may include a reduction in species diversity and increases in the abundance of a few opportunistic species. Functional changes have also been observed, including a loss of suspension feeding species and increases in deposit feeders (Ellis J.I, et al. 2012).

Table 10-3 Examples of field studies of impacts on benthic fauna around offshore plat-forms where WBM have been used for drilling.

Study	Result	References
Videosurveys with ROV was performed at three oil fields in the Faroe-Shetland Channel, where the top-hole section of three wells were drilled with WBM and where WBM and cuttings were discharged directly to the sea floor.	A thin layer of WBM cuttings completely covered the seabed within about 50 to 100 m of the three drilling rigs following the drilling operations. The abundance and diversity of benthic megafauna was much lower in the area where cuttings completely covered sediments	Jones et al. 2012

Study	Result	References
Sediments and benthic megafauna were monitored around a jack up rig in the Ragnarok field in Norway just before and a month after drilling the top-hole sections of the well and discharging WBM and cuttings directly to the seafloor.	The monitoring showed that the concentration of cuttings and WBM solids increased in sediments within 100 m down current of the drill site within one month of discharge of WBM and cuttings. The abundance of attached and less motile megafauna decreased within 50 m of the discharge site. The dominant species the sea urchin *Echinus acutus* was nearly eliminated from the immediate vicinity of the discharge site but was abundant at greater distances.	Hughes et al. 2010
Monitoring studies of impacts on benthic fauna of the drilling of six wells in about 25 m of water in the Gulf of Mexico off the Texas coast	Impacts on benthic fauna were observed within 75 m from the platform. Effects on benthic communities were probably caused by burial, changes in sediment texture and organic enrichment of sediment	Neff 2010
Monitoring study of impacts of the discharge of cuttings and WBM during the drilling of one exploratory well on 60 m depth	Decrease in abundance and loss of rare species of benthic fauna within 200 m from the platform	Currie & Isaacs 2005
Monitoring study of the effects on benthic fauna of the drilling of 39 wells using WBM off Point Arguello California	No effects were observed on the soft bottom benthic fauna	Hyland et al. 1994
Monitoring studies of fate and effects on benthos of exploratory drilling activities at two rigs on 80-140 m of water on Georges Bank off Massachusetts USA, where WBM was used for drilling. Approximately 20 million lbs. of WBM and 11 million lbs. of cuttings were discharged.	No changes were detected in benthic communities that could be attributed to drilling activities	Neff et al. 1989

In addition, studies have shown that:

- There is no evidence from field work of chemical toxicity of any WBM ingredients.
- There is no evidence of ecologically significant bioaccumulation of metals or petroleum hydrocarbons by marine animals residing or deployed in cages near WBM and cuttings discharges.

This strongly suggests that effects of WBM cuttings piles are highly localized to the immediate vicinity of the wellhead and are not being exported to the local food web (Neff 2010).

The marginal effects of drill cuttings and WBM on the benthos mainly result from sedimentation (Trannum et al. 2010). Possible mechanisms are:

- Burial of benthic fauna beneath accumulated cuttings and WBM components
- Changes in sediment grain size and texture, which render the sediments unsuitable for settling and growth of some species, while rendering the substrate more suitable for other species.

Under certain circumstances, effects may also be due to oxygen depletion in sediment resulting from biodegradation of organic material in the mud components. If the WBM contains biodegradable organic additives, it may stimulate growth of microbial communities in sediments, often leading to depletion of oxygen in the sediments. Anaerobic sulphate-reducing bacteria may further degrade the organic matter producing toxic hydrogen sulphide (Neff 2010). However, such effects are only likely on deeper waters with low current speeds at the seabed and not in a relatively shallow area (around 60 m depth) with relatively strong currents as that encountered at the Solsort and SA-WHPN field location.

Field and laboratory experiments have shown that benthic fauna affected by the discharge of cuttings and WBM components will rapidly recover to before drilling conditions. Recovery of the fauna may take 0.5-2 years, depending on the amounts discharge and the current speed in the area in question (Neff 2010).

Based on the above information, it is expected that the drilling of two wells with water-based mud at the Solsort field from SA-WHPN will have limited effects on benthic fauna within a radius of no more than 200 m, if any detectable impacts occur. If impacts are observed, it is expected that recovery of impacted fauna will take place within 0.5-2 years after the drilling ends and probably nearer to 0.5 years than 2 years.

It is assessed that the extent of impact within 200 m from the rig will be similar in case both wells are drilled without pause. This is how the drilling campaign for Solsort West Lobe is planned to be executed.

10.2.3 Impacts of the discharge of drilling chemicals

Drilling mud contains several chemicals that are discharged during the drilling operation. In addition to drilling, establishment of the wells include several operations such as cementing and completion during which several chemicals are used and discharged (confer chapter 5). When discharged, these chemicals may affect water quality and pelagic organisms.

The environmental assessment of the discharges of chemicals to sea in the different stages of the construction phase is based on the following:

- The amounts of materials and chemicals planned to be used and disposed at sea, as described in section 5.5
- The discharge patterns for the individual sub-operations
- The characteristics of the marine environment (in particular water depth and currents)
- The inherent environmental hazard properties of the chemicals.

The assessment of the latter is based on the data on environmental fate and ecotoxicological properties of each chemical and its components as documented by the suppliers of the chemicals in the so-called HOCNF (Harmonised Offshore Chemicals Notification Format) documents. These are structured according to OSPAR's guidelines (OSPAR, 2010) and provide data based on accepted standard test methods on relevant physio-chemical properties, biodegradability and toxicity to aquatic organisms within the groups of fish, crustaceans, algae and, where relevant, sediment-dwelling organisms.

10.2.3.1 PEC/PNEC approach

The expected concentration of each chemical in the sea following discharge, the so-called Predicted Environmental Concentration (PEC), is determined through application of a dispersion model using the information of usage and discharge and the environmental fate data as specific input parameters. In parallel to this, the available ecotoxicity data of each chemical are used to establish the Predicted No-Effect Concentration (PNEC) in accordance with OSPAR's guidelines. The PNEC is the concentration below which neither acute nor long term effects are expected to occur in the (marine) environment.

Subsequently, the estimated PEC value for each chemical is compared to the established PNEC value for the same chemical, thus resulting in a risk quotient, the so-called PEC/PNEC value. At the distance from the discharge point where the PEC/PNEC ratio is <1 and beyond, i.e., where the predicted environmental concentration is lower than the calculated toxic effect limit, no impacts on organisms in the marine environment are expected.

10.2.3.2 Categories and use of chemicals

The chemicals are categorised into groups with a simple colour code (refer to section 3.2.1) according to their potential environmental hazard.

The total discharges of green and yellow chemicals expected to occur during the different stages of the construction phase are shown in Table 5-11. No red or black chemicals will be discharged. The discharges are continuous during the drilling the top of the well unless anything else is mentioned in the table.

Green chemicals, which include the so-called PLONOR substances (substances considered by OSPAR to have very low impact on the marine environment), are not assessed further in this report, i.e., only yellow chemicals being discharged to the sea are included in the following environmental assessment of the discharge of chemicals.

Drilling

The planned drilling of the Solsort water injector well (WI-01) is approx. 7,200 meters, split between the top 1,400 meters drilled with Water Based Mud (WBM) and with the bottom 5,800 meters drilled with Oil Based Mud (OBM) or Formate drilling fluid. The Solsort producer well (P-01) is approx. 7,400 meters, split between the top 1,400 meters with WBM and the bottom 6,000 meters with OBM or Formate drilling fluid, see

Table 10-4 below. The reservoir section of the West Lobe wells is planned to be between 1600 - 2000 meters long and are planned to be drilled with 8-½”-9-½” hole size.

In both wells, it is an option to drill both the lower Tertiary and the reservoir section with a water-based mud type called Formate drilling fluid which is based on brine/water with added chemicals. Formate drilling fluids will be at the required mud weights primarily based on Potassium formate with minor amounts of Caesium formate included in the solutions. The Formate drilling fluid is an option in the shale section due to its excellent shale stabilization features. The preference for Formate drilling fluid in the reservoir section is due to its low formation damage characteristics based on a low solids content, preventing hole problems and stuck pipe, less sagging and less risk of pore plugging and its capacity to flow back through the sand screens. In addition, these Formate drilling fluids have little environmental impact and are less corrosive than conventional completion fluids.

Table 10-4 WI-01 and P-01 well

	Well parameters (meters)
Total well length	WI-01: 7,200 P-01: 7,400
Well length with WBM	WI-01: 1,400 P-01: 1,400
Well length with Formate drilling fluid or OBM	WI-01: 5,800 P-01: 6,000

Cementing

The drilled borehole is stabilised and tightened by means of a casing that is being adhered to the different geological layers by means of special cement. Several designated chemicals are added to the basic cement to provide it with the special features needed, including optimization of the hardening process (e.g., dispersion agents, defoamers, viscosity regulators, retarders etc.). The cementing is a short process with batch discharges of only approx. 10 minutes, which will be associated with limited discharges.

Many of the chemicals used in the cement are PLONOR but a number are classified yellow and are therefore included in the modelling of possible impacts resulting from the cementing activity and its discharges.

Completion

Completion of a well after drilling and cementing consists of a number of sub-processes such as clean-up, circulation of completion fluid and filling the space between outer casing and production pipe with completion brine. These processes require a number of chemicals to be used such as detergents, corrosion inhibitors, viscosifiers, oxygen scavengers and lubricants.

50% discharge of completion fluids to the sea is expected.

Rig (utility) chemicals

A limited number of utility chemicals are used at the rig, mainly for cleaning purposes or as lubricants during drilling and establishment of casing. The yellow rig wash chemicals will be diluted in 10 m^3 water and discharged batch-wise to sea through the drain system of the rig. It is assumed that rig wash will take place every second day and that the discharge will be about 50% of the amount applied and take approx. 1 hour per batch. The pipe dope and the jacking grease will be discharged. For these chemicals it is expected that only 10% of the total volume will be discharged. The casing dope is expected to follow the drilling mud/completion fluid in the following section. It is assumed that discharge of these chemicals takes place batch-wise over a period of 4 hours.

Dispersal modelling and impact assessment

Dispersal modelling has been carried out using a model developed by COWI, based on the CHARM-model[2] developed by the industry, chemical suppliers and members of OSPAR. The dilution part of the model is a slightly modified version of the CHARM model, and estimations of risk indicators of negative environmental effects (PNEC and PEC/PNEC ratios) are calculated according to OSPAR guidelines. They represent an assessment of the individual compounds potential effect on the environment.

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[2] CHARM = Chemical Hazard Assessment and Risk Management.

Table 10-5 summarizes the main results for the discharged chemicals (except PLONOR chemicals) during the development phase (per well).

OSPAR does not regard chemicals on the OSPAR PLONOR list to be problematic and therefore no dispersal and risk indicator calculations have been performed for these compounds. Similarly, such calculations have not been performed for compounds and products, which by common use are not discharged to the marine environment. Model calculations are done for all relevant chemicals regarding dispersion and effects in the water phase. Individual assessments of the risk of effects on epi- and infauna, has been done on chemicals with an affinity towards sediments and a slow degradability in the marine environment.

No discharges in the construction phase are continuous over longer periods. PNEC's are determined according to OSPAR to protect the environment also to long term exposures. According to the current guidelines from the EU on assessment of discharges having a duration of 24 hours or shorter, these should be based on the PNEC's for acute effects. In some instances (e.g., cementing chemicals), such an assessment will lead to a PEC/PNEC ratio <1 within shorter distance of the platform than indicated by the results below. This is valid for the cementing additives and the rig wash chemical. In the case of the cementing chemicals the distance from the platform where PEC/PNEC >1 is already short (500 metres or less), while for the rig wash chemical, the use of a PNEC based on acute effects will give significantly different results (much lower distance to reach PEC/PNEC = 1).

Modelling has been performed on also short-term, batch-wise discharges as these in some cases contribute significantly to the total amount of chemicals being discharged during one particular sub-process in the development phase. The modelling has only comprised the yellow chemicals used, not any green chemicals.

The results of the modelling are shown in Table 10-5.

Table 10-5 Overview of results of dispersal modelling comparing PEC with PNEC for chemicals used in the construction phase at Solsort West Lobe that are discharged.

Activity	Type of chemical	Max. distance (m) from discharge point at which PEC/PNEC ≥ 1	Duration of discharge (per well)
Drilling	Oxygen scavenger	<100	10 days
	Defoamer	100	10 days
	Bactericide	250	10 days
	H_2S scavenger	350	10 days
	Weight material	275	10 days
Cementing	Friction reducer	400	10 minutes (per event; 4 events per well)
	Fluid loss control additive	500	As above
	Mutual-solvent	350	As above
	Defoamer	300	As above
	Retarder	200	As above
	Emulsifier 1	200	As above

Activity	Type of chemical	Max. distance (m) from discharge point at which PEC/PNEC ≥ 1	Duration of discharge (per well)
	Emulsifier	450	As above
Completion	Surfactant	3,000 (350 m based on acute PNEC)	4 hours per well
	Bactericide	4,700 (850 m based on acute PNEC)	4 hours per well
	Oxygen scavenger	100	4 hours per well
Rig chemicals	Rig wash	1,250 (600 m based on acute PNEC)	1 hour per wash. Wash every second day per well corresponding to 60 hours per well.

As can be seen from the table, discharges leading to potential impact distances of more than 500 metres can occur in connection with the short-term activities completion and rig washing (durations of 1-4 hours/event), which, based on PNEC values for long term effects, imply a risk of effects up to 4,700 m away from the discharge point (completion, use of bactericide). However, the duration of these activities is very short (few hours per event), and, in the case of completion, will occur only once during the lifetime of the field.

Therefore, it is considered more appropriate (and in line with normal EU procedures for assessment of effects of chemicals on the aquatic environment) instead to use a PNEC for short-term effects for the impact modelling. Such calculations lead to significantly reduced risk distances as shown in parentheses in the table.

Ecological effects of the discharge of chemicals

The PEC/PNEC-dispersal modelling results show that any impacts of discharged yellow completion and utility chemicals are limited to the immediate vicinity of the platform. One of the modelled chemicals (the rig wash chemical), however, may be toxic at larger distances as shown in Table 10-5. However, the discharge with potential impact distances over 500 m take place over a very short period (within about one hour in total 60 hours per well).

It is therefore assessed that toxic effects on any eggs or larvae of fish that may be spawning in the area (such as, cod, plaice, dab, long rough dab, lemon sole, mackerel, sandeel and probably also for whiting are encountered) and other plankton organisms around Solsort and SA-WHPN will be local, marginal and without measurable impacts on the stocks.

10.2.4 Other discharges

No other discharges are expected in the construction phase, except the temporary discharge of treated sewage from the residential quarters at the drilling rig. The impact of this discharge on the marine environment is considered negligible.

10.2.5 Risk assessment - Discharges from drilling activities

Based on the above and using the criteria described in chapter 9, it is assessed that the environmental risks related to discharges from the drilling activities and from the drilling rig are **Negligible to Low.** (Table 10-6).

Table 10-6 Environmental severity and risk of impacts of discharges from the drilling rig during the drilling operation.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental Risk
Impacts of the discharge of cuttings and drilling mud (WBM)	Local	Short term	Medium	Minor impact	Definite	Low
Impacts of the discharge of drilling chemicals	Local	Short term	Small	Insignificant impact	Probable	Negligible
Discharge of treated sewage from the residential quarters at the drilling rig.	Local	Short-term	Small	Insignificant impact	Probable	Negligible

10.3 Underwater noise from site survey and drilling

10.3.1 Source of underwater noise

During the construction phase, the following operations may generate underwater noise:

- Equipment used for site survey
- Ramming of well conductor casing
- The drilling operation, including noise from the rotating drill string, machinery, pumping systems and miscellaneous banging of gear on the rig; and
- Machinery, propellers, and thrusters of ships during site survey and drilling.

10.3.2 Potential impacts on marine mammals

Underwater noise may affect marine organisms in different ways. As cetaceans (whales, porpoises and dolphins) depend on the underwater acoustic environment for orientation and communication they are believed to be the marine organisms that are most sensitive to underwater noise. Seals and fish may, however, also be affected by underwater noise.

10.3.2.1 Potential impacts of underwater noise on marine mammals

The possible effects of underwater noise on cetaceans and seals include:

- **Hearing damage**. Intense underwater noise may damage hearing of cetaceans and seals. There are two levels of damage. Temporary threshold shift (TTS), which is a reversible hearing loss, from which the animal subsequently will recover. Permanent threshold shift (PTS) which is an irreversible hearing loss. Generally, PTS will occur only after repeated TTS episodes or exposure to higher levels of sound than cause TTS (Southhall et al. 2007). Loss of hearing is particularly serious for cetaceans because they use sound for communication, navigation, and location of food. Seals may also loose hearing, but they may protect themselves from underwater noise by raising the head above the water.

- **Behavioral reactions**. Underwater noise may cause avoidance reactions and other behavioral effects of cetaceans and seals, such as changes in surfacing, breathing and diving behavior, cessation of feeding, aggression, aversion and panic (Däne et al 2013, Thompson et al. 2010, Tougaard et al 2009, Southall et al 2007, IWC 2007, Richardson et al 2005, Stone 2003, McCauley et al. 2000). Behavioral impacts to acoustic exposure are generally more variable, context-dependent, and less predictable than the effects of noise exposure on hearing.

- **Masking**. Because cetaceans depend on the underwater acoustic environment for orientation (echo location) and communication an emitted cetacean sound can be obscured or interfered with (masked) by manmade underwater noise (Tougaard 2014) and

- **Vocalization**. There are examples of whales changing their vocalization because of underwater noise. (Weilgart 2007, IWC 2007).

The most used predictor for TTS and PTS is the sound exposure level (SEL), cumulated over a period of at least two hours. Guiding threshold values of sound exposure levels that may cause TTS or PTS or behavioural/avoidance reactions for harbour porpoise, white-beaked dolphin, minke whale and seals are presented in Table 10-7.

Table 10-7 Sound exposure levels, that are harmful to cetaceans and seals.

Impact	$SEL_{(ss)}$ 1) (dB re 1μPa²s)²	$SEL_{(cum)}$ 2) (dB re 1μPa²s)³	Reference
Harbour porpoise (high frequency cetacean)			
Sound exposure level causing permanent threshold shift (PTS)		≥ 190	Tougaard 2016
Sound exposure level causing temporary threshold shift (TTS)		≥ 175	Tougaard 2016
Behavioural reactions	145	130	Tougaard 2016
White beaked dolphin (mid frequency cetacean)			
Sound exposure level causing permanent threshold shift (PTS)		≥ 198	NOAA 2018
Sound exposure level causing temporary threshold shift (TTS)		≥ 178	NOAA 2018
Minke whale (low frequency cetacean)			

Impact	SEL $_{(ss)}$ 1) (dB re 1µPa²s)²	SEL $_{(cum)}$ 2) (dB re 1µPa²s)³	Reference
Sound exposure level causing permanent threshold shift (PTS)		≥ 199	NOAA 2018
Sound exposure level causing temporary threshold shift (TTS)		≥ 179	NOAA 2018
Seals			
Sound exposure level causing permanent threshold shift (PTS)		≥ 200	Tougaard 2016
Sound exposure level causing temporary threshold shift (TTS)		≥ 175	Tougaard 2016
Behavioural reactions	145	130	Tougaard 2016

1) SEL $_{(ss)}$ = Sound Exposure Level (single stroke)
2) SEL $_{(cum)}$ = Sound Exposure Level (cumulative)

10.3.3 Potential impacts of underwater noise on fish

It has been demonstrated that fish, fish eggs and fish larvae may be injured by sudden exposure to loud underwater noise. It has for instance been observed that swim bladder damage occurred in adult anchovies at high sound levels (OSPAR Commission 2009). Fish has also been observed to flee from underwater noise (avoidance reaction) or to alter behaviour such as changing of swimming speed and/or swimming direction or to show “freeze” reaction (i.e., a reaction in which the fish suddenly stops swimming) (Mueller –Blenke et al. 2010).

10.3.4 Potential impact from site survey

Impact on habitat types, seabirds and marine mammals from site surveys are evaluated as a part of the report ”Environmental assessment of pipeline route survey” prepared by RAMBØLL on behalf of INEOS.

10.3.4.1 Impact on habitat types

The habitat type sandbank covers almost all the Natura 2000 site Doggerbank.

Due to the limited scope of work for the geophysical site survey it is assessed that based on the available project information and assessments, it is concluded that there will be no significant impact on the habitat type sandbank.

10.3.4.2 Impact on seabirds

The survey vessel sails at 3-4 knots and the scope of work are limited. The temporary disturbance from the survey vessel is therefore assessed to be short term (2-4 days) for and too far away from the designated bird species. The impact is assessed to be insignificant.

10.3.4.3 Impact on marine mammals

Potential impacts on marine mammals from the route survey are related to underwater noise and disturbance from vessel. Impacts on marine mammals range from detection of the sound to a behavioural response or physical injury.

The impact distances from the equipment used for site survey are shown in the Table 10-8 below.

Table 10-8 Potential impact distances from light seismic and sonar equipment according to the report "Environmental assessment of pipeline route survey" pre-pared by RAMBØLL on behalf of INEOS.

Sound sources	**Source level**	**Potential Impact Distances**				
	SEL in dB re 1 µPa^{2}s, 1 meter	Harbour Porpoise PTS (m)	Seals PTS (m)	Harbour Porpoise TTS (m)	Seals TTS (m)	Harbour Porpoise Behaviour (m)
Surface-towed Low-frequency SBP GeoSpark 200TIP	188	0	0	45	35	300
High Resolution Sub-bottom profiler (CHIRP, Innomar SES2000 Medium)	205 (243)	120	5	205	45	3,400
Single beam Echo-sounder (Kongsberg EA 400)	230	0	0	0	0	180

The sub-bottom profiler (Chirp, Innomar SES2000 Medium) is the most powerful sound source across the frequencies where marine mammals are the most sensitive. PTS can occur in a distance of 120 m and TTS at 205 m for harbours porpoise, while a behavioural response can occur out to a distance of 3,400 m´s. For seals the distances to both PTS, TTS and behaviour thresholds are much shorter, since they are less sensitive.

Due to the distance alone, the site survey is assessed to have no impact on marine mammals, since the nearest distance is above 45 km to the Natura 2000 site.

It is therefore assessed that there are no risk significant impacts on designated marine mammals from the site survey.

10.3.5 Impacts of underwater noise from ramming of well conductor casing

10.3.5.1 Impact on marine mammals

Conductor driving operations generates impulse underwater noise that can potentially have an impact on marine mammals. In comparison to jacket piling there are more hammer strikes at less power.

The maximum sound level 1 m from the wellhead during ramming of well conductor casings in the Danish sector of the North Sea has been measured at SEL 190 dB re 1µPa^{2}s. (Bach, Skov & Piper 2010). The sound will gradually dampen with increasing distance from the source. Figure 10-3 show a rough estimation of the levels of underwater sound during ramming of well conductor casing with increasing distance from the source. After 50 meters from the source the noise level is below the level where harbour porpoises express behavioural reactions.

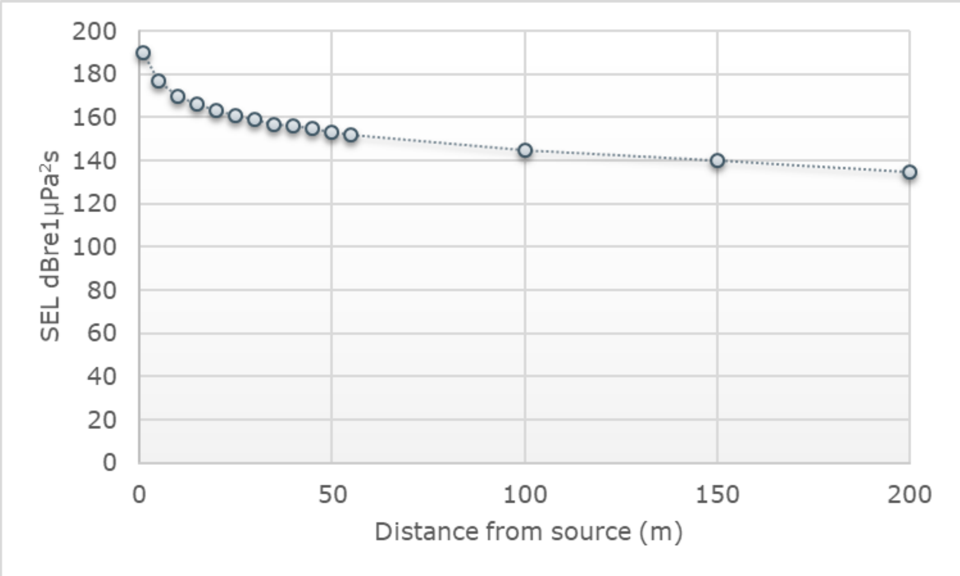

Figure 10-3 Estimated sound level during ramming of well conductor casing with in-creasing distance from the source. Estimated from a measured level at 1 m from the source at SEL 190 dB re 1µPa2s (Bach, Skov & Piper 2010) and the equation of transmission loss: TL=2

10.3.5.2 Impacts on fish

High levels of underwater noise may cause serious injuries of inner organs of fish or even kill fish. In addition, it has been demonstrated that underwater noise may damage fish eggs and fish larvae. Noise levels that may cause such effects are shown in Table 10-9.

The behaviour of fish may be affected by underwater noise and fish may flee from high levels of noise. On the other hand, some studies also indicate that fish which are exposed to high levels of noise may stay in an area, if it is an important feeding or spawning ground (Wardle et al. 2001, Pena et al. 2013).

Comparing these levels with the estimated sound levels from ramming presented in Figure 10-3 it is seen that impacts on inner organs of fish and impacts on fish eggs or larvae may occur in the immediate vicinity (within a few meters) of the ramming site, if at all. Lethal impacts on fish eggs and larvae in the immediate vicinity of the ramming site will not in any way affect the stocks of fish in the area as fish eggs and larvae has a high natural mortality and as the number of any affected eggs and larvae will be infinitesimally small compared to the standing stocks of eggs and larvae.

Table 10-9 Levels of underwater noise that have been reported to harm fish, fish eggs and fish larvae (Andersson et al. 2017).

Effect	SPL (peak) (dB re 1µPa)[1]	SEL (ss) (dB re 1µPa²s)[2]	SEL (cum) (dB re 1µPa²s)[3]
Risk of serious injuries of inner organs or risk of death	≥ 207	≥ 174	≥ 204
Damage of fish eggs and fish larvae	≥ 217	≥ 187	≥ 207

1) SPL (peak) = Sound Pressure Level= Maximum overpressure generated by ramming.
2) SEL (ss) = Sound Exposure Level (Single Strike) = Sound energy level emitted during a single ramming strike.
3) SEL (cum) = Sound Exposure Level (Cumulative) = Cumulative sound energy level emitted during several ramming strikes over a certain period.

10.3.6 Impacts of underwater drilling noise

10.3.6.1 Impacts of drilling noise on marine mammals

Field studies around the drilling rig *Noble Koskaya* and its support vessel *Northern Seeker* in the German sector of the Doggerbank have shown that drilling noise and noise from shipping during drilling apparently do not affect the behaviour of harbour porpoise. The studies measured porpoise activity using acoustic C-POD and T-POD data loggers that measured and recorded the porpoise "click" sounds at different distances from the drilling site. Porpoise activity appeared to be independent of rig activity except for rig-docking/rig departure manoeuvres (Todd et al. 2007, Todd et al. 2009). The drilling noise at the well was measured at 120 dB re 1µPa, i.e., below the threshold for triggering off avoidance and other behavioural impacts of 140 dB re 1µPa (Southall et al. 2007).

Bach et al (2010) also monitored "click" activity around two platforms in the North Sea using T-PODs. They also concluded that drilling activities in general do not affect porpoise and other small cetaceans and that behavioural effects are only expected during the ramming of conductors.

To current knowledge, data from field studies on impacts on seals of underwater noise during drilling are not available.

Based on a comparison of measured underwater noise levels from different drilling rigs (Table 10-10) and that seals do not react to sound pressures up to 160 dB re 1µPa (Tougaard 2014), it is assessed that drilling noise will not affect seals beyond a distance of 100 m from the rig if at all.

Table 10-10 Underwater noise level at different distances from drilling rigs.

Source	Sound levels at different distances from the source (dB re 1µPa)				References
	At the Source	100 m	125 m	400-500 m	
Underwater noise from drilling rig	120	-	-	-	Todd et al., 2007
Underwater noise from jack-up drilling rig	163	123			Richardson et al., 1995
Underwater noise from drilling rig	145-190				Thomsen, 2009
Underwater noise from drilling rig	-	-	117	115	McCauley, 1998

10.3.6.2 Impacts of drilling noise on fish

The literature provides an ambiguous picture of the reaction of fish to underwater noise, see Table 10-11. Some species flee from noise and others do not react to noise. There is even evidence that some species are attracted to noise (Scholik & Yan 2002, Nedwell et al. 2004). Field studies have shown that several species of fish may be disturbed by noise from passing vessels and they may flee from the vessel while other species are not affected (Freon et al. 1993). It has also been demonstrated that species, which normally would flee from vessel noise can adapt to frequent noise and become unaffected (Steward, 2003).

The fact that offshore drilling rigs and platforms in general attracts fish and that the abundance and diversity of fish may be higher than the surrounding waters indicate that drilling noise generally do not disturb fish (Løkkeborg et al., 2002, Soldal et al., 2002, Fabi et al., 2002, Stanley & Wilson 1997, Love et al., 2000).

Table 10-11 Levels of underwater noise that has affected the behaviour of fish in laboratory experiments.

Effect	SPL (dB re 1μPa)	SPL (peak) (dB re 1μPa)[2)]	SEL (ss) (dB re 1μPa²s)[3)]	Ref.
Changes of behaviour [1)] observed for cod		140 - 161		Mueller –Blenke et al. 2010
Changes of behaviour [1)] observed for sole		144 - 156		Mueller –Blenke et al. 2010
Changes of behaviour observed for sprat			≥ 135	Hawkins et al 2014
Avoidance reactions of herring	122 - 138			Blaxter, and Hoss 1981

1) Changing of swimming speed and/or swimming direction or “freeze” reaction, in which the fish suddenly stops swimming.
2) SPL (peak) = Sound Pressure Level= Sound Pressure Level= Maximum overpressure generated by ramming.
3) SEL (ss) = Sound Exposure Level (Single Strike) = Sound energy level emitted during a single ramming strike.

10.3.7 Risk assessment - Underwater noise

Based on the above and using the criteria described in chapter 9, it is assessed that the environmental risks related to underwater noise generated during drilling is **Negligible** (Table 10-12).

Table 10-12 Environmental severity and risk of impacts of underwater noise generated during the site survey and drilling operation.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental Risk
Impacts of underwater noise during site survey	Local	Short term	Small	Insignificant impact	Probable	Negligible
Impacts of underwater noise during ramming of well conductor casing	Local	Short term	Small	Insignificant impact	Probable	Negligible
Impacts of drilling noise from rig and	Local	Short term	Small	Insignificant impact	Probable	Negligible

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental Risk
support vessesls						

10.4 Artificial light

As the drilling rig operates 24 hours per day, it will be illuminated during the dark hours. The rig, and in particular the drilling floor, must be continuously lit to enable work to be carried out properly and to ensure the safety of the crew. The platform must also be properly equipped with navigation lights to alert ships and aircraft. Furthermore, flaring during clean-up of wells produces a horizontal flame, that causes substantial light emissions. In clear weather, this flame may be visual from up to 10 km from the platform. Naturally, this effect is stronger at night than during the day.

Artificial light may affect seabirds and migration land birds in different ways, both positively and negatively.

10.4.1 Positive effects of artificial light

At night, lights and flares may be beneficial for foraging gulls because they attract prey to the surface waters (zooplankton and/or small fishes). Lights from offshore platforms may thus create additional foraging opportunities for gulls that normally forage by daylight, thus supplementing their diets and, potentially, increasing their survival and reproductive success (Ronconi, Allard and Taylor 2015, Tasker et al., 1986).

10.4.2 Negative effects of artificial light

Artificial light at sea may attract certain species of birds especially during bad weather and overcast nights. There are examples that illumination from offshore platforms under such circumstances can attract and disorient the birds and have a trapping effect that leads birds to circle around the light source. In particular, this is the case for migratory songbirds, waders, ducks, and geese, not so much by the light source's intensity, but by specific spectra within the light source (Deda et al. 2006, Van De Laar 2007). The circling behaviour may reduce their energy reserves and especially for migrating songbirds making them unable to cross the North Sea.

Reports of attracted birds, which collide with the platform and are killed or incinerated in the flare are also known. For migrating land birds, early reports highlighted rare events where hundreds or thousands of birds were incinerated in flares, though dedicated “flare watches” at other platforms observed no direct mortality. Information on mortality rates associated with collision and incineration of seabirds remains uncertain. One study has estimated annual rates of mortality in flares to be in the range of “a few hundred birds per platform per year” (Ronconi, Allard and Taylor 2015). Another study concluded that although incineration of birds in flares occur in the North Sea, such incidences are probably infrequent and are ultimately the result of weather phenomena driving migratory birds off course to begin with (Bourne 1979).

10.4.3 Risk assessment - Artificial light during construction

Based on the above and using the criteria described in chapter 9, it is assessed that the environmental risks related to artificial light during construction will have a **positive** effect in terms of improving foraging opportunities for seabirds. Impacts related to collision of birds is **negligible** (Table 10-13).

Table 10-13 Environmental severity and risk of impacts of artificial light during construction.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental Risk
Improvement of night foraging opportunities for seabirds	-	-	-	-	-	Positive effect
Risk of bird collision due to light attraction	Local	Short term	Medium	Minor impact	Low	Negligible

10.5 Air emissions

The emissions related to the planned activities during the construction phase are described in the following. The main activities causing emissions during construction are (including emissions during transport):

- Site survey
- Drilling activities

The estimated duration of the activities (site survey and drilling) and the estimated fuel consumption are provided by INEOS. Emission factors and conversion factors used in the following are supplied by INEOS and were used in the OSPAR report 2020 for South Arne.

10.5.1 Emissions related to site survey activities

The duration of the site survey for relief well are estimated to be approximately 21 days. The conduction of the survey itself will take between 2 and 4 days, but due to potential standby in case of weather conditions and transport onshore/offshore the activities regarding the survey are set to be operational for 21 days. Emissions to air from survey activities are related to:

- Supply vessel fitted with needed equipment

The needed crew and equipment are transported to and from the area by the same vessel. Thus, the whole duration of the operation including transport is accounted for regarding the associated emissions.

There will only be one supply vessel needed for the site survey for relief well and for other transport needs. In the below Table 10-14 is the estimated emissions from the vessel.

Table 10-14 Estimated emissions related to the site survey activities.

Site survey activities	Numbers	Days	Fuel consumption [m^3/day]	CO_2 [ton]	NO_X [ton]	SO_X [ton]	CH_4 [ton]	nmVOC [ton]	CO_2-eq [ton]
Supply vessel	1	21	4.8	255	3	0.34	0.009	0.71	256

10.5.2 Emissions related to drilling activities

The construction of the Solsort West Lobe Wells will include drilling of two wells and the estimated time for drilling is 144 days per well including completion and clean-up of the well (INEOS well and drilling data, 2019). Emissions to air from drilling activities are related to:

- Energy production at the jack-up rig
- Transportation of crew and material by helicopter, standby boat and supply boat
- Flaring during well clean-up or well testing
- Volatile Organic Compound (VOC) emissions from the oil-based mud
- Well clean-up by burning of gasses.

Energy consumption at the rig will mainly be used for drilling the wells including power supply to pumps and compressors. Energy consumption for other purposes such as the accommodation module etc. is expected to be marginal. The energy is provided by generators powered by diesel engines.

A standby vessel is required, when drilling activities are conducted, and thus the standby boat is operating 24 hours while the rig is present.

All materials, supplies, waste etc. will be transported offshore/onshore by supply vessels. It is estimated that three vessels will be in operation approx. 11 hours per day in 140 days per well equivalent to 64 days, which will be 128 days in total for two wells (INEOS 2021).

Transportation of crew between shore and offshore is performed by helicopter. They are assumed to be in operation 3 hours per day equivalent to 18 days per well, 35 days in total during drilling of two wells (INEOS, 2021). The standard emission factors for helicopters are from E&P Forum (E&P Forum, 1994).

No well testing will be conducted during the drilling period. However, clean-up of the wells will take four days, where the produced oil will be exported to South Arne for production and the gas will be flared. It is estimated that 230 Sm^3/day will be flared. The emission is calculated based on standard emission factors for flaring from Oljeindustriens Landsforening 2012 (Norsk Olje og gass, 2019).

During recirculation and treatment of the cuttings, evaporation of water and small fractions of Volatile Organic Compounds (VOCs) from the oil-based mud can be expected. However, cooling systems will be applied during the handling of the cuttings and the VOC emissions will be limited and thus are not quantified.

An estimation of the emissions related to the drilling activities is carried out in Table 10-15.

Table 10-15 Estimated emissions related to the drilling activities for two wells.

Drilling activities	Numbers	Days	Fuel consumption [m^3/day]	CO_2 [ton]	NO_X [ton]	SO_X [ton]	CH_4 [ton]	nmVOC [ton]	CO_2-eq [ton]
Rig	1	280	11.4	8,085	99	11	0.3	3	8,094
Standby boat	1	280	4.8	3,404	42	4.6	0.13	1.4	3,408
Tugs	2	15	20	3,040	37	4.1	0.11	1.2	3,043
Supply vessel	3	128	4.8	4,681	57	6.3	0.17	1.9	4,686
Helicopters (kerozene)		35	1.2	109	2	0.3	0.009	0.08	109
Well clean-up[1)]		4	-	2,153	11	0.006	0.22	0.06	2,159
Total [ton]				**21,471**	**247**	**26**	**1**	**8**	**21,497**

[1)] The SO_X emission factor for well clean-up is field specific and thus not provided by Norsk Olje og gass (2019) but is based on information from the previous EIA for Solsort WHP.

10.5.3 Environmental impacts from air emissions

In Table 10-16 a summary of the emissions from the different activities during the construction phase can be seen.

Table 10-16 Summary of the estimated emissions to air during the construction phase of the Solsort West Lobe project. CO2-eq consist of CO2 and CH4. The global warming potential for CH4 is 28 (IPCC, 2014)

Construction phase	CO_2-eq [ton]	NO_X [ton]	SO_X [ton]	nmVOC [ton]
Site survey	256	3	0.34	0.1
Drilling activities	19,339	237	26	8
Well clean-up	2,159	11	0.006	0.06
Total [ton]	**21,753**	**251**	**26.41**	**8.16**

From the table drilling activities comprises 89% of the total CO_2-eq emission related to the construction phase and well clean-up comprises 10% of the total CO_2-eq emission and the site survey only 1%.

Compared to the total Danish CO_2-eq emission in 2017, the construction phase for the Solsort West Lobe project constitute of less than 0.1%.

With regards to the emissions with more local and regional impact such as NO_X, SO_X, and VOC the emissions are considered relatively low due to the location far from shore.

Compared with the total national yearly emissions, the emissions of NO_X, SO_X, VOC, and PM2.5 are responsible for 0.32%, 0.25%, 0.01%, and 0.24%, respectively, as compared to the emission from 2019, (Department of Environmental Science, 2019).

10.5.4 Risk assessment - Air emissions during construction

Based on the above and using the criteria described in chapter 9, it is assessed that the environmental risks related to air emissions is **negligible or low** depending on the type of component emitted**.** (Table 10-17).

Table 10-17 Environmental severity and risk of impacts of air emissions during construction.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental Risk
Impacts of air emissions (VOC)	Local	Short term	Small	Insignificant impact	Low	Negligible risk
Impacts of air emissions (NO_X, SO_X)	Regional	Short term	Small	Minor impact	Low	Negligible risk
Impacts of air emissions (CO_2-eq)	Regional	Short term	Small	Minor impact	Low	Negligible risk

10.6 Waste

All waste generated during construction will be transported to Esbjerg by vessel. The waste will be further sorted out to improve recycling, send for further treatment at approved waste treatment plants, send for combustion or for final disposal.

NORM may occur in relation to construction of the wells. Procedures are prepared and implemented for safe handling of equipment contaminated with NORM and reviewed by Authorities.

The waste treatment onshore will not have an impact on the marine environment. Risk related to waste is shown in Table 10-18.

Table 10-18 Risk related to waste from both South Arne and Solsort during construction.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of waste	Regional	Long term	Small	Minor impact	Very low	Negligible

10.7 Impact on cultural heritage

Drilling and discharge of cuttings during drilling (described in Chapter 5)) may potentially burry and damage cultural heritage. The only cultural heritage that potentially could be affected in the project area are ship and plane wrecks. There are no registered wrecks in the project area and the area is generally not a hot spot for shipwrecks. Potential findings of wrecks or other historical artifacts identified during site investigations will be reported to Slots- og Kulturstyrelsen.

Based on the arguments above the environmental risk related to cultural heritage is assessed to be negligible, cf. Table 10-19.

Table 10-19 Risk related to damage of cultural heritage during construction.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Damage of wrecks	Local	Permanent	Small	Minor	Very low	Negligible

10.8 Impact on hydrography

The substructure of the rig will be temporary located in the water column. The structure consists of 3 legs with a total cross section area of 2013 m^2. The legs are placed in an open structure and are considered too small to have any impact on the hydrography of the North Sea. In addition to that the rig will placed in the location temporary.

Based on the arguments above the environmental risk related to hydrography is assessed to be negligible, cf. Table 10-20.

Table 10-20 Risk related to damage of hydrography.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts on seabed	Local	Short term	Small	Insignificant impact	Low	Negligible risk
Impacts on water column	Local	Short term	Small	Insignificant impact	Low	Negligible risk
Impacts on benthic fauna	Local	Short term	Small	Insignificant impact	Low	Negligible risk

11. Environmental impacts during production

11.1 Potential impacts

Figure 11-1 and Table 11-1 provide overviews of the potential effects during the production phase, which are assessed in the present impact assessment. Effects from discharges and emissions related to host platform concerns only the increase caused by the new production well.

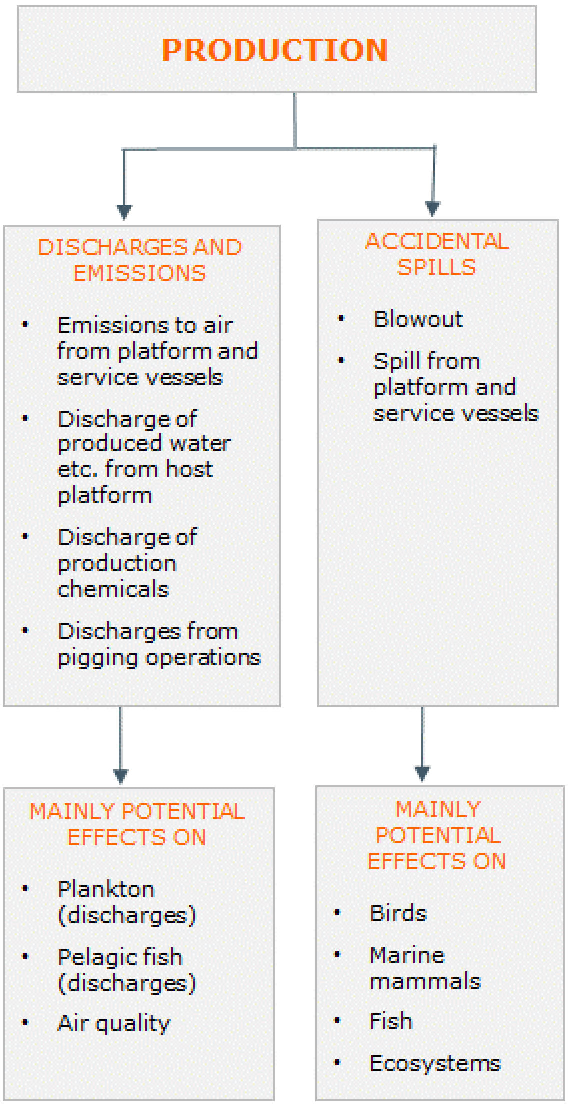

Figure 11-1 Overview of operations during production and the receptors that may primarily be affected by the different operations which has been assessed in the EIA.

Table 11-1 Overview of impacts during the production phase assessed in the EIA

	Potential Impacts
Discharge and emissions	
Increased discharge of produced water from existing host platform	› The discharge may affect marine organisms, particularly pelagic organisms such as plankton including fish eggs and larvae
Emissions to air	› Release of particulates and gaseous compounds (SOx, NOx, VOC, CO, CO_2, CH_4) from generators, compressors and other machinery on the production platform and due to flaring operations
Accidental spills	
Blowout	› Extremely rare events. Experience from previous blowouts and oil spills at sea have shown that it is mainly birds, marine mammals, fish, coastal ecosystems, fisheries, aquaculture and tourism than may be affected › Economic loss to fisheries, aquaculture and tourism due to oiling
Accidental spills from platforms and ships	› Mainly birds, plankton, fish eggs and larvae may be affected

This chapter deals with environmental impacts of planned activities during the operation phase. Environmental impacts of accidental spills during the operation phase are dealt with in chapter 13.3 and socioeconomic impacts are described and assessed in chapter 13.5.

11.2 Planned discharges and emissions from host platform

11.2.1 Production

The wells will be drilled utilising the most appropriate slots on SA-WHPN. The production and injection flowlines will be installed within the existing allocated future flowline space envelope and utilise existing future slot control provisions on SA-WHPN and in the well head control panel. Production fluids will be metered by a new dedicated multiphase flow meter (MPFM). Post metering, the Solsort produced fluids will be routed to the existing production header and comingled with native South Arne production at SA-WHPN and then transported onto South Arne main platform via the existing multiphase subsea production pipeline via SA-WHPE. The West Lobe produced water will be reinjected as part of the South Arne produced water reinjection into the South Arne field and the Solsort West Lobe. Production before and after tie-in of the Solsort wells are shown in section 6.1.

A new produced water filter package for water injection pump D, filtering to 180 microns, will be installed on South Arne intermediate deck adjacent to the existing filter package for water injection pump B.

Injection water and gas lift gas will also be supplied from the South Arne facilities. The maximum oil production rate is expected to be 14000 BOPD.

New wax inhibition injection pumps will be provided on SA-WHPE to inject continuously into the SA-WHPE Production Header to mitigate against potential wax formation in the crude oil coolers, storage and export systems.

According to the SA EIA (2007) it was expected to discharge up to 50-60 tonnes oil per year with the produced water based on the assumption of oil in discharged produced water was 20-25 mg/l and produced water reinjection of 50%.

Discharge of oil with the produced water after tie-in of the Solsort wells will be below 9 tonnes based on the assumption that oil in discharged produced water will be around 10 mg/l and produced water reinjection in the area of 80-90% and by that below the described discharges in the SA EIA (2007).

11.2.2 Discharge of chemicals

The impact from discharge of chemicals during production is not impacted by the tie-in of the Solsort West Lobe wells.

However, occasionally (with intervals from at least 6 months up to several years), there will be a need for well service maintenance of which some types of jobs (e.g., acid jobs (8 jobs over the lifetime of the field) and wireline jobs (3 jobs over the lifetime of the field) will result in short-terms discharges of yellow chemicals. The discharges from the well service jobs will typically take place within just 2-4 hours/job (Table 11-2).

Table 11-2 Overview of results of dispersal modelling comparing PEC with PNEC for well service chemicals planned to be used at Solsort West Lobe wells.

Well service activity	Type of chemical	Max. distance (m) from discharge point at which PEC/PNEC ≥ 1*	Duration of dis-charge (per job)
Acid jobs	Frac additive	3400 (600)	2 hours
	Corrosion inhibitor	4700 (2800)	2 hours
	Iron stabilizer	700 (<100)	2 hours
Wireline jobs	Brine lubricant	400 (<100)	2 hours

* Figures in parentheses are calculated based on PNEC values for short-term effects

As appears from the table, the discharges from the well service jobs imply a risk of acute effects on marine organisms at distances up to 4700 metres from the platform, based on use of long-term PNEC values. However, as the discharges will take place within a very short period and only with intervals of more than one year, it is considered more appropriate to base the risk considerations on PNEC values for short-term effects, which results in a distance up to 2800 metres from the platform. The results of this assessment are shown in parentheses and give much shorter maximum effect distances than the modelling based on long-term PNECs. The dilution calculations are based on the conservative assumption that 20% of the well service chemicals used will be discharged to the sea.

11.2.2.1 Cumulative effects – Whole effluent test

Chemical analysis and bioassays (test of acute ecotoxicity of produced water on bacteria, algae and crustacea) have been conducted for produced water samples from South Arne in 2010. The results of the study were concentrations of a large number of contaminants and acute toxicity data as shown in Table 11-3.

Table 11-3 Some of the results from the whole effluent test – DTI July 2010 – Whole Effluent Assessment (WEA) for discharge from the offshore industry within Danish waters – Conducted for Hess.

DHI-no.	Sample name	Test organism	NOEC mL/L	EC/LC 10 mL/L	EC/LC 50 mL/L
864	Hess Denmark South Arne Degasser	*Vibrio fischeri (30 min)*	-	-	33.5 (29.2-38.4)
		Skeletonema costatum	3.0	10.2 (8.5-11.7)	17.2 (15.1-19.9)
		Acartia tonsa	-	18 (<1-46)	>100 (estimated to 139 (91.5-352))

Parameter	Result	Method	Precision	D.L.*
pH	6.9	DS 287	± 0.05	-
Bicarbonate, mg HCO3/l	390	Titration	2 % relative	-
Chloride, g Cl/l	28	Ion chromatography	5 % relative	-
Sulphate, mg SO4/l	11	Ion chromatography	5 % relative	-
Bromide, mg Br/l	260	Ion chromatography	5 % relative	-
Sodium, g Na/l	16	AAS	5 % relative	-
Potassium, mg K/l	230	AAS	5 % relative	-
Magnesium, mg Mg/l	320	AAS	5 % relative	-
Calcium, mg Ca/l	1200	AAS	5 % relative	-
Arsenic, µg As/l	33	ICP-MS	5 % relative	2.4
Cadmium, µg Cd/l	< 2	ICP-MS		2.0
Chromium, µg Cr/l	31	ICP-MS	5 % relative	0.2
Copper, µg Cu/l	43	ICP-MS	6 % relative	4
Mercury, µg Hg/l	< 3	ICP-MS		3
Nickel, µg Ni/l	< 1	ICP-MS		1
Lead, µg Pb/l	< 4	ICP-MS		4
Zinc, µg Zn/l	70	ICP-MS	8 % relative	1
Iron, mg/l	2.4	AAS	5 % relative	-
Barium mg/l	230	ICP-MS		0.1

Parameter (µg/l)	Result	Method	Precision	D.L.*
Phenanthren/Anthracen	29	GC/MS	± 15%	0.2
Acenaphthylene / Acenaphthene	17	GC/MS	± 15%	0.2
Fluorene	5.7	GC/MS	± 15%	0.2
Fluoranthene	0.90	GC/MS	± 15%	0.2
Pyrene	0.39	GC/MS	± 15%	0.2
Benzo(a)anthracene/Chrysene/Triphenylene	0.80	GC/MS	± 15%	0.2
Benzo(b+k)fluoranthens	<0.2	GC/MS	± 15%	0.2
Benzo(a+e)pyrene/Perylene	< 0.2	GC/MS	± 15%	0.2
Indeno(123cd)pyrene	< 0.2	GC/MS	± 15%	0.2
Dibenzo(ah)anthracene	<0.2	GC/MS	± 15%	0.2
Benzo(ghi)perylene	<0.2	GC/MS	± 15%	0.2
Sum of PAHs	**54**			

The results show among others that the acute toxicity (EC/LC50) is above 10 mg/l and that the concentration of mercury is below the detection limit of 3 µg/l and benzo(a+e) pyrene/Perylene is below the detection limit of 0,2 µg/l.

11.2.3 Air emissions

Tie-in of the Solsort West Lobe wells are covered by the results in additional production on the host platform, South Arne, since the multiphase is transported to South Arne, where the processing of the oil and gas takes place. The emissions to air during the operation phase will subsequently be at the host platform and be related to combustion of fuel gas and diesel, tanker loading of export oil and flaring.

It is assumed that the emissions to air are proportional to the production volume for diesel and fuel gas consumption and tanker loading. However, the flaring is independent of the production and thus are likely to be unchanged after Solsort West Lobe production has been tied in.

In comparison with the overall national emissions of CO_2 from the oil and gas industry, the production of oil originated from Solsort West Lobe wells will equal 5.7% of the CO_2 emissions of 2013 (Danmarks olie- og gasproduction, 2013).

The emissions to air related to production and maintenance of the two Solsort West Lobe wells are covered within the emissions to air from planned production and maintenance for the South Arne field as the well are utilising the most appropriate slots on the SA-WHPN platform already covered by the South Arne EIA.

Emissions may be higher during start-up and commissioning of the production from the Solsort West Lobe wells, due to non-scheduled closures and increased flaring from unstable production.

11.2.4 Risk assessment - Planned discharges and emissions from host platform

Based on the above and using the criteria described in chapter 9, it is assessed that the environmental risk of presence of planned discharges and emissions from host platform (South Arne) will be **negligible** (Table 11-4).

Table 11-4 Environmental severity and risk of discharge and emissions related production and well service related to the Solsort West Lobe wells.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental Risk
Impacts of discharge of produced water	Local	Long term	Small	Insignificant impact	Low	Negligible
Impacts of air emissions (VOC)	Local	Long term	Small	Insignificant impact	Low	Negligible
Impacts of air emissions (NO_X, SO_X)	Regional	Long term	Medium	Insignificant impact	Low	Negligible
Impacts of air emissions (CO_2-eq)	Regional	Long term	Medium	Insignificant impact	Low	Negligible

12. Environmental effects during decommissioning

12.1 Potential impacts

The expected lifetime of the production wells is approximately 25 years. The decommissioning of the production wells will be conducted in accordance with Danish legislation and international agreements in force at the end of the well's lifetime.

Figure 12-1 provides an overview of the potential effects during the decommissioning of wells, which are assessed in the present impact assessment. Effects from emissions will only increase caused by decommissioning of the new production ad injection wells.

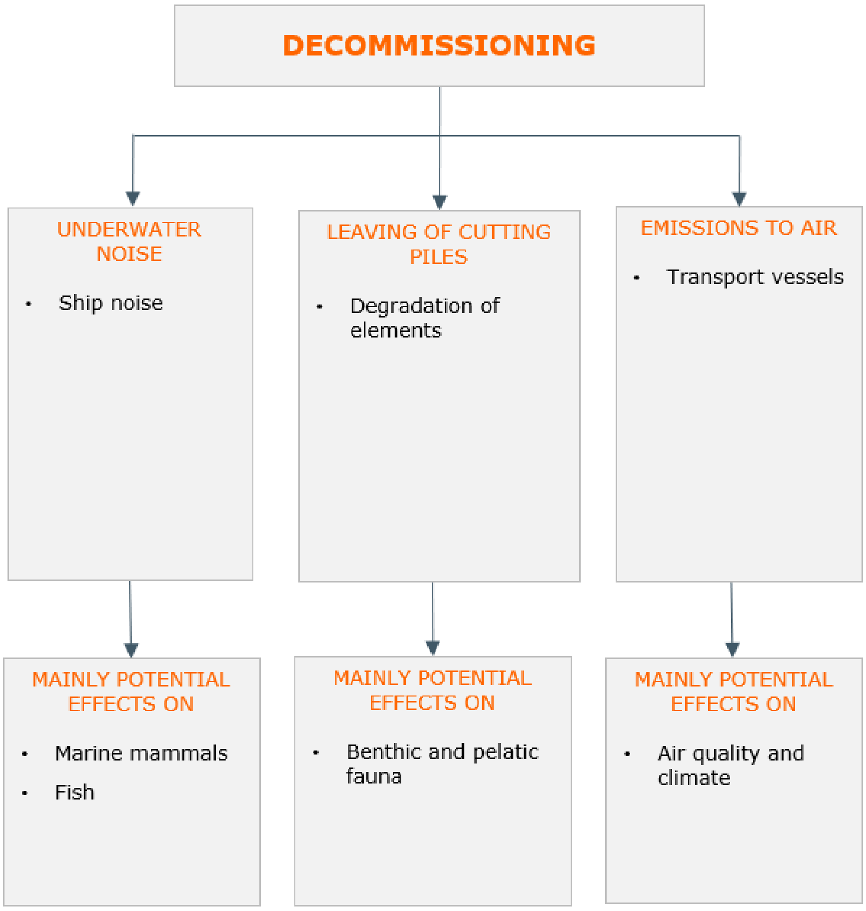

Figure 12-1 Overview of operations during decommissioning and the receptors that may primarily be affected by the different operations which has been assessed in the EIA.

12.1.1 Decommissioning procedure

The following is a general description of how production wells may be decommissioned:

- Production strings and casings are pulled out and transported onshore for reuse or recycling
- Production wells are plugged and sealed with concrete fillings in predetermined depths of the wells. The concrete fillings prevent the petroleum hydrocarbons from escaping from the wells into the marine environment.

12.2 Possible impacts

12.2.1.1 Cutting piles

When a field on deeper waters is abandoned, cuttings piles from the drilling operations are often encountered beneath platforms. Such piles are sometimes removed during decommission. However, cuttings piles are, not likely to develop in the relatively shallow waters (60 m) at Solsort and SA-WHPN with relatively strong currents on the seabed that will disperse the cuttings.

12.2.1.2 Air emissions

The decommissioning of the Solsort production and injection wells will include plugging of wells (INEOS, 2019). The emission to air from the Solsort West Lobe production wells is insignificant compared to the full decommissioning of the South Arne field and related installations.

12.2.2 Risk assessment - Decommissioning of production wells

Based on the above and using the criteria described in chapter 9, it is assessed that the environmental risk of the decommissioning of the production wells will be **negligible** (Table 12-1).

Table 12-1 Environmental severity and risk of decommissioning of production and injection wells.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental Risk
Leaving of cutting piles	Local	Short-term	Small	Insignificant impact	Highly probable	Negligible risk

13. Environmental impact of accidental oil and chemical spills

The impacts of the following types of accidental spills have been assessed in this chapter:

- Spill of oil and emission of gas during an accidental blowout. This may occur during the construction, operation and decommissioning phase.
- Accidental spill of chemicals from the drilling rig during the construction of wells.
- Accidental spill of chemicals from the host platform during the production phase.

Blowouts causing discharge and dispersal of oil are extremely rare events. However, in case of blowout the environmental impacts may be severe. Experience from previous blowouts and oil spills at sea have shown that it is mainly birds, marine mammals, fish and coastal ecosystems that may be affected by large oil spills.

13.1 Environmental impact of an oil release during a blowout incident

The worst-case scenario in terms of accidental oil spill is an uncontrolled blowout during drilling of a well or during normal production.

A blowout is the uncontrolled release of crude oil and/or natural gas from a well after pressure control systems have failed. A drilling blowout can result from a range of causes. These include loss of well control because of design, equipment and/or human failure. Loss of well control is among the major emergency incidences that would have low probability of occurring but high risk of causing large uncontrolled gas or oil release into the marine environment that could cause wide reaching effects.

13.1.1 Risk of blowout

Blowout is an extremely rare event and extensive preventative/control measures are implemented to reduce the likelihood of such events. It has been estimated that the risk (frequency) of a blowout occurring at Solsort is 9.7×10^{-6} per year - The risk (frequency) of a blow out during drilling is higher that during production. (IOGP – Risk Assessment Data Directory – Report No. 434-2, March 2010).

A blowout will last until the well is under control again. This may take anywhere from a few hours if control can be regained using the safety systems present, up to several months if an additional well needs to be drilled to regain control over the original well. History shows that most wells can be brought back under control within one to a few days.

13.1.2 Fate and effect of oil

During a blowout the oil is spread with the currents, simultaneous undergoing a wide array of processes including evaporation, dispersion, emulsification, dissolution, oxidation, sedimentation and biodegradation. Oil components and their breakdown product may affect marine and coastal habitats and species. In general, the most severe impacts of an oil spill will occur if the oil slick passes concentrations of seabirds or if the oil ends up in near coastal waters and on shorelines. For a more detailed description of the fate and effects of an oil spill reference is made to Appendix A.

13.1.3 Methodology

Impacts of oil released during a blowout has been assessed from the results of oil spill modelling, known dose-response relations between concentrations of oil components and effects on marine organisms and effects observed during previous oil-spills.

13.1.3.1 Oil spill modelling

Oil spill response Limited UK carried out an oil spill modelling of blowouts at Solsort using the OSCAR statistical oil drift model developed by SINTEF, Norway. OSCAR is a 3D modelling tool used to predict the movement and fate of oil on the sea surface and throughout the water column. Details of the modelling are reported in DONG energy (2015).

Four blowout scenarios were modelled:

- Scenario 1. Seabed release with a release rate of 4,432 m^3/day during summer (April-September)
- Scenario 2. Seabed release with a release rate of 4,432 m^3/day during winter (October-March)
- Scenario 3. Surface release with a release rate of 4,368 m^3/day during summer (April-September)
- Scenario 4. Surface release with a release rate of 4,368 m^3/day during winter (October-March).

The setup of the four scenarios is summarized in Table 13-1.

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Table 13-1 Oil spill modelling. Summary of setup for spill scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total oil Volume released	332,400 m^3	332,400 m^3	327,600 m^3	327,600 m^3
Release rate	4,432 m^3/day	4,432 m^3/day	4,368 m^3/day	4,368 m^3/day
Duration of release[1)]	75 days	75 days	75 days	75 days
Depth of release	62.4 m	62.4 m	0 m	0 m
Time of year	Summer (April-September)	Winter (March-October)	Summer (April-September)	Winter (March-October)
Total Run Duration	82 days	82 days	82 days	82 days

1) The duration of release of 75 days was chosen, as it is the time that will take to drill a relief well.

The modelling represents worst-case scenarios without unmitigated spills and a release duration of 75 days. The release duration is a conservative estimate of the time taken to drill a new relief well. Efficient contingency measures will reduce the spreading of spills significantly and thereby the extent and magnitude of environmental damage.

The South Arne oil spill contingency plan will be updated and will include an enclosure covering the drilling activities described in the present EIA and work-over activities accordingly to ensure that the set up for oil spills is “fit for purpose”.

13.1.3.2 Environmental assessment

The assessment of the environmental impacts of accidental blowout is based on a matrix using all four scenarios representing a worst-case scenario in which no mitigating oil spill response measures are taken. The simulations have been made using both stochastic and deterministic modelling.

Stochastic modelling possesses some inherent randomness versus a deterministic model where the output is fully determined by the parameter values and the initial conditions.

The use of a stochastic model means that the blowout can be analysed statistically. However, the prediction represents the gross area that may potentially be affected by a spill as it combines the impact area of several single spill events and therefore does not represent how a blowout will look.

In contrast, the deterministic model simulates a single spill at a chosen date under the weather conditions at that point in time. Thus, it predicts the actual trajectory of a single spill event, but it does not consider the statistical uncertainty of the fact that the spill trajectory will be different under different weather conditions.

Efficient oil spill response measures will reduce the spreading of spills significantly and thereby the extent and magnitude of environmental damage is most likely smaller than the model results indicate.

Table 13-2 provides a list of the threshold used in the impact assessment. Details of the oil the fate and effect of oil spill is described in Appendix A.

Table 13-2 Sea surface, water column and shoreline thresholds for impact scoring

Species/habitat exposed to oil	Threshold	Justification
Seabirds, emulsion on water surface	1 µm	The 1 µm threshold is considered below levels which would cause harm to seabirds from exposure of oil. Exposure above threshold will lead to effects such as transferring oil to eggs reducing hatching success (French-McCay 2009).
	10 µm	The 10 µm threshold for oil on water surface has been observed to lead to 100% mortality of impacted seabirds and other wildlife associated with the water surface (French-McCay 2009).
Seabirds, shoreline	"Light oiling" or above on shoreline	Light oiling of shoreline may result in mortal impact on seabirds.
Marine mammals (fur-bearing), oil emulsion water surface	10 µm	The 10 µm threshold for oil on water surface has been observed to mortally affect fur-bearing marine mammals such as seals (French-McCay 2009).
Marine mammals (fur-bearing), oil emulsion on shoreline	"Light oiling" or above on shoreline	Light oiling impacting shoreline may result in mortal impact on fur-bearing marine mammals such as seals, if they get impacted when hauling onto or resting at beaches .
Marine mammals (cetaceans), oil emulsion on water surface	100 µm	Cetaceans are less sensitive to oil compared to seals, as it does not stick to their skin. Cetaceans can inhale oil and oil vapour when surfacing to breathe leading to internal injuries (French-McCay 2009).
Fish, THC in water column	25 ppb	Following guidelines from the Norwegian Oil Industry Association effects of acute oil pollution on fish eggs and larvae will be seen in THC concentrations >25 ppb
	70.5 ppb	According to OSPAR 2014/5 concentrations >70.5 ppb is considered as having potential for chronic impacts to juvenile fish and larvae that might be entrained within the oil plumes
	500 ppb	The 500 ppb threshold is considered conservative high exposure level in terms of potential for toxic effects leading to mortality of 50% of all marine life if impacted by an acute oil spill

Species/habitat exposed to oil	Threshold	Justification
Seabed habitat	25 ppb	Seabed habitats considered are protected reefs and areas with protected cold-water corals, areas with a high ecological production. This threshold is used to identify when the most sensitive marine life (fish eggs and larvae) begins to be affected by acute oil pollution on. Based on guidelines from the Norwegian Oil Industry Association.
Shoreline habitats	"Light oiling" or above on shoreline	The Environmental Sensitivity Index (ESI) is used for assessing the sensitivity of various types of shoreline to acute oil pollution.

13.1.4 Modelled dispersion of oil during a blowout with no deployment

13.1.4.1 Spreading of oil

Figure 13-1 shows the modelled probability that the sea surface in 10x10 km grid cells could be hit by >1 tonnes of oil released at Solsort during summer (April-September) and during winter (October-March), respectively.

A number of individual trajectories were analysed to create the stochastic results for each scenario. Each trajectory began on a different start date, so that each oil spill was simulated using a range of wind and current conditions. Thus, Figure 13-1 shows the combined probabilities of 142 trajectories (summer) and of 119 trajectories (winter), respectively. This means that the simulation does not show the result of a single oil spill, but rather the combined probabilities for a cell in the model to be impacted by oil.

It is seen that released oil during a blowout incident will mainly be transported towards northeast with the prevailing currents, but may also be transported to German, Dutch and UK waters.

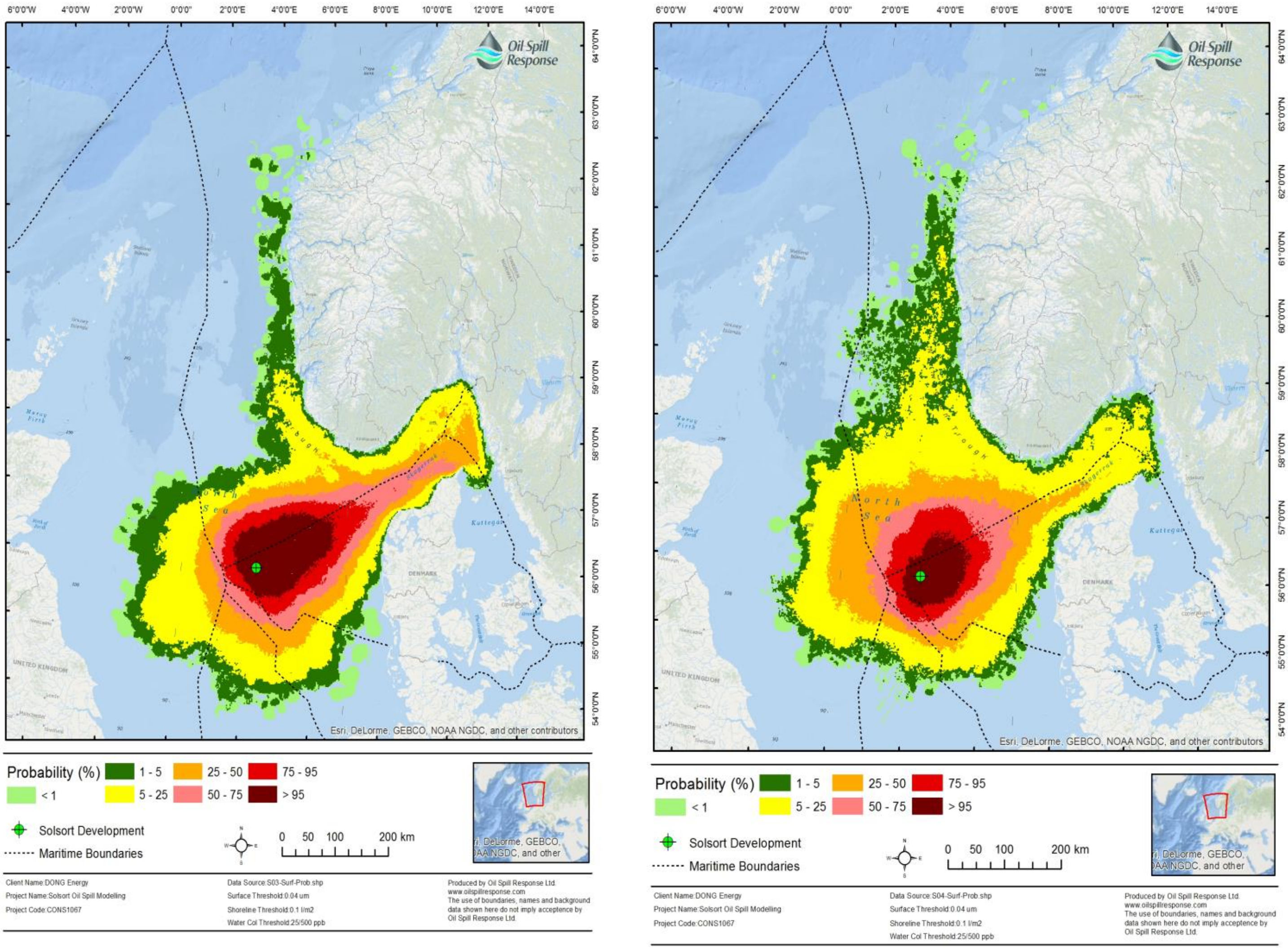
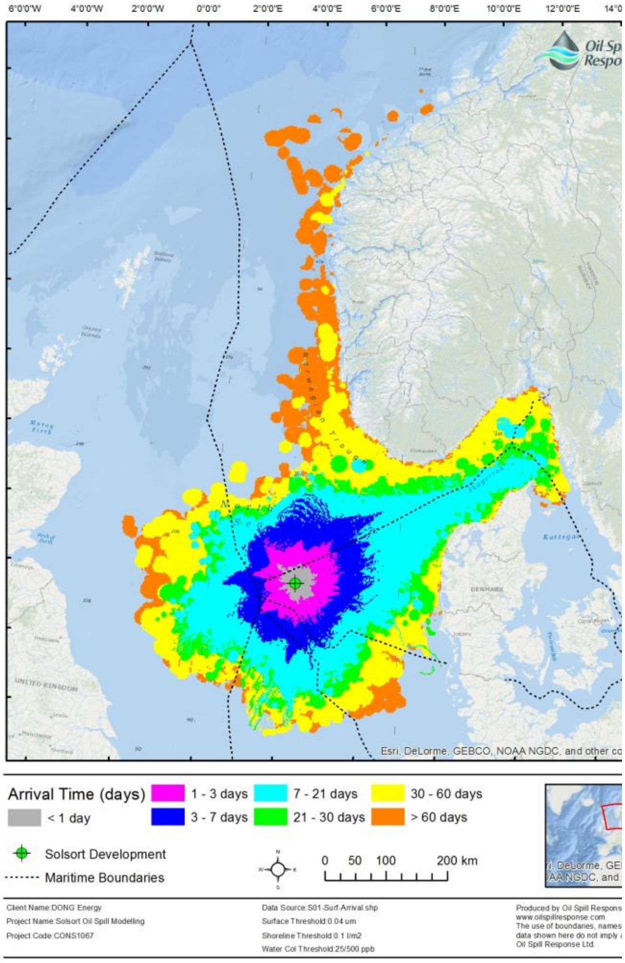


Figure 13-1 Result of oil spill modelling of a worst case, unmitigated surface release of a blowout at Solsort during summer (April-September) (left) and winter (October-March) (right). Combined probability of 142 trajectories that the sea surface in 10x10 km grid cells could be impacted by oil release from Solsort West Lobe wells (From DONG Energy 2015).

Figure 13-2 shows the seasonal resolution of arrival times (since start of the release) within the influence area to 10 x 10 km grid cells (drift time). It is seen that it will take approximately 2 weeks for oil to reach shore. However, it should be noted that although all shores are statistically affected by oil in case of a blowout according to Figure 13-1, Figure 13-3 shows that the amount of oil that hits the shore has a thickness smaller than 5 µm.



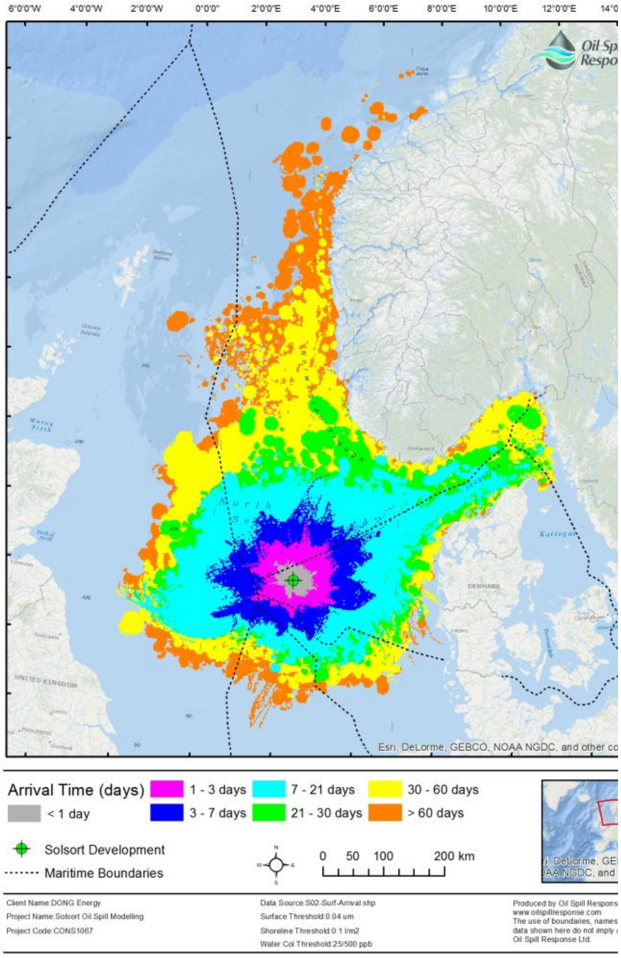


Figure 13-2 Result of stochastic oil spill modelling of a worst case, unmitigated surface release of oil during a blowout at Solsort during summer (April-September) (left) and winter (October-March) (right). The figures show the seasonal resolution of arrival times (since start of the release) within the influence area to 10 x 10 km grid cells.

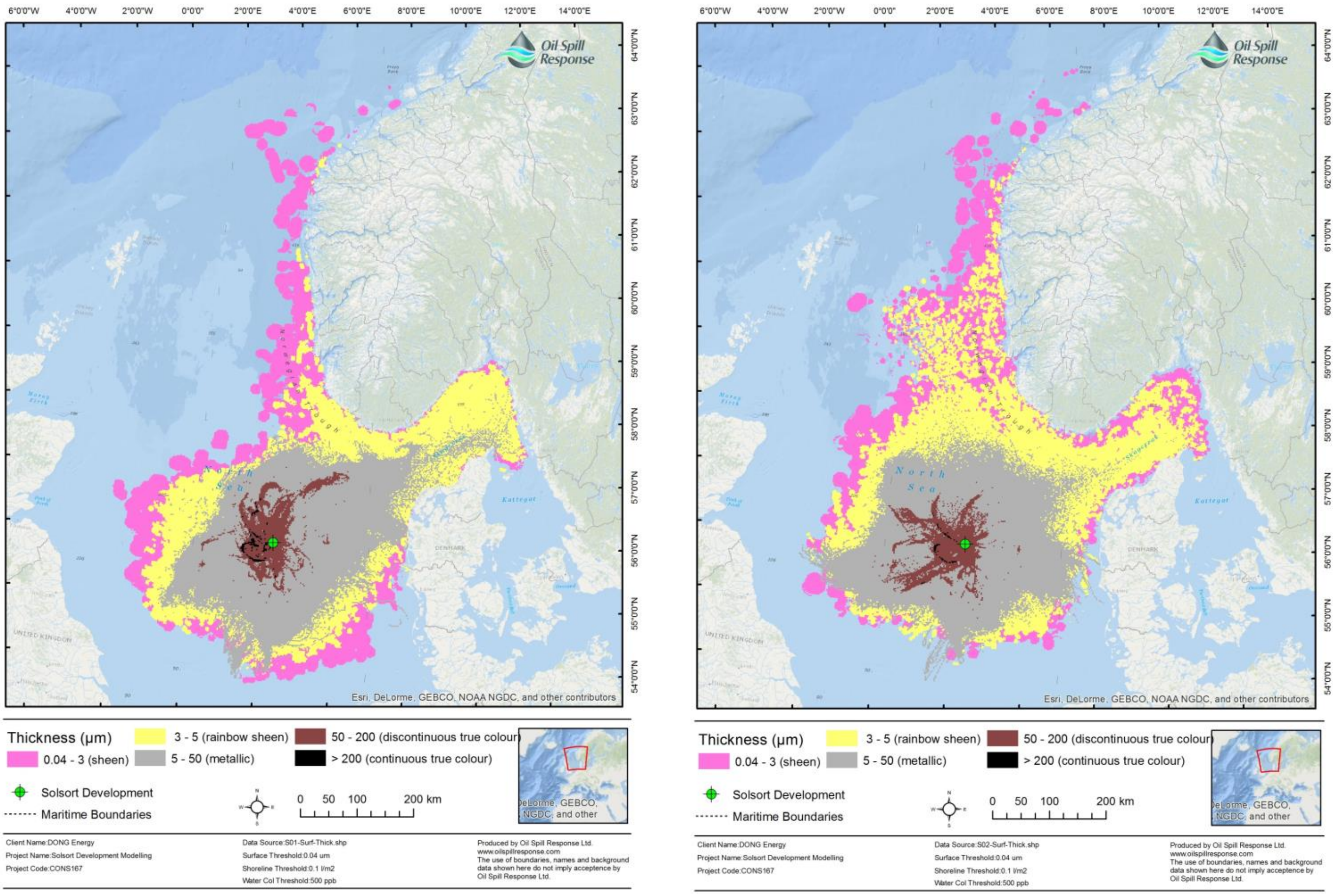


Figure 13-3 Seasonal resolution of surface oil thickness within the influence area to 10 x 10 km grid cells. Result of oil spill modelling of a worst case, unmitigated surface release of a blowout at Solsort during summer (April-September) (left) and winter (October-March) (right). (From DONG Energy 2015). The thickness named sheen marked as pink is 0.04-0.3 and not as stated in the figure and the rainbow sheen marked as yellow is 0.3-5.

A worst-case trajectory that results in most oil ashore has been selected and the result of the simulation is shown in Figure 13-4.

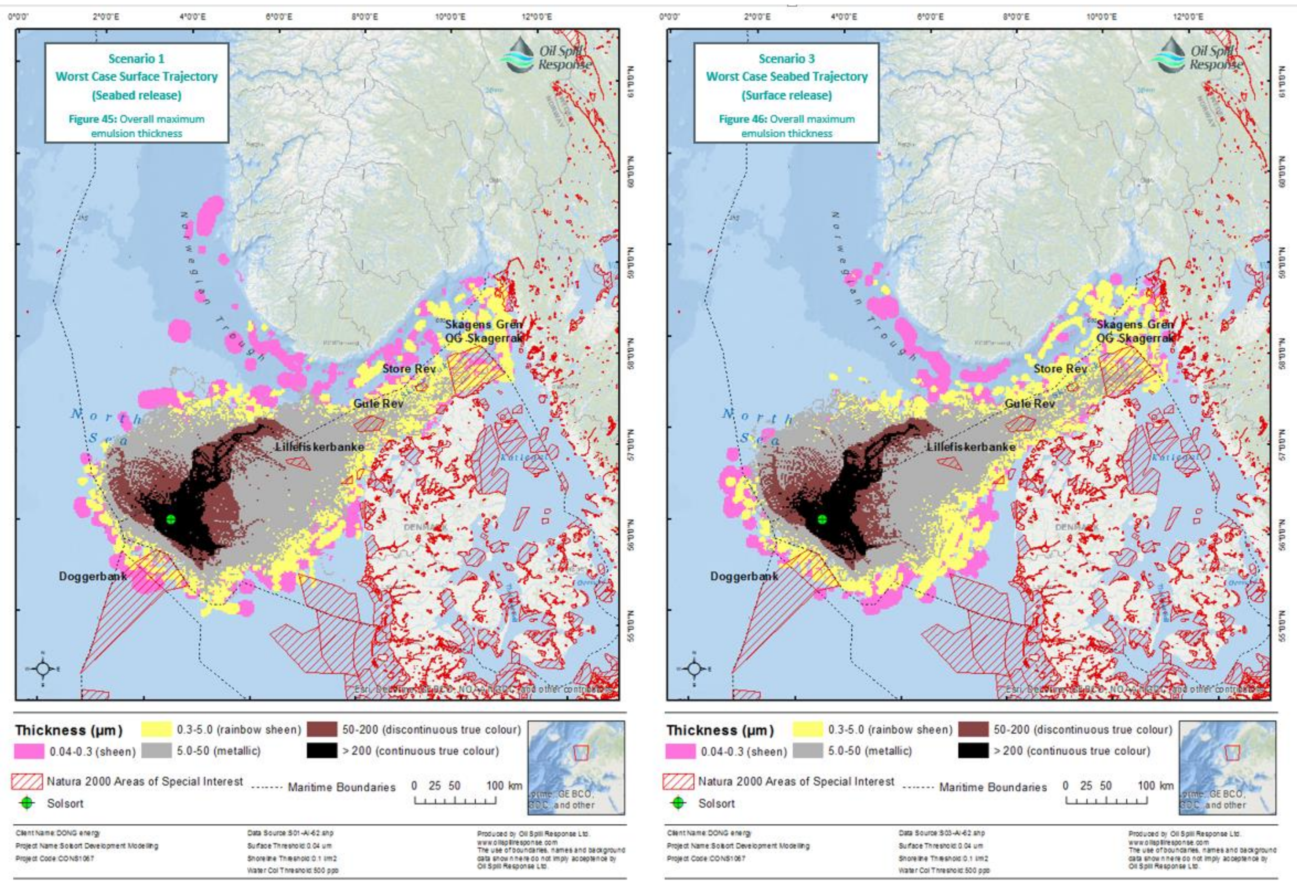


Figure 13-4 Result of oil spill modelling of a worst case, unmitigated surface and seabed release

Table 13-3 shows the expected surface oil layer thickness corresponding to the oil mass according to the Bonn Agreement (2016). Five levels of oil appearances are distinguished in the Bonn Agreement.

Birds are generally considered to be affected by surface oil when the emulsion thickness exceeds 1 µm whereas seals and cetaceans (incl. harbour porpoise) are more tolerant to surface oil. Latter being affected when emulsion thickness exceeds 10 µm and 100 µm for seals and cetaceans respectively (French-McCay 2009).

Table 13-3 Levels of oil appearances distinguished according to the Bonn Agreement (2016).

Code	Description -Appearance	Layer thickness (µm)	Tonnes per 100 km^2
1	Silver/Gray	0.04 - 0.30	4 - 300
2	Rainbow	0.30 - 5.0	300 - 5000
3	Metallic	5.0 - 50	5000 - 50,000
4	Discontinuous true oil colour	50 - 200	50,000 - 200,000
5	Continuous true oil colour	> 200	> 200,000

The modelling showed a similar picture for seabed release of oil. However, it should be noted that oil released from a seabed may behave differently to oil spilled on the surface. Although oil spilled on the surface may reach the water column through natural dispersion caused by wind energy the majority will typically remain on the surface and undergo weathering processes such as evaporation and spreading. Large underwater oil plumes can be caused by oil spilled from the seabed due to buoyancy fluxes in the water column. In some cases, oil becomes trapped at a certain density gradient and does not reach the surface.

The modelling shows that the maximum total oil concentration in the water column is <150 ppb and the maximum dissolved oil concentration is <10 ppb (for seabed release). For comparison, 25 ppb is the threshold at which the most sensitive marine life will begin to be affected. It is based on guidelines from the Norwegian Oil Industry Association concerning the effects of acute oil pollution on fish eggs and larvae. 500 ppb is the threshold at which acute toxicity is caused to over 50% of the marine life based on a literature review conducted by BP.

In the following, the model results are assessed in relation to potential impacts on sea birds, marine mammals, fish eggs- and larvae, shorelines and Natura 2000 sites.

13.1.5 Impacts on sea birds of oil released during a blowout incident

It is well-documented that seabirds are extremely vulnerable to oil spills and that large amounts of seabirds are often killed in connection with an oil spill in areas where seabirds are concentrated. The reason for seabirds being especially vulnerable is that they are often in contact with surface water and that the oil destroys the buoyancy and the isolating quality of the plumage. Birds smothered in oil will usually die of cold or starvation or drown. Even very small spots of oil may be fatal, especially during winter. Mainly seabirds that stay on the sea surface for longer periods are at risk, but all types of seabirds may be affected (Trosi et al 2016). The threshold for emulsion thickness considered as harmful for birds is 1 µm (French-McCay 2009) (roughly 100 t per 10 x 10 km, Table 13-3). Exposure above this threshold will lead to effects such as transferring oil to eggs reducing hatching success. Emulsion thickness of more than 10 µm will lead to immediate killings.

In the unlikely event of a blowout incident at Solsort West Lobe well the oil will most likely be transported towards northeast with the prevailing currents and pass the internationally important bird areas in the north eastern part of the North Sea. The probability that this area will be impacted is high in case of an oil blowout (75-> 95%). The drift time to these areas are 1-7 days (DONG energy 2015).

The area is important for gulls and auks (i.e., mainly little auk, but also guillemot and razorbill (Skov et al. 1995, Skov et al. 2007). The auks are particularly vulnerable to oil spills as they spend most of their time on the sea surface. The birds are particularly vulnerable during winter where most species are clustering. It is estimated that around 1 million birds are present in the North Sea during winter (Skov et al. 2007). The northern part of the Danish EEZ in the North Sea is considered an intermediate important conservation area for seabirds (Skov et al. 2007). Consequently, there is a high risk of oiling and killing of birds in this area in the unlikely event of a blowout. On the other hand, the important bird areas in and immediately off the Wadden Sea will not be affected.

13.1.6 Impacts on marine mammals of oil released during a blowout incident

The modelling shows that oil from a blowout may hit areas where harbour porpoise, grey seals or harbour seal may be encountered. Harbour porpoises and seals are generally less vulnerable to oil spill than birds (i.e., threshold for seals is estimated to 10 µm while the threshold for cetaceans is 100 µm, French-McCay 2009) (10 µm corresponds to ca.10 t oil per 10x10 km (Table 13-3)). As their heat insulation is due to their layer of blubber a porpoise or seal smothered in oil will not be fatal as is the case with a bird.

13.1.6.1 Harbour porpoise

Comparative little is known about the effects of oil on cetaceans (whales, dolphins and porpoises), but based on scant records of cetacean mortality associated with oil spills, it has been suggested that an oil spill may only affect small numbers of cetaceans. Several authors suggest that the threat of most immediate concern is inhalation of evaporated volatile toxic components from the oil slick on the sea surface if they emerge at the surface to breathe in the middle of an oil slick. This risk is greatest near the source of a fresh spill because volatile toxic vapours evaporate and disperse relatively quickly. When concentrated vapours are inhaled, mucus membranes may become inflamed, lungs can become congested, and pneumonia may ensue. Inhaled fumes from oil may accumulate in blood and other tissues, leading to possible liver damage and neurological disorders. As porpoises rely on blubber for insulation their thermoregulatory ability does not seem seriously hampered by contact with oil (Helm et. al. 2015).

Harbour porpoises in the Central North Sea, may be affected in the unlikely incidence of a blowout at Solsort. However, as the oil slick during a blowout is transported in a relatively narrow band in the direction of the currents and as the density of porpoises is relatively low (0.01-8 individuals/km² only a tiny fraction of the populations of Harbour porpoise in the North Sea is likely to be affected. It is therefore not likely that a potential oil contamination from a blowout will significantly affect the population sizes of the Harbour porpoises in the North Sea.

13.1.6.2 Seals

Seals may be affected by direct contact with oil in a variety of ways. Oil can coat all or portions of their body surface and they may inhale toxic fumes of hydrocarbons, which affects their lungs. In addition, they may ingest oil directly or ingest oil-contaminated prey. As seals rely on blubber for insulation their thermoregulatory ability does not generally seem seriously to be hampered by contact with oil. However, observations suggest that some individuals have become so encased in oil that they were not able to swim and subsequently drowned. In addition, observation also suggest that eyes, oral cavity, respiratory surfaces and urogenital surfaces are particularly sensitive to contact with oil (Helm et al. 2015).

It cannot be excluded that seals in the Central North Sea may be affected. However, as the oil slick during a blowout is transported in a relatively narrow band in the direction of the currents and as seals are relatively rare in the Central North Sea only a tiny fraction of the populations of seals is likely to be affected. It is therefore not likely that a potential oil contamination from a blowout will significantly affect the population sizes of the seals.

13.1.7 Impacts on fish eggs and larvae of oil release during a blowout incident

Eggs and larvae are considered the most sensitive life stages of fish in terms of acute impacts of spilled oil.

The Norwegian Oil Industry Association use 25 ppb as the concentration at which fish eggs- and larvae and other sensitive marine life begin to be affected by oil components. A literature review conducted by BP suggested that oil content greater than 500 ppb will cause acute toxicity to over 50% of the marine life in the area (DONG Energy 2015).

Figure 13-5 and Figure 13-6 show the simulated probability that the water column in 10x10 km grid cells might be impacted by concentrations ≥ 25 ppb (upper figure) and ≥ 500 ppb (lower figure) during a surface release of oil at Solsort during summer and winter, respectively.

It is seen that high probabilities of encountering concentrations above 25 ppb that may affect fish eggs and larvae are found within up to 75 km from Solsort. Eggs and/or larvae of cod, mackerel, plaice, herring and sandeels that may be encountered in this area may therefore be affected by an oil-blow-out.

There is only a small probability (< 1-5%) that larvae in the important nursery areas for larvae of cod, whiting, Norway pout, haddock and sandeel at the productive hydrographical front in the north-eastern part of the North Sea will be affected by an oil blow-out.

The modelling showed a similar picture for a seabed release of oil (DONG energy 2015).

There is no evidence to date that any oil spill in open offshore waters has affected the size of fish populations although oil is very toxic to fish eggs and larvae. Several studies have demonstrated that massive kills of fish eggs and larvae near oil spills may occur without causing any detectable effects on fish populations. The lack of effects on numbers in subsequent adult populations following massive kills of eggs and larvae is probably because most fish species produce vast numbers of eggs and larvae and because most species have extensive spawning grounds (ITOPF 2019, IPIECA 2000, Falk-Petersen & Kjørsvik 1987, Serigstad & Adoff 1985).

It is therefore assessed that an oil blow-out will not affect the fish stocks despite increased mortality of fish eggs and larvae.

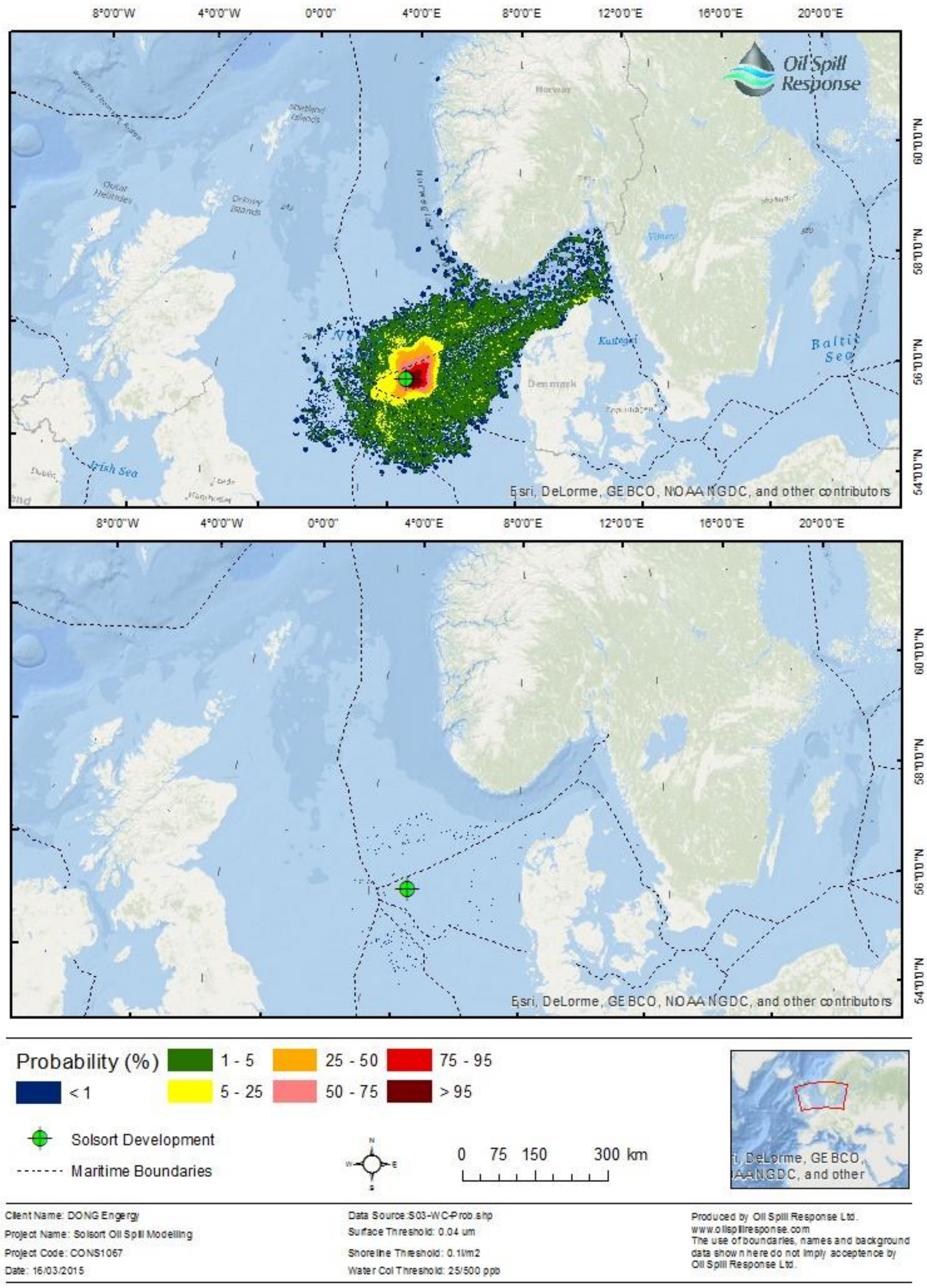


Figure 13-5 Water column contamination due to surface release during summer (April–September) at Solsort. Probability that 10x10 km grid cells could be impacted by concentrations ≥ 25 ppb (upper figure) and ≥ 500 ppb (lower figure). (From DONG Energy 2015).

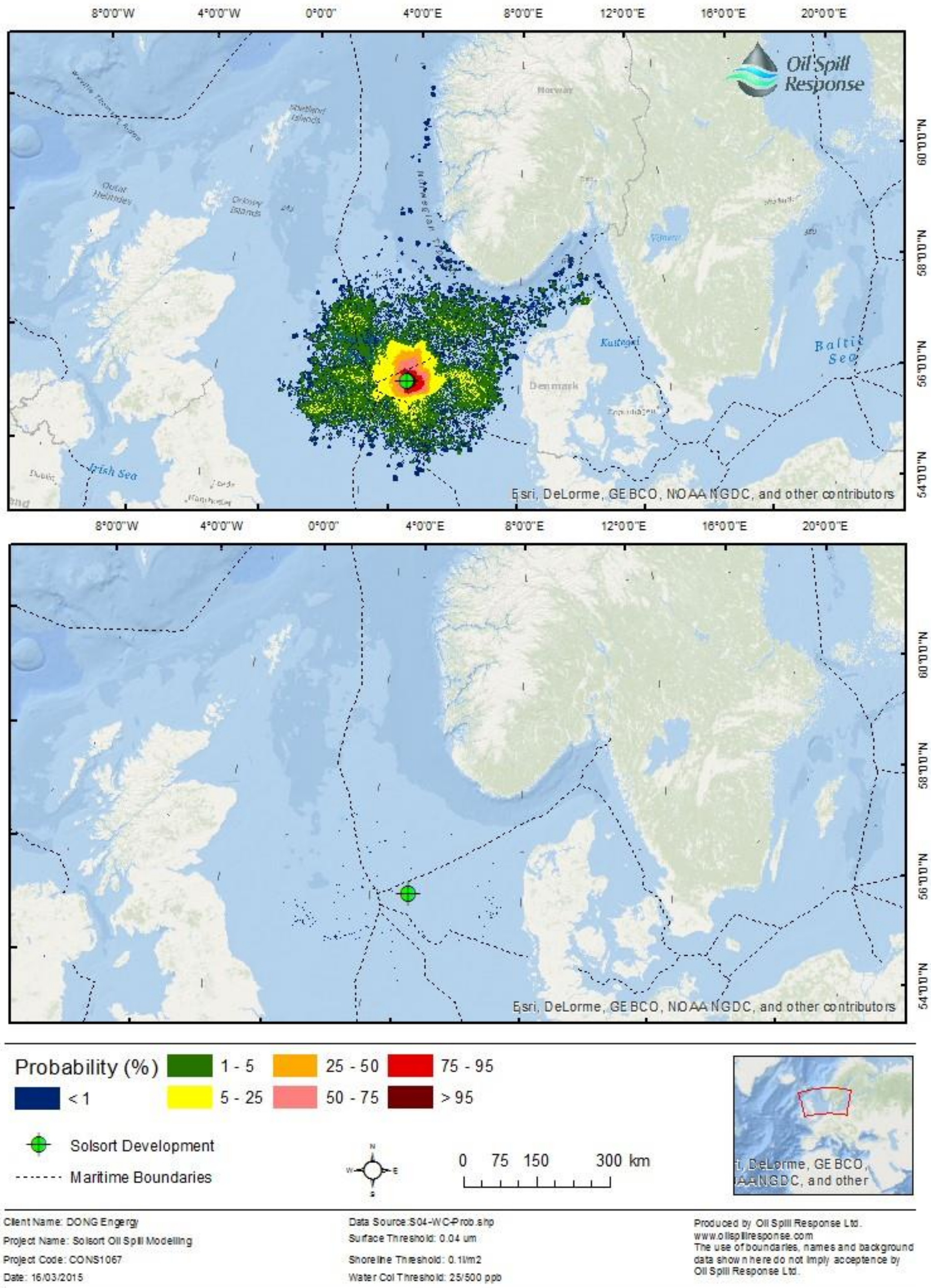


Figure 13-6 Water column contamination due to surface release during winter (October-March) at Solsort. Probability that 10x10 km grid cells could be impacted by concentrations ≥ 25 ppb (upper figure) and ≥ 500 ppb (lower figure). (From DONG Energy 2015).

13.1.8 Impacts of oil stranded on shorelines during a blowout incidence

Shorelines, more than any other part of the coastal environment, are exposed to the effects of floating oil. Oil stranded on beaches often gives rise to concern because it may affect sensitive coastal habitats and important socioeconomic conditions. Further, the cleaning of oiled beaches may be costly. The vulnerability of shorelines to oil spills differs considerably depending on the type of habitat and with respect to how easy they are to clean up after an oil spill.

The OSCAR modelling showed, that in case of a blow-out with surface release during summer, oil may strand on beaches along the west coast of Vendsyssel and Thy and the western side of Harboøre Tange. Oil may also strand on the south coast of Norway and in a very small area in the northern part of the Swedish Skagerrak coast. The probability is, however quite low in most of the areas, i.e., 1-5%. In some areas, the probability is 5-25% and at Skagen it is 25-50% (Figure 13-8). Along the affected Danish coast, the degree of oiling will only be light to moderate. The oiling on the Norwegian south coast and the Swedish coast will mostly be light (Figure 13-9).

The Danish coastlines, which may be hit by stranded oil are generally exposed, gently sloping sandy beaches. These types of beaches are not particularly vulnerable to oil as they are not very productive ecologically. In addition, the oil does not penetrate the sand readily, facilitating mechanical removal (IPIECA 1996). As the drift time from Solsort to the shoreline will be in the range 30-60 days (DONG energy 2015), the stranded oil will mostly be in the form of tar balls. This can be seen from Figure 13-7, which illustrates the breakdown processes of oil over time. The most volatile components have evaporated, and emulsification and dispersion have almost terminated after approximately a week, leaving only hard degradable oil components that can form tar balls by wave impacts. Tar balls are even easier to remove on sandy beaches compared to less weathered oil. However, the stranded oil in the summer period may be a nuisance to holidaymakers bathing from the beach.

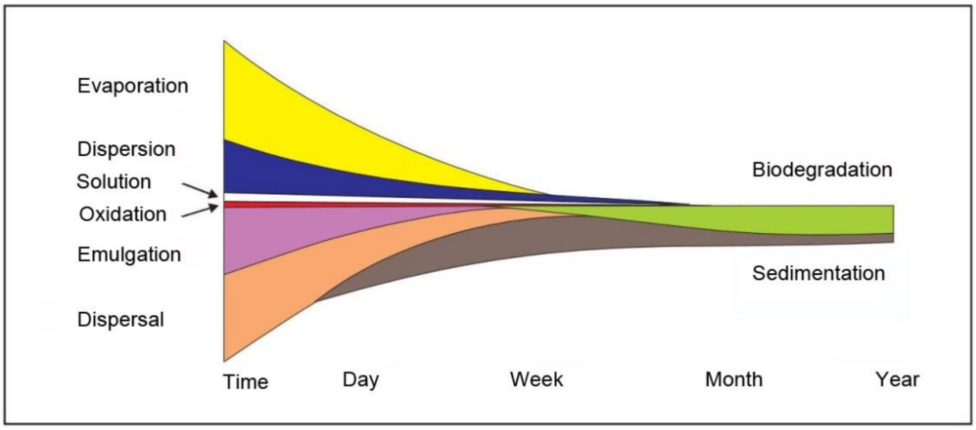


Figure 13-7 Overview of the relative significance of the different physical and chemical processes that affects spilled oil at sea as a function of time (after ITOPF 2002).

The biologically highly productive tidal flats and saltmarshes in the Wadden Sea in the southern part of the Danish coast will not be affected.

The Norwegian and Swedish coastlines that may be hit by oil are rocky shores that are more sensitive to oil spills compared to the Danish sandy shores. However, with a drift time of 30 to more than 60 days (DONG energy 2015) most of the oil will be in the form of tar balls, which are considerably less damaging as they are no longer sticky or toxic.

The overall probability of shoreline impact of an unmitigated blow-out ranges between 80-98% for winter and summer releases, respectively. Shoreline oiling is likely to range between very light and moderate, as defined by ITOPF's recognition of shoreline oiling guidelines. Under the worst-case metocean conditions, the quickest impact on the shoreline in Denmark will be between 14-19 days. Shoreline impact may also happen in Norway (after 24-37 days) and Sweden (after 27-45 days). There will be no shoreline impact in UK, Germany or the Netherlands.

In case of a blow-out with surface release during winter, the extent of affected shorelines will be considerably smaller than for a release during summer. Along the Danish coast, only the stretch on the west coast of Vendsyssel between Hirtshals and Skagen may be hit by oil. In addition, a considerably smaller area along the Norwegian coast may affected and the Swedish coast will not be hit by a worst case mass release onshore result during surface release in summer (April-September) result in 3 MT ashore efter 21 days and 120 MT after 82 days. A worst case winter mass release result in 6 MT after 21 days and 30 MT after 82 days. The modelling showed that the risk, the extent and the degree of oiling of shorelines during a seabed release of oil is quite similar to a surface release (DONG energy 2015).

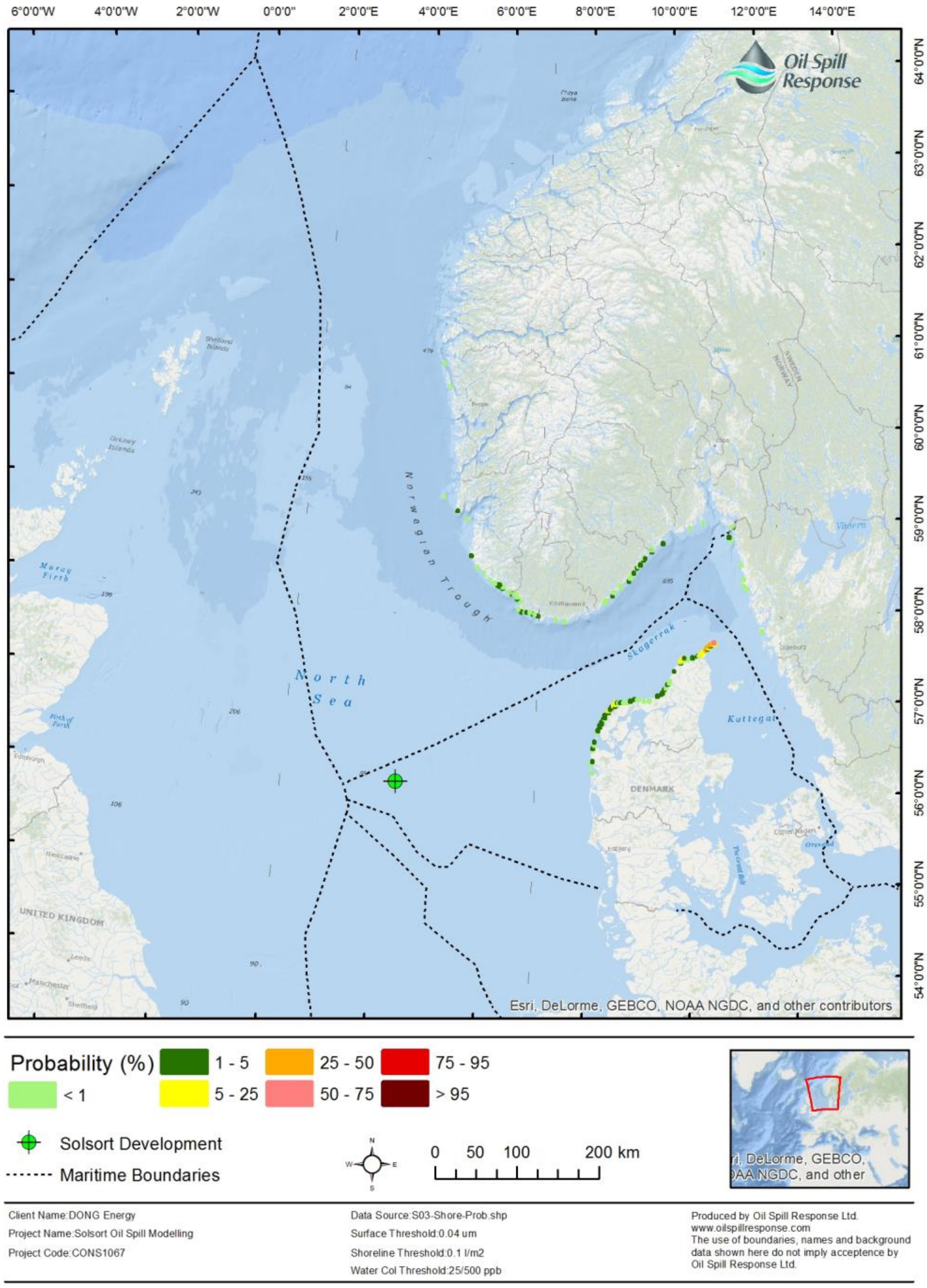


Figure 13-8 Shoreline contamination from a worst case, unmitigated surface release during summer (April–September). Combined probability of 142 trajectories that 10x10 km coastal grid cells will be impacted by oil release at Solsort. (From DONG Energy 2015).

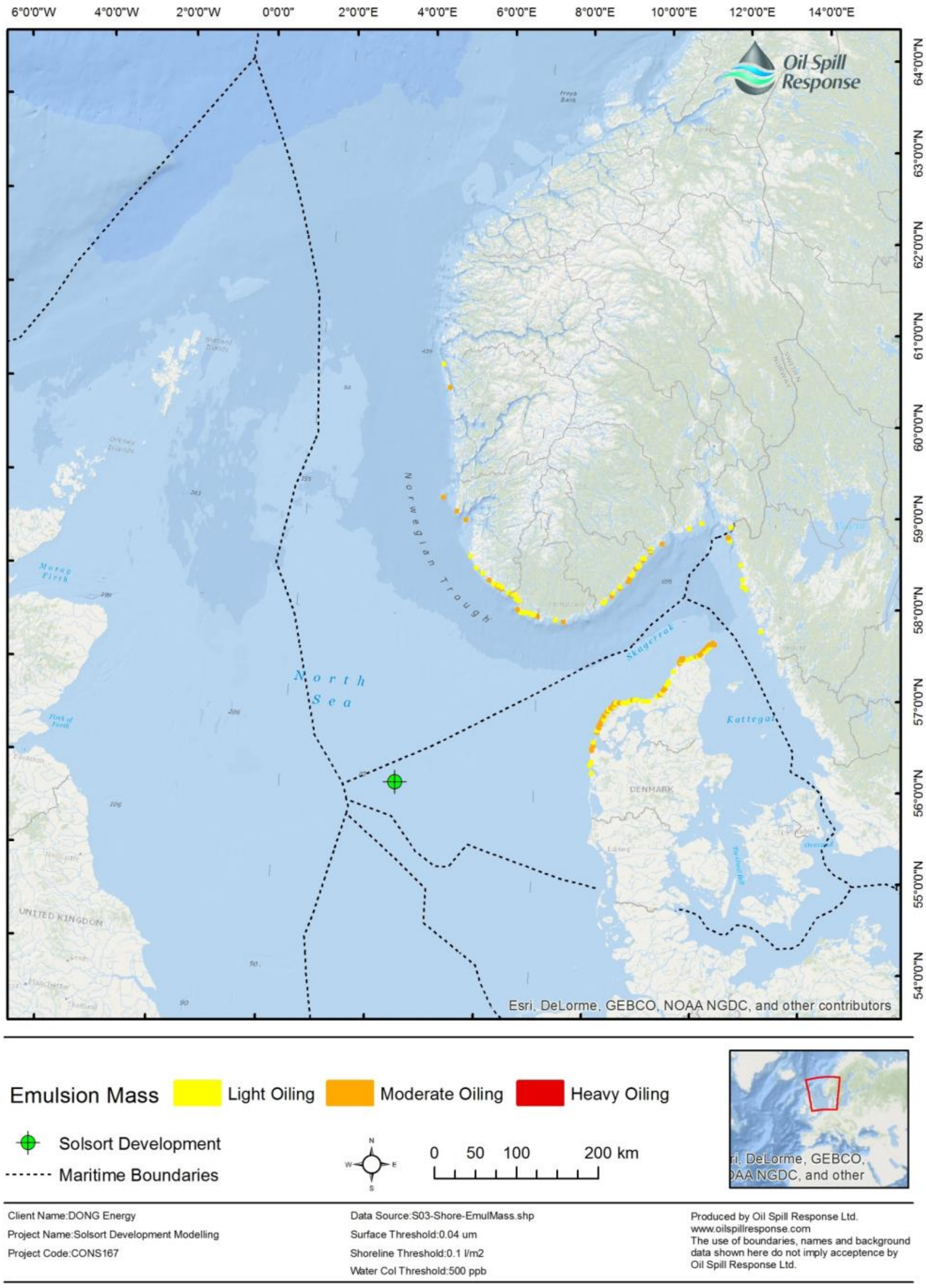


Figure 13-9 Shoreline contamination due to surface release during summer (April–September). Degree of oiling due to oil release at Solsort. (From DONG Energy 2015).

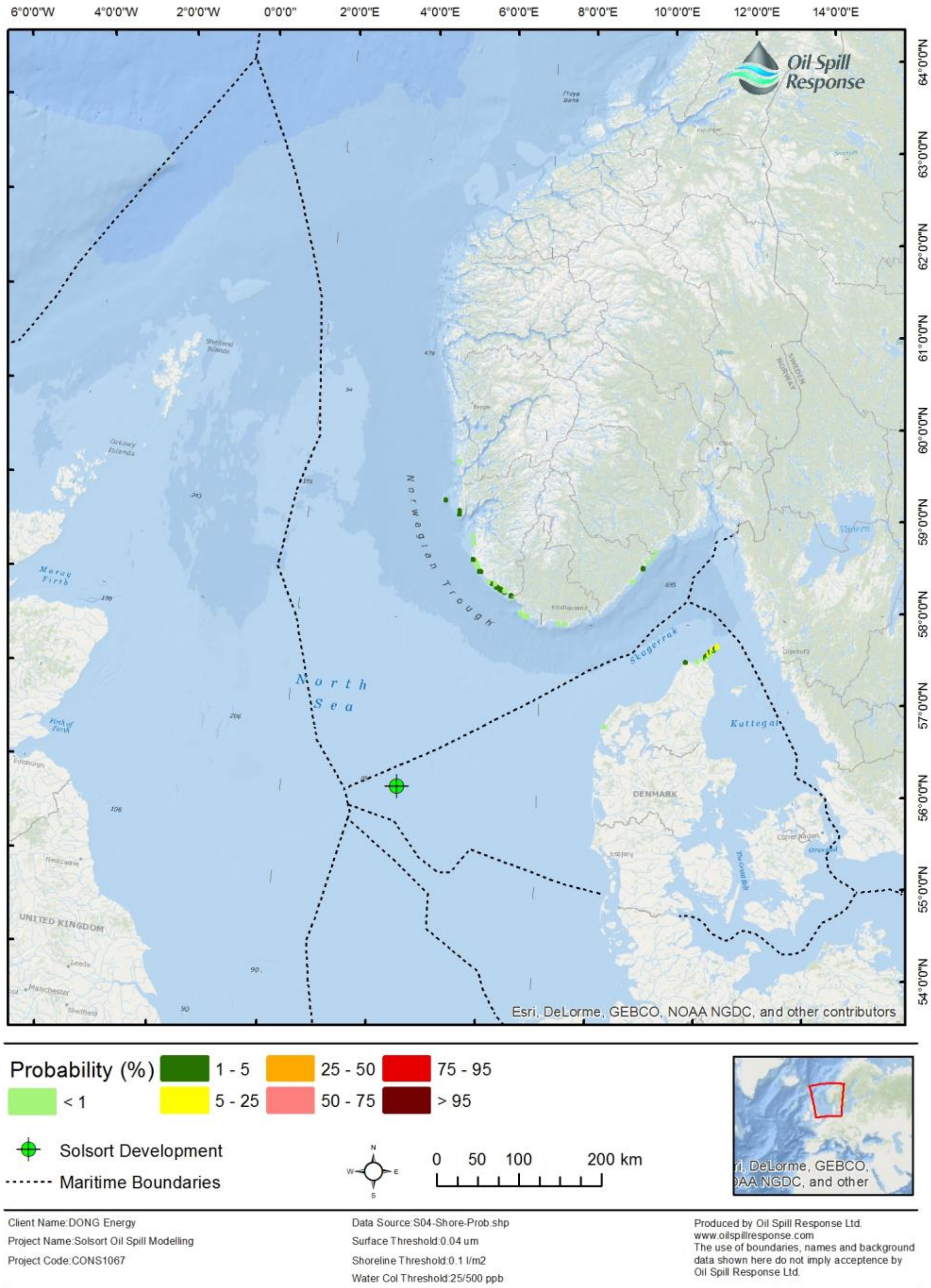


Figure 13-10 Shoreline contamination due to surface release during winter (October-March). Combined probability of 142 trajectories that 10x10 km coastal grid cells could be impacted by oil release at Solsort. (From DONG Energy 2015).

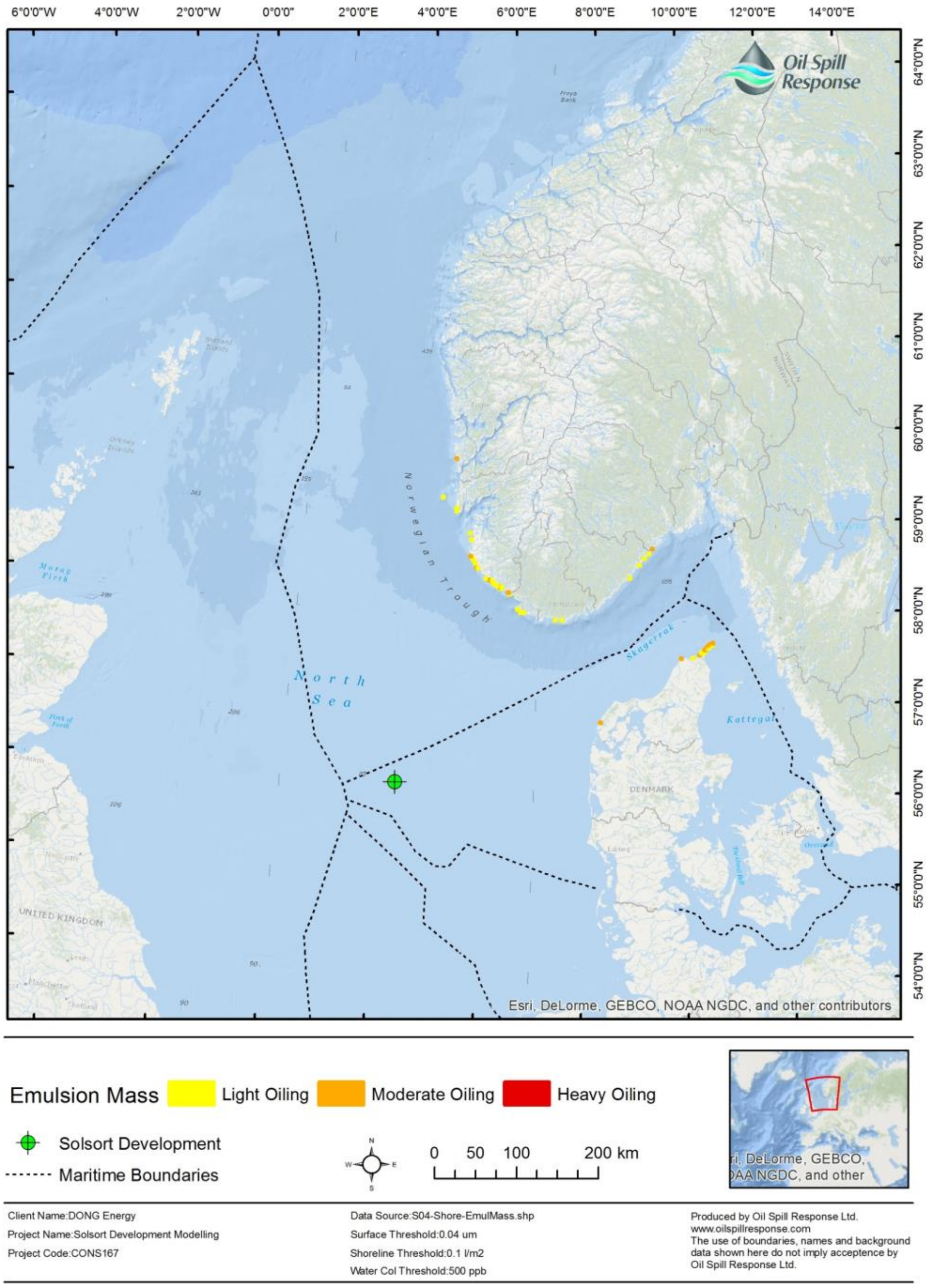


Figure 13-11 Shoreline contamination due to surface release during winter (October-March). Degree of oiling due to oil release at Solsort. (From DONG Energy 2015).

Table 13-4 Model results. Fastest time for oil to reach the shoreline of different countries. DONG Energy 2015.

Scenario	Description	Country	Fastest time to reach shoreline	Shoreline oiling thickness
Scenario 1	Seabed release (summer)	Denmark	14 days and 1 hour	0.04-5.00 µm
		Sweden	27 days and 17 hours	0.04-5.00 µm
		Norway	33 days and 12 hours	0.04-5.00 µm
		United Kingdom	No shoreline oiling	
		Netherlands	No shoreline oiling	
		Germany	No shoreline oiling	
Scenario 2	Seabed release (winter))	Denmark	13 days and 14 hours	0.04-5.00 µm
		Sweden	37 days and 12 hours	0.04-3 µm
		Norway	30 days	0.04-5.00 µm
		United Kingdom	No shoreline oiling	
		Netherlands	No shoreline oiling	
		Germany	No shoreline oiling	
Scenario 3	Surface release (summer)	Denmark	14 days and 18 hours	0.1 mm – 10 mm (light to moderate)
		Sweden	42 days and 7 hours	0.1 mm – 10 mm (light to moderate)
		Norway	36 days	0.1 mm – 10 mm (light to moderate)
		United Kingdom	No shoreline oiling	
		Netherlands	No shoreline oiling	
		Germany	No shoreline oiling	
Scenario 4	Surface release (winter)	Denmark	19 days and 4 hours	0.1 mm – 10 mm (light to moderate)
		Sweden	45 days and 22 hours	0.1 mm – 1.0 mm (light oiling)
		Norway	24 days and 21 hours	0.1 mm – 10 mm (light to moderate)
		United Kingdom	No shoreline oiling	
		Netherlands	No shoreline oiling	
		Germany	No shoreline oiling	

13.1.9 Impacts on Norwegian SVOs

The modelling shows that Norwegian SVOs may be hit by oil in case of an unmitigated blowout (Figure 13-2) i.e.:

- There is a probability of 5-25 % probability that SVO "*Makrellfelt*", which is a spawning area for mackerel from May to July will be hit by oil. The calculated drift time from Solsort is 30-60 days.

- Sandeel field south may also be hit (probability 50-75%; drift time 3-7 days. The sandeel field south is spawning and foraging areas for sandeel (*Ammodytes* sp.). Furthermore, the Sandeel field south is a valuable habitat for common guillemot (*Uria aalge*) and northern fulmar (*Fulmaris glacialis*) from April to December. The model results show that the concentration of oil in these areas above 25 ppb, which is above the concentrations that are harmful to fish eggs and larvae. Spawning in this area is therefore at risk. Likewise, there is a risk of oiling and killing of birds on the Sandeel field South.

13.1.10 Impacts on German, Dutch and UK Natura 2000 areas south-southeast of Solsort

In the unlikely event of a blowout, the German and Dutch Natura 2000 areas south-south-west of Solsort are likely to be affected by the spill, especially the German area i.e. (cf. Table 13-5):

- There is a 50-95 % probability that oil hits the German *DE 1003301 Doggerbank* and the drift time of oil to this area is 1-7 days.

- The Dutch *NL 2008-001 Doggerbank* may be hit, the probability being 1-75 % and the drift time 3->60 days depending on the distance from Solsort.

The model shows that the UK SAC, *UK0030352 Doggerbank* is not likely to be hit.

Table 13-5 Results of oil OSCAR spill modelling of oil spill following a blowout at Solsort. Probabilities that the German and the Dutch Natura 2000 sites close to Solsort are hit by oil and drift time of oil during summer and winter in case of seabed release and surface release.

Type of blow-out	Season	Site	Probability that the area may be hit by oil	Drift time from blowout to site
Seabed release	Summer	DE 1003301 Doggerbank	50-95 %	1-7 days
		NL 2008001 Doggerbank)	1-75 %	3-30 days
	Winter	DE 1003301 Doggerbank	50-95 %	1-7 days
		NL 2008001 Doggerbank	1-50 %	3-60 days
Surface release	Summer	DE 1003301 Doggerbank	50-95 %	1-7 days
		NL 2008001 Doggerbank	1-75 %	3-60 days
	Winter	DE 1003301 Doggerbank	50-95 %	1-7 days

Type of blow-out	Season	Site	Probability that the area may be hit by oil	Drift time from blowout to site
		NL 2008001 Doggerbank	1-75 %	3 ->60 days

The basis for the designation of the two areas are the habitat type 1110 *Sandbanks* and the habitat species 1351 *Harbour porpoise*, 1365 *Harbour seal* and 1364 *Grey seal*.

13.1.10.1 Impacts on harbour porpoise

Comparative little is known about the effects of oil on cetaceans (whales, dolphins and porpoises), but based on scant records of cetacean mortality associated with oil spills, it has been suggested that an oil spill may only affect small numbers of cetaceans. Several authors suggest that the threat of most immediate concern is inhalation of evaporated volatile toxic components from the oil slick on the sea surface if they emerge at the surface to breathe in the middle of an oil slick. This risk is greatest near the source of a fresh spill because volatile toxic vapours evaporate and disperse relatively quickly. When concentrated vapours are inhaled, mucus membranes may become inflamed, lungs can become congested, and pneumonia may ensue. Inhaled fumes from oil may accumulate in blood and other tissues, leading to possible liver damage and neurological disorders. As porpoises rely on blubber for insulation their thermoregulatory ability does not seem seriously hampered by contact with oil. (Helm et al. 2015).

It cannot be excluded that harbour porpoises in the Central North Sea may be affected in the unlikely incidence of a blowout at Solsort. However, as the oil slick during a blowout is transported in a relatively narrow band in the direction of the currents and as the density of porpoises is relatively low (0.01-8 individuals/km² (cf. Figure 18-2), only a tiny fraction of the populations of harbour porpoise in the North Sea is likely to be affected. It is therefore not likely that a potential oil contamination from a blowout will significantly affect the population sizes of the harbour porpoises in the North Sea.

13.1.10.2 Impacts on seals

Seals may be affected by direct contact with oil in a variety of ways. Oil can coat all or portions of their body surface and they may inhale toxic fumes of hydrocarbons, which affects their lungs. In addition, they may ingest oil directly or ingest oil-contaminated prey. As seals rely on blubber for insulation their thermoregulatory ability does not generally seem seriously to be hampered by contact with oil. However, observations suggest that some individuals have become so encased in oil that they were not able to swim and subsequently drowned. In addition, observation also suggest that eyes, oral cavity, respiratory surfaces and urogenital surfaces are particularly sensitive to contact with oil (Helm et al. 2015).

It cannot be excluded that seals in the German and Dutch Natura 2000 areas may be affected. However, as the oil slick during a blow-out is transported in a relatively narrow band in the direction of the currents and as seals are relatively rare in the Central North Sea only a tiny fraction of the populations of seals is likely to be affected. It is therefore unlikely that a potential oil contamination from a blow-out will significantly affect the population sizes of the seals.

13.1.10.3 Impacts on habitat type 1110 sandbanks

In addition, there may be a risk of sedimentation of oil on the habitat type 1110 *Sandbanks* which are slightly covered by sea water all the time, especially in the German area, thereby affecting the benthic infauna community that has been characterised as a Bathyporeia-Fabulina (Amphipod-Tellina) community, with the crustacean *Bathyporeia elegans* and the bristle worms *Spiophanes bombyx* and *Spio decorata* as characterising species.

13.1.10.4 Impacts on Danish Natura 2000 areas

In case of a blowout, nine Danish Natura 2000 areas east and north-east of Solsort are at risk of oil contamination to a larger and lesser extent dependent on distance from the blow-out and the position in relation to the axis of the prevailing direction of the oil slick drift.

The different sites can be grouped in terms of risk of being hit by oil and drift time as follows (Table 13-6):

- DK00VA257 *Lille Fiskebanke* and DK00VA259 *Gule Rev* are closest to Solsort in the prevailing direction of the oil slick drift. There is a relatively high risk that these sites will be hit by oil i.i.e.,0-75 % probability during summer and the drift time is 7-21 days.

- DK00VA258 *Store Rev* DK00FX112 *Skagens Gren* og *Skagerrak* are situated at larger distances from Solsort in the prevailing direction of the oil slick drift. The risk of being hit by oil is therefore smaller compared to *Lille fiskebanke* and *Gule rev* (i.e. 25-50 % during summer). The drift time will be 7-21 and 7-30 days, respectively

- DK00VA301 *Lønstrup Rødgrund* is located outside the axis of the prevailing drift direction at a quite large distance from Solsort. The risk that the area is hit by oil is therefore less than 5-25 % during summer and a drift time of 21-30 days

- DK00VA348 *Thyborøn stenvolde*, DK00EX023 *Agger Tange*, DK00VA340 *Sandbanker ud for Thyborøn* and DK00VA340 *Sydlige Nordsø* are at the edge of the prevailing direction of the oil slick drift. The probability of being hit by oil is small i.e. 1-5 % and the drift time 30-60 days.

For all sites, the probability of being hit by oil is a little less during winter.

Table 13-6 Results of OSCAR oil spill modelling following a blowout at Solsort. Probabilities that Danish Natura 2000 sites north-east of Solsort are hit by oil and drift time of oil during summer and winter in case of seabed release. Surface release is identical in terms of probability and drift time.

Season	Site	Probability that the area will be hit by oil	Drift time from blowout to site
Summer	DK00VA257 *Lille Fiskebanke*	50-75 %	7-21 days
	DK00VA259 *Gule Rev*	50-75 %	7-21 days
	DK00VA258 *Store Rev*	25-50 %	7-21 days
	DK00FX112 *Skagens Gren og Skagerrak*	25-50 %	7-30 days
	DK00VA301 *Lønstrup Rødgrund*	5-25 %	21-30 days
	DK00VA348 *Thyborøn Stenvolde*	1-5 %	30-60 days
	DK00EX023 *Agger Tange*	1-5 %	30-60 days
	DK00VA340 *Sandbanker ud for Thyborøn*	1-5 %	30-60 days
	DK00VA347 *Sydlige Nordsø*	1-5 %	30-60 days
Winter	DK00VA257 *Lille Fiskebanke*	25-50 %	7-21 days
	DK00VA259 *Gule rev*	25– 50 %	7-21 days
	DK00VA258 *Store Rev*	5-25 %	7-21 days
	DK00FX112 *Skagens Gren og Skagerrak*	1-25 %	21-30 days
	DK00VA301 *Lønstrup Rødgrund*	1-5 %	21-30 days
	DK00VA348 *Thyborøn stenvolde*	1-5 %	30-60 days
	DK00VA347 *Sydlige Nordsø*	1-5 %	>60 days
	DK00EX023 *Agger Tange*	Not affected	
	DK00VA340 *Sandbanker ud for Thyborøn*	Not affected	

The basis of the designation of these Natura 2000 areas are listed in Table 18-1. The table also provide an overview of the assessments of impacts on the Habitat types and Habitat species in the areas. The assessments are substantiated in the following.

13.1.10.5 Impacts on marine mammals

Harbour porpoise and seals are included in the basis for designation in most of the potentially affected Natura 2000 areas. As described above, impacts on harbour porpoise may primarily be caused by toxic fumes from the oil slick on the surface

The oil will have drifted a week or more upon arrival to all the potentially Danish affected Natura 2000 areas (Table 13-7). Within a week, the toxic fumes will have evaporated (Cf. Figure 13-7). It is therefore assessed that the risk of harmful impacts of an oil blowout on harbour porpoise within the Natura 2000 areas is negligible.

13.1.10.6 Impacts on seabed habitats

The basis for designation at all sites except DK00EX023 *Agger Tange*, includes a seabed habitat (either 1170 Reef or 1110 Sandbanks). The drift time to DK00VA *Lille Fiskebanke,* DK00VA259 *Gule Rev*, DK00VA *Store rev* and DK00FX112 *Skagens Gren* og *Skagerrak* are in the range 7-30 days (Table 13-6).

The sedimentation of oil is at its maximum after a drift time of a week (Cf. Figure 13-7). Consequently, there may be a risk that the seabed habitats in these areas may be affected by settled oil.

The probability of oil entering the other areas are low i.e., 1-5 % (5-25 % at DK00VA301 *Lønstrup Rødgrund*. In addition, the drift time to these sites are 1-2 months (Table 13-6), by which time sedimentation is relatively low (Figure 13-7). It is therefore assessed that the risk of harmful impacts of an oil blow-out on seabed habitats in these areas is negligible.

13.1.10.7 Impacts on birds

Species of seabirds are included in the basis for designation at DK00EX023 *Agger Tange* and DK00VA347 *Sydlige Nordsø.*

Seabirds are very vulnerable to oil spill because they often are in contact with surface water and exposure to the sticky oil destroys the buoyancy and the isolating quality of the plumage. Birds smothered in oil will usually die of cold, starvation or drowning. Seabirds that stay on the sea surface for longer periods are mainly at risk, but all types of seabirds may be affected.

However, the probability of an oil slick entering the two areas are low (1-5 %) and the drift time has been modelled to 1-2 months (Figure 13-2). By this time most of the oil will be in the form of tar balls, which are considerably less damaging than fresher oil as they are no longer sticky or toxic.

Table 13-7 Assessment of impact on habitats and species that are basis for the designation of Danish Natura 2000 that may be affected by oil spill, in the unlikely event of a blowout at Solsort.

Natura 2000 area	Basis for designation	Assessment of impacts resulting from a blow-out at Solsort
DK00VA257 *Lille Fiskebanke*	1170 Reef 1351 Harbour porpoise	› Some risk of impacts on reef › Negligible risk of harmful effects on harbour porpoise (cf. text above)
DK00VA259 *Gule rev*	1170 Reef 1351 Harbour porpoise	› Some risk of impacts on reef › Negligible risk of harmful effects on harbour porpoise (cf. text above)
DK00VA258 *Store rev*	1170 Reef 1351 Harbour porpoise	› Some risk of impacts on reef › Negligible risk of harmful effects on harbour porpoise (cf. text above)
DK00FX112 *Skagens Gren og Ska-gerrak*	1110 Sandbanks which are slightly covered by sea water all the time 1180 Submarine structures made by leaking gases 1351 Harbour porpoise 1365 Harbour seal	› Some risk of impacts on sand-banks and submarine structures › Negligible risk of harmful effects on harbour porpoise and harbour seal (cf. text above)
DK00VA301 *Lønstrup Rødgrund*	1170 Reef 1351 Harbour porpoise	› Negligible risk of harmful effects on reef › Negligible risk of harmful effects on harbour porpoise (cf. text above)
DK00VA348 *Thyborøn Stenvolde*	1170 Reef 1351 Harbour porpoise	› Negligible risk of harmful effects on reef › Negligible risk of harmful effects on harbour porpoise (cf. text above)
DK00EX023 *Agger Tange*	19 different species of sea birds in-cluding species of terns, ducks and wading birds.	› Negligible risk of harmful effects on birds (cf. text above)
DK00VA340 *Sandbanker ud for Thy-borøn*	1110 Sandbanks which are slightly covered by sea water all the time 1351 Harbour porpoise	› Negligible risk of harmful effects on sandbanks › Negligible risk of harmful effects on harbour porpoise (cf. text above)
DK00VA347 *Sydlige Nordsø*	1110 Sandbanks, which are slightly covered by sea water all the time 1351 Harbour porpoise 1365 Harbour seal 1364 Grey seal Red-throated diver, Black-throated diver and Little gull	› Negligible risk of harmful effects on sandbanks › Negligible risk of harmful effects on harbour porpoise, harbour seal and grey seal (cf. text above) › Negligible risk of harmful effects on birds (cf. text above)

13.1.10.8 Conclusion

It is concluded that the Solsort West Lobe wells will not negatively affect the conservation status of habitats and species, for which potentially affected Natura 2000-sites have been designated as well as species listed on Annex IV of the EU Habitats directive (Directive 98/43EEC of 21 May 1992). Nor will the project affect the integrity of the areas negatively.

The conclusion in based on following arguments:

- The risk that a blowout occur is extremely low since all safety systems and measures are in place on the platform and rig.
- The oil slick is transported in a relatively narrow band in the direction of the surface currents.
- The South Arne Operator's oil spill contingency plan will be activated, and oil spill combat will be carried out, which will reduce the spreading of oil and mitigate impacts of any spill.

13.2 Environmental impacts of gas released during a blowout incident

In the unlikely event of a blowout at Solsort, gas may also escape from the formation.

In general, the extent of environmental impacts of escaped gas is not comparable to the impact of oil blow-outs. The bulk of the gas, bubbles to the surface and escape to the atmosphere within a relatively small area around the platform and does not disperse in the water to the same extent as oil. On the other hand, field and laboratory investigations have demonstrated that severe environmental impacts may be observed in the immediate vicinity of the platform. The investigations clearly proved that severe damages and mass mortality on zooplankton, benthic fauna and fish might occur within the small gas affected area (Table 13-8).

Although gas blow-out has smaller environmental impacts than oil blow-outs, the gas may pose a severe safety risk for personnel on rig, platform and vessels. If the gas ignites and cause fires or explosions, installations and equipment will be destroyed and in case personnel is not evacuated in due time, injuries or loss of life of personnel may occur. However, the risk of this is minor due to the existing contingency arrangements involving evacuations of personnel from platforms.

Table 13-8 Field-and laboratory studies on impacts of methane gas in the marine environment.

Study	Observations	References
Field survey in connection with a gas blow-out at drilling rigs in the Azov Sea summer/autumn 1982 and in 1985	95% of the escaped gas was methane. The concentration of methane in the vicinity of the well was 4-6 mg/l. The concentration had decreased to 0.07-1.4 mg/l 200 m from the well. In areas with a high concentration of methane, the biomass of benthos declined. Some declining of the zooplankton biomass also occurred in the vicinity of the accidental well Fish in the vicinity of the well clearly developed significant intoxication symptoms such as impaired movement coordination, weakened muscle tone, pathologies of organs and tissues, damaged cell membranes, disturbed blood formation, modifications of protein synthesis, radically increased total peroxidase activity, and some other anomalies typical for acute poisoning of fish.	Glabrybvod 1983 AzNIRKH 1986
Laboratory investigations of impacts of natural gas on fish	Fish clearly avoided concentrations of dissolved gas of 0.1-0.5 mg/l	Sokolov and Vinogradov 1991
Laboratory investigations of acute toxicity of natural gas on fish and zooplankton	48h LC_{50} for fish = 1-3 mg/l 96h LC_{50} for zooplankton = 5.5 mg/l	Umorin et al 1991
Laboratory investigations of acute toxicity of natural gas on zooplankton, benthic fauna and fish fry	96h LC_{50} for zooplankton, benthic fauna and fish fry = 0.6-1.8 mg/l	Borisov et al 1995
Laboratory investigations of impacts of natural gas on fish	Exposure to 1 mg/L and above induced intoxication symptoms (Impaired movement coordination, impaired oxygen absorption. disorientation. Lethal effects were observed after two days.	Patin 1993

13.3 Environmental impacts of accidental spills of chemicals

The risk of accidental chemical spills at Solsort is considered low as SA-WHPN is being controlled from the platform, which will also (in a closed pipeline system) supply Solsort West Lobe wells with the chemicals necessary for the production. Hence, there will be no transport to or handling of significant quantities of chemicals at SA-WHPN. Hydraulic oil is used in a closed system for wellhead control panel and actuated valves. As this is a closed loop system, there will be no discharge to sea

13.4 Oil spill contingency plan

INEOS has established a legal binding cooperation arrangement with Total E&P Denmark, for mutual assistance in case of an oil spill incident from one of the operator's production installations (INEOS, 2019). This arrangement ensures that four containerized DESMI fast sweep oil collection systems will be available for containing and collecting spilled oil, depending on the magnitude of the spill. In case of blow-out, further resources will be provided by Oil Spill Response Ltd (OSRL).

In Denmark, the preferred response strategy is containment and recovery of spilled oil. Dispersant spraying may be chosen, subject to approval from the DEPA (made official). Details on the specific equipment available for the preferred response strategy (mechanical containment and recovery) for the three tier responses are outlined in Table 13-9.

Study update for effectiveness and capacity of oil spill equipment within INEOS will be conducted. Results from the study will be used for evaluation of capacity and equipment and will feed into the update of the Oil Spill Contingency Plan. The plan will be communicated with the authorities. The oil spill contingency plan will also be updated with drilling and work-over activities.

The period where the risk of an oil spill is highest is during drilling of the reservoir section and lower completion, with a duration of 30 to 40 days per well. INEOS will evaluate if having a strike kit on rig for early mobilisation or onshore to be shipped out for spill combat should be a part of the specific contingency plan for drilling.

Mobilization of the Tier 1 scenario will in 80% of the cases be within 3 hours. The tier 2 scenario will be within 16 hours and for the offshore limitation of the spill in relation to tier 3 scenario it will take 21 hours.

Table 13-9 Characteristics of the Tier 1, Tiers 2 and Tier 3 oil spills and available resources for combatting the three types of spill (INEOS, 2019)

Tier	Characteristics of oil spill	Resources for each Tier
Tier 1	Tier 1 oil spills are likely to be small. The spill can be managed by using INEOS Oil & Gas Denmark pre-arranged vessel resources through contact to Hess. Characteristics of a Tier 1 oil spill: › Spill occurs within immediate site proximity › Minor environmental impact › Spill can be easily managed using oil spill response resources available on site › Spill source has been secured	One containerised DESMI Speed Sweep 1500 system. With an in-built Ro-Skim 1500 skimmer connected to a DOP 250 pump system with a capacity of 100-125 m^3/hour. The sweep system is operated along with a DESMI Ro-Kite 1500 allowing operation of the system by one vessel. The system is stored permanently on *Esvagt Innovator*-the Platform Supply Vessel for Syd Arne Facility-ready for immediate deployment. Esvagt Innovator- liquid storage capability for recovered oil: 1200 m^3. Operated by INEOS.
Tier 2	An incident in which Total, DK Tier 2 response resources and support are required to control the spill. Characteristics of a Tier 2 oil spill: › Spill extends beyond the immediate site proximity › Tier 1 resources are overwhelmed, additional combat resources are required › Potential impact to sensitive areas and/or communities › Spill source cannot be immediately secured	One containerized DESMI Speed Sweep 1500 system with in-built skimmer (as described for Tier 1). The system is stored permanently on *Total* Platform Supply Vessel *Maersk Tracker* for Total E&P DK Danish offshore installations-ready for immediate deployment. *Maersk Tracker* liquid storage capability for recovered oil: 750 m^3 One containerised DESMI Speed Sweep 1500 system with in- built skimmer (as described for Tier 1). The System is stored on the Total E&P offshore installation *Maersk Guardian*- in case of mobilization the system-ready for deployment within 8 hours onto one of their supply vessels (Havila type). Total offshore with 750 m^3 liquid storage capability.

Tier	Characteristics of oil spill	Resources for each Tier
		One containerised DESMI Speed Sweep 1500 system with in-built skimmer (as described for Tier 1). The system is stored onshore in Port of Esbjerg ready for deployment onto a vessel of opportunity. The timeline for this will be dependent on vessel availability and location (estimated at 24 hours) All three systems re owned and operated by Total E&P DK. INEOS, DK Tier1 equipment is also available.
Tier 3	An incident where assistance is required from international (Oil Spill Response Ltd (OSRL)) and national resource. Characteristics of a Tier 3 oil spill: › Uncontrolled well blow- out/loss of well control/HPHT well incidents/Loss of total storage volume › Spill has crossed international maritime boundaries › Tier 1 and 2 resources are overwhelmed requiring international Tier 3 resources to be mobilised (e.g., OSLR) › Risk of significant impact to sensitive areas and local communities	Tier1 and 2 equipment available. INEOS is an Associated member of OSLR and has immediate Oil Spill Response Ltd (OSRL) and has immediate access to Tiers 3 technical advice, resources and expertise 365 days a year/24 hours/ day. In case of a Tiers 3 oil spill OSRL will provide further equipment. INEOS can mobilise up to 50% of the global stockpile of equipment. If there is more than one spill INEOS Oil & Gas Denmark can mobilise 50% of what remains. The nearest stockpile of equipment is in Southampton in UK.

13.5 Risk assessment accidental spills

Based on the above and using the criteria described in chapter 9, it is assessed that the environmental risks related to accidental spills during construction and operation of the Solsort WHP platform is **Low** to **Negligible** (Table 13-10).

Table 13-10 Environmental risk of accidental spills during construction and operation of the Solsort WHP platform.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Likelihood of impact	Environmental Risk
Impacts of oil release during blow-out	Inter national	Medium term	Large	Major impact	Very low	Low risk
Impacts of gas release during blow-out	Local	Short term	Large	Moderate impact	Very low	Negligible risk
Impacts of accidental spills of chemicals	Local	Short term	Low	Insignificant impact	Low	Negligible risk

14. Environmental risk of non-indigenous species (NIS)

The term non-indigenous species means that the species is introduced outside its natural, past or present range (Miljø- og Fødevareministeriet 2019). The vessels used for construction, production and decommissioning activities can potentially introduce non-indigenous species to the North Sea area through marine fouling on vessels or through discharge of ballast water from the vessels. All vessels have a classified approved ballast water management system and certified according to International Oil Pollution Prevention (IOPP) where it is dictated that ballast water must be exchanged at deep waters on open sea between two destinations. The presence of oil and gas platforms may also represent a pathway for NIS.

Distribution of non-indigenous (NIS) related to oil and gas installations are described in OGD's report from February 2017 "Descriptor-based review of 25 years of seabed monitoring data collected around Danish offshore oil and gas platforms". The inventory of the benthic species was compared with catalogues of NIS (AquaNIS, Olenin et al. 2014). The trend in abundance, the temporal occurrence and spatial distribution were evaluated. Four of the more than hundreds of NIS reported in the North Sea were identified in the benthic samples collected at platforms and reference stations from 1989-2015. NIS were typically found in low numbers with an average of 1.2 +/- 0.3 individuals per 0.1 m². The rare occurrence and low abundance reported is not indicative of a well-established population considering that the four benthic NIS observed have been present in the North Sea coastal areas for several decades.

All vessels are coated with antifouling paint to reduce marine fouling. In addition, there is an economic incitement to remove marine fouling from the vessels regularly to minimize use of fuels. The severity of a potential impact is theoretically major if the non-indigenous species become invasive. However, based on the arguments above the environmental risk of introduction of invasive species is assessed to be **Low** (Table 14-1).

Table 14-1 Risk related to non-indigenous species vessels under construction.

Impact	Extension of impact	Duration of impact	Magnitude of impact	Severity of impact	Probability of impact	Environmental risk
Impacts of non-indigenous species	Regional/national	Long term	Moderate	Major impact	Very low	Low

15. Summary of environmental severity and risks

Table 15-1 and Table 15-2 summarises the assessed environmental severities and risks of the Solsort West Lobe development.

*Table 15-1 Environmental severity and risk of **planned activities** during the **construction** phase.*

Impact	Severity of impact	Probability of impact	Environmental Risk
Impacts of discharges from the drilling rig			
Impacts of the discharge of cuttings and drilling mud (WBM)	Minor Impact	Definite	Low risk
Impacts of the discharge of drilling chemicals	Insignificant impact	Probable	Negligible risk
Impacts of underwater noise			
Impacts of underwater noise during site survey	Insignificant impact	Probable	Negligible risk
Impacts of underwater noise during ramming of well conductor casing	Insignificant impact	Probable	Negligible risk
Impacts of drilling noise from rig	Insignificant impact	Probable	Negligible risk
Impacts of underwater noise from support vessels	Insignificant impact	Probable	Negligible risk
Impacts of artificial light			
Improvement of night foraging opportunities for seabirds	-	Probable	Positive effect
Risk of bird collision due to light attraction	Minor impact	Low	Negligible risk
Air emissions during construction			
Impacts of air emissions (VOC)	Insignificant impact	Low	Negligible risk
Impacts of air emissions (NO_X, SO_X)	Minor impact	Low	Negligible risk
Impacts of air emissions (CO_2-eq)	Minor impact	Low	Negligible risk
Impacts from waste			
Impacts of waste	Minor impact	Low	Negligible risk
Impacts of cultural heritage			
Risk of damage of wrecks	Minor impact	Very low	Negligible risk
Impact on hydrography			

Impact	Severity of impact	Probability of impact	Environmental Risk
Impacts on seabed	Insignificant impact	Low	Negligible risk
Impacts on water column	Insignificant impact	Low	Negligible risk
Impacts on benthic fauna	Insignificant impact	Low	Negligible risk
Impacts of accidental spills			
Impacts of oil release during blow-out	Major impact	Very low	Low risk
Impacts of gas release during blow-out	Moderate impact	Very low	Negligible risk
Impacts of accidental spills of chemicals	Insignificant impact	Low	Negligible risk

Table 15-2 Environmental severity and risk of impacts of ***planned activities*** *during the* ***operation*** *phase,* ***accidental spills*** *and* ***decommissioning.***

Impact	Severity of impact	Probability of impact	Environmental Risk
Impacts of planned discharges and emissions from host platform			
Discharge of produced water	Insignificant impact	Probable	Negligible risk
Impacts of air emissions	Insignificant impact	Low	Negligible risk
Impacts of accidental spills			
Impacts of oil release during blow-out	Major impact	Very low	Low risk
Impacts of gas release during blow-out	Moderate impact	Very low	Negligible risk
Impacts of accidental spills of chemicals	Insignificant impact	Low	Negligible risk
Impacts of decommissioning of wells			
Impacts from leaving cutting piles	Insignificant impact	Highly probable	Negligible risk

16. Socio-economic assessment

This chapter consists of an assessment of the potential derived socio-economic consequences for the population or the society in the surrounding area, which could arise from the environmental impact of the project. The surrounding area is defined as the entire west coast of Jutland.

16.1 Method

The socio-economic assessment contains a coverage of the potential socio-economic changes that will result from carrying out the project. The assessment is based on the following sources:

- The descriptions of environmental effects in chapters 10 to 15.
- Statistics from the Danish AgriFish Agency and Statistics Denmark concerning the socio-economic importance of fishing, and the tourist sector in the surrounding area.

The assessment in this chapter is a general assessment of the derived socio-economic consequences without detailed impact assessments and particular economic analysis. Also, the analysis does not consider the consequences of the environmental impacts on the staff who visit the platform in connection with operational tasks.

16.2 The scope

The proposed project potentially results in environmental impacts which can bring on either negative or positive changes experienced by local businesses and societal groups or the society. Some of these environmental impacts can potentially lead to socio-economic consequences. The socio-economic consequences considered in this chapter are:

- Changes in employment
- Changes in fishing industry and tourism due to accidental oil spill and gas escape
- Consequences due to potential discharges and atmospheric emissions.

16.3 The importance of the commercial fishery and tourism industries today

16.3.1 The employment in the fishing sector

According to Statistics Denmark (Statistikbanken.dk 2021), 2,288 people were employed in the fishing sector[3] in 2019 in Denmark (exclusive fish shops, auction houses, wholesale, fishery industry etc.), corresponding to 0.1% of all Danish employees. Of them, 1,781 were employed with marine fishing (77%). Hence, marine fishing represents a high proportion of the total employment in the fishing sector in Denmark. In addition, 3,418 is employed in the fishing industry (Manufacture of fishmeal and Processing and preservation of fish, crustaceans and molluscs). However, compared to the total number of employees in Denmark, the number of employees in the fishing sector is small.

[3] Includes fishing, i.e. fishing catching, collecting and harvesting wildlife aquatic organisms (primarily fish, mollusks and crustaceans) including plants from sea- and coastal inland waters.

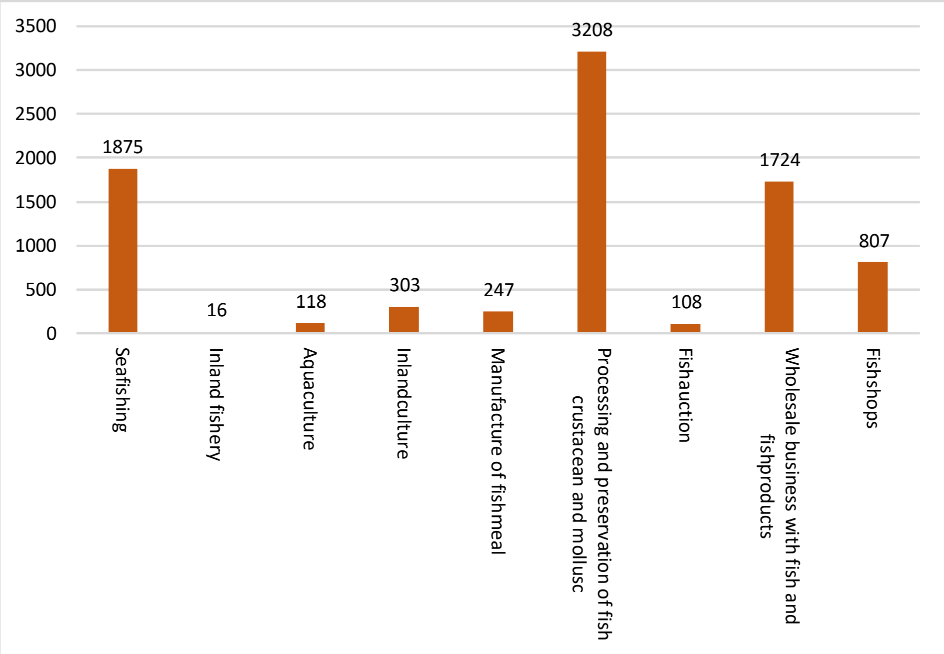


Figure 16-1 Number of people employed in the fishing industry in Denmark in 2013 distributed on sectors. Source: Danish Fisheries Agency, 2014 (based on Statistics Denmark – Register based Labour force Statistic (RAS)).

In 2013[4] most of the employed in the fishing industry (including fish shops, auction houses etc.)[5] worked in the sector 'Processing and preservation of fish, crustacean and mollusc', corresponding to 38 % of the total employed in 2013 (Figure 16-1). The second largest sector is 'Sea fishing', and the third largest is 'Wholesale business with fish and fish products', which constitute 22% and 21% of the total employed in the fishery sector, respectively.

The processing sector thus plays a particularly important role in the total number of employees in the commercial fishery. In this connection, it should be mentioned that the Danish fishermen's landings form only part of the sector's total supplies of fish catch and raw materials (Danmarks Pelagiske Producentorganisation et al. (2018).

Commercial fishery is of particular importance in Jutland, especially in North Jutland (Figure 16-2). Thus, 83% of the total employment in the fishing sector are resident in Region North Jutland, Region Mid Jutland and Region South Jutland, while only 17% are resident in Capital Region and Region Zealand. In case of an oil spill, the commercial fisheries and fishing sector located at the west coast of Jutland, especially North Jutland, is at risk of being economically affected.

[4] 2013 is the latest data concerning the number of employed in the total fishing industry (including shopping).

[5] The total of this statistic differs from the one in mentioned earlier in the text (2,328 people were employed in the fishing industry). It includes fish shops, wholesale trade, auction houses etc.

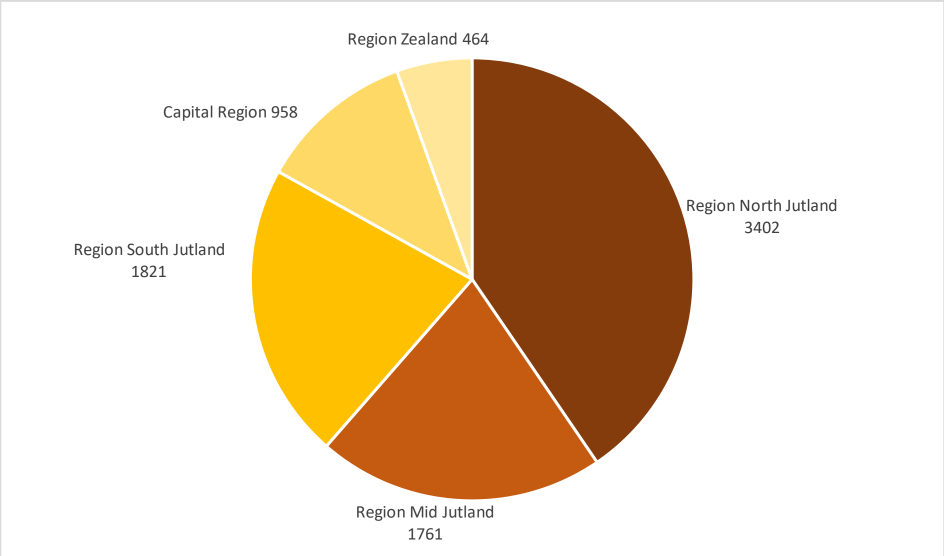


Figure 16-2 Number of people employed in the fishing industry in Denmark in 2013 distributed on Regions. Source: Danish Fisheries Agency[6].

16.3.2 The employment in the tourism industry today

The tourist sector in Denmark creates about 170.000 jobs, corresponding to 6% of all jobs in Denmark (VisitDenmark, 2019). A great part of these jobs is in the gastronomy industry and in the retail sector (VisitDenmark, 2019). 38% of the jobs is created in The Capital Region, 20% in Region South Jutland, 18% in Region Mid Jutland, 11% in Region North Jutland, and 10% in Region Zealand.

The gross value added from the tourist sector were 45 billion in 2012 corresponding to 2.4% of the total gross value added in Denmark (VisitDenmark, 2019).

An oil spill could affect both the number of employed in the tourist sector and the gross value added from the sector. Because the coastal tourism only constitutes a part of the tourist sector and because this part is most dominant in June, July and August, the effect of an oil spill is expected to be limited, although dependent on the amount of oil spilled.

16.4 Derived consequences of environmental impacts

16.4.1 Consequences on employment due to the project

The drilling period is estimated to 280 days, with 140 days per well. Solsort Operator of the Solsort West Lobe area will in corporation with South Arne Operator carry out the drilling, completion and clean-up and bring the wells in production. Thus, the drilling of the two wells is expected to have a minimal effect on employment in the construction phase.

In the operational phase South Arne Operator will be responsible for the ongoing operation and servicing of the two wells. The effect on the employment will therefore also be minor.

16.4.2 Changes in fishing industry and tourism due to accidental oil spill and gas escape

Blowout and rupture of pipelines causing discharge and dispersal of oil are extremely rare events. However, in case of blowout and rupture the environmental impacts may be severe.

[6] See: https://fiskeristyrelsen.dk/fiskeristatistik/alders-og-beskaeftigelsesstatistik/

When evaluating the potential socio-economic consequences of oil spills, the following sectors can be expected to be affected:

- The fishing industry, which consists of fishermen and businesses that are indirectly linked to the fishing industry. Two types of fishery are relevant for the analysis: deep-sea fishery and coastal fishery. For the deep-sea fishery, spawning areas can be affected. For coastal fishery, shallow waters, fjords, bays and beaches can be affected during and following an oil spill.

- Fish farms along the coastal areas and interconnected businesses, which can be affected in the same manner as businesses, involved in coastal fishery.

- Tourism businesses along the coast, which can be affected by oil spills that reaches the shore or shallow waters.

The following consequences have been identified:

- Short term loss of income following a decrease or loss in fish stock, fishing areas, production facilities and recreational facilities. These consequences will be temporary, since they will cease after a clean-up has been conducted, and the fishing stock has recovered.

- Long-term decrease in turnover due to loss of consumers' "goodwill". A loss of goodwill can occur if consumers lose faith in fishery products, tourist spots or beaches. A loss will potentially occur if long-term changes in quality is detected, i.e. if the taste in a future fishing stock is affected, or if local market shares within the affected industries decrease due to opportunistic competitors in other regions.

In socio-economic point of view, the immediate consequences of an oil spill are limited, since an oil spill do not cause significant harm to large fish stocks or destroy tourism or processing businesses at a national level. However, the immediate consequences on local societies can be substantial, especially if the societies in question are vulnerable due to size or dependency on fishery, fish farming or tourism as the primary economic activity.

Multiple scenarios of the unlikely event of a blowout have been modelled. These include different release depths during winter and summer.

The model results show that in case of a blow-out during the summer, oil may strand on beaches along the west coast of Vendsyssel and Thy, the western side of Harboøre Tange, on the south coast of Norway and in a very small area in the northern part of the Swedish Skagerrak coast. Hence, the oil spill will affect Region North Jutland, which has the highest relative amount of employed in the fishing industry and which at the same time has relative many coastal tourists (Chapter 13).

The probability of an oil spill actual affecting areas is however extremely small i.e.:

- Firstly, the risk that a blowout will occur is extremely small.

- Secondly, the probability that these coastlines will be affected by oil in case of a blowout is quite low in most of the areas, i.e. 1-5%. In some areas, the probability is 5-25% and at Skagen it is 25-50%. Along the affected Danish coast, the degree of oiling will only be light to moderate. The oiling on the Norwegian south coast and the Swedish coast will mostly be light (See chapter 13).

- Thirdly, in case of an uncontrolled blow-out or other types of spills INEOS Oil spill contingency plan will be activated, which will significantly reduce the spreading of oil and mitigate impacts of the spill.

In case spilled oil is stranding on the coastlines in question it will mostly be in the form of tar balls, which is relatively easy to remove, especially on sandy beaches (Cf. Chapter 13). In case of a blow-out during the winter, the extent of affected shorelines will be considerably smaller compared to a blow-out during the summer.

The risk of oil spill in connection with rupture of pipelines is as mentioned above low. In case of a rupture, the pressure in the pipelines will drop and the system will be closed immediately.

Finally, it is assessed that a potential oil spill will not affect the fish stocks due to impacts on fish eggs and larvae and therefore do not have a socio-economic effect on the fishing industry (Cf. chapter 13)

16.5 Other consequences

Other consequences include potential impacts from noise, light, discharges and air emissions. As most of the activities take place 250 km from the coast, they will typically not affect neither the population along the coast nor the fishery industry in total.

16.5.1 Consequences of discharges

The construction of wells can lead to

- Discharge of cuttings and drilling mud solids (water-based mud)
- Discharge of chemicals (chemicals from drilling mud, cementing, completion, rig utility and pressure testing)
- Discharge of treated sewage from the drilling rig.

None of the discharges is expected to result in persistent socio-economic effects. Oil based muds and cuttings will not be discharged but collected and sent to shore for recycling and further treatment or possible re-injected in dedicated cutting injection well. The effects of the discharges are assessed in chapter 10.

16.5.2 Consequences of underwater noise

Several of the construction activities in connection with site survey and the drilling of the two wells will generate underwater noise (Cf. chapter 10.3).

It is assessed that the environmental risks related to underwater noise generated during site survey and drilling is Negligible (Cf. Chapter 10). In line with this, it is expected that the activities will not result in persistent socio-economic effects

16.5.3 Consequences of artificial light

The drilling rig will be illuminated during the dark hours and the flaring during clean-up of wells will produce a horizontal flame, that causes substantial light emissions. In clear weather, this flame may be visual from up to 10 km from the platform (CF. chapter 10.4) and be stronger at night than during the day.

Due to the distance and the assessment of the environmental risk, it is assessed that the artificial light will not result in socio-economic impacts.

16.5.4 Consequences of atmospheric emissions

Air emissions are created during the construction and production phases, and can be traced to multiple sources, among which are:

- Emissions from energy production and compressors
- Emissions from transport activities
- Emissions from flaring
- Emissions from maintenance activities.

However, most of the emissions take place 250 km from the coast and will not affect neither the population along the coast nor the fishery industry in total.

17. Cumulative effects

Cumulative effects are the combined effects of projects or ongoing activities within a region. Potential cumulative effects from the development of Solsort WHP fall in two categories. Impacts from construction and operation of Solsort West Lobe wells may interact with:

- impacts from other oil and gas activities, and
- impacts from other activities such as wind farms, cable and pipeline installation and fishery and shipping in the region.

The assessment of potential cumulative effects from the development of Solsort is based on the strategic environmental assessment for the project area carried out in 2012 (Danish Energy Agency, 2012) and the technical report from DCE on the human uses, pressures and impacts in the eastern North Sea (Andersen et al., 2013) and information from DEA.

In addition to the above-mentioned references the DEA has appointed a number of areas for future wind farms (Reservation of additional areas for national tendering of offshore wind farms according to the Energy agreement dated 29 June 2018. Reservation dated 28 August 2019). These areas are although closer to the coastal area about 100 km from the area with oil and gas installation, so no cumulative effects are expected.

EU has appointed a number of cross border infrastructure projects that links the energy systems of EU countries. The projects are typically oil or gas pipelines or cables. The list of these projects is published regularly on an EU homepage (https://ec.europa.eu/energy/en/topics/infrastructure/projects-common-interest). These types of projects can have some environmental impact as underwater noise, sediment spill and discharge of chemicals during construction but no impacts are expected during normal operation.

Potential cumulative effects from the Solsort West Lobe wells are only likely to occur during the construction phase. In the production phase, no extra noise will be generated, and there will be no extra emission or discharges from the Solsort West Lobe wells.

17.1 Cumulative effects with oil and gas related activities

The South Arne field is not located in close vicinity to other oil and gas installations (see Figure 2-1). The closest installation is Harald 30 km from South Arne.

Monitoring surveys have been carried out around Danish platforms in the North Sea for more than 20 years. Results from these surveys show that the impacts of a platform on the physical environment and biological communities reaches no further than 2 km from the platform. Hence, the installation Harald do not impact the South Arne field during normal operation and discharge of oil and chemicals and the other way around .

Other temporary impacts such as noise generation and chemical discharges during construction of wells or installations can possibly have an impact further away from the source. INEOS is not aware of any planned activities at Harald, which has the potential to cause impacts at larger distances (more than 2 km from the platform), during the construction phase of the Solsort West Lobe wells.

Informed by Danish Energy Agency they are currently not evaluating applications for oil and gas installations or construction activities close to the South Arne area, which can have cumulative effect on the environment.

17.2 Cumulative effects with other activities

A mapping of cumulative human pressures and impacts has been carried out for the North Sea (Andersen et al. 2013). The work combines a number of human activities with ecosystem components and presents three indices describing the intensity of human use, the magnitude of the resulting pressures and the potential for cumulative human impacts. The impact index (potential for cumulative human impacts) is shown in Figure 17-1. As it appears from the figure, the South Arne platform is situated in an area of low risk of causing an impact in combination with other activities. The area to the southeast of the South Arne field, where the number of platforms is high, has a higher risk of cumulative effects.

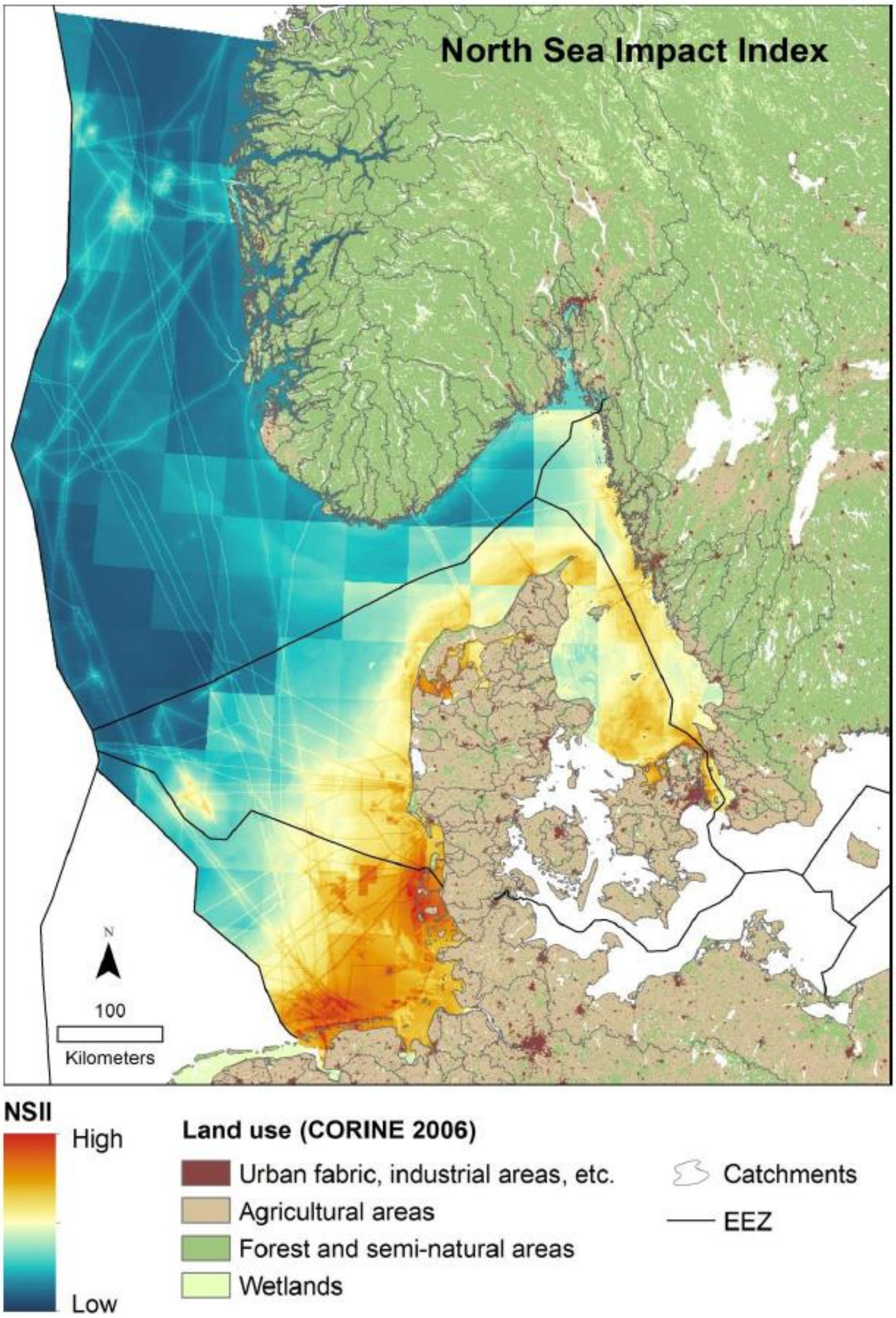


Figure 17-1 The North Sea Impact Index. From Andersen et al. (2013).

The DEA has prepared a map of the areas dedicated to windfarms as shown on Figure 17-2.

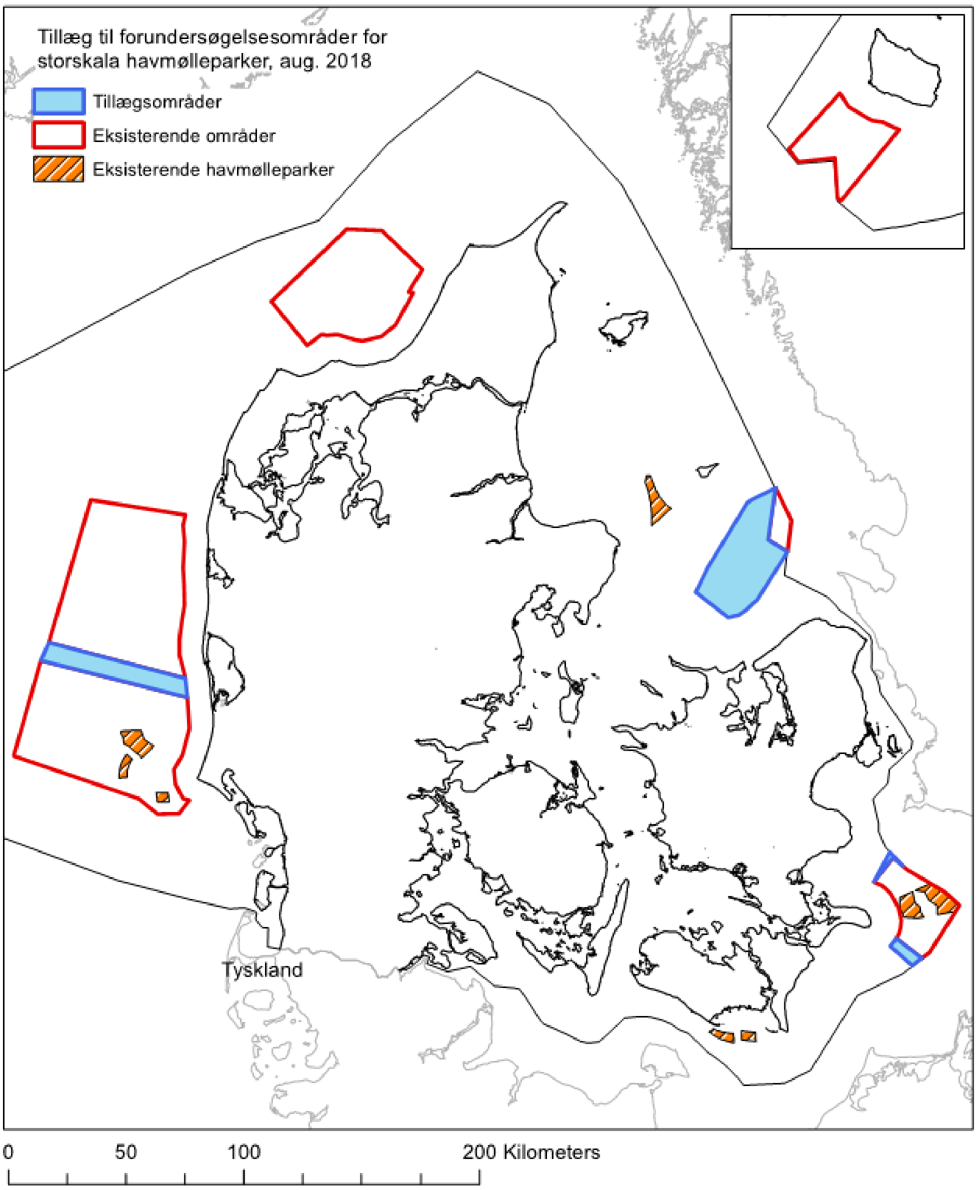


Figure 17-2 Areas appointed for wind farm projects

18. Natura 2000 screening

The Solsort West Lobe wells development must meet the requirements of a Natura 2000 screening set by the Danish authorities in Consolidated Act No. 1595 of 06/12 2018 on identification and administration of international conservation areas and protection of species. This chapter makes up the Natura 2000 screening.

The Natura 2000 screening examines the likely effects of the Solsort West Lobe wells development alone and in combination with other projects upon Natura 2000 sites. The screening includes a description of the legal framework, the basis of the designations and an assessment of the likely environmental impacts of the Solsort field on Natura 2000 sites by referring to previous chapters.

18.1 Objective and procedures

According to the EU Habitats Directive 92/43/EEC of the Council of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, projects are not allowed to significantly impact habitats or species that form the basis of a Natura 2000 designation.

A Natura 2000 screening aim to assess if the project alone or together with other plans and projects is likely to have significant effects on Natura 2000 sites. The screening is based on existing data.

If the Natura 2000 screening shows that the project is likely to have a significant impact on a Natura 2000 site, an appropriate assessment must be conducted according to Article 6 of the Habitat Directive (Directive 92/43/EEC) implemented in Danish regulation as the Nature Protection Act (Consolidation act no. 240 of 13/03/2019). In the appropriate assessment it is assessed if the project will adversely affect the integrity of the site. This is evaluated by assessing the implications for the conservation objectives of the sites. If a significant effect cannot be excluded, alternative solutions must be assessed. In the absence of alternatives, compensatory measures must be assessed (Figure 18-1).

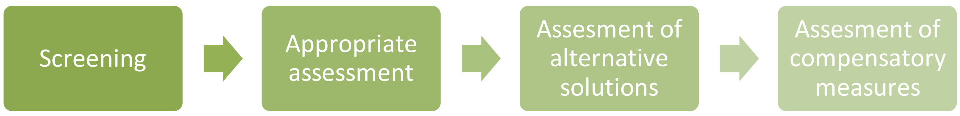


Figure 18-1 Stages of the Article 6 procedures in the assessment of a plan or a project potentially affecting a Natura 2000 site. The current stage of the Natura 2000 assessment of the Solsort field is the screening phase.

18.2 Existing Conditions

18.3 Identification of Natura 2000 sites

South Arne and Solsort is situated far from Danish designated Natura 2000 areas (Figure 8-20). The closest Natura 2000 area is the German Special Area of COncervation (SAC) *Doggerbank* (DE 1003-301) which is located 45 km from Solsort. The Doggerbank extends into the Dutch sector of the North witch is also a designated Natura 2000 area (NL 2008-001) and the UK *Doggerbank* in the UK sector (UK0030352) Sea and Natura 2000 area. In the unlikely event of a major oil spill during a blowout, Danish Natura 2000 areas may also be affected. Table 18-1 lists Natura 2000 sites that potentially can be affected by oil spill or underwater noise.

Table 18-1 Habitats and species that are basis for the designation of Danish Natura 2000 areas northeast of Solsort that may be affected by oil spill, in the unlikely event of a blowout at Solsort. Note: only habitats and species that may be affected by an oil spill is shown.

Natura 2000 area	**Basis for designation**
UK0030352 Doggerbank	1110 Sandbanks 1351 Harbour porpoise 1365 Harbour seal 1364 Grey seal
NL 2008 -001 Doggerbank	1110 Sandbanks 1351 Harbour porpoise 1365 Harbour seal 1364 Grey seal
DE 1003-301 Doggerbank	1110 Sandbanks 1351 Harbour porpoise 1365 Harbour seal 1364 Grey seal
DK00VA348 *Thyborøn stenvolde*	1170 Reef 1351 Harbour Porpoise
DK00VA257 Jyske Rev, *Lillefiskebanke*	1170 Reef 1351 Harbour Porpoise
DK00VA340 *Sandbanker ud for Thyborøn*	1110 Sandbanks which are slightly covered by sea water all the time 1351 Harbour Porpoise
DK00VA259 *Gule rev*	1170 Reef 1351 Harbour Porpoise
DK00VA301 *Lønstrup rødgrund*	1170 Reef 1351 Harbour Porpoise
DK00VA258 *Store rev*	1170 Reef 1351 Harbour Porpoise
DK00FX112 *Skagens Gren og Skagerrak*	1110 Sandbanks which are slightly covered by sea water all the time 1180 Submarine structures made by leak-ing gases 1351 Harbour Porpoise 1365 Harbour seal
DK00EX023 *Agger Tange*	19 different species of sea birds including species of terns, ducks and wading birds.
DK00VA347 *Sydlige Nordsø*	1110 Sandbanks, which are slightly covered by sea water all the time 1351 Harbour Porpoise 1365 Harbour Seal 1364 Grey Seal Red-throated diver, Black-throated diver and Little gull

18.4 SAC *DE 1003-301 Doggerbank*

The German SAC DE 1003-301 *Doggerbank* is situated approximately 45 km south of South Arne/Solsort. DE 1003-301 *Doggerbank* covers 1,624 km². and is situated on a receding flank of the Doggerbank (the Tail end) with water depths increasing from 29 m to about 40 m.

18.4.1 Basis for Designation

The basis for the designation of DE 1003-301 *Doggerbank* is:

- The Annex I habitat type 1110 Sandbanks, which are slightly covered by sea water all the time and
- The Annex II species 1351 *Harbour porpoise* and 1365 *Harbour seal*.

18.4.2 Status and conservation objectives Habitat type 1110 *Sandbanks*

More than 95% of the area of the SAC is sandbanks with mostly fine sands containing many shell fragments and is representative of the open offshore sublittoral zone (Bundesamt für Naturschutz 2008).

The sandbanks are without vegetation and are colonised by a community of benthic infauna that can be characterised as a Bathyporeia-Fabulina (Amphipod-Tellina) community, with the crustacean *Bathyporeia elegans* and the bristle worms *Spiophanes bombyx* and *Spio decorata* as characterising species. Other common species that may be encountered include the crustaceans *Bathyporeia nana, Scopelocheirus hopei* and *Megaluropus agilis,* the bristle worms *Anaitides lineata* and *Sigalion mathildae* and the bivalves *Dosinia sp.* and *Gari fervensis* (Bundesamt für Naturschutz 2008).

Some 38 species on the German Red Lists have so far been recorded in the Doggerbank area. (Bundesamt für Naturschutz 2008).

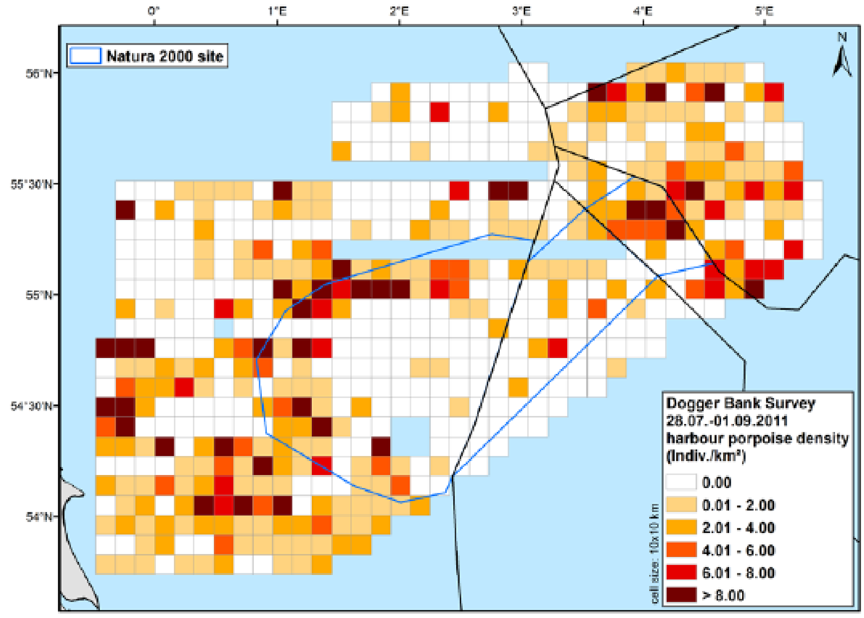
18.4.3 Status and conservation objectives 1351 *Harbour porpoise*

18.4.3.1 Occurrence of Harbour Porpoise

Aerial surveys of the spatial distribution of marine mammals in the Doggerbank area was carried out in August-September 2013 and during summer 2011 (Geelhoed et al. 2014).

The surveys showed that the Doggerbank area constitutes an important habitat for harbour porpoises (*Phocoena phocoena*) in the North Sea. The 2013 survey resulted in an abundance estimate of ca. 45.000 individuals. This represents a substantial proportion of the abundance estimate for the North Sea and adjacent waters (i.e., ca. 12%).

The main aggregations were encountered outside the shallow parts of the Doggerbank. In 2011 and 2013 high densities of harbour porpoise was observed on the western/ south-western slope of the bank and the area between the bank and the UK coast. In 2011, high densities were also observed in the Danish sector north-east of the Doggerbank.



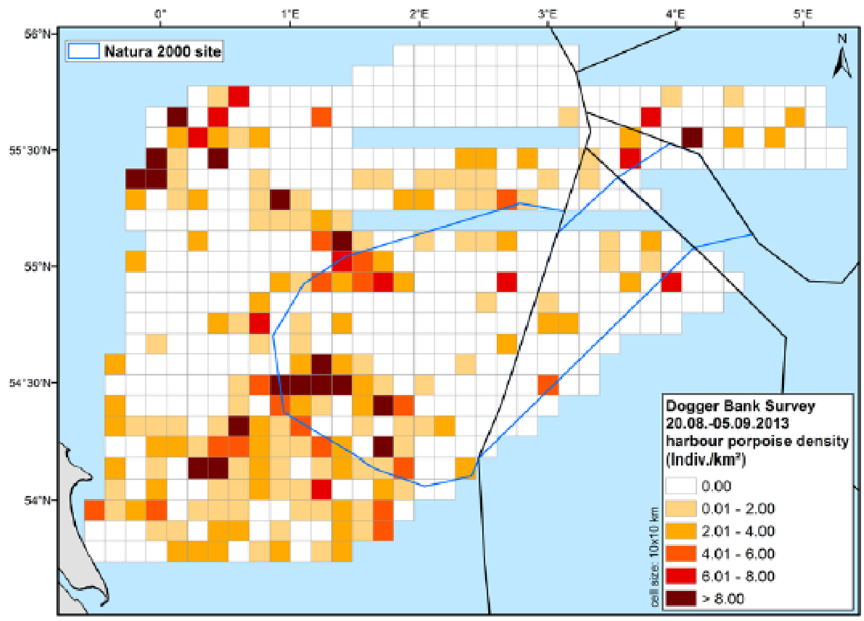


Figure 18-2 Spatial distribution of harbour porpoise density (number/km^2) in the Doggerbank area during 2011 (top) and 2013 (bottom. From Geelhoed et al. 2014).

18.4.3.2 Biology of harbour porpoise

Harbour porpoise is the most abundant cetacean species in the North Sea. A clear seasonal pattern is apparent in the presence of harbour porpoises. A peak in numbers in coastal waters of the southern North Sea is reached between February and April and in late spring, a northward migration towards more offshore waters is observed (Haelters & Camphuysen 2010).

Harbour porpoises feed mostly on fish such as cod, whiting, mackerel, herring and sprat. They tend to be solitary foragers but do sometimes hunt in packs. The mating season is July-August. The gestation period typically lasts 10–11 months and most births occur in late spring and summer. Calves are weaned after 8–12 months.

18.4.4 Status and conservation objectives 1365 *Harbour seal*

Harbour seal (*Phoca vitulina*) is the only species of seal that has been observed regularly in the central part of the North Sea. Harbour seals are primarily coastal, depending on isolated and undisturbed land areas for resting, breeding and moulting (such as undisturbed islands, islets sandy beaches, reefs, skerries and sand-banks). They are gregarious animals and when not actively feeding, they will haul onto a terrestrial resting site. The harbour seal does not generally venture more than 20 kilometres offshore. However, radio-tagging experiments using satellite tracing have indicated that harbour seals may undertake foraging migrations far out into the North Sea from their core areas along the coast (Tougaard et al. 2003, Tougaard 2007). They are known to prey primarily on fish such as herring, mackerel, cod, whiting and flatfish, and occasionally upon shrimp, crabs, molluscs and squid. Females give birth once a year, with a gestation period of approximately nine months. Harbour seal breed in large numbers in the Wadden Sea. It is less common along the British coast.

18.5 SAC *NL 2008-001 Doggerbank*

18.5.1 Basis for Designation

The basis for the designation of NL 2008-001 *Doggerbank* is:

- The Annex I habitat type 1110 Sandbanks, which are slightly covered by sea water all the time and
- The Annex II species 1351 *Harbour porpoise*, 1365 *Harbour seal* and 1364 *Grey seal*

There is currently no basis analysis and management plan for the SAC NL 2008-001 Doggerbank. The general conservation objective is to protect habitat types and species that are the basis for the designation.

18.5.2 Status of and conservation objectives of Habitat type 1110 *Sandbanks*

The habitat type covers approximately 4.700 km² which is almost all the designated Natura 2000 area. The area is shallow with water depth in the range 24-40 m. There is limited literature about the Dutch part of the Doggerbank, but its major characteristics is assumed to be comparable to the UK section of the bank. I.e., it is composed of fine sand with no vegetation.

18.5.3 Status and conservation objectives 1351 *Harbour porpoise*

The status of harbour porpoise (*Phocoena phocoena*) in the central North Sea is described in section 18.4.3 above. The total number of harbour porpoises on the Dutch Continental Shelf has been estimated at 46,580 individuals (Geelhoed 2017) (Figure 18-3). The highest abundance was observed offshore, while the Dogger Bank was a less important habitat accounting less than 3 % of the total population in Dutch North Sea.

It has not been possible to find specific information on conservation objectives for harbour porpoise in NL 2008-001 *Doggerbank*.

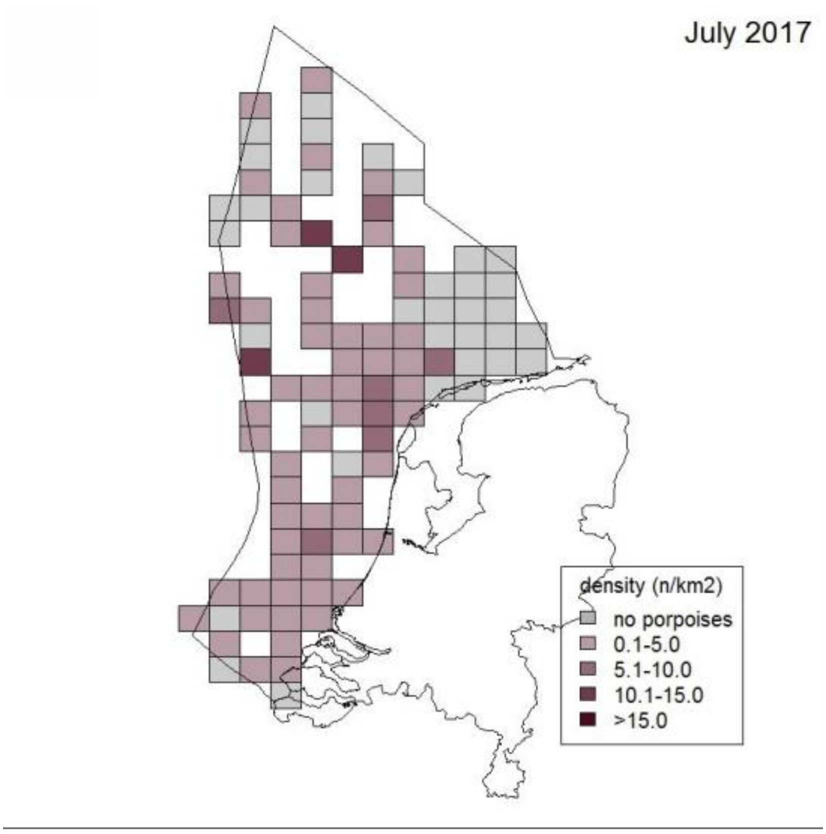


Figure 18-3 Density of Harbour porpoises in the Dutch North Sea. From Geelhoed et al. 2017.

18.5.4 Status and conservation objectives 1365 *Harbour seal*

There are no specific data on the status of harbour seal (*Phoca vitulina*) in NL 2008-001 Doggerbank. However, arial surveys were conducted in 2017 in the Dutch part of the North Sea where there were a few sightings. It is however assumed that they migrate to the area from the Wadden Sea to forage. The harbour seal population in the Dutch part of the North Sea is estimated to 6000 individuals (Nordseelocket). Of these most occur in the Wadden Sea.

18.5.5 Status and conservation objectives 1364 *Grey seal*

The Dutch North Sea zone is an important area for Grey seal in terms of foraging and migration. Seals spend most of their time near their breeding colonies (haul outs), but the grey seal may also migrate long distances to forage. Seals foraging at the Doggerbank are reported to belong to hauls from the Frisian Front and the Wadden Sea but may as well originate from the UK (Brasseur et al. 2010). 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.

18.6 SAC *UK0030352 Doggerbank*

18.6.1 Basis for Designation

The basis for the designation of *UK0030352 Doggerbank* is:

- The Annex I habitat type 1110 Sandbanks which are slightly covered by sea water all the time and
- The Annex II species 1351 *Harbour porpoise*, 1365 *Harbour seal* and 1364 *Grey seal*

18.6.2 Status and conservation objectives Habitat type 1110 *Sandbanks*

The habitat type 1100 Sandbanks covers almost the entire UK Doggerbank. Large parts of the sandbanks are in the southern part covered by less than 20 m water. The bank is without vegetation and is moderately mobile with clean sandy sediments. The fauna of the banks is impacted by bottom trawling which has reduced the number of long lived or fragile organisms. The fauna is therefore dominated by robust short-lived invertebrates including polychaetes such as *Nephthys cirrosa*. The major parts of the bank are intact. Sandeels are an important prey resource found at the bank supporting a variety of species including fish, seabirds and cetacean (JNCC, 2017).

18.6.3 Status and conservation objectives 1351 *Harbour porpoise*

The Doggerbank is a core area for harbour porpoises and the population is well documented. In 2013 the Harbour porpoise population at Doggerbank was investigated by aerial surveys. The total population was estimated to 45.000 individuals. Of these more than half were observed on the slope of the bank in the UK sector of the Doggerbank (Geelhoed et al. 2014) (see also section 18.4). In the shallow part of the banks, the density of harbour porpoises is generally lower.

18.6.4 Status and conservation objectives 1365 *Harbour seal*

Harbour seal (*Phoca vitulina*) is known to visit the Doggerbank (Geelhoed et al. 2014). There are no specific data on the population occurring on Doggerbank, but it is a common foraging visitor.

18.6.5 Status and conservation objectives 1364 *Grey seal*

The grey seal (*Halichoerus grypus*) breeds in several colonies on islands on the east coasts of Great Britain. Tagging experiments have indicated that grey seals breeding in Great Britain migrate long distances into the North Sea from their breeding colonies (McConnell et al. 1999) and migrate to the Doggerbank to forage. 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.

18.7 Potential impacts assessed

The potential effects from construction, production and decommissioning of the new concept for Solsort have been assessed as a part of the environmental impact assessment in chapter 10 to 15. The results of these assessments have been used as basis for the Natura 2000 preliminary appropriate assessment (Natura 2000 screening) of the new concept for Solsort.

The following potential impacts on Natura 2000 sites and Annex IV species have been assessed:

- Impacts of a major oil spill during an uncontrolled blowout
- Impact of underwater noise from site survey for shallow gas at relief well site, ramming of well conductor casing, drilling noise and support vessels.

Other operations and incidences taking place during the construction, operation and decommissioning of the production wells are not considered to potentially affect the distant Natura 2000 sites.

18.8 Impacts of oil spill during blowout

A blowout is the uncontrolled release of crude oil and/or natural gas from a well after pressure control systems have failed. The probability of a blowout occurring is very low but in case a blowout occurs, wide reaching and severe impacts on the marine environment may occur.

Impacts of a blowout at Solsort on Natura 2000 habitats and species has been assessed in chapter 13. The assessment is based on an OSCAR statistical oil drift model and known effects of oil on the habitats, and species that form the basis for the designating of the Natura 2000-areas.

It is concluded that the Solsort West Lobe wells will not negatively affect the conservation status of habitats and species, for which potentially affected Natura 2000-sites have been designated as well as species listed on Annex IV of the EU Habitats directive (Directive 98/43EEC of 21 May 1992). Nor will the project affect the integrity of the areas negatively.

The conclusion is based on following arguments:

- The probability that a blowout will occur is extremely small.
- The prevailing current at the Solsort is east going which reduces likelihood of affecting the nearest Natura 2000 areas (German and Dutch Natura 2000 areas 45 km south of Solsort).
- In the unlikely event of a blowout and in a case when oil spill combat is not carried out, impacts on the conservation status of 1351 *Harbour porpoise*, 1365 *Harbour seal* and 1365 *Grey seal* as well as the conservation status and integrity of 1110 Sandbanks in the nearest Natura 2000 areas (German and Dutch Natura 2000 areas 45 km south of Solsort) is assessed to be limited:

Harbour porpoises, Harbour seals and Grey seals may be affected by oil, but it is assessed that only a tiny fraction of the populations the three species in the North Sea is likely to be affected. It is therefore not likely that a potential oil contamination from a blow-out will significantly affect the population sizes of the three species.

There may be a risk of sedimentation of oil on the habitat type 1110 *Sandbanks*, especially in the German area, thereby affecting the benthic infauna community.

- An unmitigated blowout incidence is assessed to cause only low to insignificant impacts on the Natura 2000 habitats and species in the UK Natura 2000 area at Doggerbank as well as Danish Natura 2000 off the Danish west coast.
- In case of an uncontrolled blow-out or other types of spill INEOS's oil spill contingency plan will be activated, which will reduce the spreading of oil and mitigate impacts of the spill.

18.9 Impacts of underwater noise

The assessment of impact from underwater noise on Natura 2000 species is assessed in detail in chapter 10.3.6. The assessment includes impacts of following operations:

- Site survey
- Ramming of well conductor casing.
- The drilling operation proper, including noise from the rotating drill string, machinery, pumping systems and miscellaneous banging of gear on the rig; and
- Machinery, propellers and thrusters of ships operating in connection with the drilling operations.

Underwater noise may affect marine organisms in different ways. Cetaceans (whales, porpoises and dolphins) are particular vulnerable to underwater noise since they depend on acoustics for orientation and communication. The cetacean species Harbour porpoise is on the designation basis of a number of Natura 2000 sites in the North Sea and may potentially be affected by underwater noise during construction of wells and drilling operations.

Based on the distance from the Solsort and South Arne fields to the nearest Natura 2000 site (45 km from Solsort) it is concluded that underwater noise from site survey, ramming of well conductor casing and drilling noise will have insignificant impact on the conservation objectives of the habitat types and species in the Natura 2000 sites. Impacts in terms of permanent and temporary hearing loss for marine mammals are limited to distances within 5m and 20m from the ramming site, respectively. Avoidance reactions or other behavioural effects seen in marine mammals may take place within a distance 100 m from the ramming site.

In addition, it is expected that the noise from site survey, ramming, drilling and vessels will scare cetaceans (Annex IV species) to safe distances from the working field. If noise work occurs, a marine mammal observer (MMO) can look for mammals in the vicinity of the area. If Harbour porpoises and other cetaceans are not scared away, 'pingers' (seal scarers) can be used as mitigating measures.

18.10 Conclusion

It is concluded that the Solsort West Lobe wells will not negatively affect the conservation status of habitats and species, for which potentially affected Natura 2000-sites have been designated as well as species listed on Annex IV of the EU Habitats directive (Directive 98/43EEC of 21 May 1992). Nor will the project affect the integrity of the areas negatively.

19. Danish Marine Strategy II

19.1 Potential impacts that are assessed

The activities during construction, production and decommissioning of the Solsort West Lobe wells may potentially affect the Marine Strategy Framework Directive's (MSFD) 11 descriptors for Good Environmental Status (GES). The project activities that may potentially affect GES are listed below in Table 19-1.

Table 19-1 Activities potentially affecting the MSFD's 11 descriptors of Good Environmental Status (GES) of the European seas. According to the Danish Marine Strategy II, chapter 7.7 the main impacts are due to planned and unplanned discharge of oil and chemical, underwater noise and light. The impacts are marked with bold text

Project phase	Activity
Construction	› **Ship noise, noise from installation of rig and ramming of well conductor casing, drilling noise, site survey.** › Physical disturbance and damage of the seabed › **Planned discharge of chemicals** and treated sewage. › **Accidental spill and blowout events** › Spreading of non-indigenous species though ballast water and marine fouling on vessels
Production phase	› **Discharge of produced water and chemicals** › Waste › **Accidental spill and blowout event**s › Spreading of non-indigenous species though ballast water and marine fouling on vessels and oil and gas production platforms as steeping stones for distribution of NIS.
Decommissioning	› **Ship noise, noise from rig and removal of installation during decommissioning** › Physical disturbance and damage of the seabed during decommissioning › Spreading of sediment › **Planned discharge of chemicals** and treated sewage. › Waste › **Leaving cutting piles** › Spreading of non-indigenous species though ballast water and marine fouling on vessels

In the following sections the impacts are compared with the environmental targets from the Danish Marine Strategy II.

The descriptors D1, D4 and D6 are related to the existing conditions of the marine environment while descriptor D2, D3, D5 and D7-D11 are related to the impact on the marine environment from human activities.

According to the Danish Marine Strategy II (Miljø- og fødevareministeriet 2019) which implement the MSFD, the most important impacts in the North Sea/Skagerrak are caused by the parameters: nutrients, non-indigenous species, fisheries, noise, contaminants, marine litter (micro plastic in sediment), shipping and physical modifications (Danish Marine Strategy II figure 19.16). The most important parameters from the project are planned and unplanned discharge of chemicals and oil to the sea and underwater noise.

19.2 Descriptor 1 – Biodiversity

The environmental targets for descriptor 1 from the Danish Marine Strategy II for birds, marine mammals and fish are shown in Table 19-2 . It is also marked if the descriptor is impacted by the Solsort West Lobe project.

Description of the status of birds, marine mammals and fish in the project area are described in 8.8, 8.9 and 8.10. The environmental targets for descriptor 1 are described in Table 19-2.

Table 19-2 Environmental targets for descriptor 1 according to the Danish Marine Strategy II

	Targets	Impact from the Solsort West Lobe project	Comments
Birds	1.1 Incidental by-catch of birds is at a level that does not threaten the species in the long term	Not applicable	
	1.2 Populations and habitats for birds are conserved and protected in accordance with objectives under the Birds Directive	Population identified in the project area, which are covered by the Danish Marine Strategy I - monitoring programme: Kittiwake (Rissa tridactyla) and Guillemot (Uri aalge) The trend for the population is unknown according to table 22.4 in the Danish Marine Strategy II.	Population described in Section 8.8. The project area is not considered as important for seabirds.
	1.3 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status, and works to ensure that the status for biological diversity is in accordance hereto	Not applicable	The oil and gas industry are not involved in the work with establishment of threshold values
	1.4 More knowledge about by-catch of seabirds is collected pursuant to the relevant monitoring programmes.	Not applicable	
Marine mammals	1.5 Need for protection initiatives for HELCOM and OSPAR Red List species is assessed. If there are any Red List species that are endangered or not sufficiently protected, the Ministry of Environment and Food will assess specifically the need for further initiatives in collaboration with relevant ministries.	Information is included about the population of harbour porpoise, harbour seal and grey seal in the projects area covered by the Danish Marine Strategy I monitoring programme. The project area is although not a core area for these species.	Population described in section 8.9.
	1.6 Incidental by-catch of harbour porpoise is reduced as much as possible, and as a minimum to a level below 1.7% of the total population	Not applicable	
	1.7 Incidental by-catch of seals is at an adequately low level that does not threaten populations in the long term.	Not applicable	

	Targets	Impact from the Solsort West Lobe project	Comments
	1.8 Harbour porpoise, harbour seal and grey seal achieve favourable conservation status in accordance with the timeline laid down in the Habitats Directive.	The impact is temporary and will not influence on the population.	Impacts on marine mammals from drilling noise is described in 10.3.6 and unplanned oil release is described in 13.1.6. Mitigating actions described in section 21.2.
	1.9 The Ministry of Environment and Food contributes to setting population-specific threshold values for by-catches of harbour porpoise in a regional context with a view to subsequently setting environmental targets for vulnerable populations of harbour porpoise.	Not applicable	
	1.10 More knowledge about by-catches of marine mammals is collected pursuant to the relevant monitoring programmes.	Not applicable	
	1.11 The Ministry of Environment and Food carries out an analysis of by-catches of shark and ray in Danish marine areas, and the possibility of a DNA-based approach to determining species is investigated.	Not applicable	
Fish	1.12 The Ministry of Environment and Food establishes a national indicator to evaluate the status of Danish fish that are not exploited commercially, and the opportunities to further develop regional indicators are investigated.	Not applicable	O&G industry not involved in establishment of indicators.
	1.13 The abundance of plankton follows the long-term average.	The primary production of plankton is generally higher in the coastal regions compared to offshore areas. Solsort and South Arne are in an area with low plankton production	The conditions of plankton in the project area are described in section 8.4.
	1.14 The Ministry of Environment and Food is tracking developments and improving the knowledge base about plankton through monitoring.	The condition of plankton in the project area is described in section 8.4.	The primary production of plankton is generally higher in the coastal regions compared to offshore areas.

19.3 Descriptor 2 – Non-indigenous species (NIS)

The environmental targets for descriptor 2 are described in Table 19-3.

Distribution of non-indigenous species (NIS) related to oil and gas installations are described in OGD's report from February 2017 "Descriptor-based review of 25 years of seabed monitoring data collected around Danish offshore oil and gas platforms", see section 14. The environmental targets for descriptor 2 are described in Table 19-3.

Table 19-3 Environmental targets for descriptor 2 according to the Danish Marine Strategy II

	Goals	Impact from the Solsort West Lobe project	Comments
NIS	2.1 The number of new non-indigenous species introduced through ballast water, ship fouling and other relevant human activities is decreasing	Two species identified as NIS in the South Arne area. The rare occurrence and low abundance reported is not indicative of a well-established population considering that the four benthic NIS observed in the areas with oil and gas installations have been present in the North Sea coastal areas for several decades.	Non-indigenous species are described in section 8.7.3. Impacts from NIS described in section 14.
	2.2 The distribution of certain invasive species is, as far as possible, at a level so that significant adverse effects are stable or decreasing.	Two species identified as NIS in the South Arne area. The rare occurrence and low abundance reported is not indicative of a well-established population considering that the four benthic NIS observed in the areas with oil and gas installations have been present in the North Sea coastal areas for several decades.	Non-indigenous species are described in section 8.7.3 Impacts from NIS described in section 14.
	2.3 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status, and works to ensure that the number of new non-indigenous species and impacts from invasive species are in accordance hereto	Not applicable	The oil and gas industry not involved in the work with establishment of threshold values

19.4 Descriptor 3 – Commercially exploited fish stocks

The commercially exploited fish in the area are described in section 8.10.3. Table 8-17 shows the state of the stock. The only stock in poor condition is cod. The area around South Arne and Solsort are although not considered as a core area for cod, see table 8-14. The environmental targets for descriptor 3 are described in Table 19-4.

Table 19-4 Environmental targets for descriptor 3 according to Danish Marine Strategy II

	Targets	Impact from the Solsort West Lobe project	Comments
Commercially exploited fish stock	3.1 The number of commercially exploited fished stocks regulated pursuant to the MSY principles in the Common Fisheries Policy is increasing.		Descriptions of fish in the project area is described in section 8.10. Commercially exploited fish stocks are described in 8.10.3.
	3.2 Within the framework of the Common Fisheries Policy, fish mortality (F) is at levels that can ensure a maximum sustainable yield (Fmsy).	The impact from O&G in relation to fish mortality is expected to be insignificant. Short term impact can be expected in connection with an unplanned oil spill, see section 16.4.2.	

	Targets	Impact from the Solsort West Lobe project	Comments
	3.3 Within the framework of the Common Fisheries Policy, spawning biomass (B) exceeds the level that can ensure a maximum sustainable yield (MSY Btrigger)	Commercially exploited fish stocks are described in 8.10.3.	

19.5 Descriptor 4 – Food webs

Based on these assessments the potential impacts on the environmental targets for descriptor 4, marine food webs, in connection to construction works, production and decommissioning of the new Solsort concept, are assessed not to prevent or delay the achievement of good environmental status for this descriptor.

Marine food webs can potentially be affected by physical disturbance of the seabed, underwater noise, artificial light, planned discharge of chemicals and unplanned oil spill (blowout). The environmental targets for descriptor 4 are described in Table 19-5.

Table 19-5 Environmental targets for descriptor 4 according to Danish Marine Strategy II

	Targets	Impact from the Solsort West Lobe project	Comments
Food webs	4.1 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status and works to ensure that the anthropogenic impacts on the food web are in accordance hereto.	No impact	The oil and gas industry are not involved in establishment of thresholds
	4.2 The Ministry of Environment and Food contributes to regional knowledge and methodology development on marine food webs.	The seabed monitoring programme conducted around the oil and gas installations conducted every 3 years gives input to the knowledge of the benthic fauna.	The existing conditions of the food web is described in section 8 including plankton, benthic fauna, fish, birds and marine mammals. The impacts on the food web are described in section 10-15.
	4.3 The Ministry of Environment and Food is tracking the development in the food web through monitoring the individual sub-elements of the web	The seabed monitoring programme conducted around the oil and gas installations conducted every 3 years gives input to the knowledge of the benthic fauna.	The existing conditions of the food web is described in section 8 including plankton, benthic fauna, fish, birds and marine mammals.

19.6 Descriptor 5 – Eutrophication

As described in the Daish Marine Strategy 2, section 12 the loads related to eutrophication is mainly due to discharge from land-based activities. The environmental targets for descriptor 5 are described in Table 19-6.

Table 19-6 Environmental targets for descriptor 5 according to the MSDF II

	Targets	Impact from the Solsort West Lobe project	Comments
Eutrophication	5.1 The Ministry of Environment and Food contributes to regional work regarding establishment of threshold values and determination of good environmental status for the North Sea, including the Skagerrak, and works to ensure that anthropogenic eutrophication and its effects are in accordance hereto	No impact	
	5.2 Danish inputs of nitrogen and phosphorus (TN, TP) comply with the maximum acceptable inputs stipulated under HELCOM.	No impact.	Impact described in 8.7.4
	5.3 Coastal waters: Target loads and needs for measures for fjords, estuaries and coastal waters determined in accordance with the Water Framework Directive are complied with. Targets and needs are described in the Danish river basin management plans	No impact as activities not in the coastal waters.	

19.7 Descriptor 6 – Sea Floor Integrity

The physical disturbance of the seafloor from oil and gas installation is limited as described in table 13.3 in the Danish Marine Strategy II. The only impact from the Solsort project on the seafloor will be during the location of the spud cans and discharge of water-based mud. The impact will be temporary. The environmental targets for descriptor 6 are described in Table 19-7.

Table 19-7 Environmental targets for descriptor 6 according to the Danish Marine Strategy II

	Targets	Impact from the Solsort West Lobe project	Comments
Losses and physical impacts	6.1 Ministry of Environment and Food contributes to work regionally and in the EU regarding establishment of threshold values and determination of good environmental status, and works to ensure that losses, physical disturbance and adverse effects on the sea floor are in accordance hereto.	As mentioned in the	
	6.2 The knowledge base about the Danish sea floor, as well as the abundance and the location of the benthic habitats and their status, is improved pursuant to the monitoring programme (NOVANA)	The only impact from the Solsort project on the seafloor will be during the location of the spud cans of the rig on the seafloor. The project will give input on physical disturbance as required. The physical disturbance is temporary.	Impact on the seafloor is described in section 8.7.5

	Targets	Impact from the Solsort West Lobe project	Comments
	6.3 Through regional work and the work in the EU, better understanding of the impacts on the sea-floor in relation to losses, disturbances and adverse effects is achieved.	The only impact from the Solsort project on the seafloor will be during the location of the spud cans of the rig on the seafloor. The project will give input on physical disturbance as required. The physical disturbance is temporary.	Impact on the seafloor is described in section 8.7.5
	6.4 In connection with licensing offshore activities requiring an environmental impact assessment (EIA), the approval authority encourages assessment and reporting to the Danish Environmental Protection Agency (monitoring programme) of the extent of physical losses and physical disturbances of benthic broad habitat types.	The only impact from the Solsort project on the seafloor will be during the location of the spud cans of the rig on the seafloor. The project will give input on physical disturbance as required. The physical disturbance is temporary.	Impact on the seafloor is described in section 8.7.5
Habitat types and sea floor	6.5 The marine habitat types under the Habitats Directive achieve favourable conservation status in accordance with the timeline laid down in the Habitats Directive.	The habitat in the area is offshore circalittoral mud, which total area in the North Sea is 18,170 km². The area of the spud cans is very small compared to the area of the habitat and is considered to have no impact on the habitat in the area.	Impact on the habitat type is described in section 8.7.5
	6.6 The northern Sound is designated as a marine protected area pursuant to the Marine Strategy Framework Directive, and new licences to extract mineral resources are stopped. This will not result in any changes in relation to the existing fisheries regulation.	No impact	
	6.7 The most important habitats contain the typical species and communities for Danish marine areas.	The habitat in the area is offshore circalittoral mud, which total area in the North Sea is 18,170 km². The area of the spud cans is very small compared to the area of the habitat and is considered to have no impact on the habitat in the area.	Impact on the habitat type is described in section 8.7.5
	6.8 When threshold values for losses, disturbances and adverse effects are established through cooperation at regional and Union level, the Ministry of Environment and Food will initiate a project to form the basis for establishing environment targets in accordance with the thresholds and good environmental status.	No impact	
	6.9 Need for protection initiatives for HELCOM and OSPAR Red List habitats is assessed. If there are any natural habitats on the Red Lists that are endangered or not sufficiently protected, the Ministry of Environment and Food will assess specifically the need for further initiatives in collaboration with relevant ministries.	The habitat in the area is offshore circalittoral mud, which total area in the North Sea is 18,170 km². The area of the spud cans is very small compared to the area of the habitat and is considered to have no impact on the habitat in the area.	Impact on the habitat type is described in section 8.7.5

	Targets	Impact from the Solsort West Lobe project	Comments
	6.10 The need for additional marine protected areas or other initiatives in the Baltic Sea and the North Sea is assessed, and a similar assessment is subsequently carried out for the Danish Straits.	No impact	

19.8 Descriptor 7 – Alteration of hydrographical conditions

The hydrographical conditions are both described in the South Arne EIA and in section 8.1 in the present EIA. The substructure of the rig will be temporary located in the water column, but the extension of the structure is considered to give only very local impact and not be able to measure.

The project will alter the hydrographical conditions locally around the rig. The hydrographical conditions will revert to existing conditions once the rig disappears.

The environmental targets for descriptor 7 are described in Table 19-8.

Table 19-8 Environmental targets for descriptor 7 according to the Danish Marine Strategy II.

	Targets	Impact from the Solsort West Lobe project	Comments
Alteration of hydrographical conditions	7.1 Anthropogenic activities that are particularly associated with physical loss of the sea floor, and which cause permanent hydrographical changes • only have local impacts on the sea floor and in the water column, and • are designed to take account of the environment and what is technically possible and financially reasonable to prevent harmful effects on the seabed and in the water column.	Only limited and local temporary impact.	Hydrographical conditions described in 8.1 and impacts described in section 10.8.
	7.2 In connection with licensing offshore activities requiring an environmental impact assessment (EIA), the approval authority is encouraging reporting to the Danish Environmental Protection Agency (monitoring programme) of hydrographical changes and the adverse effects of these.	Only limited and local temporary impact.	Hydrographical conditions described in 8.1 and impacts described in section 10.8.

19.9 Descriptor 8 – Contaminants

Several monitoring studies have shown that the bulk of discharged cuttings and WBM components deposit in the immediate vicinity of the wellhead. Alterations to benthic infauna communities following the discharge of cuttings and WBM are generally restricted to within 100-200 m from the platform.

The impact from discharge of chemicals during production is not impacted by the tie-in of the Solsort West Lobe wells. Well service chemicals can although have an impact in up to 4700 m from the platform. These chemicals are although only used as batch treatment for up to 2 hours and is not a continuous impact. The environmental targets for descriptor 8 are described in Table 19-9.

Table 19-9 Environmental targets for descriptor 8 according to the Danish Marine Strategy II.

	Targets	Impact from the Solsort West Lobe project	Comments
Contaminants	8.1 Discharges of contaminants in the water, sediment and living organisms do not lead to exceeding of the environmental quality standards applied in current legislation	According to the Danish Marine Strategy Directive II threshold values are decided for PFOS, PBDE, Benz(A)pyrene and mercury. Only Benz(A)pyrene and mercury are present around the installations in very small concentrations. The values can although not directly be compared as the thresholds are defined by concentrations in fish or mussels.	Contaminant at the seabed around Solsort and SA is described in section 8.7.6. Discharge of oil and chemicals during construction, production and decommissioning of the two wells are described in section 5.5, 5.7.3, 6.3 and 7.2. The impact from planned and unplanned discharges of oil and chemicals are described in section 10.2, 11.2.2, 12.2.1.1 and 13.
	8.2 Emissions, discharges and losses of PBDE and mercury are ceased or phased out	See 8.1	
	8.3 The Ministry of Environment and Food contributes to work regionally and in the EU regarding establishment of threshold values and determination of good environmental status and works to ensure that the quantities of contaminants are in accordance here to.	Information about chemicals used offshore is communicated to the Authorities as part of the discharge applications and permit reporting conditions.	
	8.4 There is a gradual decrease in the levels of imposex/intersex in marine gastropods.		
	8.5 By 2021, a process has been carried out to trace the source of the most polluting substances which prevent meeting the environmental targets laid down for surface water bodies in the Water Framework Directive. If necessary, the relevant licences and permits will be revised as far as possible	See 8.1	
	8.6 The Ministry of Environment and Food is working to ensure that more indicators for contaminants are established	See 8.1 and 8.3	
	8.7 The Ministry of Environment and Food ensures increased coordination between policy areas/directives when new national environmental quality requirements are set for selected substances in matrices, where there is monitoring data.	See 8.1 and 8.3	
	8.8 The Ministry of Environment and Food is working to develop additional regional joint tests for biological impacts.	See 8.1 and 8.3	

	Targets	Impact from the Solsort West Lobe project	Comments
	8.9 The spatial extent and duration of acute pollution events is gradually reduced as much as possible through prevention, monitoring and risk-based scaling of contingency and response facilities.	Acute pollution events are extremely rare events. The risk of accidental spill and blow-out is furthermore prevented through a number of mitigating measures	Minimizing the effect of acute pollution events is described in section 21.2.
	8.10 Adverse effects on marine mammals and birds from acute pollution events are prevented and minimised as much as possible. For example, this may be secured by means of floating booms as well as through contingency plans for marine mammals and birds injured in oil spills	Acute pollution events are extremely rare events. The risk of accidental spill and blow-out is furthermore prevented through a number of mitigating measures.	Minimizing the effect of acute pollution events is described in section 21.2.
	8.11 Up to the next monitoring programme (2020), the Danish Environmental Protection Agency will examine how the adverse effects of the most significant pollution events can be monitored and registered in the specific cases	O&G operators is in cooperation with the Authorities about effective contingency plans. Unplanned discharge of oil and chemicals are reported to the Authorities.	Minimizing the effect of acute pollution events is described in section 21.2.

19.10 Descriptor 9 – Contaminants in seafood and human consumption

As mentioned in It is seen that South Arne installations are situated in an area with low fishery intensity and . the area is not considered as a core area for seafood.

The environmental targets for descriptor 9 are described in Table 19-10.

Table 19-10 Environmental targets for descriptor 9 according to the Danish Marine Strategy II

	Targets	Impact from the Solsort West Lobe project	Comments
Contaminants in seafood and human consumption	9.1 Emissions of contaminants generally do not lead to exceeding of the maximum residue levels applicable in the food legislation for seafood.	Discharge of chemicals during drilling and production may increase the level of contaminants in fish and other seafood. Measurable contaminants in fish and other seafood only occur because of major oil spill.	Impacts from major oil spills are described in section 13.
	9.2 Emissions of contaminants generally do not lead to exceeding of the maximum residue levels applicable in the food legislation for seafood.	See 9.1	Impacts from major oil spills are described in section 13.
	9.3 The Danish Environmental Protection Agency is monitoring developments in relation to emissions of POPs (including dioxins) from wood-burning stoves to assess the need for further initiatives.	No impact	
	9.4 The Danish Environmental Protection Agency is gradually	No impact	

	Targets	Impact from the Solsort West Lobe project	Comments
	improving emission estimations of POPs into the air		
	9.5 Danish Veterinary and Food Administration is inspecting concentrations of contaminants, particularly dioxins and PCBs to monitor developments in organisms at risk of containing high concentrations.	Information about chemicals used offshore is communicated to the Authorities as part of the discharge applications and permit reporting conditions.	

19.11 Descriptor 10 – Marine litter

All waste generated during construction, production and decommissioning will be transported to Esbjerg by vessel. The waste will be further sorted out to improve recycling, send for further treatment at approved waste treatment plants, send for combustion or for final disposal.

The environmental targets for descriptor 10 are described in Table 19-11.

Table 19-11 Environmental targets for descriptor 10 according to the Danish Marine Strategy II

	Targets	Impact from the Solsort West Lobe project	Comments
Marine litter	10.1 The amount of marine litter is reduced significantly to achieve the UN goal that marine litter is prevented and significantly reduced by 2025.	No impact as all waste is transported to shore.	Impacts described in 10.6.
	10.2 The Ministry of Environment and Food contributes to work regionally and in the EU regarding establishment of threshold values and determination of good environmental status, and works to ensure that the quantities of marine litter are in accordance hereto	No impact	
	10.3 Losses of fishing gear in Danish waters are prevented to achieve the UN goal that marine litter is prevented and significantly reduced by 2025	No impact from O&G	
	10.4 The Ministry of Environment and Food implements the National Plastics Action Plan and the associated Political Agreement on collaboration of 30 January 2019, with a view to improving recycling of plastic and reducing plastic litter and pollution from plastic litter	No impact from O&G.	
	10.5 The Ministry of Environment and Food is working to develop indicators and measurement methods for microplastics in seabed sediments and the water column.	O&G will cooperate with Authorities about the framework for the seabed monitoring programme taking place every 3 years	
	10.6 The Danish Fisheries Agency draws up an estimate of the amount of lost fishing gear in Danish marine areas up to 2020.	No impact	

	Targets	Impact from the Solsort West Lobe project	Comments
	10.7 The Ministry of Environment and Food prepares a catalogue of potential and targeted measures to prevent marine litter	No impact	

19.12 Descriptor 11 – Underwater noise

Underwater noise can be expected during the construction phase in relation to seismic survey and ramming of the conductor in connection with drilling.

The environmental targets for descriptor 11 are described in Table 19-12.

Table 19-12 Environmental targets for descriptor 11 according to the Danish Marine Strategy II

	Targets	Impact from the Solsort West Lobe project	Comments
Underwater noise	11.1 As far as possible, marine animals under the Habitats Directive are not exposed to impulse sound which leads to permanent hearing loss (PTS). The limit value for PTS is currently assessed as 200 and 190 dB re.1 uPa2s SEL for seals and harbour porpoise, respectively. The best knowledge currently available is on these species. However, it is likely that these limits will be revised as new knowledge on the area becomes available. The values are the sound-exposure level accumulated over two hours.	During site survey and construction of wells marine mammals will be disturbed due to underwater noise from seismic survey, ramming of well conductor casing, noise from drilling, noise from installation of rig and ship noise. However, noise levels will not exceed the thresholds for PTS.	Impacts from site survey and drilling are described in section 10.3
	11.2 Anthropogenic activities causing impulse sound are planned such that direct adverse effects on vulnerable populations of marine animals from the spatial distribution, temporal extent, and levels of anthropogenic impulsive sound are avoided as far as possible and such that these effects are assessed not to have long-term adverse effects on population levels.	See 11.1	Impacts from site survey and drilling are described in section 10.3
	11.3 Activities by the authorities under the Ministry of Defence that cause impulse noise in the marine environment are, as far as possible, being assessed and adapted to reduce possible adverse effects on marine animals under the Habitats Directive, provided this does not conflict with national security or defence objectives. Defence Command Denmark applies current NATO standards when carrying out environmental assessments.	No impact from O&G	
	11.4 When conducting preliminary seismic studies, adequate remedial action is taken in accordance with the Danish Energy Agency's guidelines on standard terms and conditions for preliminary studies at sea.	The preliminary studies are conducted according to the DEA guideline	Seismic site survey described in section 5.3.1 and impacts described in section 10.3.4

	Targets	Impact from the Solsort West Lobe project	Comments
	11.5 The Ministry of Environment and Food contributes to work regionally and in the EU regarding establishment of threshold values and determination of good environmental status and is working to ensure that the level of underwater noise is in accordance hereto.	No impact	
	11.6 In connection with licensing offshore activities requiring an environmental impact assessment (EIA), the approval authority is encouraging reporting to the Danish Environmental Protection Agency (monitoring programme) of registrations of impulse noise.	No monitoring programme has been agreed.	Impacts from site survey and drilling are described in section 10.3
	11.7 Through increased monitoring, the Ministry of Environment and Food is improving knowledge about the extent and levels of low-frequency noise in the Baltic Sea and the North Sea.	No monitoring programme has been agreed.	Impacts from site survey and drilling are described in section 10.3

19.13 Summary of impacts on descriptors

The potential impacts from the Solsort project activities are compared with the targets for on the 11 descriptors as described in section 19.2 to 19.12.

The environmental impacts of the environmental components of the descriptors are assessed in chapter 10 to 15.

The main impacts are as described in the Danish Marine Strategy II on D1, D6, D8 and D11. The impacts on these four indicators are summarized below in Table 19-13.

Table 19-13 Potential impacts on the environmental targets in the Danish Marine Strategy II which implements EU's Marine Strategy Framework Directive (MSFD).

Descriptor	Environmental subject (Danish Marine Strategy II)	Assessment of potential impact
D1 **Biodiversity**	Birds	Population identified in the project area, which are covered by the Danish Marine Strategy I - monitoring programme: Kittiwake (Rissa tridactyla) and Guillemot (Uri aalge) The trend for the population is unknown according to table 22.4 in the Danish Marine Strategy II.
	Marine mammals	Information is included about the population of harbour porpoise, harbour seal and grey seal in the projects area covered by the Danish Marine

Descriptor	Environmental subject (Danish Marine Strategy II)	Assessment of potential impact
		Strategy I - monitoring programme. The project area is although not a core area for these species. The impact is temporary and will not influence on the population.
	Fish (plankton)	The primary production of plankton is generally higher in the coastal regions compared to offshore areas. Solsort and South Arne are in an area with low plankton production
D6 Sea floor integrity	Losses and physical impacts	The only impact from the Solsort project on the seafloor will be during the location of the spud cans of the rig on the seafloor. The project will give input on physical disturbance as required. The physical disturbance is temporary.
	Habitat types and seafloor	The habitat in the area is offshore circalittoral mud, which total area in the North Sea is 18,170 km^2. The area of the spud cans is very small compared to the area of the habitat and is considered to have no impact on the habitat in the area.
D8 Contaminants (concentrations and species health)	Contaminants	According to the Danish Marine Strategy Directive II threshold values are decided for PFOS, PBDE, Benz(A)pyrene and mercury. Only Benz(A)pyrene and mercury are present around the installations in very small concentrations. The values can although not directly be compared as the thresholds are defined by concentrations in fish or mussels.
	Acute pollution events	Acute pollution events are extremely rare events. The risk of accidental spill and blow-out is furthermore prevented through a number of mitigating measures
D11 Underwater noise	Adverse effects	During site survey and construction of wells marine mammals will be disturbed due to underwater noise from seismic survey, ramming of well conductor casing, noise from drilling, noise from installation of rig and ship noise. However, noise levels will not exceed the thresholds for PTS.

Based on the assessment above it is concluded that the Solsort West Lobe wells will not prevent or delay the achievements of good environmental status for each descriptor as defined in the Danish Marine Strategy II.

The impact from both use of seabed, underwater noise and discharge of chemicals will occur during the projects construction period. Discharge of mud can have a temporary impact on the seabed as placing of the spud cans, which indirectly impacts the targets of descriptor D6. The mud will although be in the area for a very short period.

During production the physical presence of the platform can serve as steppingstone for NIS.

The impact from discharge of chemicals during production is evaluated for each chemical. In 2010 a whole effluent test was conducted for the produced water from South Arne including all components. The result of the whole effluent test is described in 11.2.2.1.

20. Cross-border impacts

A specific ESPOO report will be prepared for the Solsort West Lobe project. It contains a description of the project-related transboundary environmental and socioeconomic impacts, which are caused by project impacts generated in Denmark and potentially affecting the marine territories (EEZ and/or territorial waters) of Norway, Sweden, Germany and UK.

An overview of potential transboundary impacts has been prepared – see Table 20-1 below.

Table 20-1 Screening of potential transboundary impacts

Activity	Potential impact	Transboundary evaluation
Environmental impacts of activities during the construction phase		
Presence of drilling rig	› Impacts on fisheries and shipping due to exclusion zones around drilling rigs	› Local impact only.
Discharge of drill cuttings, drilling mud (WBM) components and cementing chemicals (only discharge of green and yellow chemicals) and of treated sewage	› Physical smothering of seabed mainly affecting benthic fauna › Water contamination from suspended cuttings, solids and drilling chemicals and impact on pelagic organisms › Sediment contamination from drilling chemicals affecting benthic fauna › Discharge of treated sewage	› Local impact only at short distances from the platform. › Local impact only. Several field studies have consistently shown that drilling waste solids are diluted and deposited within 30 meters from the rig. › Local effect only in the vicinity of the drilling sites › Negligible local impact
Well completion	› Discharges of completion fluids can impact on water quality and marine fauna. However, only green chemicals are discharged.	› Local or no impact.
Noise from site survey, drilling operation and ramming of well conductor casing	› Impact on marine mammals and fish	› Impacts from site survey and ramming in Danish waters only (up to 20 km from site). Soft start procedures will be used. › Noise from site survey and drilling operations are local.
Accidental spills and blowout	› Mainly birds, marine mammals, fish, coastal ecosystems, fisheries, aquaculture and tourism may be affected. Blowouts are extremely rare events › Economic loss to fisheries, aquaculture and tourism due to oiling	› Potential transboundary impacts are possible › Potential transboundary impacts are possible
Environmental impacts of activities during the production and decommissioning phase		
Accidental spills Blowout	› Extremely rare events. Experience from previous blowouts and oil spills at sea have shown that it is mainly birds, marine	› Potential transboundary impacts are possible

Activity	Potential impact	Transboundary evaluation
	mammals, fish, coastal ecosystems, fisheries, aquaculture and tourism than may be affected › Economic loss to fisheries, aquaculture and tourism due to oiling › Mainly birds, plankton, fish eggs and larvae may be affected.	› Potential transboundary impacts are possible › Potential transboundary impacts are possible

21. Mitigating measures

In the following is a brief description of how and which mitigating measures are applied, either through environmental management procedures conducted generally by INEOS in relation to the development of Solsort West Lobe wells and the specific mitigating measures, which can be taken.

21.1 INEOS Corporate Policy

INEOS Oil & Gas Denmark systematically works on reducing the environmental impact of its offshore activities. This has the following influence on a project like the development of Solsort:

- Continuous work on reducing the project's impact on the environment from an overall perspective
- Implementation of work routines to prevent incidents
- Implementation of an emergency response system to ensure that consequences of incidents are reduced as much as possible
- Continuous and systematic work on reducing the use and discharge of chemicals
- Implementation of working procedures for storage of chemicals at the platform to reduce the risk of incidents and spills
- Analysis and registration of incidents and near-miss events to prevent unintended environmental impact in the future
- The principles of BAT and BEP (best available technology and best environmental practice) are used in the process of selecting the technical solutions
- The Solsort West Lobe wells will be part of South Arne Operator environmental emergency response system with established working procedures to minimize the effects of incidents or to effectively collect spills, should an incident happen.
- INEOS works in cooperation with operators of spill response equipment on emergency response agreements and has agreements with other offshore operators (national as well as international via Operators Co-operative Emergency Service) for mutual assistance in case of major offshore accidents.

21.2 Project specific environmental management

21.2.1 Non-indigenous species

International vessels can introduce non-indigenous species though marine fouling and discharge of ballast water.

The vessels will follow IMO guidelines that implements the Ballast Water Convention and the risk of introduction of new species with ballast water is not assessed to be higher than the risk from marine traffic in general. Requirements of ballast water treatment system and regular removal of marine fouling are included as mitigating measures. However, even without implementing mitigating measures the risk of introduction of new species is considered very low.

21.2.2 Oil Spill Contingency Plan

21.2.2.1 Prevention of blow-out during drilling

Throughout the well construction phase (i.e. drilling and completion operational activities) a two-barrier company policy is always adhered to.

The primary well barrier is the 1st mitigation against a hydrocarbon release from the reservoir. The 2nd well barrier serves as a back-up in case the primary well barrier fails.

In general, the primary barrier is the fluid column in the wellbore that provides a hydrostatic over-pressure against the maximum anticipated reservoir pressure.

The second barrier is a compilation of the wellbore pressure envelope. Thus, the installed steel casings and the annulus cement columns downhole are part of the secondary well barrier.

During drilling and completion the rig's Blow-Out Preventer (BOP) is the part of the secondary barrier. Thus, in the event of a well "kick", where an influx is encountered at the reservoir level, the BOP will be closed to contain the influx volume. The subsequent procedure is to calculate a revised drilling (or completion) fluid density and then displace the previous fluid with the revised fluid of higher density to establish (re-gain) hydrostatic over-balance against the reservoir pressure.

The BOP remains on the well slot until the well is drilled and completed. Upon completion the BOP will be removed, and a Xmas Tree will be installed on top of the wellhead.

During the production (or injection) phase of the well, the wellhead (including casing and tubing hangers and seal assemblies) and Xmas Tree becomes the primary barrier (as gas/oil can flow to surface for production purposes). All wells will have a safety valve installed in the production tubing string (SCSSSV) that will enable an immediate well shut-in in case a surface leak should develop.

In some special occasions where a hydrostatic over-balance exerted by the actual fluid column is either impossible or undesirable, a "Managed Pressure Drilling" (MPD) or ultimately "Under-Balanced Drilling" (UBD) techniques can be utilized. These special circumstances require special additional pressure containment equipment at surface. The main purpose is to control the hydrostatic pressure in real-time to ensure that an influx from the reservoir is contained.

The two-barrier philosophy is industry practice and is founded in INEOS Energy's Drilling and Completion standards and procedures and is also in accordance with Danish legislation."

21.2.2.2 Oil spill response

INEOS has established a legal binding cooperation arrangement with Total E&P Denmark for mutual assistance in case of an oil spill incident from one of the operator's production installations (INEOS 2019). This arrangement ensures that four containerized DESMI fast sweep oil collection systems will be available for containing and collecting spilled oil, depending on the magnitude of the spill. In case of blow-out, further resources will be provided by Oil Spill Response Ltd (OSRL).

In Denmark, the preferred response strategy is containment and recovery of spilled oil. Dispersant spraying may be chosen once approval from the DEPA has been confirmed (made official). Details on the specific equipment available for the preferred response strategy (Mechanical containment and recovery) for the three Tier responses are described in chapter 13.4.

21.2.3 Underwater noise

Mitigation measures for the site survey will include:

- Passive Acoustic Monitoring and Marine Mammal Observer (MMO)
- Soft start procedure
- Procedures for line shifts
- Procedures for unintended and intended interruptions
- Observations of marine mammals will be reported to the Danish Energy Agency. The report will include place, timing, number of individuals, information about reaction and the activity that took place when the observation was made.

In the construction phase the impacts of underwater noise on marine mammals and fish during ramming of well conductor casing into the seabed may be prevented by "soft start up" of the ramming, which will scare any individuals away before full ramming power is employed.

Additionally, deterrent devices and marine mammal observers can be applied. The latter is specially trained observers, who screens the immediate area (up to 500 m) visually and acoustically of presence of marine mammals prior to and during ramming. If marine mammals are detected, ramming will be paused and usually resumed after a period of 20 minutes without animal observations. Deterrent devices are acoustic sounders applied before ramming, which are designed to frighten off marine mammals without causing damage.

21.2.4 Cultural heritage

In the construction phase location of the drilling rig will be based on a seabed survey, which can identify if any wrecks are in the area in despite of what is expected looking into existing information from Slots- og Kulturstyrelsen about the area.

22. Monitoring programme

The monitoring programme for the site survey and during drilling of the South Arne West Lobe wells are to be agreed with the Authorities as part of the permitting processes.

A monitoring programme is already in place for South Arne for the production phase in agreement with relevant authorities and based on legal requirements in legislation and permits.

The Danish Marine Strategy II – part 2 includes a planned monitoring programme for all the descriptors for the period 2021-2026. The described monitoring programme in this section will support the programme.

The monitoring during decommissioning will be described in the decommissioning plan for South Arne installations.

Some specific monitoring is described below.

22.1 Construction Phase

22.1.1 Drilling of wells

The amount of cuttings generated is established by use of a volumetric calculation based on section hole size and the distance drilled. This is calculated and reported daily for all sections (hydrocarbon bearing as well as non-hydrocarbon bearing).

During drilling of potential hydrocarbon bearing sections (reservoir sections) samples of drilling fluid and cuttings are obtained every 500 ft for which the water, oil and solids ratio is established by use of a retort test. Combined with the calculated volume of cuttings and the volume of drilling fluid discharged the total amount of reservoir oil discharged with cuttings and water-based mud is calculated. Based on a calculation mentioned above it is anticipated that approximately 10.6 tonnes of reservoir oil is contained in cuttings and drilling fluid. This amount is based on 9 ¼" section being oil bearing reservoir the entire way which most likely will not be the case and therefore the amount of reservoir oil might be less. Impact will be less as the cuttings from the reservoir drilling is being skipped and ship to shore for further treatment or re-injected into a CRI well.

22.1.2 Production Phase

The environmental monitoring programme for South Arne is expected to include:

Daily monitoring of:

- Dispersed oil in produced water (mg/l)
- Volume of discharged produced water (m^3)
- Flaring volume (m^3)
- Volume of diesel or fuel gas used in the turbine (m^3)
- CO_2 emissions (ton)
- NO_X emissions (kg and mg NOx/m^3)

Quarterly monitoring of:

- Radioactive substances in discharged produced water
- Oil in water correlation curve
- Use of chemicals (kg)

Yearly monitoring of:

- Dissolved oil in produced water
- Control measurements for calibration of the NO_X emission prediction model

Based on the monitoring results the following are reported to authorities:

- Monthly report on oil in produced water and year to date oil discharge including explanation of any irregularities in the production, which has caused higher values
- Yearly prognosis for use and discharge of production chemicals, which is updated if a new chemical is approved and taken into use
- Yearly reporting on emission of CO_2 and NO_X
- Use and discharge of drilling chemicals if drilling has taken place

In addition to the monitoring described monthly information about the waste produced at the installation and handled onshore is generated by the waste handling company.

The monitoring programme for the production phase is not specifically linked to the two Solsort West Lobe wells and the planned modifications but a general programme for a production platform in the North Sea.

22.1.3 Decommissioning Phase

The monitoring programme during the decommissioning phase is to be agreed with the Authorities as part of the decommissioning plan. The plan should cover decommissioning of the South Arne field and Solsort West Lobe wells.

23. Data quality and limitations

23.1 The surrounding environment

The North Sea is a well-mapped area in terms of biological and physical parameters. The Solsort field is located close to other platforms, which are well surveyed, e.g., South Arne.

At the Solsort field, the biological and physical parameters such as benthic infauna and sediment composition are assumed to resemble those of the adjacent areas.

23.1.1 Plankton

The plankton distribution and species composition in the North Sea is well known due to continuous surveying which has been ongoing for a number of years. The surveying is carried out from ships equipped with automated plankton samplers collecting samples from all over the North Sea.

23.1.2 Benthic infauna

The benthic infauna in the North Sea, including the Solsort field, is well described in a comprehensive study of benthic fauna in the North Sea published in 2010. These findings were confirmed by a baseline study carried out at South Arne in 2012, 2015 and 2018 in the area around the South Arne field together with a reference station near Solsort (Hess Denmark 2012, 2015, 2018)

23.1.3 Fish

Fish distribution in the North Sea is well documented. ICES has an electronic atlas based on ICES' International Bottom Trawl Survey (IBTS), which has been carried out since 1970. The ICES database is linked to DATRAS; hence, maps show the most recent available data.

Distribution of fish spawning areas are based on published data available from ICES' Working Group 2 on North Sea cod and plaice egg surveys in the North Sea (WGEGGS2). The working group collects data on fish eggs and larvae of many species in the North Sea.

23.1.4 Birds

The sea bird distribution in the North Sea is based on a substantial amount of reports and data, including data from the OBIS Seamap (2013) and the online database hosted by the Joint Nature Conservation Committee (JNCC) in the UK. Several European organisations have contributed with data to this database using standardized methods for bird counting primarily from ships.

23.1.5 Marine mammals

Data on the description of the distribution of marine mammals in the North Sea is considered adequate for this environmental impact assessment. Recently, several studies have investigated the distribution of seals and harbour porpoise in the North Sea (SCANs survey data, Geelhoed et al. 2014, Gilles et al. 2016, Sveegaard et al. 2018. Some of the studies were initiated as part of environmental impact assessments of offshore windfarms.

23.2 Environmental assessment of planned discharges

The assessment of planned discharges of chemicals is based on the experience from other drilling of wells.

The amount and type of chemicals to be used have been assessed based on best available estimates from INEOS together with experience from previous projects and information from chemical suppliers. The specific chemicals to be used has not yet been settled, however, the environmental impact (colour code) will not increase. The assessment of the impacts from the discharge of chemicals is based on ecotoxicological data provided in the HOCNF documents for the chemicals or pre-screening documents. These data have been used in the modelling of impacts, by a dispersal model, which considers the conditions in the North Sea.

The assessment of discharges of cuttings and water-based mud on the benthic fauna is based on the experience from many years of monitoring of these effects, reported in the literature.

The assessment of planned discharges of chemicals is based on:

- Discharge amounts of the different types of chemicals
- Discharge patterns
- Assessment of the ecotoxicity of the chemicals

These data have been used in the modelling of impacts.

The dispersal modelling has been carried out using a model developed by COWI, based on the CHARM-model[7] developed by the industry, chemical suppliers and members of OSPAR. The dilution part of the model is a slightly modified version of the CHARM model, and estimations of risk indicators of negative environmental effects (PNEC and PEC/PNEC ratios) are calculated according to OSPAR guidelines. The dispersion model calculates PEC/PNEC ratios in up to 5000 meters from the discharge point.

Using the dilution model, the distance at which the chemical will impact the pelagic environment may be calculated. Rapid dilution of the discharges and biodegradation in the water column is ignored.

The distance at which the chemical will impact the benthic environment is calculated under the assumption that the sedimenting particles settle evenly around the platform under the influence of a standard refreshment rate of the seawater. Biodegradation in the sediment is assumed to occur only approx. 10 % of the time due to bioturbation of anaerobic marine sediments and resulting oxygen depletion.

The potential for bioaccumulation of discharged chemicals is assessed based on information on bioconcentration factors (BCF) or octanol-water partition coefficients (P_{ow}). The potential for bioaccumulation is not quantified.

The model considers the conditions in the North Sea with a current velocity of 0,05 m/s.

The input and the model are attached with a range of uncertainties including:

- Uncertainties related to the actual products to be used
- Uncertainties related to estimated amounts of chemicals to be used and discharged
- Uncertainties related to the chemical testing including ecotoxicity of the chemicals
- Uncertainties related to the model.

The products modelled are what is expected to be used now. However, the exact product is not yet decided upon, and thus the exact ecotoxicity profile can vary. However, it can be expected that the products used will be within the predicted pre-screening categories.

[7] CHARM = Chemical Hazard Assessment and Risk Management (Thatcher et al., 2017).

The exact amounts and discharges are estimated at the moment, and thus can be expected to be a conservative estimate and may vary with up to a factor 2.

The results are based on a range of assumptions of the processes taking place and are based on testing results. E.g., the partitioning coefficient are based on Log Pow values and the ecotox data is also based on tests conducted for different trophic levels. These data are also attached with uncertainties and thus an assessment factor is applied in the magnitude of a factor 10-1000.

The model is likewise attached with uncertainties e.g., the concentration in the sea is attached with uncertainties due to fluctuations in the discharge and variations in the sea current. Thus, the model includes conservative calculations of the conditions.

As described above the results are attached with a whole range of uncertainties ranging from a factor min. 10-1000, which added together could impact the results. However, conservative estimates are incorporated and thus the results are highly conservative.

23.3 Environmental assessment of accidental discharges

The distribution of a potential oil spill from the Solsort West Lobe wells is projected by the OSCAR model, which is regarded as a highly reliable model that has been in use for many years.

23.4 Environmental assessment of emissions to air

The assessment of emissions to air is attached with some uncertainties regarding the fuel consumption, emission factors, days of operation of vessels etc.

The emission factors that are used calculating emissions from vessels are generic emission factors. This also means, that the actual emission from vessels could be different if measuring the emissions.

Likewise, the fuel consumption are generic data, as the actual vessel fleet is not decided upon yet, and thus it could be other types of vessels used when carrying out the work. However, it tries to use data for vessels that could be expected to be used.

The estimated days of operation are estimated and include weather delays and other unforeseen events. Thus, these can be expected to be conservative.

23.5 Environmental assessment of noise and light

The environmental impact of noise of site survey, ramming and ship noise on marine mammals and the impact of light on birds are well documented.

23.6 Socio-economic assessments

The socio-economic assessments are based on up-to-date fisheries data from the Danish AgriFish Agency covering the years 2014-2018.

23.7 Cumulative effects

The cumulative effects are based on the strategic environmental assessment for the project area carried out in 2012 (Danish Energy Agency, 2012) and the technical report from DCE on the human uses, pressures and impacts in the eastern North Sea (Andersen et al., 2013) and information from DEA.

In addition to the above-mentioned references the DEA has appointed a number of areas for future wind farms (Reservation of additional areas for national tendering of offshore wind farms according to the Energy agreement dated 29 June 2018. Reservation dated 28 August 2019).

Information on EU projects on common interest is published regularly on an EU homepage (https://ec.europa.eu/energy/en/topics/infrastructure/projects-common-interest).

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ICES (2019g). Advice on fishing opportunities, catch and effort. Whiting (*Merlangius merlangus*) in subarea 4 and Division 7 (North Sea and eastern English Channel)

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APPENDIX A FATE AND EFFECT OF OIL SPILL

Introduction

This appendix briefly describes the fate and effects of oil spilled at sea.

Fate of oil

Oil released during a blow out or other types of spill undergoes the following processes:

- Spreading;
- Evaporation;
- Dispersion;
- Dissolution;
- Emulsification;
- Oxidation;
- Sedimentation and
- Biodegradation

The processes of spreading, evaporation, dispersion, emulsification and dissolution are most important during the early stages of a spill whilst oxidation, sedimentation and biodegradation are more important later on and determine the ultimate fate of the oil (Figure 2).

Rate and scale of the different processes are dependent on:

- The physical and chemical characteristics of the oil;
- Temperature, wind and currents and
- Whether the oil is spilled beneath or on the surface of the water

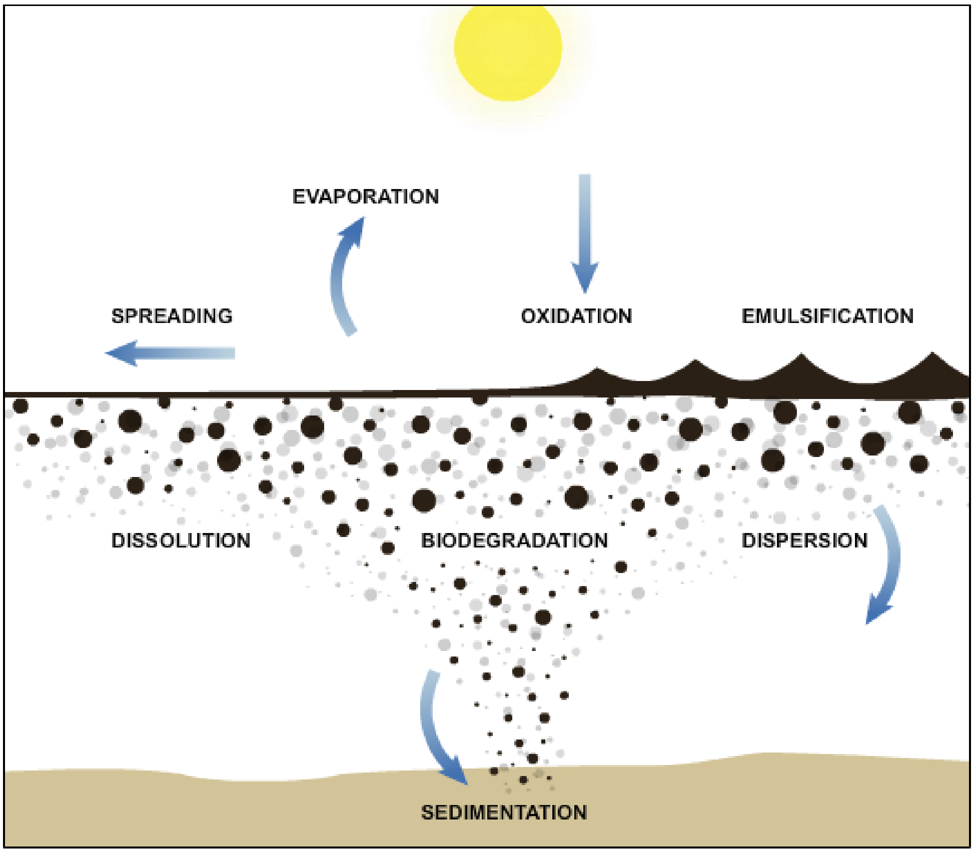

Figure 1 Processes affecting oil spilled at the surface (Source: Flowing data 2010)

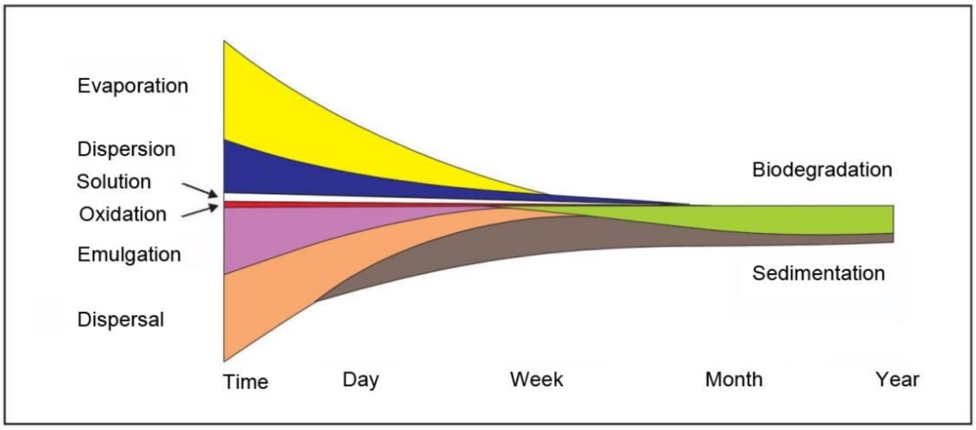

Figure 2 Overview of the relative significance of the different physical and chemical processes that affects spilled oil at sea as a function of time (after ITOPF 2002).

Tabel 1 Processes that affects oil spills (ITOPF 2019 and 2002)

Description of processes
Spreading. On the sea surface the oil will quickly be spread by wind and currents in a film of thin, narrow slicks parallel to the wind and current direction and will cover extensive areas of the sea surface.
Evaporation. The volatile components of the oil will evaporate to the atmosphere within a short period of time. The rate of evaporation is dependent on temperature, atmospheric pressure and the surface area of the oil film, the rate increasing with increasing temperature, decreasing atmospheric pressure and increasing surface area.
Dispersion. Waves and turbulence can break all or part of the oil slick into fragments and droplets of varying size that will be mixed into the upper layers of the water column. Some of the smaller droplets will remain suspended in the water column while the larger ones will tend to rise back to the surface, where they may either coalesce with other droplets to reform a slick or spread out to form a very thin film.
Dissolution. The lighter water-soluble components of the oil, such as light aromatic hydrocarbons compounds like benzene and toluene, may dissolve into the surrounding water but most of these components will evaporate
Emulsification. Due to wave action sea water droplets may become suspended in the oil, forming water-in oil emulsions (often called chocolate mousse), which is usually very viscous and quite persistent.
Oxidation. Hydrocarbons can react chemically with oxygen forming either soluble compounds or persistent tar balls with a solid outer crust surrounding a softer, less weathered interior. Such tar balls, are often found on shorelines
Sedimentation. Some heavy refined products or dispersed oil that mix with suspended solids have a higher density than seawater and may sink to the bottom. This process mainly takes place on shallow waters that are often laden with suspended solids providing favourable conditions for sedimentation.
Biodegradation. Seawater contains a range of microorganisms that can degrade oil components to water soluble compounds and eventually to carbon dioxide and water. However, some compounds in oil are very resistant to attack and may not degrade.

Potential biological impacts of oil spill

In the unlikely event of a blowout of oil and in a situation when oil-spill response measures cannot be activated, the environmental impacts may be severe. The sensitivity of different groups of organisms and habitats vary markedly. Table 1 and table 2 give overviews of the vulnerability of different groups of species and habitats in open waters and on shallow coastal waters and shorelines, respectively.

In general, environmental impacts of oil spill are most severe if the slick of petroleum hydrocarbons reaches shallow coastal waters and the shore, or if the slick passes concentrations of seabirds which are particularly sensitive to oil spills.

Table 2 Overview of potential impacts of oil spills on different groups of organism and habitats in open waters.

Potential impacts in open waters.
Impacts on plankton. Plankton populations are not particularly vulnerable to oil spills. It is well established that plankton is sensitive to oil exposure and consequently short-term impacts would be expected in the immediate vicinity of the oil. However, plankton is abundant, will naturally suffer very high levels of mortality and has an enormous regeneration capacity. As a result, long lasting effects on plankton is not expected and long-term effects of oil spills on phyto - or zooplankton communities have not been observed to date (ITOPF 2002, Khalaf 2006, Anon 1985, Falk Petersen et al. 1998 and Kühnholt 1977). **Impacts on pelagic fish, fish eggs and fish larvae.** There is no evidence to date that any oil spill in open offshore waters has affected the size of fish populations. Laboratory experiments have shown that oil is very toxic to fish eggs and larvae (Falk-Petersen & Kjørsvik 1987, Serigstad & Adoff 1985, Tilseth, Solberg & Westrheim 1984). However, in several studies effects on pelagic fish eggs and larvae were not observed in the field following oil spills. One reason for this may be that toxic concentrations of oil components are generally confined to the uppermost parts of the water column immediately beneath an oil slick and that fish eggs and larvae are encountered below the toxic water layers. Other studies have demonstrated massive kills of fish eggs and larvae in the vicinity of oil spills without causing any effect on fish populations. The lack of effects on numbers in subsequent adult populations following massive kills of eggs and larvae is probably because most fish species produce vast numbers of eggs and larvae and because most species have extensive spawning grounds (IPIECA 2000). Impacts on adult offshore pelagic fish have not been demonstrated. Fish eggs or larvae are not considered particularly sensitive to oil. This is because they do not surface. Hence contact with floating oil is usually minimal (see Neff, 1991), certainly compared to seabirds, marine mammals and turtles. Hydrocarbon levels that effect fish are considerably higher than levels contained in surface oil slicks (see Volkman et al., 1994). **Impacts on seabirds**. In open waters, mainly seabirds are threatened by oil spills. It is well-documented that seabirds are extremely vulnerable to oil spills and that large amounts of seabirds are often killed in connection with an oil spill in areas where seabirds are concentrated. The reason for seabirds being especially vulnerable is that they are often in contact with surface water and that the oil destroys the buoyancy and the isolating quality of the plumage. Birds smothered in oil will usually die of cold or starvation or drown. Event very small spots of oil may be fatal, especially during winter. Mainly seabirds that stay on the sea surface for longer periods are at risk, but all types of seabird may be affected (Trosi et al 2016, Garcia 2003, Peterson et al. 2003, Exxon Valdez Oil Spill Trustee Council 1994, Burger 1993). **Impacts on cetaceans and seals**. Whales, dolphins and seals are less vulnerable than birds, but they may be affected due to evaporation of volatile toxic components from the oils slick on the sea surface. If they emerge at the surface to breathe in the middle of an oil slick, they may inhale toxic vapours. Exposure to toxic petroleum hydrocarbon fumes may irritate eyes and lungs, cause drowsiness, impairs coordination or breathing which in turn may bring about drowning (Trosi et al 2016, Hammond et al. 2004).

Table 3 Overview of potential impacts of oil spills on different groups of organism and habitats on shallow coastal waters and shoreline.

Potential impacts on shallow coastal waters and shoreline.
Impacts on sea grasses. In most cases, oil will flow above the seagrass without causing damage. However, sea-grass beds may be affected if oil is brought in contact with seagrass as described for corals above (Durakoet al. 1993). **Impacts on shallow water benthic fauna and demersal fish**. Benthic fauna organisms are generally very sensitive to oil spill and elevated concentrations of toxic oil components in the water. There are numerous examples of severe impacts on benthic fauna following oil spills. However, impacts have only been observed on shallow water along the coasts where toxic concentrations may reach the seabed. In general, benthic fauna has a high recovery potential. Recolonization by most species is quite rapid but the recovery of certain sensitive species may be prolonged (such as species of crustaceans and mussels) (Basque Research 2009, SEEEC 1998, Dyrynda 1996, IPIECA 2000, Kingston, et al. 1995, Kingston et al. 1997, Dauvin 1998). There are also examples of demersal fish and spawning grounds for fish with demersal eggs on shallow waters have been affected by oil spills (Exxon Valdez Oil Spill Trustee Council 2009, Brown and Carls 1998, Peterson et al. 2003, Wright et al. 1997) **Impacts on waterfowl and shorebirds**. Shorebirds and waterfowl are often concentrated on tidal flats and are very vulnerable to oil spills. Apart from the impacts on plumage described for the offshore birds, waterfowl and shorebirds may be affected as a result of toxic effects after the ingestion of oil during preening, ingestion of oiled prey, inhalation of oil fumes or absorption of oil through skin or eggs and indirect effects resulting from destruction of bird habitats or food resources (Evans et al. 1993) **Impacts on shorelines**. Shorelines, more than any other part of the coastal environment, are exposed to the effects of floating oil. Oil stranded on beaches often gives rise to concern because it may affect several ecological and social conditions. Further, the cleaning of oiled beaches may be costly. The vulnerability of shorelines differs considerably depending on the type of habitat with respect to how easy they are to clean up after an oil spill. The sensitivity of different coastal habitat can be ranked as follows (with increasing sensitivity: 1) Exposed headlands and wave-cut rocky platforms, 2) Fine grained sandy beaches, 3) Beaches of mixed sand and coarser sediments (gravel, pebbles and boulders) 4) Beaches of a range of gravel, pebbles and boulders, 5) Sheltered rocky shores, 6) Sheltered tidal flats, 7) saltmarshes (IPIECA 1996).

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