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Konseptutvikling av en offshore supply base plassert i Barentshavet

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Master Thesis

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Offshore Supply Base

A Concept for the Barents Sea

Sunniva Fossen Haugen

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MASTER THESIS

for

SUNNIVA FOSSEN HAUGEN

FALL 2012

An Offshore Supply Base (OSB) concept for the Barents Sea

It is estimated that 22% of the world's undiscovered petroleum resources are located in the Arctic, 84% projected to be offshore, majority in West and Eastern Siberian Basin (US Geology Survey, 2008). Hence, this project concerns the associated field and destination logistics in the Barents Sea following the settlement of the disputed area between Norway and Russia. However, the distinct conditions of Arctic Sea, such as remoteness or the lack of marine infrastructure, represent a challenge to be surpassed in order to ensure a safe and economical feasibility of any operation in the high north. Therefore, this project is concerning with the development of a new type of Offshore Supply Base (OSB) to be used as a bridge element to overcome the large distance from the oil and gas fields to shore.

The following aspects shall be considered for the OSB concept:

- Offshore Supply Bases (OSB) that combines transhipment functionality, oil spill response centres and eventual emergency repair yard capabilities
- Development of OSB structures in high seas close to field operation, including storage and SAR with offshore/near shore helicopter services
- Impact of the harsh environment

The work shall be carried out in the following steps

1) Familiarization with the Arctic Sea region, especially the Barents Sea (infrastructure, inhabitants, general conditions)
2) Literature review of offshore platform concepts suitable for supply bases (criteria and constraints incl. polar codes)
3) Assessment of the robustness of the choice of OSB in view of future environmental conditions
4) Development of the OSB concept

5) Presentation of the findings and results

1) The conditions, assumptions and limitations of your study shall be discussed with respect to physical relevance
2) Conclusions and recommendations for further work

Literature studies of specific topics relevant to the thesis work may be included.

The work scope may prove to be larger than initially anticipated. Subject to approval from the supervisors, topics may be deleted from the list above or reduced in extent.

In the thesis the candidate shall present his personal contribution to the resolution of problems within the scope of the thesis work.

Theories and conclusions should be based on mathematical derivations and/or logic reasoning identifying the various steps in the deduction.

The candidate should utilise the existing possibilities for obtaining relevant literature.

Thesis supervisors

Preface

This master thesis is written by Sunniva Fossen Haugen in the 10th and final semester at The Norwegian University of Science and Technology, Faculty of Engineering Science and Technology, Department of Marine Technology. The aim of the thesis is to investigate possible conceptual solutions for placing an Offshore Supply Base in the Barents Sea. The thesis counts for 30 credits, it has been conducted as a standalone project and is not related to the project thesis from my 9th semester.

The work with the thesis has been very interesting and has given me valuable insight to an area which is currently under great focus as the petroleum companies are looking further and further north in their search for undiscovered petroleum resources. The thesis describes the current and possible future situation in the Barents Sea and presents an Offshore Supply Base concept which may improve upon the emergency preparedness and logistical gaps that are present today.

First and foremost I would like to thank my supervising professor Sören Ehlers who have given me great guidance throughout the work with this master thesis. I would also like to thank my fellow students at office C1.077 for moral support and valuable discussions. Lastly I would like to thank my parents for always believing in me throughout the master studies.

Trondheim, 19. January 2013

Sunniva Fossen Haugen

Summary

The global demand for petroleum is increasing and the exploration and production of oil and gas resources are moving to new locations. This has led to an increased focus on the possibilities of extracting petroleum in the High North, also in the Norwegian part of the Barents Sea. There are already fields that have been opened for petroleum production in the Barents Sea South, where the Snow White field is already producing gas and the Goliat field will start producing oil in 2014. In addition an impact assessment has been executed for the opening of a new possible field in the Barents Sea South East. Developing new oil fields this far north is challenging. There are metocean challenges mainly regarding low temperatures, sea ice, icing, polar lows and low visibility. This forces the business itself to find new technical solutions and the authorities to develop new standardizations and regulations which are applicable to the more challenging environment of the Arctic. However, the most prominent challenges are the long distances and lack of infrastructure. This makes it difficult to develop petroleum production solutions which are both safe and economically feasible. To reduce the safety and logistical gaps caused by the lacking in infrastructure, an Offshore Supply Base (OSB) can be placed in the Barents Sea. The Norwegian part of the Barents Sea can be divided into two parts, where the Barents Sea South is generally ice free all year and the Barents Sea North has ice covered waters every winter.

This thesis has looked into two OSB concepts, where one is located in the south of the Barents Sea and the other one is located in the north. The main constraints set for the two concepts were that the OSB should be able to

- Improve SAR-coverage
- Improve the emergency oil spill preparedness of the Barents Sea
- Provide logistical services

There are no current plans of developing oil fields in the Barents Sea North. In addition there are technical limitations regarding applicable structures for the OSB because of the presence of sea ice. Therefore a concept where an OSB is placed in the Barents Sea South is concluded to be the best solution. The resulting concept is a multipurpose ship placed at approximately 73.1N 27.1E. The OSB will have a permanently placed SAR-helicopter and extended hospital functionalities. It will also be able to function as a NOFO-tanker in emergency oil spill operations. The logistical services that have been suggested are storage and workshop possibilities. The service speed of the vessel shall be minimum 15 kn. Locating the OSB to the suggested position enables a SAR-helicopter to have a 3 hour radius which covers the entire new suggested oil field in the Barents Sea South East. The OSB will also be able to cover the entire Norwegian part of the Barents Sea within 24 hours in case of an oil spill emergency.

Basing the OSB on a ship-shaped monohull enables the possibility of rebuilding an existing vessel such that it is fit to purpose, which may be a cheaper option than a new build. The exact size of the vessel should be based on the amount of oil spill the OSB will be able to receive and the extended logistical services the OSB is able to provide. These constraints should be established by executing a conceptual business plan and oil spill risk analysis.

Summary in Norwegian

Den globale etterspørselen etter petroleum er økende, og produksjon av olje-og gassressurser flyttes til stadig nye lokasjoner. Dette har ført til et økt fokus på mulighetene for å utvinne petroleum i nordområdene, også i den norske delen av Barentshavet. Det er allerede felt som er åpnet for oljeutvinning i Barentshavet Sør, Snøhvit produserer allerede gass og Goliat-feltet vil begynne å produsere olje i 2014. I tillegg er en konsekvensutredning utført for åpningen av et nytt mulig felt i Barentshavet Sørøst. Å utvikle nye oljefelt så langt nord er utfordrende. Det er flere metocean-relaterte utfordringer som lave temperaturer, havis, ising, polare lavtrykk og lav sikt. Dette tvinger petroleumsbransjen til å finne nye tekniske løsninger og myndighetene tvinges til å utvikle nye standarder og forskrifter som gjelder for det utfordrende miljøet i Arktis. Men de mest fremtredende utfordringene er de lange avstandene og mangelen på infrastruktur. Dette gjør det vanskelig å utvikle petroleumsløsninger som både ivaretar sikkerheten og er økonomisk gjennomførbare. For å redusere sikkerheten og logistiske hull forårsaket av mangler i infrastrukturen, kan en Offshore Supply Base (OSB) plasseres i Barentshavet. Den norske delen av Barentshavet kan deles inn i to deler, hvor Barentshavet Sør er generelt isfritt hele året og Barentshavet Nord har isdekket farvann hver vinter.

Denne oppgaven har sett på to OSB-konsepter, hvor ett er plassert i den sørlige delen av Barentshavet og det andre er plassert i nord. De viktigste betingelsene som er satt for de to konseptene er at OSBen skal kunne

- Forbedre SAR-dekning
- Forbedre oljevernberedskapen i Barentshavet
- Tilby logistikktjenester

Det er for øyeblikket ingen planer om å utvikle oljefelt i Barentshavet Nord. I tillegg er det tekniske begrensninger vedrørende valg av mulige offshore installasjoner for OSBen på grunn av tilstedeværelsen av havis. Derfor er et konsept der en OSB er plassert i Barentshavet Sør ansett å være den beste løsningen. Det resulterende konseptet er et multipurpose skip plassert på ca. 73.1N 27.1E. OSBen vil ha et SAR-helikopter permanent plassert på innretningen og vil kunne tilby utvidet sykehusfunksjonalitet. Den vil også være i stand til å fungere som en NOFO-tankskip under oljevernaksjoner. Logistikktjenestene som har blitt foreslått er verksted og lagringsmuligheter. Hastigheten til fartøyet skal være minimum 15 knop. Den foreslåtte plasseringen til OSBen gjør at et SAR-helikopter plassert på innretning vil ha en 3 timers radius som dekker hele det nye foreslåtte oljefeltet i Barentshavet Sørøst. OSBen vil også være i stand til å dekke hele den norske delen av Barentshavet innen 24 timer i tilfelle en oljevernberedskap.

Å basere OSBen på et skipsformet enkeltskrog gjør det mulig å konvertere et eksisterende fartøy, som kan være et billigere alternativ enn et nybygg. Den nøyaktige størrelsen på fartøyet skal være basert på mengden av oljeutslipp OSBen vil kunne motta og de utvidede logistikktjenester OSBen er i stand til å gi. Disse betingelsene bør etableres ved å utføre en konseptuell forretningsplan og risikoanalyse vedrørende mengde oljesøl den bør kunne motta.

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Acronyms

AIS	Automatic Identification System
DWT	Deadweight tonnage
FPSO	Floating Production Storage and Offloading
GEO satellite	Geosynchronous satellite
GSM	Global System for Mobile
HEO satellite	Highly Elliptical Orbit Satellite
HF	High Frequency
IMO	International Maritime Organisation
INMARSAT	International Maritime Satellite
LEO satellite	Low Earth Orbit satellite
LRIT	Long Range Identification and Tracking
MARPOL	International Convention for the Prevention of Pollution From Ships
Metocan	Meteorological and oceanographic
MF	Medium Frequency
NOFO	Norwegian Clean Seas Association for Operating Companies
NPD	The Norwegian Petroleum Directorate
OR-vessel	Oil Recovery vessel
OSB	Offshore Supply Base
SAR	Search and Rescue
SOLAS	Safety of Life at Sea

1 Introduction

Historically the Barents Sea has been an area where fishing has been the main activity, in addition to some shipping. New reports have shown that an estimated 22% of the world's undiscovered petroleum resources are located in the Arctic which has led to an increased interest in petroleum exploitation in the High North. Following the agreement between Russia and Norway in 2011 about the earlier disputed area in the Barents Sea, the interest in the Norwegian part of the Barents Sea have increased even further. Assessments regarding opening new oil fields in the Barents Sea South have been conducted. Currently there are no concrete plans of opening oil fields in the Barents Sea North, but this is not an unlikely possibility. The development of new petroleum fields in the Barents Sea is not without challenges, there are metocean related challenges such as low temperatures, sea ice, icing and in general harsh weather. But first and foremost the challenge is that the Barents Sea is still considered a remote area which is lacking marine infrastructure. This makes it difficult to ensure safe and economic feasibility when conducting marine and offshore operations in the Barents Sea. To improve upon this situation, placing and Offshore Supply Base (OSB) in the Barents Sea could be a possible solution. Based on the metocean characteristics of the Barents Sea and the present and future outlook of marine and offshore activities, this thesis should present a conceptual proposal of such an OSB.

Figure 1 Offshore rig in icy water (Photo: Rosneft.ru)

The thesis is divided into two main parts where the first part discusses the current and future possible situation in the Barents Sea regarding metocean conditions, infrastructural conditions and regulations that are applicable to the area. The second part of the thesis discusses possible conceptual solutions for the implementation of an OSB in the Barents Sea.

2 General Conditions

To establish what type of concept that is appropriate for the OSB and at what location it should be positioned the current and future possible conditions of the Barents Sea has to be identified. The general conditions have been divided into two main parts the metocean and the infrastructural conditions. Lastly, in this chapter, the regulations which are applicable to the area are also described.

2.1 Metocean Conditions

In this chapter the metocean conditions are described, meaning the meteorological and oceanographic conditions of the Barents Sea.

2.1.1 Temperatures

The temperatures in the Arctic areas follow an expected distribution as they in average are lower further north and further east. The average temperature distribution for the Barents Sea throughout the year is shown in Figure 2.

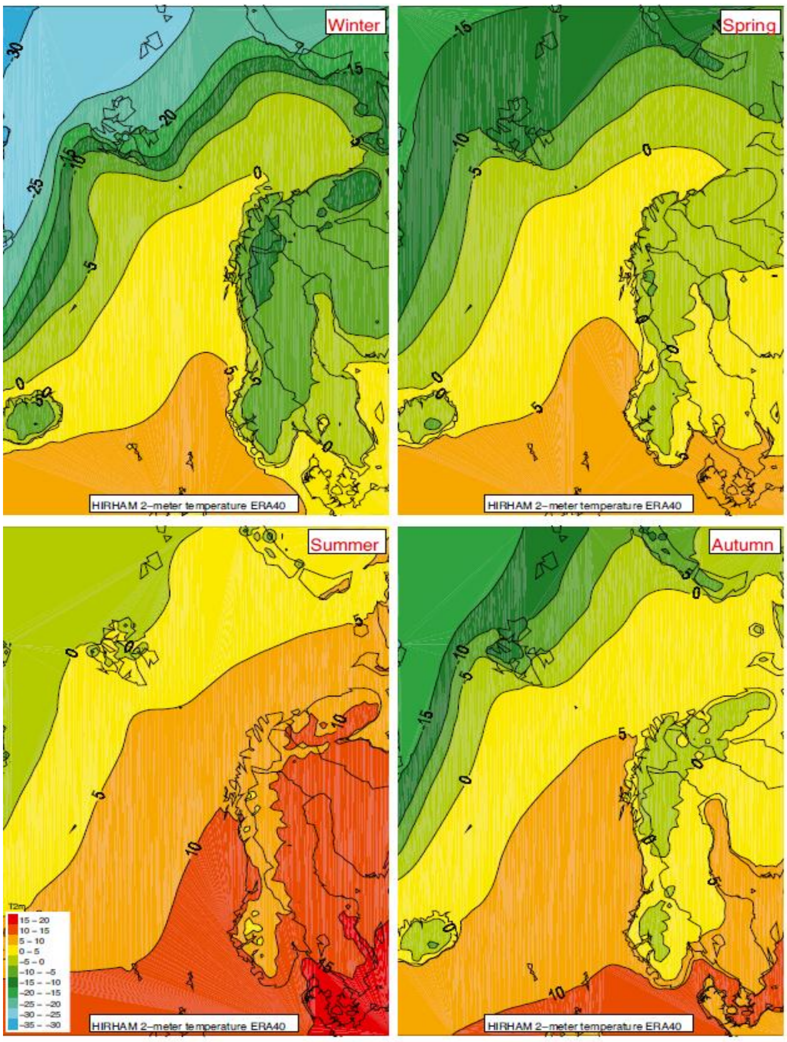

Figure 2 Average temperatures 1961-2000 (1)

In general the temperatures in the Arctic areas are expected to increase and the ice coverage is expected to decrease because of a combination of a reduction of the ozone layer and melting of the existing ice layer. How fast the temperatures in the ocean will increase is not determined. There have been carried out several research projects and created numerous models of the increase in temperature, but the results vary. However, there seems to be an agreement that the Arctic will be close to ice free during the summer by 2050, and by 2100 most of the year round ice coverage will be gone. It is also expected that as the air and sea temperatures rise more extreme weather will occur.

2.1.2 Wind Speeds

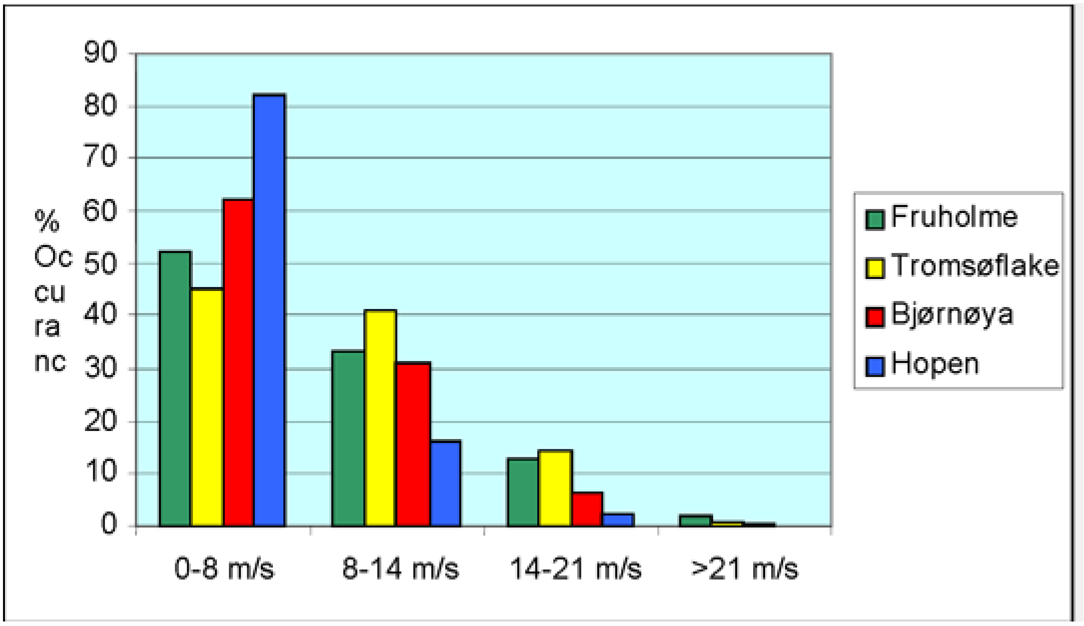

Figure 3 Occurrence of wind speeds in percentage (2)

In the Barents Sea the wind direction in the winter is usually from the southwest except from close to the coast where the direction is northeast due to land sea breezes. In the summer the wind is more equally distributed between the main wind axes. At 10 m above sea level the maximum average annual wind speed has a range of 25 m/s – 28 m/s[1], which is classified as full storm on the Beaufort scale. Near Fruholmen there is a higher storm frequency than the other measured areas in the Barents Sea. The reason is thought to be a corner effect, i.e. a strengthening of the wind field due to the topography of the mainland. It has been seen that these storms can affect areas as far as 180 km off the coast.

In general the average wind speeds become lower when moving further north and/or east. Figure 4 shows this trend throughout the year.

[1] Jacobsen, Sigurd R.: Evacuation from Petroleum Facilities Operating in the Barents Sea: Arctic Technology II University of Stavanger, May 2010

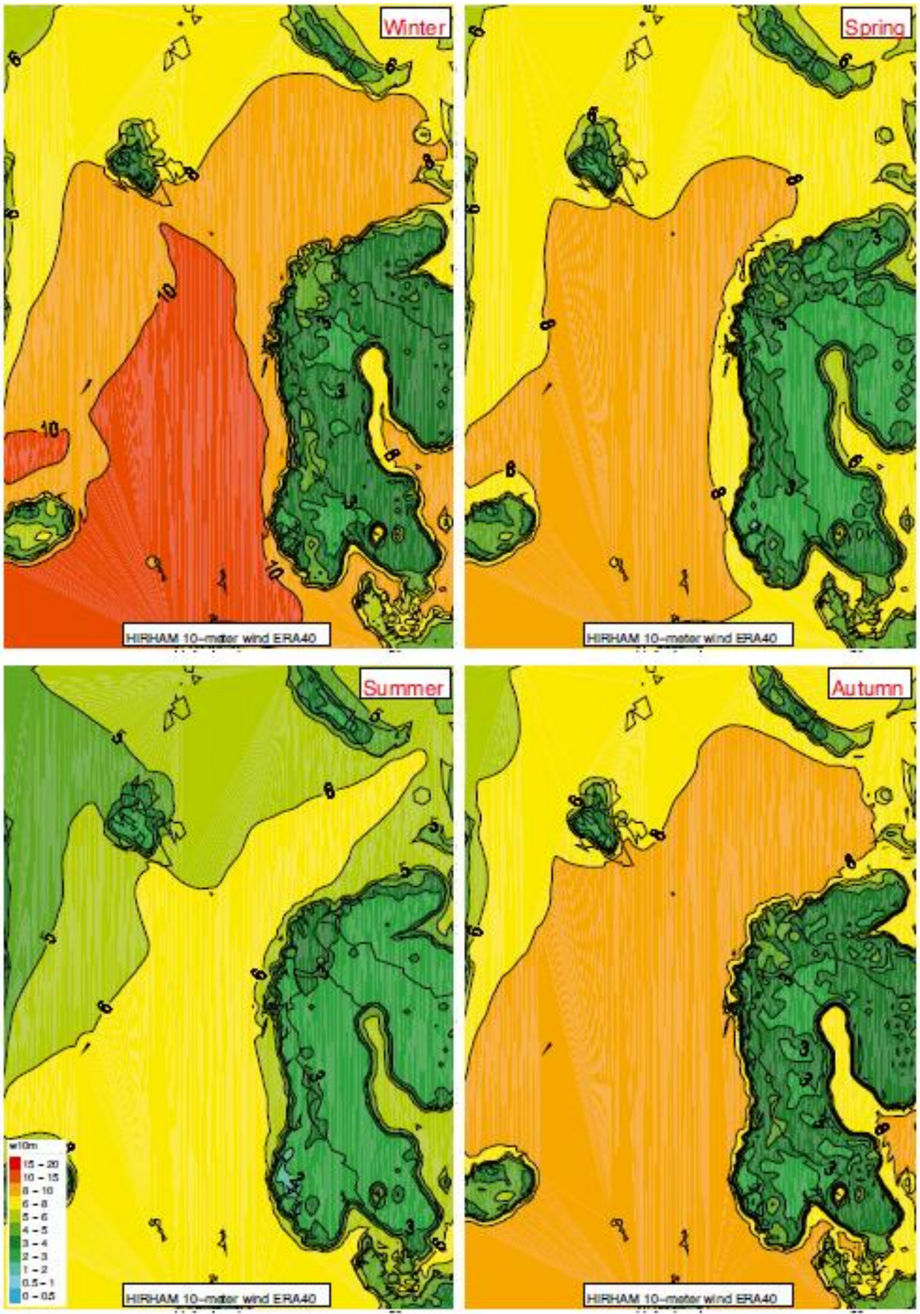

Figure 4 Average 10 meter wind speed (m/s) 1961-2000 (1)

2.1.2.1 Polar Lows

An Arctic phenomenon that affects the wind and weather in general is the occurrence of polar lows. Extreme wind speeds can be caused by polar lows or polar front conditions. The polar lows arise when cold arctic air erupts over the sea which causes heat and moisture to be transferred from the sea together with energy transformation within the atmosphere. The phenomena typically occur 2-4 times a month in the Norwegian and the Barents Sea. Because the polar low is driven by the warmer sea the polar low dies out when it hits shore. The duration is usually between 6 – 48 hours and they develop suddenly. Currently there are few meteorological stations in the Barents Sea and the satellites only cover the area for a limited period each day. Therefore it is difficult to forecast when the polar lows occur. A polar low causes the wind speed to increase into storm strength within a short amount of time, usually this takes between half an hour and up to two hours. The wind is usually of storm strength, sometimes the wind speeds can reach hurricane strength, but this is more seldom. The polar lows can cause challenging situations for the marine vessels operating in the area as the visibility becomes poor because of the heavy snowfall that often accompany the polar lows. In addition there is a danger of high waves and heavy wind in this kind of weather. The polar lows are most frequent between Bear Island and Northern Norway, but occur in all coastal areas outside Norway.

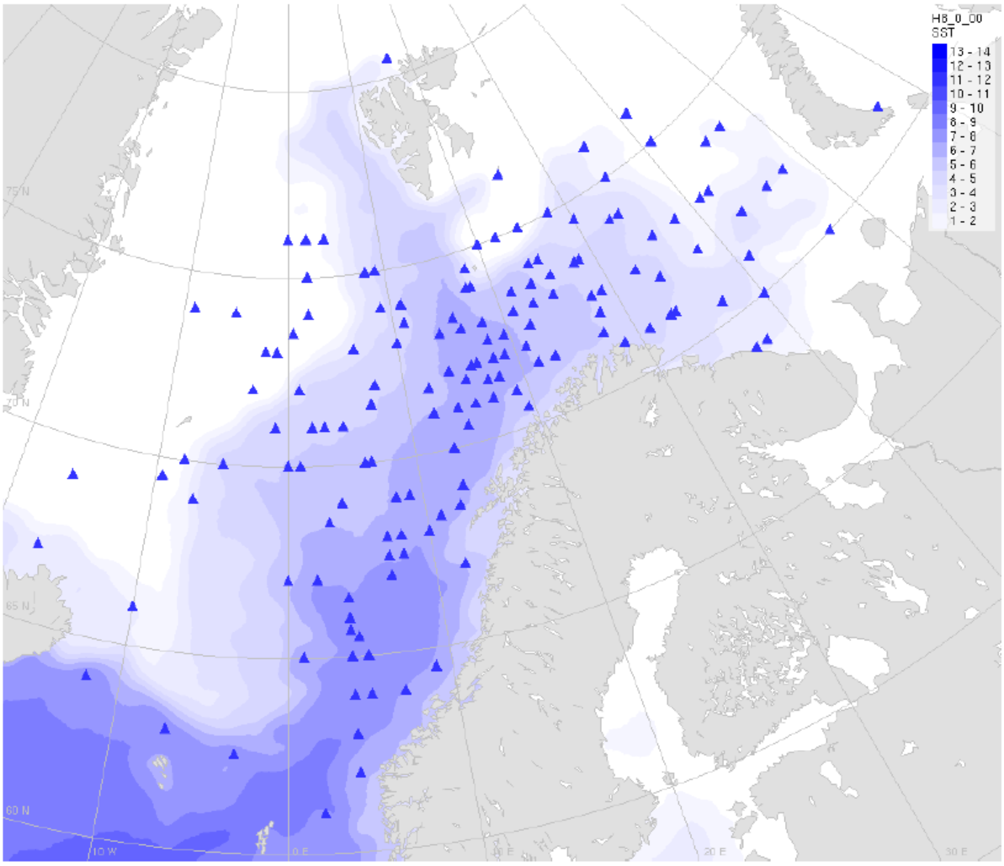

Figure 5 Formation areas for polar lows 2000-2012 (3)

The polar lows can occur between October and May throughout the year with the highest frequency between December and March. As Figure 5 shows the trend is that the occurrence of polar lows decline further north and further to the east. If the climate changes as expected and the average temperatures rises in the High North there will be a decrease of the polar lows altogether, but an increase in polar lows further north as the ice edge moves further north. This is because the atmosphere reacts more rapidly than the ocean, what will happen then is that the temperature difference between the air and the ocean will decrease, because of this the atmosphere will become more stable which prevents the occurrence of polar lows.

2.1.3 Visibility

In the Barents Sea 120 days per year typically have poorer visibility than 2 km, respectively with 76 days less than 2 km because of snowfall and 64 days with a visibility less than 1 km because of fog. Because of the poor visibility there is an increased risk of collisions between vessels or vessels and offshore structures. To reduce this risk, measures have been taken in the form of establishing fixed shipping lanes 30 nm outside the Norwegian coast from the Russian border to Rust. Poor visibility is also an issue for other marine operations. For instance it can create critical situations if external medical help is needed on a vessel or marine structure and the helicopter is not able to fly because of the weather conditions at the time. Helicopter service is an important aid in case of evacuation and rescue operations and it can be very critical if it cannot be used. Also the poor visibility can interrupt and be a hazard for supply vessels serving the marine installations in the Barents Sea. Table 1 shows the visibility throughout the year measured from different stations in the Barents Sea area.

Table 1 Visibility in the Barents Sea (3)

	Good visibility (> 10 km)	Moderate visibility (4-10 km)	Poor visibility (1-4 km)	Fog
Vardø	80-90%	5-8%	3-7% (9-12% Dec.-Jan)	1-3% (4-7% Jul., Aug., Feb.)
Bear Island	50-60%	12-19%	10-19%	Jun.-Sept.: 11-27%, Oct.-May: 4-8%
Svalbard Airport	>80%	2-10%	1-6%	0-2%
New-Ålesund II	>80%	9-14%	6-13%	5-7%
Hopen	50-60%	12-19%	11-17%	Jun.-Sept.: 11-27%, Oct.-May: 4-8%

In addition to reduced visibility because of the weather conditions there is the polar night. The polar night is a phenomenon which occurs during winter time. The presence of the polar night takes away the choice of carrying out difficult marine operations or helicopter services during daylight, as there will only be dusk during the lightest part of the day.

Table 2 Polar nights in the High North (4)

Location	Entire sun present	Polar night from	Sun back
Tromsø	May 20th – July 22nd	November 27th	January 15th
Hammerfest	May 16th – July 27th	November 22nd	January 20th
Jan Mayen	May 14th – July 28th	November 20th	January 21st
Bear Island	May 1st – August 10th	November 7th	February 4th
Longyearbyen	April 20th – August 22nd	October 26th	February 16th
Rossøya	April 12th – August 29th	October 19th	February 23rd
North-Pole	March 20th – September 23rd	September 25th	March 18th

2.1.4 Ice

The Arctic climate creates an extra threat to the marine and offshore activities situated in the area. Because of the low temperatures there is ice, icebergs and other hazards in the Arctic and parts of the Barents Sea. These factors increase the probability of unwanted incidents as compared to the rest of the Norwegian shelf.

The ice in ice-infested waters can be divided into three main groups:

Table 3 Types of ice in ice-infested waters

Level ice	A sheet of ice with close to uniform thickness, it is formed under relatively calm conditions. Is present in almost all ice infested waters and can cause both static and time-varying forces on offshore structures.
Ice ridge	Formed when level ice sheets are fractured by thermal forces. These forces cause fractured ice pieces to be pushed above and below the former level ice sheet, which form a “sail” above ice sheet and a “keel” underneath. Strength of ice ridges higher than that of level ice which makes it a danger to offshore structures. Keel of ice ridge may touch seabed -> danger to pipelines.
Icebergs	Large ice blocks separated from glaciers near coastline. Comes from fresh water glaciers -> Mechanical strength much higher than sea ice. Pose a huge threat to offshore structures as they are often enormous of size, must be monitored and towed away or destroyed in case of possible collision.

The sea ice is also further divided into the two categories first-year ice and multi-year ice. The first-year ice is ice that has grown only through one winter while the multi-year ice is ice that has survived at least one summer’s melt. Regarding the thickness and strength of these two types of sea ice the first year ice is up to 120 cm thick and has low ice-strength properties. The multi-year ice is up to 3 meters or more thick and has high ice-strength properties.

If there is an impact between an offshore structure and ice the forces that are experienced vary depending on the ice failure mode and geometry of the structure. Each of the ice’s failure modes creates different ice force magnitudes. If the ice sheet is in interaction with a cylindrical structure it typically fails in a crushing, buckling or radial cracking manner. If the ice sheet is in interaction with a sloping or conical structure the ice sheet fails in a bending manner and the ice force is reduced to at least 2/3 of the force which is experienced when in collision with a cylindrical structure.

Because of the danger of encountering ice is also present in the Barents Sea, the designer of the marine structure in question has to take into account additional loads. These loads can be divided into global or local loads, depending if the load is acting on parts of or the whole structure. Ice can also complicate marine operations, if there is ice in the waters where the operations are to be held, for instance in case of installation work, transportation or position keeping. The sea ice also poses a threat when it comes to rescue operations and oil spill response, for instance the sea ice can make the traditional rescue boats unusable. The Barents Sea will normally freeze when the temperature reaches -1.7 °C to -1.9°C depending on the salinity of the water.

The Barents Sea can be divided into different areas where each area has a different likelihood of ice coverage during the year. These areas are shown in Figure 6.

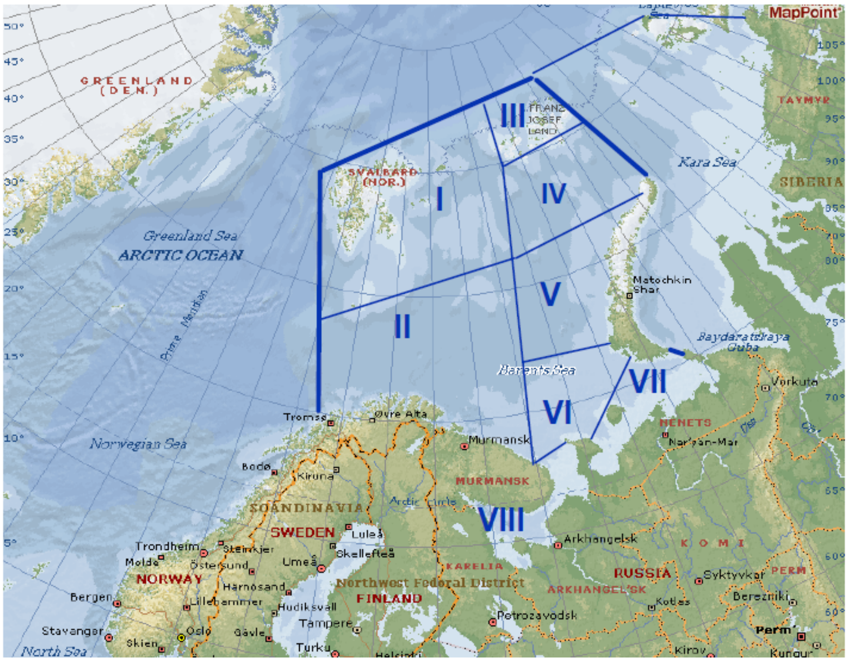

Figure 6 Borders and sub-areas of the Barents Sea. The bold lines show the borders (5)

Table 4 Ice coverage, The Barents Sea

I	Barents Sea North, usually ice every winter
II	Barents Sea South, generally ice free
III	Franz Josef Land, usually ice every winter
IV	Northeast Barents Sea, usually ice every winter
V	Novozemelsky, in-between
VI	Koala, in-between
VII	Pechora, usually ice every winter
VIII	White Sea, usually ice every winter

As for data regarding the extent of ice in the Barents Sea, satellites have given good coverage since 1972. However, in the Norwegian parts of the Barents Sea little data have been produced when it comes to statistics describing ice thickness, size of ice ridges, presence of pressure zones, statistics on short term drift velocity and physical and mechanical properties.

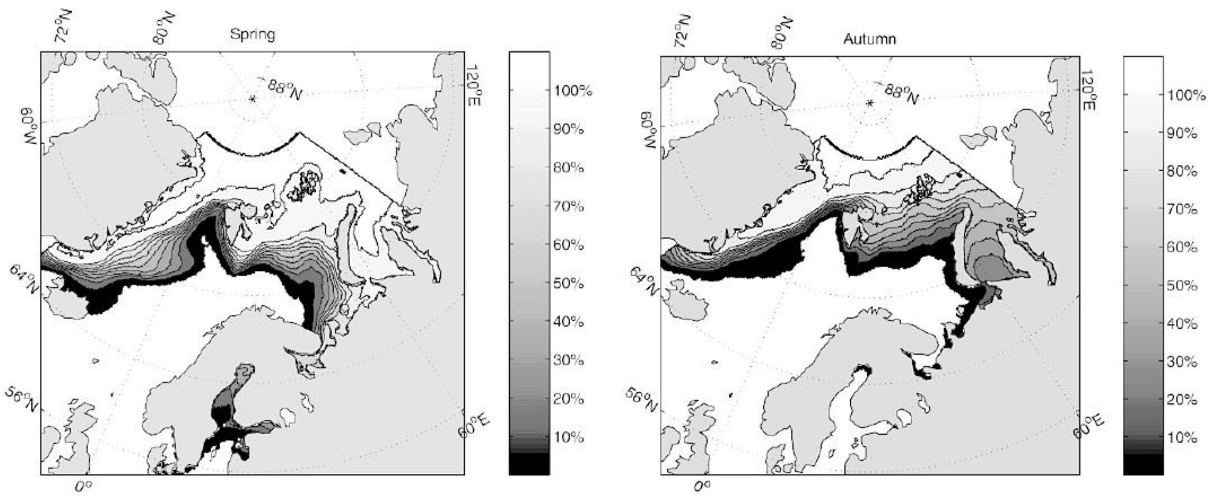

Figure 7 Seasonal means of sea-ice extent in the Nordic Seas over the period 1967-2002 (5)

Figure 7 shows the average ice extent in the Arctic Sea during spring and autumn and the percentage of which the given ice extent has occurred from 1967-2002. In general the ice extent is at its highest levels between February and April and on its minimum between July and October. As can be seen the ice extent rarely goes far below Svalbard in the Norwegian part of the Barents Sea. A closer look at the maximum ice extent experienced in the Barents Sea during the 2000s show that, there are yearly deviances that has to be accounted for.

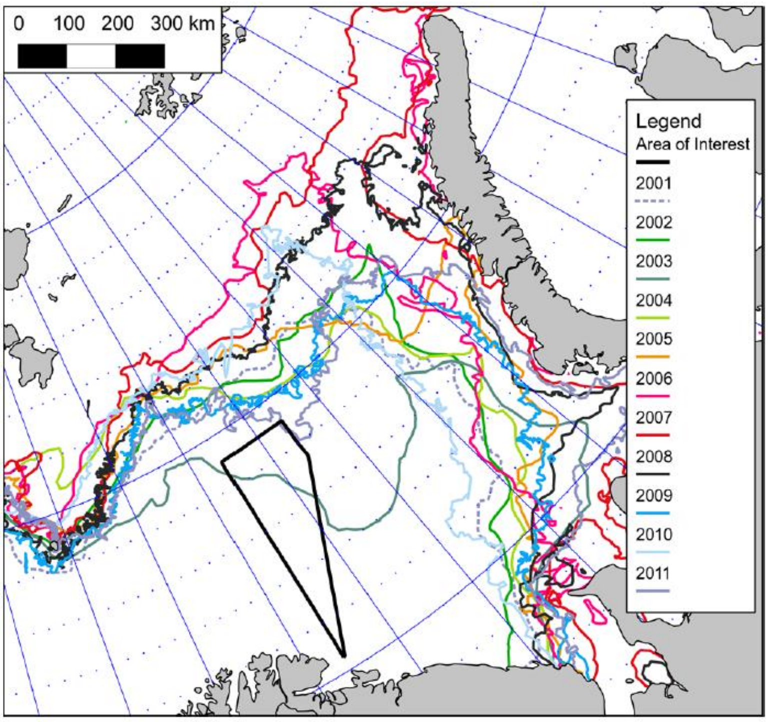

Figure 8 Yearly maximum ice extents 2001-2011 (3)

The general trend is that there is less ice extent throughout the year, this is especially true for the summer half-year while it has been more stable for the winter.

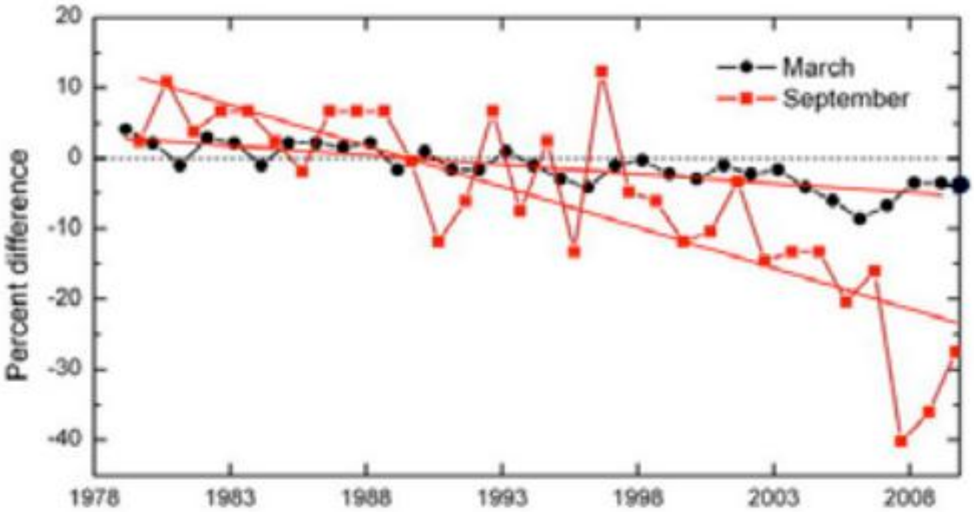

Figure 9 Summer and winter development of sea ice extent in the Arctic 1979-2010, deviations from the mean values for the years 1979-2000 (6)

In addition some other trends have been observed. There are smaller peaks in the maximum ice extent every 9th year while the larger peaks return with an interval of 17-19 years. Therefore it is expected that a new peak in the ice extent will happen between 2014-2016.

Regarding icebergs some research and observations have been done. However, also here more information is needed. There are not enough reliable observations of icebergs and their mass to give a good enough foundation for an accurate probability distribution. Also, in the Norwegian archives observations of smaller growlers and bergy bits have been ignored and only the larger icebergs have been included. Figure 10 shows the locations of icebergs that have been spotted on the Norwegian sector in April from 1928-2005.

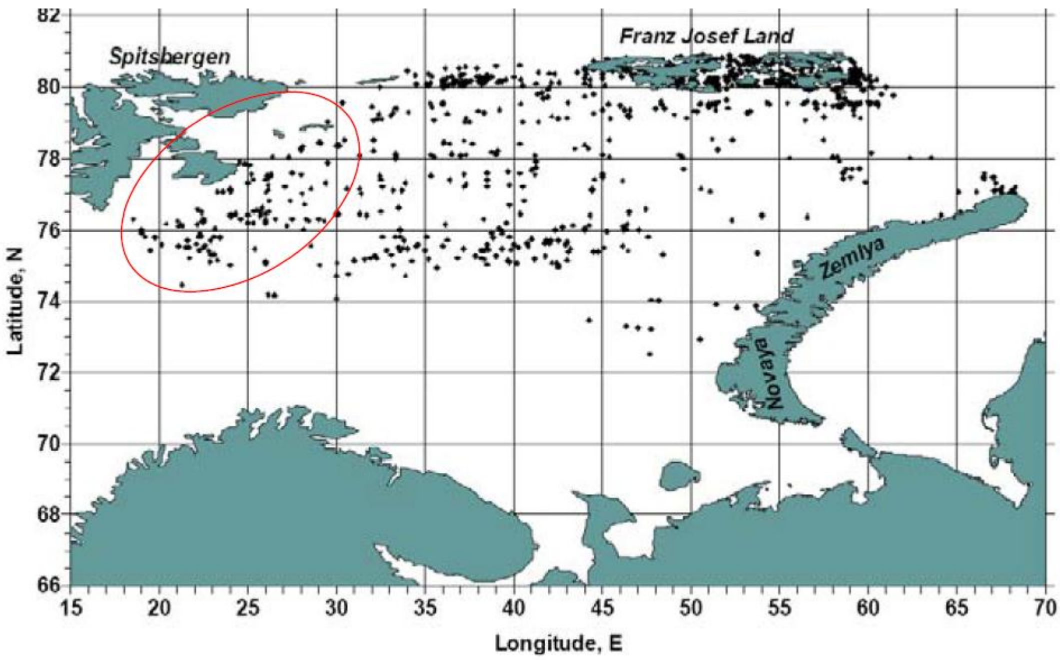

Figure 10 Locations of icebergs observed in April 1928-2005 (5)

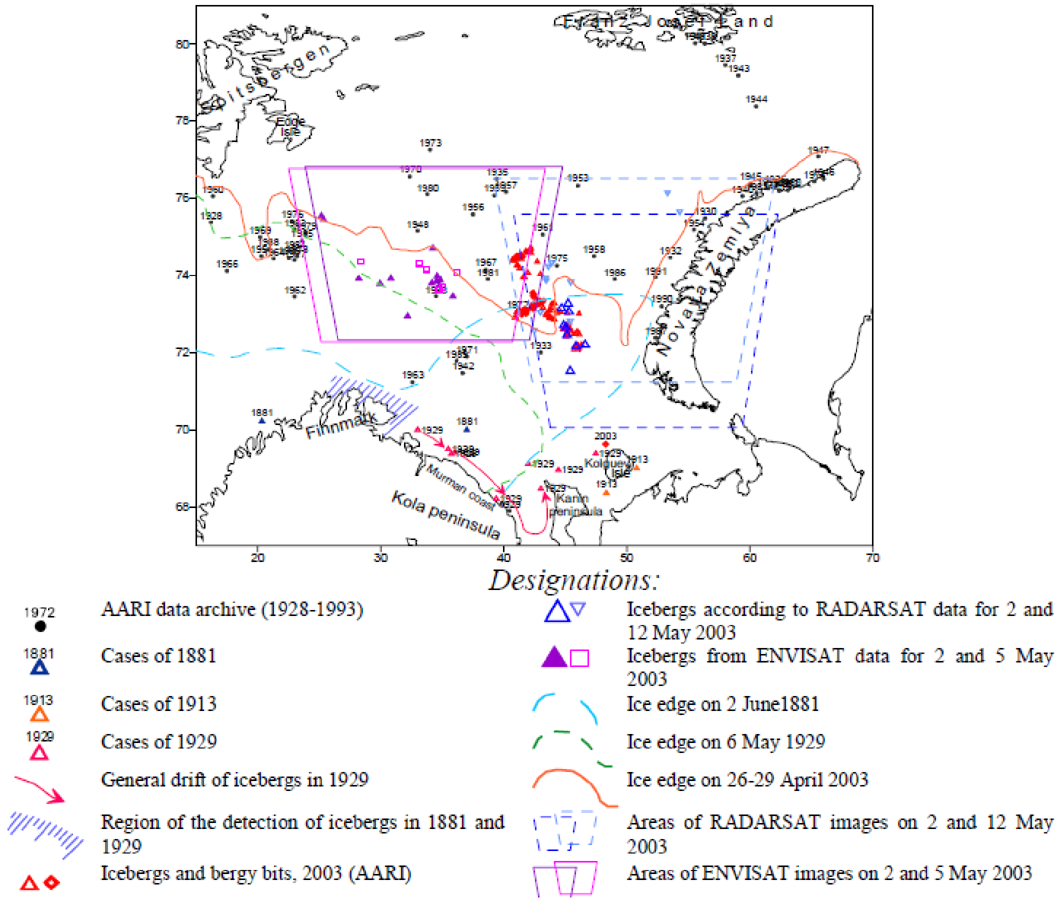

Figure 11 Locations of extreme iceberg sightings in the Barents Sea (5)

Figure 11 show some extreme sightings of icebergs in the Barents Sea. As indicated in the figure there have been observations of icebergs moving into the normally ice free part of the Barents Sea. The last time this happened was in 2003 when the ice edge was at an extreme level. There have also been a few observations of icebergs as far south as just off the coast of Finnmark, but that happened as far back as in 1881 and 1929 and it is not considered a very likely possibility today.

Another ice-related problem that occurs in the High North is icing on vessels and offshore structures. Icing is a phenomenon that occurs most frequently in open sea rather than in ice covered waters. The severity of icing depends on several factors like sea temperature, salinity, wind and wave conditions. Icing can be divided into two categories: icing caused by sea spray and atmospheric icing. Atmospheric icing is caused directly by the weather conditions, e.g. under-cooled fog or rain. The sea spray-induced icing occurs when a vessel slams into oncoming waves or offshore structures are hit by waves. In the Norwegian part of the Barents Sea the highest rate of icing is between October and May, where the chance of severe icing is highest in January and February. Sea spray induced icing normally occurs when the air temperature is less than -2°C and the wind speed is more than 11 m/s[2]. Icing is normally a more extensive problem for sea going vessels than for offshore structures. This is because they are exposed for both types of icing and it has been found that icing decreases with the

[2] Thelma, Kalde Utfordringer – Helse og arbeidsmiljø på innretning i Nordområdene (May 2010)

height of the installation, which is favourable for offshore installations. Research has found that icing above 15 m over sea level is relatively rare[3].

When there is icing there are several additional safety hazards that are introduced. As a direct threat to the crew working on the installation it is a problem that gangways and equipment become slippery. There is an increased risk of falling objects in form of e.g. ice lumps, escape equipment/routes and equipment can freeze and become blocked. The crew is also more prone to errors and accidents. The layer of ice that cover all or parts of the vessel naturally has a weight and a dimension which therefore change the loads on the structure which in turn change the stability. With today's knowledge this is not considered a problem. In addition icing can cause a reduced effect of radars and communication systems.

To reduce the problem with icing measures have to be done in the planning and design phase of the installation. Suggested measures can be heat tracing on critical areas of the hull and on important equipment, use of ice reducing chemicals and use of materials and coating that hinders icing to happen.

2.1.5 Vulnerable areas

Some areas in the Barents Sea are regarded as extra vulnerable in respect to physical features and biological diversity. The areas in question can be seen in the Figure 12.

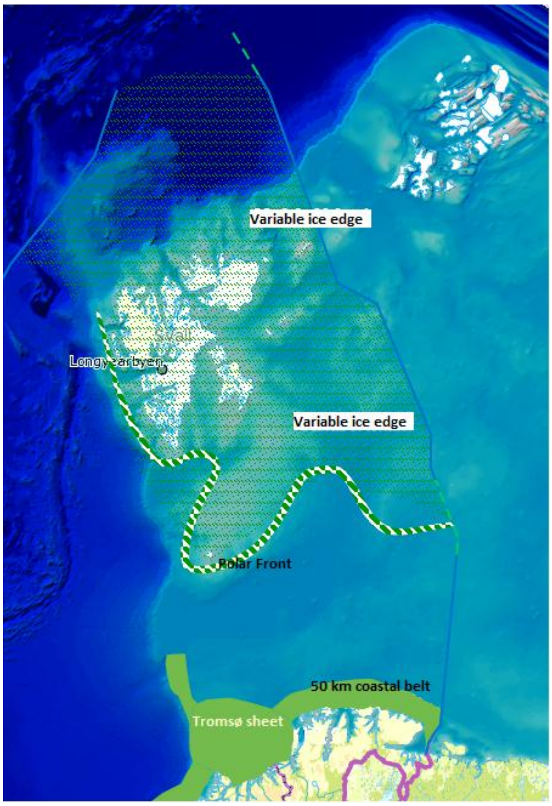

Figure 12 Vulnerable areas in the Barents Sea (7)

[3] Fett, R W, Englebretson, R E and Perryman, D C. Forecasters Handbook for the Bering Sea, Aleutian Islands, and Gulf of Alaska. Monterey, CA : Naval Research Laboratory, 1993.

These areas need to be especially protected against pollution and possible marine or offshore accidents.

The Polar Front is an area where the warmer water from the Atlantic Ocean meets the Arctic water which is colder and has less salinity. The Polar Front is valuable because it is a limited area where there is high production and high biological diversity. The ecological system connected to the Polar Front is vulnerable in respect to acute oil pollution and climatic changes.

The Ice Edge is an especially productive ecological system in the Barents Sea. The melting of the ice during the summer half of the year creates a unique environment which gives high production of zooplankton. This attracts sea birds, fish and mammals living in the sea and makes it a vulnerable area. Petroleum pollution is especially dangerous for the bird life.

The 50 km coastal belt is especially vulnerable because of the diverse and rich wildlife that is set there. The area is a popular fishing place and in along the coast of Finnmark coral reefs have been found. Because of this the area is vulnerable in respect to acute oil pollution.

2.1.6 Sea Conditions

2.1.6.1 Floor Conditions and Water Depths

The depth of the Norwegian part of the Barents Sea is between 200- 500 m, generally it lies between 200-300 m and the average depth is 230 m. On the Russian side of the Barents Sea the depth is generally between 200-300 m. The seabed of the Barents Sea mainly consists of sand, clay and some areas with stone.

2.1.6.2 Waves

Similar to the average wind speeds and the occurrences of polar lows the average significant wave height also declines as one move to the north and/or the east in the Barents Sea. In addition the average significant wave height is lower than in the Norwegian Sea and the North Sea.

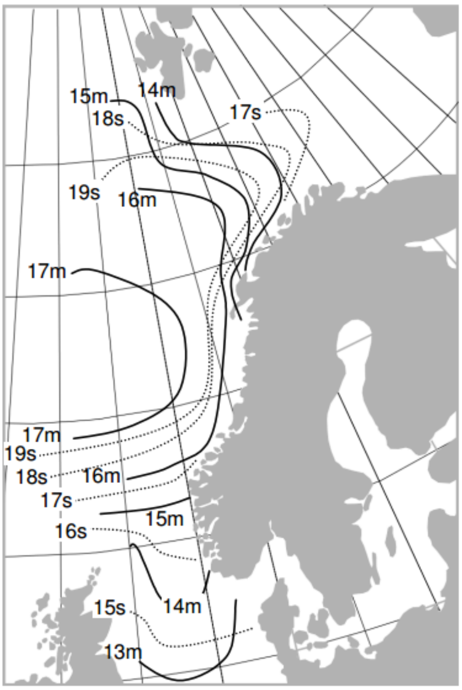

Figure 13 Significant wave height Hs as related maximum peak period Tp with annual probability of occurrence of 10^-2 for sea-states of 3 h durations. ISO-curves for wave heights are indicated with solid lines while wave period lines are dotted (8)

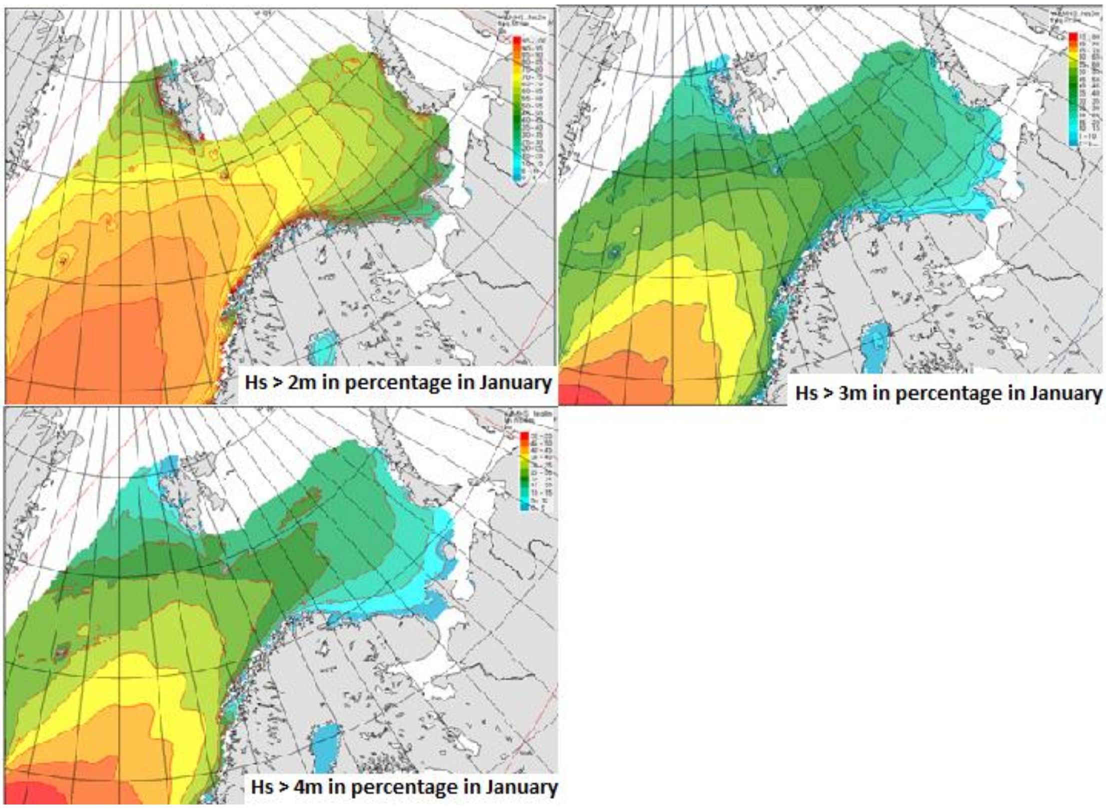

Figure 14 Significant wave height January (9)

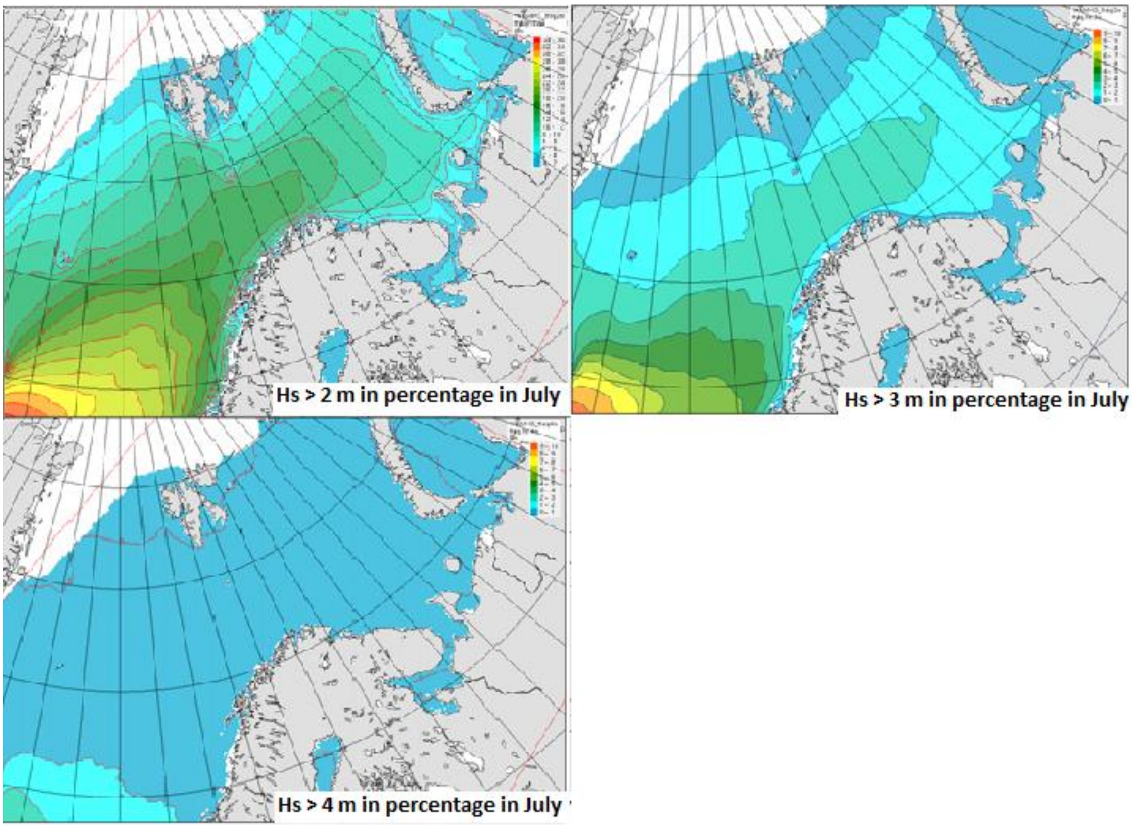

Figure 15 Significant wave height July (9)

2.2 Infrastructure

In addition to ice related issues and relatively harsh weather conditions the long distances between land and offshore structures is also a problem that needs to be addressed and accounted for in the Barents Sea. The long distances impose problems when it comes to transport and logistics for instance. More importantly it creates issues when it comes to Search and Rescue (SAR) services and emergency preparedness.

2.2.1 Shipping Traffic

Figure 16 shows the activities and the shipping routes in the Arctic Ocean in 2010. The reduction in sea ice the later years has resulted in an increase in shipping traffic going through the Northern Sea Route or the Northwest Passage. Despite of this significant relative increase the absolute increase is still small compared to the traffic using other solutions than sailing through the Arctic Ocean.

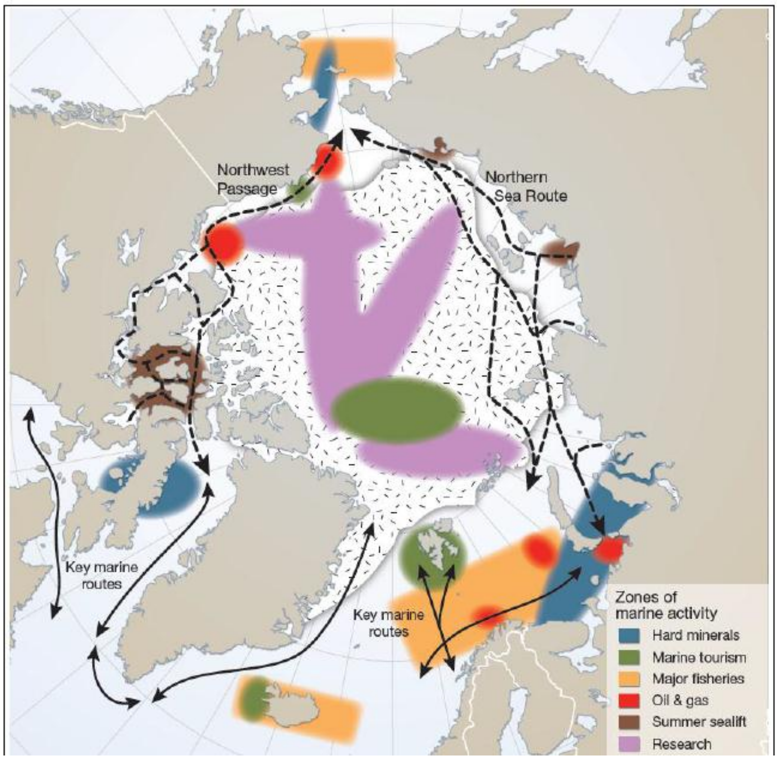

Figure 16 Activities in the Arctic Ocean 2010 (10)

In the Barents Sea specifically the shipping traffic is dominated by vessels carrying general cargo, bulk and tankers. In 2007 the Ministry of Fisheries and Coastal Affairs made it mandatory for tanker and cargo vessels above 5000 GT to sail in the traffic separation scheme between Vardø and Røst. The traffic separation scheme is about 30 nm outside the coast of Norway. The reason behind this regulation is a prognosis of increased shipping of petroleum and petroleum products from Russia. The mandatory shipping lanes are a central policy instrument for reducing the risk of collisions and acute oil pollution from vessels. The smaller general cargo vessels generally sail closer to the coast due to less impact by the weather. There is also activity from other vessels, for instance offshore vessels and service vessels. The main source of marine activity in the Barents Sea is fishing vessels. In 2008 they took up 60%

of the total amount of vessels recorded in the Barents Sea. There has been an increase in the shipping traffic around Svalbard. The increase is mainly due to more cruise ship traffic. Other typical traffic around Svalbard is expedition vessels, cargo vessels, research vessels and fishing vessels.

According to the Norwegian Coastal Administration there will be an increase of 3% in the shipping traffic in the Barents Sea and outside Lofoten within 2025. The main reason for this is an expected increase of 4% for large gas- and oil tankers. The traffic created by fishing vessels is expected to decrease, from a share of 60% to a share of 50% of the total.

In the administrative area the transit shipping traffic account for more than half the total traffic, this is not including the traffic that takes place closer to the coast. If this is also accounted for then the transit shipping traffic takes up about 25 % of the total. The transit shipping traffic mainly consists of large tankers and bulk vessels going to and from Russian harbours.

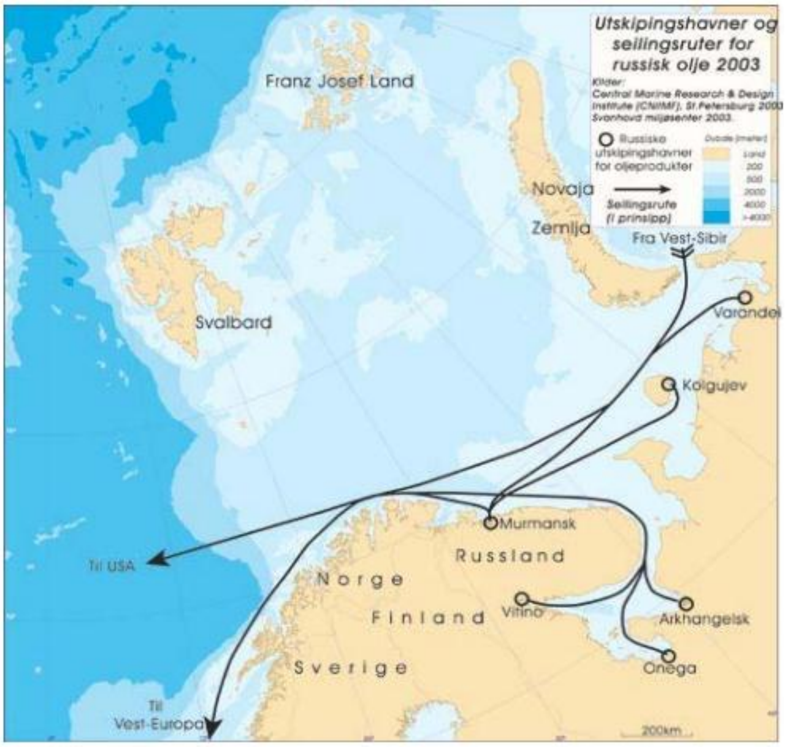

Figure 17 Discharge ports and shipping routes for Russian oil 2003 (11)

The amount of cargo transported in the main shipping lane between Vardø – Røst increased significantly in 2009 and it is expected that it will keep increasing in the following years[4]. Because of the increased offshore activity in the Barents Sea region 10 % of the total sailed distance is caused by offshore supply vessels and other offshore service vessels.

[4] Administration, The Norwegian Coastal. Utredning av konsekvenser av skipstrafikk i området Lofoten - Barentshavet. Ålesund : The Norwegian Coastal Administration, 2004

Table 5 Prognosis for development in ship traffic 2008-2025 in percentage (12)

Vessel (DWT)		Nordland	Troms and Finnmark	Average in the administrative area in the Barents Sea
Oil tankers	< 1000	2 %	2 %	2 %
	1000-4999	5 %	4 %	4,3 %
	5000-9999	8 %	6 %	6,5 %
	10000-24999	-20 %	-20 %	-20 %
	25000-49999	-45 %	87 %	94,5 %
	50000-99999	117 %	87 %	94,5 %
	>100000	77 trips to USA	77 trips to USA	77 trips to USA
Chemical-/ product vessels		11 %	18 %	16,3%
Gas tankers	5000-9999	18 %	10 %	12 %
	10000-49999	17 %	15 %	15,5 %
	50000-99999	15 %	23 %	21 %
	>100000	2062 %	2062 %	2062 %
Cargo vessels		13 %	29 %	25 %
Passenger vessels		5 %	5 %	5 %
Cruise		11 %	11 %	11 %
Offshore vessels		-20 %	22 %	11,5 %
Other activities		5 %	5 %	5 %
Fishing vessels		-29 %	-9 %	-14 %

2.2.2 Helicopter Service

As described there are many challenges when operating in the Barents Sea. There are metrological challenges as low temperatures, polar lows, poor visibility icing and a long winter season. There are also challenges related to long distances and not fully developed infrastructure. In this regard it is important to have access to helicopter services. The helicopters need to be suited for the environment which is to be faced in the High North. The Goliat field has reached an agreement with the Norwegian helicopter service. The helicopters that will be used are two long range helicopters of the type Eurocopter EC225. These are new builds that are especially built to endure the rough weather and conditions in the Barents Sea. They will have a range of 857 km, a cruising speed of 260.5 km/h and a capacity of 19 passengers + 1 cabin attendant (13). The distance from Hammerfest to Longyearbyen for instance is 875 km, the distance to Goliat is approximately 85 km and the distance to Snow White is approximately 130 km.

2.2.3 Communication

Communication is very important at sea, especially in emergency situations. It is important that the vessels or offshore structures are able to alert and communicate with external emergency preparedness crews. The High North does not have a completely satisfactorily communication system as of today. There are two main reasons for this. There have been marine activities in the Arctic since the beginning of time, but the relative amount of activity has not been very extensive so the communication system has not been developed sufficiently. There are also problems related directly to the geographical location of the Arctic. Because the Arctic is so close to the North Pole the area is affected by geomagnetic storms, which in turn affects the radio and satellite signals. As of today broadband communication for ships is not possible in the area between Svalbard and the North Pole.

In relation to the impact assessment study made for the possible opening of the new area "The Barents Sea South-East" an overview of the most important communication means in the High North, the result of this overview is presented in Table 6. The colour explanation is as follows:

Red: Unavailable systems
Orange: Needs more research
Green: Available

Table 6 The most important communication systems in the High North, classified after functionality in different degrees of latitude (14)

	System	Characteristics	Polar (>80°N)	Sub-Polar (70°N-80°N)	Other areas (<70°N)
Land based systems	HF, MF	Unstable because it depends on atmospheric conditions. Typically difficult to reach through the auroraial zone. Firstly only developed for voice	Low reliability if it is desirable to reach base stations outside the aurorial zone.	Low reliability if it is desirable to reach base stations outside the aurorial zone.	OK, but unsuitable for digital communication
	VHF	Line.of.sight (typically around 30 nautical miles), voice. Data only relevant in correlation with the GMDSS system.	No land based stations, but functional in ship-to-ship communication, which is essential in SAR-services.	Very few land based stations, but functional in ship-to-ship communication which is essential in SAR-services	Relatively many land based stations, and functional ship-to-ship communication, which is essential in SAR-services
	GSM, 3G	Line-of-sight (typically around 10 nautical miles from the base station). System covers both voice and data traffic.	No land based stations makes the system unusable.	Few land based stations makes the system usable only in waters especially close to the coast.	Many land based stations make the system usable in waters close to the coast.
Satellite systems	GEO sat., inc. Inmarsat	The system use geostationary satellites with orbit over the equator. This gives medium capacity. Low to medium latency.	Is outside the coverage area and is therefore not available.	Potential problems with the quality and the availability when this is in the borderland of the coverage area.	OK (with the exception of fjords and similar areas where structural obstacles hinders direct contact with the southern hemisphere).
	LEO satellites; Irridium	The system use satellites with a pole-to-pole orbit. This gives high coverage in the pole areas. Low data speed, maximum 128 kbps.	Few problems except from low data speed.	Few problems except from low-speed data.	Few problems, except from low data speed.
	HEO satellites	Capacity equal to GEO. Not available at the present time.	Expected to have coverage, capacity and quality in Polar and Sub-Polar areas. The reserve capacity can be used in other sea areas. Not yet implemented.		

Today in correlation to offshore operations VHF voice communication is mainly used when inside the coverage area of the VHF stations, either for ship-to-ship or ship-to-land base communication. When outside the coverage area the Inmarsat system voice communication is used.

In the Barents Sea Automatic Identification System (AIS) is used to track the vessels and offshore installations. The vessels are equipped with an AIS transponder which sends information regarding identity, position, speed, direction, vessel type, cargo etc. In 2010 Norway launched a new AIS satellite which improved the coverage area in the Barents Sea. Figure 18 illustrates the area which is now being covered, the yellow dots represents the vessels which signals are being picked up by the new satellite. AIS is very useful as it makes it easier and faster for the sea traffic central and the rescue centres to find the positions for vessels that are in need of assistance or rescue.

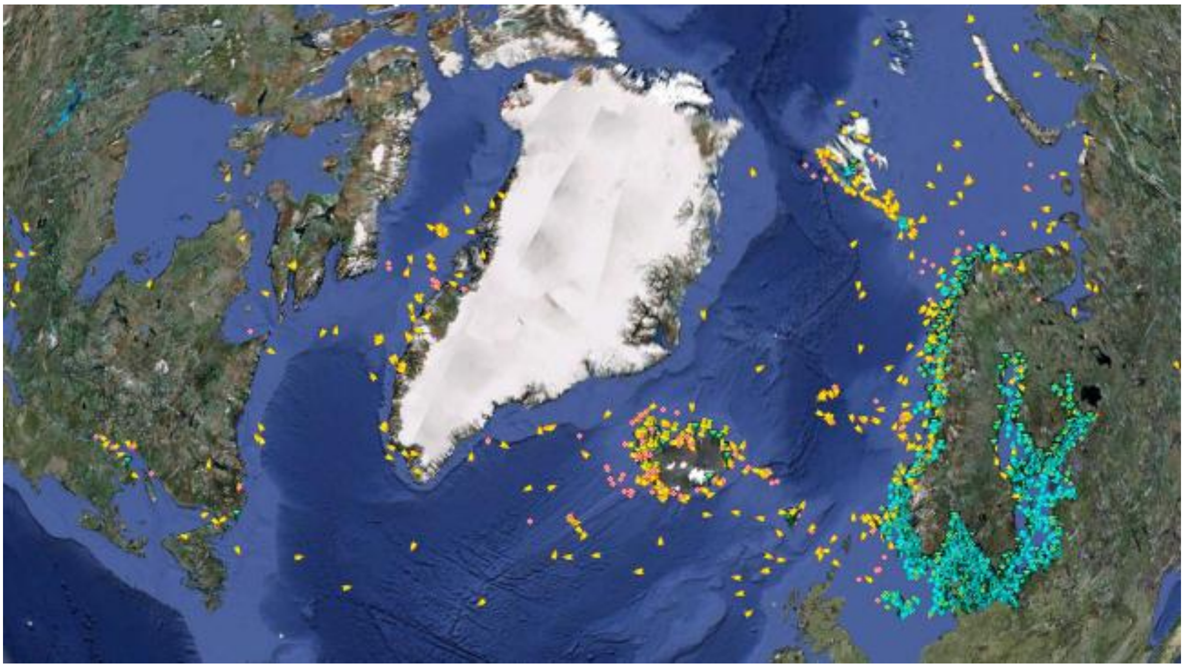

Figure 18 First satellite picture for AISSat 1 traffic information (14)

The International Maritime Organisation (IMO) requires all passenger vessels and cargo vessels above 300 GT that are sailing in international waters and all mobile offshore drilling units that are registered in SOLAS (Safety of Life at Sea) to have installed AIS transceivers and transponders on board.

In addition to the AIS-system the traffic centrals are also able to receive information about the sea going traffic through Long Range Identification and Tracking (LRIT). For passenger vessels and cargo vessels above 300 GT sailing in international waters and for mobile offshore drilling units the use of LRIT satellite system is obligatory according to IMO.

2.2.4 Offshore Activities

Figure 19 show the areas which currently are opened for petroleum activities and areas where the opening process has started.

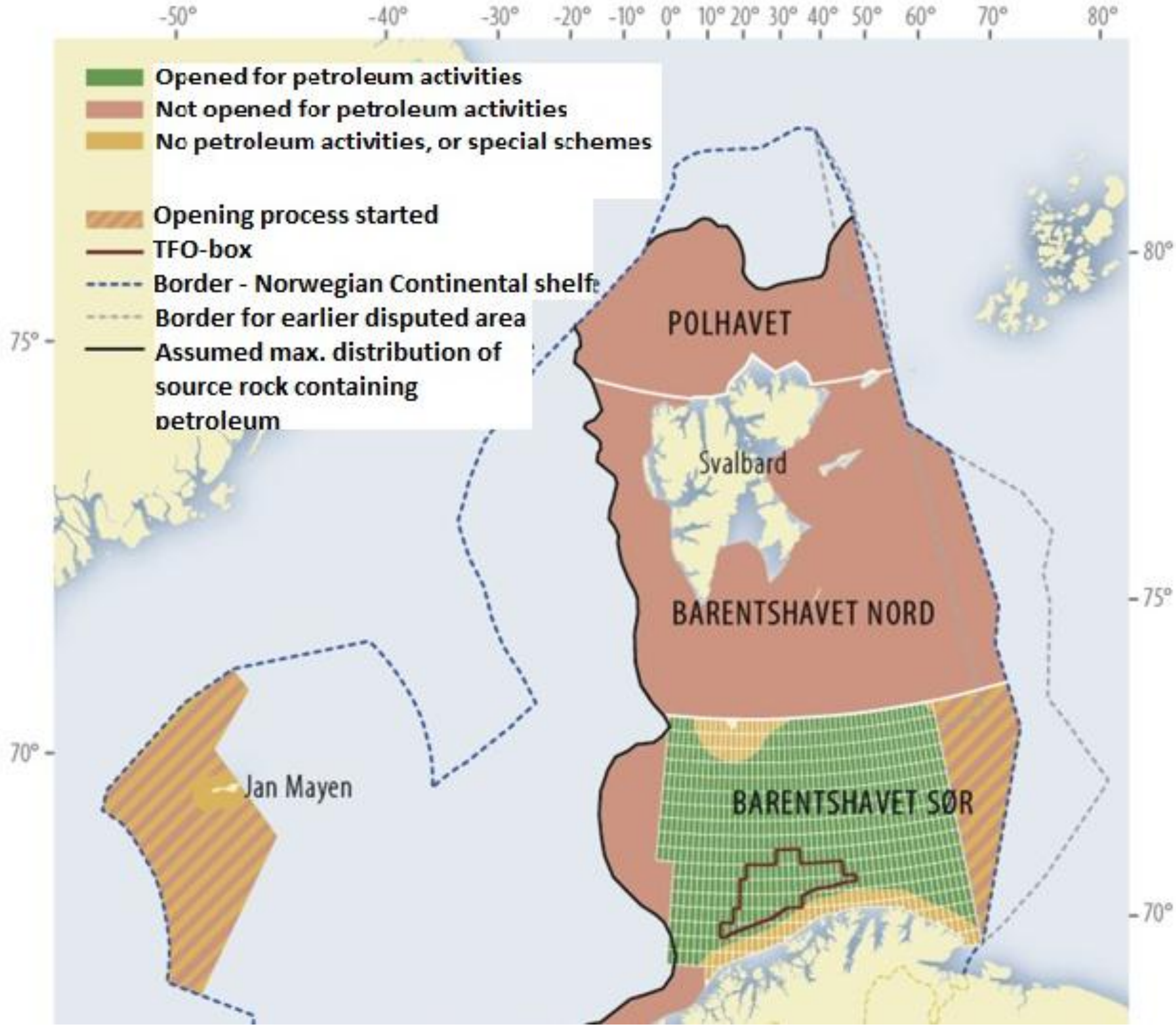

Figure 19 Areas opened for petroleum activities (2011) (15)

2.2.4.1 Snow White

Snow White (Snøhvit) is a natural gas field located 140 km northwest of Hammerfest at 70° north. It is estimated to contain 193 billion m^3 natural gas, 113 million barrels of condensate and 5.1 million tonnes of natural gas liquids. It was discovered in 1984 and the production started in 2006. The Snow White field is a subsea gas field that is connected to a land-based plant on Melkøya. Snow White feeds the field with gas through a 160 km long submarine gas line. The subsea gas field is located at 340 m depth.

Figure 20 Subsea pipe line connection Snow White - Melkøya (16)

2.2.4.2 Goliat

The Goliat field contains both oil and gas. It was discovered in 2000 and production is expected to start in 2014[5]. It is located 85 km northwest of Hammerfest. The field is to be equipped with an FPSO (Floating Production Storage and Offloading unit) of the Sevan 1000-consept, which is a circular vessel. The FPSO has 8 subsea frames and has the ability to connect to altogether 32 wells. It is planned for 22 wells at starting up, but with the possibility to drill 10 more for future utilisation of the petroleum reserves. The FPSO can store 151 000 m^3 oil at the time and the FPSO will be served by tankers at a regular basis which charters the oil to land. The gas reserves that are discovered in the field will first be pumped back into two injection wells after it has been collected from the field. The reason for this is that there is no available capacity at the Snow White installation. The gas will be processed later when means for exporting it is ready. The Goliat field is placed at water depths that vary between 320-420 m.

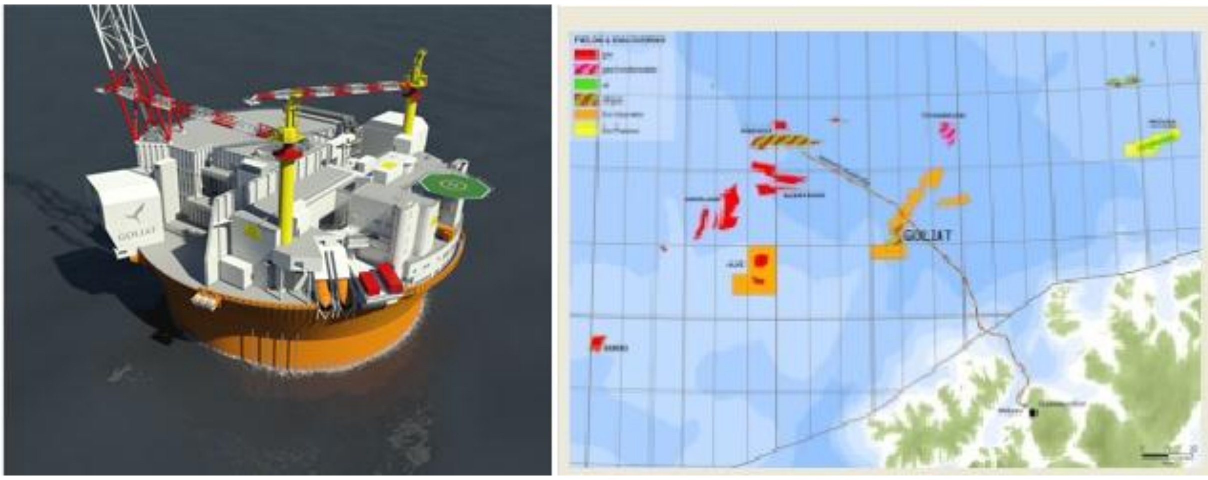

Figure 21 The Goliat field (17)

[5] http://www.eninorge.com/no/Nyheter/Nyheter/2012/Produksjonsstart-pa-Goliat-forskyves/

2.2.4.3 *Skrugard*

The Skrugard field is located 100 km northwest of the Snow White field. It is planned to be equipped with an FPSO and is situated at an area with a water depth of 370 m. The main petroleum product discovered in this field is oil. Since the field is situated outside the established infrastructure it is possible that a new field centre with processing and transport centre will be opened there.

2.2.4.4 *Havis*

The Havis field is considered to be the Skrugard twin field as it also contains mainly oil and lies in the same area as the Skrugard field. It is situated approximately southwest of the Skrugard discovery and has the same production license, but has is its own independent structure and there is no communication between the two discoveries. The water depth where the Havis field is located is about 365 m. It is estimated that the field contains an oil reserve of 39 700 000 Sm^3.

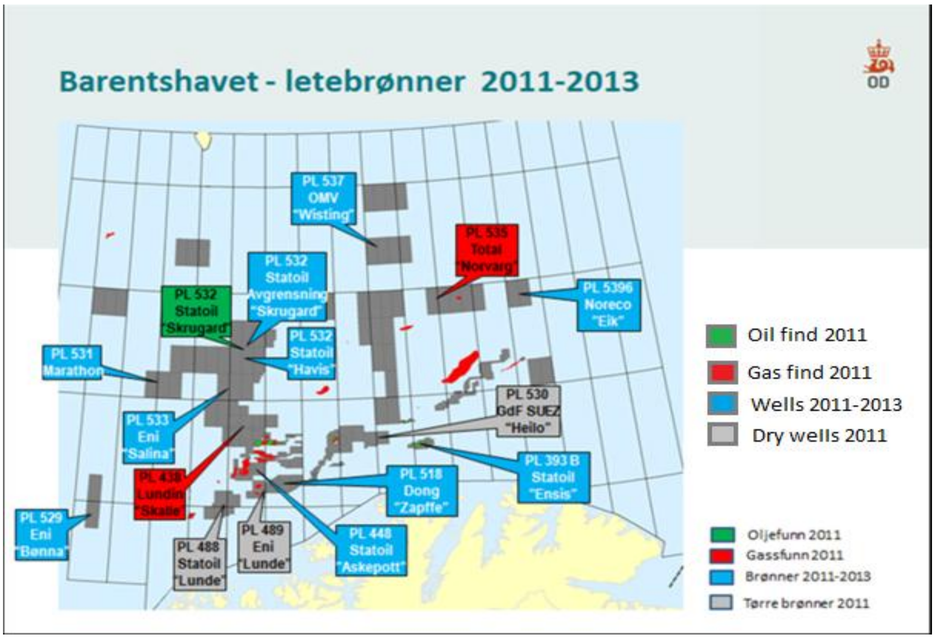

Figure 22 The Barents Sea: Existing oil and gas fields and future exploratory wells (18)

2.2.4.5 *Future possible offshore activities*

The Norwegian Petroleum Directorate (NPD) has presented four different possible future scenarios for petroleum related activities in the Barents Sea. A scenario is described by the NPD as a story of what could happen and not a prognosis or expectation of the future. Also it is not described as a vision of a wanted future, but it is different future possible scenarios that may serve as an aid encouraging new ideas regarding choices that are being made today. As can be seen in Figure 23 the new possible petroleum fields are pictured to be situated southeast in the Barents Sea and east and south of Svalbard as well as outside Lofoten.

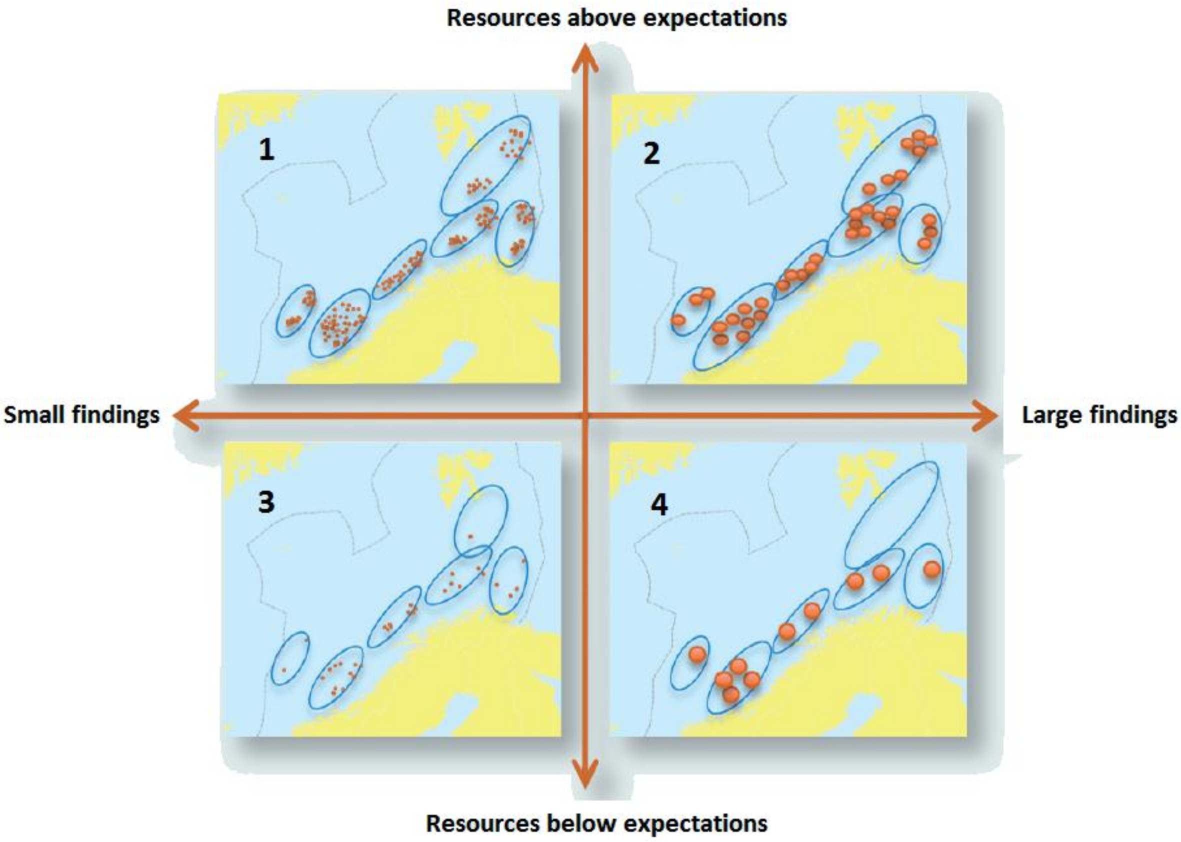

Figure 23 Future possible petroleum scenarios (19)

The area which is situated southeast in the Barents Sea has already undergone an assessment and the area has been opened for seismic activities which are expected to be finished in the spring of 2013. If sufficient petroleum resources are found and the area is opened for petroleum extraction then the assessment has pictured the first exploration well in the area to be drilled in 2017.

The areas closer to Svalbard have not yet undergone an assessment, but in the scenarios presented by the NPD the first exploration well will be drilled in 2025.

2.2.5 Emergency Preparedness

It is expected to be an increase in marine and offshore activities in the High North. Because of this a more extensive emergency preparedness scheme will be needed. For the Norwegian part of the Barents Sea the most important actors related to emergency preparedness are:

- The Norwegian coast guard
- The Norwegian sea rescue
- The joint rescue coordination centres
- The coastal radio
- Local emergency preparedness resources
- The military's 330 squadron
- The vessel traffic service
- The Norwegian Coastal Administration

- The Norwegian mapping authority
- The meteorological institute
- Private tugboat companies
- Norwegian Clean Seas Association for Operating Companies (NOFO)

In May 2011 a new SAR agreement was reached between the countries bordering the Arctic Ocean. Figure 24 shows the areas where the individual countries have responsibility for the SAR-services.

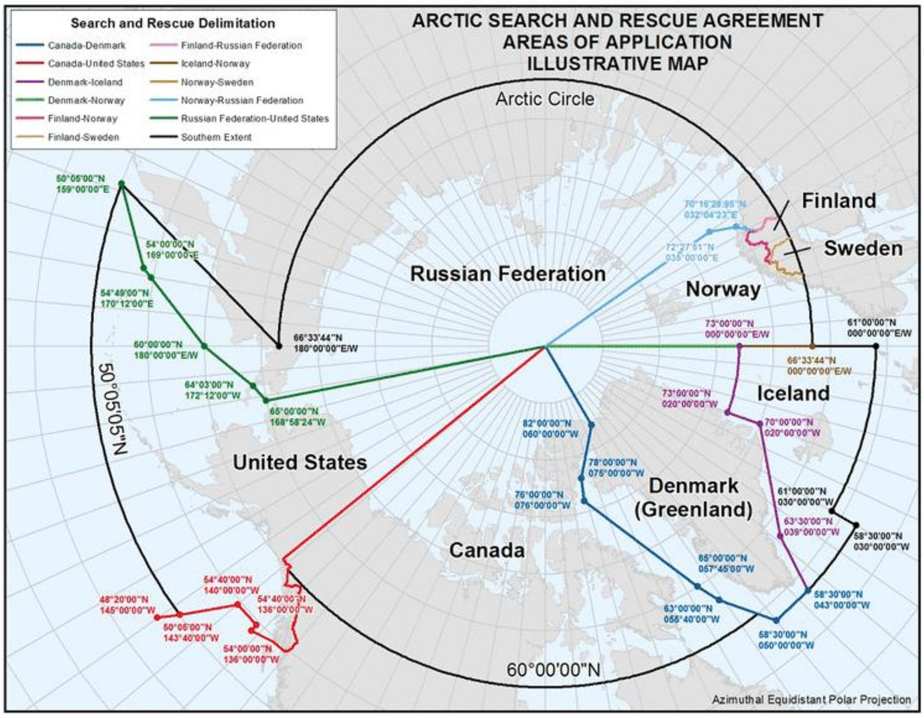

Figure 24 Arctic Search and Rescue agreement (20)

A major challenge connected to the emergency preparedness in the High North is the long distances from the preparedness resources located onshore. In addition the traffic density is relatively low which reduces the number of vessels that can be used for assistance in an emergency situation. The marine and offshore activities in the High North are expected to increase because of the heightened interest in the petroleum resources located in the High North and because of the extended possibilities of shipping traffic as the ice coverage decreases. Although this will increase the number of vessels that can assist in an emergency situation it also increases the risk of an emergency situation to happen. The low air and water temperatures make a fast SAR response crucial in case of a man overboard situation as the survival time is reduced. In addition the increased petroleum activities also make a quick response oil spill recovery system very important.

2.2.5.1 SAR-helicopter coverage

The main SAR resources in Norway today consist of helicopters, coast guard vessels and vessels operated by Norwegian Sea rescue. The rescue helicopters that are in service in Norway are the 330 squadron which is a public rescue service and private SAR helicopters that service the installations on the Norwegian continental shelf. The 330 squadron is stationed six different places in Norway. In the north it has one department in Bodø and one in Banak. A Eurocopter EC225 is stationed at Hammerfest by Statoil and ENI. There is also stationed a SAR helicopter of the type Super Puma AS332L1 in Longyearbyen on Svalbard, but since Svalbard is a designated demilitarized zone this helicopter is serviced by the Governor of Svalbard and not the 330 squadron.

In relation to petroleum activities there are certain demands related to the SAR-services. Most importantly is that in case of an accident where people are severely injured they are to be rescued and brought to a hospital within 3 hours. With the resources available today this is not possible for the majority of the Barents Sea. Figure 25 shows the areas that are covered within a 3-hour operation time with the helicopter SAR-resources available today.

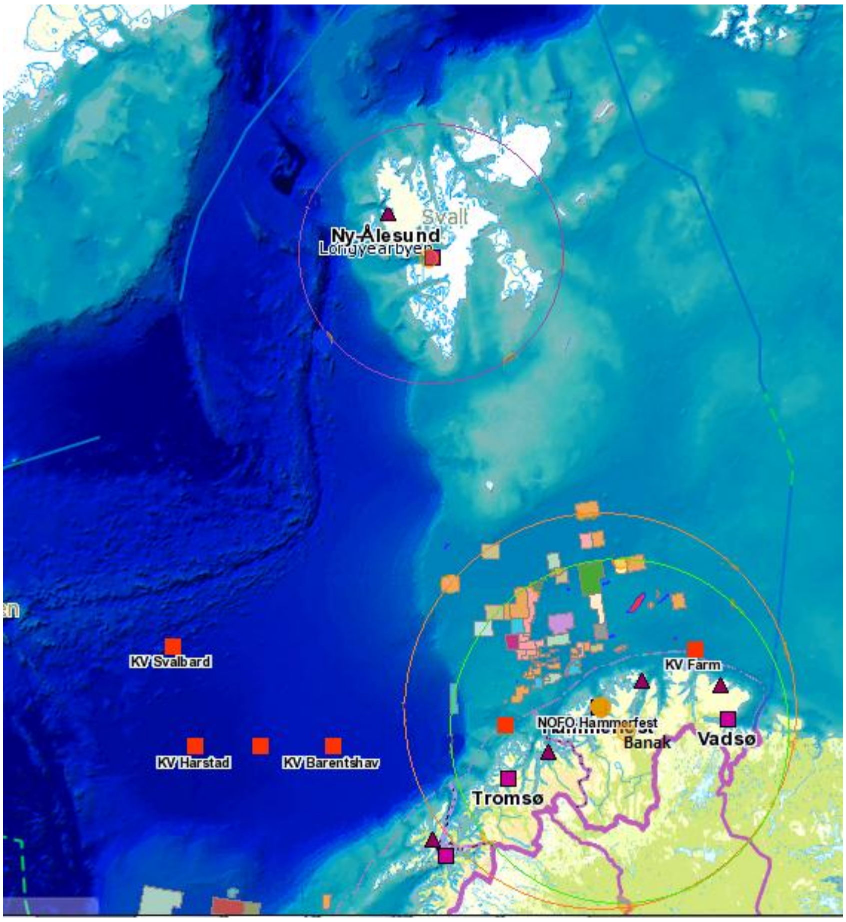

Figure 25 SAR-helicopter 3 hr action radius in the Barents Sea, Hammerfest: red circle, Banak: green circle, Longyearbyen: purple circle

The 3 hour action radius for the SAR-helicopters is based on the resources available today and represents 3 hours where maximum speed, response time and salvation time is included. It should also be noted that the Eurocopter EC225 placed in Hammerfest has a mobilization time of 60 minutes, but during daytime the mobilization time for bringing people out to the installations is 15 minutes. The response time in Hammerfest is therefore also set to 15 minutes. It should also be noted that the main hospital is in Tromsø, but there are also hospitals in Hammerfest and Kirkenes which can extend the action radius slightly.

Table 7 SAR-coverage today (21) (22) (23)

	Hammerfest (Statoil & ENI)	**Banak**	**Longyearbyen**
Helicopter type	Eurocopter EC225	Westland Sea King	Super Puma AS332L1
Response time	15 min	15 min	60 min
Max. speed	149 kn	130 kn	141 kn
Cruising speed	145 kn	100 kn	136 kn
Max. range	463 nm	220 nm[6]	463 nm
No. of people in need of rescue	3	3	3
Salvation time[7]	9 min	9 min	9 min
Action radius 3 hrs (max speed)	193 nm	169 nm	130 nm
Action radius 3 hrs (cruising speed)	188 nm	130 nm	125 nm

At present time the SAR-helicopter service cover the main areas where there are petroleum activities within the 3 hour SAR-limit. This limit is only applicable to actors within the petroleum services and the total SAR-helicopter service covers a larger area. The Norwegian Armed Forces have set a practical maximum action radius for the Westland Sea King helicopter to be 220 nm. Seeing as the maximum flight range of the SAR-helicopters stationed in Hammerfest and Longyearbyen is 463 nm the same action radius is assumed to apply also here. The maximum action radius will then be as shown in Figure 26.

[6] Maximum practical action radius including 15 minutes response time, 20 minutes total rescue time and 30 min hover time (data given by the Norwegian Armed Forces)
[7] Based on an assumption of 3 min pick-up time per person

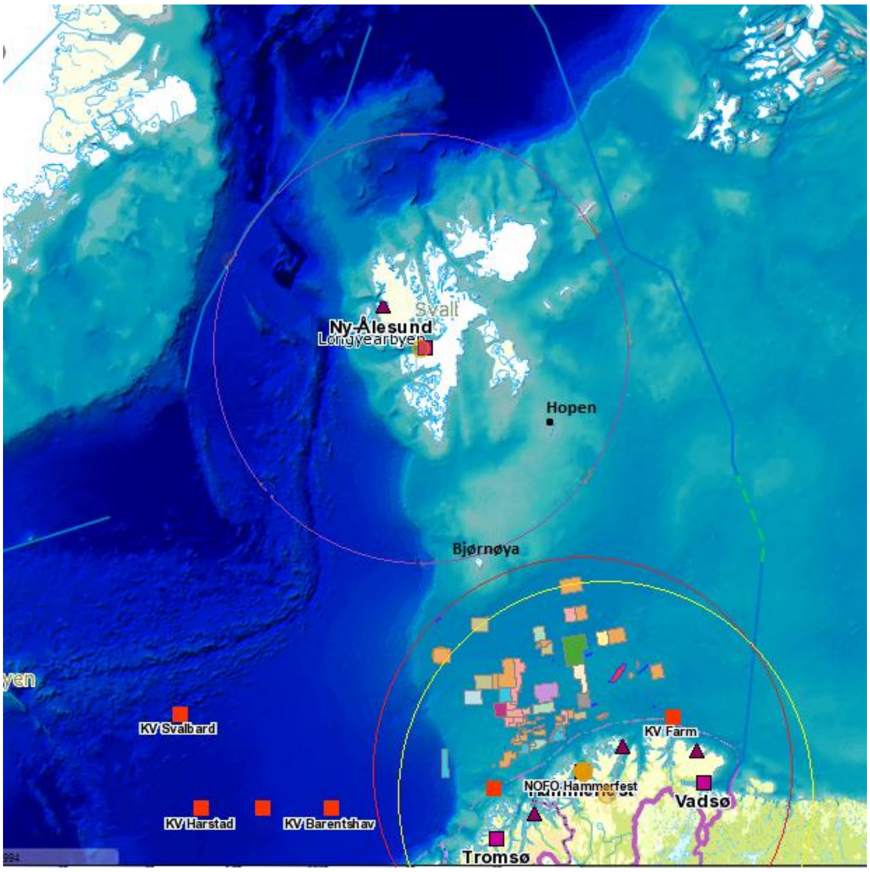

Figure 26 Maximum practical action radius SAR-helicopters

It is also possible to refuel the helicopters at Hopen and Bear Island which increases the coverage area even more. This makes it possible to cover the entire Norwegian part of the Barents Sea south of Svalbard. As time is a crucial factor when rescue is needed in a cold and harsh climate the SAR-coverage can still be considered as fairly poor. In relation to the border-agreement in the Barents Sea between Norway and Russia, a new area in the south east has also undergone investigation for possibly being opened for petroleum activities. If this area is opened large parts of it will be outside the 3 hour limit. To reduce the area not covered it may be possible to place a SAR-helicopter north-east in Finnmark, assuming this helicopter will be of the type Eurocopter EC225 which has the largest action radius of the existing helicopters today it will still not cover the entire area in question.

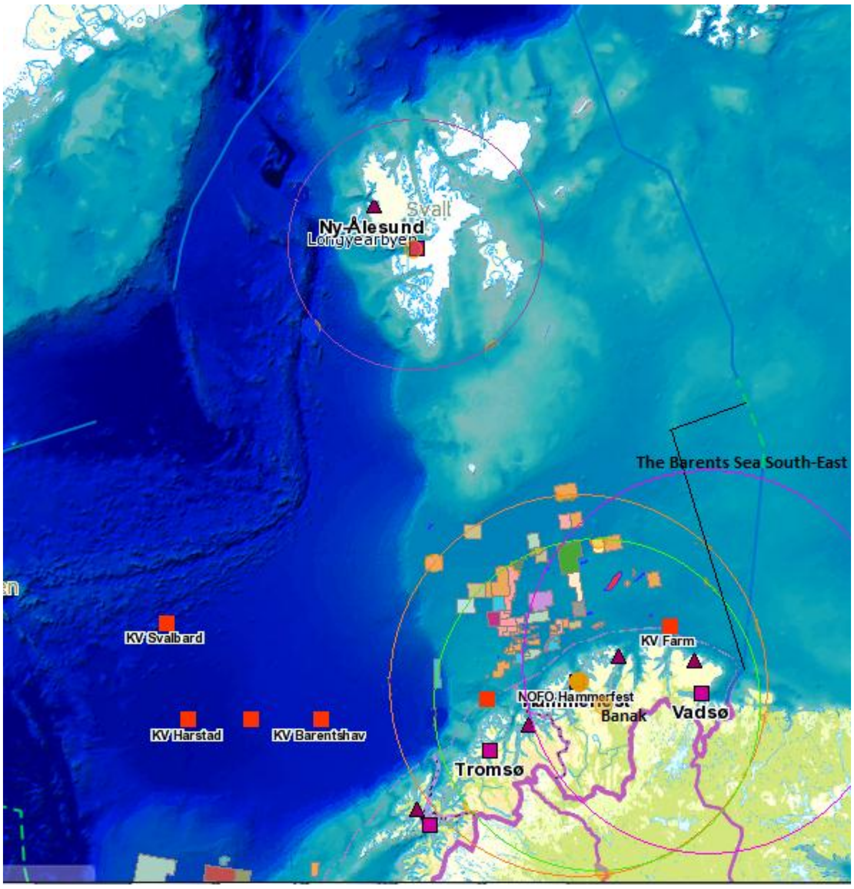

Figure 27 Maximum helicopter radius without refuelling helicopter. Orange: Hammerfest. Green: Banak. Purple: Kirkenes. Light purple: Longyearbyen

In case there is a helicopter accident it is required that at least 21 persons shall be rescued within 120 minutes. If the accident happens outside the two hour range of the onshore stationed helicopter the requirement can only be fulfilled by standby emergency preparedness vessels or SAR helicopters stationed on offshore installations.

2.2.5.2 Emergency Oil Spill Preparedness

The oil spill emergency response in Norway is handled by three different parties: private emergency response, municipal emergency response and national emergency response. The oil spill emergency response is dimensioned from environmental risk. The actors involved in the activities that are propagating this risk are responsible for providing the adequate oil spill emergency response. If there is oil spill from vessels the Norwegian Coastal Administration have the responsibility for the oil spill emergency response, if there is oil spill from offshore installations it is the operators responsibility. The Climate and Pollution Agency in Norway have the authority to determine special demands to the emergency response. For the petroleum business it is NOFO which is in charge of maintaining the petroleum operator's oil spill emergency response obligations. The municipal oil emergency response is obligated to take action when there are minor incidents of acute pollution, which is not covered by the private emergency response, inside the municipality's border. The Governments oil spill emergency response is obligated to take responsibility when there are incidents of acute pollution which are not covered by neither private nor municipal emergency response.

On the Norwegian continental shelf the strategy behind avoiding acute pollution is based on a principle of barriers. There have been defined four different barriers:

1. Combating pollution on open sea near the source of pollution
2. Combating pollution on open sea and towards the coastal zone
3. Combating pollution in the coastal zone and in the fjord areas and protection of vulnerable natural resources
4. Combating pollution on shore

For oil fields that are in production the emergency response in barrier 1 and 2 are to be dimensioned so that it can handle up to 90 percentile of the expected blowout rate while for fields that are still in the drilling phase barrier 1 and 2 are dimensioned after a weighted blowout rate. The 3rd and 4th barrier are dimensioned after the expected amount of oil spill that reach those areas. Earlier experience show that the main sources of acute emission near the coast and the shoreline are from shipping accidents.

The preferred technique to collect spilled oil in Norway is mechanical collection. A mechanic oil collecting system mainly consists of an emergency response vessel, lenses and oil skimmers. In waters that are partially or completely covered with ice there are some difficulties related to mechanical collection. The lenses used to collect oil are problematic to use in ice concentrations that exceed 15-30 %. The oil inflow to the skimmers can be hindered by the ice, the oil separates from the ice, the viscosity of the ice increases because of the low temperatures which creates difficulties for traditional skimmers and the low temperatures may cause the equipment to freeze. There have been developed skimmers for use in ice, but the effect of mechanical collection of spilled oil in ice is still poorer than collection in ice free waters.

Another method used to combat oil spills is to use chemical dispersion where chemicals are sprayed onto the oil floe to increase the natural dispersion rate of the oil. The chemical is sprayed onto the oil floe using either ships, helicopters or airplanes. This causes the oil to break down into smaller oil drops which is diluted and broken down by microorganisms. Before using this method an assessment has to be made considering the effectiveness of it and also if the chemicals themselves pose a threat to any nearby environment. The use of dispersion chemicals in ice covered waters have been tested and found to be a possibility. The difference from the use of these chemicals in open sea and waters with ice is that the chemical itself needs energy for the dispersion process to start, in open water sufficient energy is usually provided by waves, but this is not possible if the ice coverage is to extensive. Therefore, to start the process in ice covered waters alternative methods has to be used. Trials using the thrusters on larger vessels have proven to be efficient also in relatively high degrees of ice coverage (70-80%)[8]. A positive effect of icy waters in relation to the dispersion method is that the ice causes the deteriorating time for oil decreases which leaves an increased time frame for the use of dispersion chemicals.

[8] DNV, Oljevern beredskapsanalyse for lokasjoner i det sørøstlige Barentshavet (2012)

A third method that is used is to burn the oil at the site of the ice floe. This method has proven to be the method with the most potential in waters with high ice coverage. The burning has to be done under controlled circumstances and certain factors have to be considered:

- The properties of the oil and its rate of degradation
- The thickness of the oil floe
- Wave activities
- Wind
- Temperature of combustion

The degree of ice coverage affects the burning technique in different ways:

- 0-30%: Lenses can be used to gather oil and create sufficient thickness for the burning to be effective
- 30-60%: Difficult to obtain sufficient thickness, the use of herder chemicals to gather oil is under trial.
- 60-70%: The ice can act as a barrier which creates sufficient concentration of oil

In the High North oil spill emergency response equipment is located in areas shown in Figure 28.

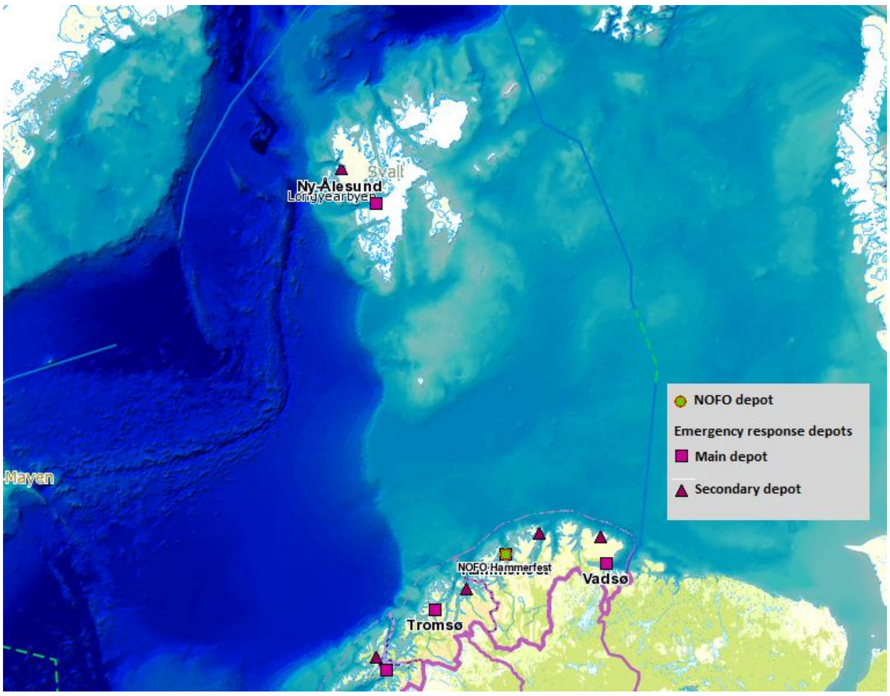

Figure 28 Location of oil spill emergency response depots

The NOFO-depot that is located in Hammerfest contains three complete NOFO-systems. One NOFO system consists of:

- 1 oil recovery vessel with tank capacity of 1000-2000 m^3
- 1 tug vessel
- 400 m Norlense NO 1200 R with 1200 mm freeboard
- FRAMO Transrec 150 oil recovery system 420 m^3/h

- Miscellaneous equipment and crew

The system has a maximum capacity of recovering 2400 m^3/day.

To empty the tanks of the oil recovery vessels (OR-vessel) an oil tanker is needed, according to NOFO the maximum complete respond time for an oil tanker needed for the Barents Sea is 75 hours.

In the assessment regarding the possible opening of the Barents Sea South-East area a standby complete NOFO system during the exploratory drilling phase has also been added. The complete responding time for the standby system is set to 2 hours, which is the safety limit before vessels are allowed to approach the damaged installation. The time the NOFO-system based in Hammerfest will use to respond depends on the drilling location, mobilization time at the NOFO-base in Hammerfest and the speed of the vessels. NOFO has found that an average speed of 14 knots for the OR- and tug-vessel is appropriate. The respond time from Hammerfest is as presented in Figure 29.

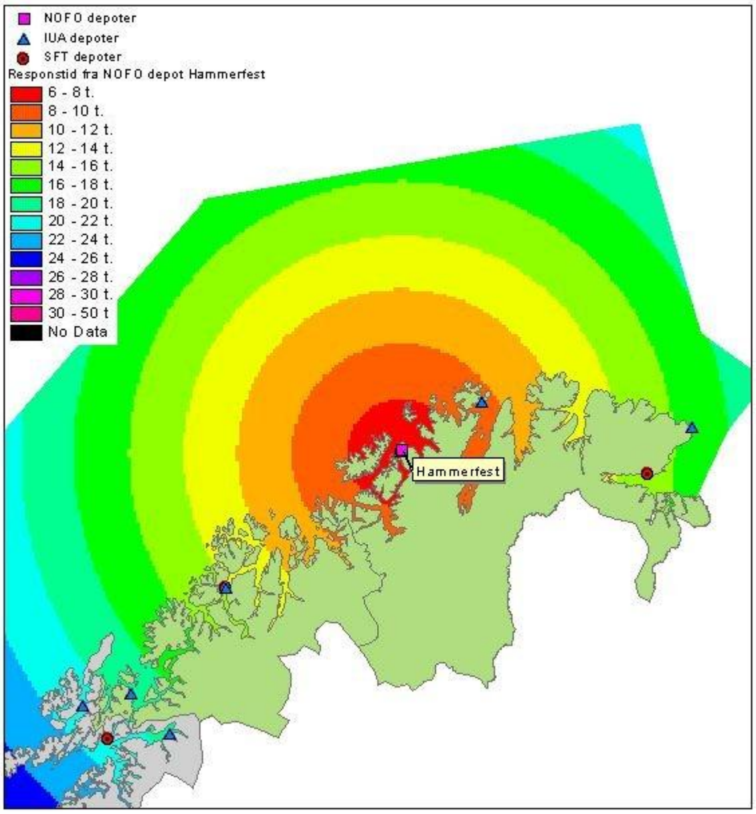

Figure 29 Complete responding time NOFO Hammerfest including 6 hr mobilisation time (24)

If there is an oil spill emergency in the northern part of the new oil field in the Barents Sea the complete respond time of oil spill emergency preparedness vessels stationed in Hammerfest will be as follows:

Table 8 Oil spill response example: Resources

Drilling location	74.3N 35.6E
Mobilisation time OR-vessel	6 hrs
Mobilisation time tug vessel	1 hr
Avg. vessel speed	14 knots

Table 9 Oil spill response example: Responding time

<table>
<tr><th>Vessel</th><th>Mobilisation [hrs]</th><th>Transit [hrs]</th><th>Placing of scud [hrs]</th><th>Complete responding time [hrs]</th></tr>
<tr><td>Complete NOFO system (standby)</td><td>2</td><td>x</td><td>1</td><td>3</td></tr>
<tr><td>Oil Recovery vessel</td><td>6</td><td>22</td><td>1</td><td rowspan="2">29</td></tr>
<tr><td>Tug vessel</td><td>1</td><td>22</td><td>1</td></tr>
<tr><td>Oil tanker</td><td>-</td><td>-</td><td>-</td><td>75</td></tr>
</table>

As the table shows the most limiting factor in an oil spill emergency preparedness operation is the response time of the oil tanker. In the oil spill emergency preparedness assessment for the new oil field in the south east of the Barents Sea it has been assumed that there will be higher demands regarding the availability of tankers, or other possible ways for the OR-vessels to empty their tanks. No proposition on how to solve this has been presented. Further the assessment calculates with emergency preparedness teams that are capable of recovering 20% of an oil spill during the winter and 40% during the summer. This is based on an oil spill scenario where the oil spill rate is 1194 ton/day for a total of 15 days and the oil spill recovery has been going on for a total of 30 days. The oil emergency preparedness system set up used in the calculations is shown in Table 10.

Table 10 Emergency oil spill preparedness system set up, the Barents Sea South East area (25)

<table>
<tr><th>Barrier</th><th>Name of system</th><th>Distance [km]</th><th>Responding time [t]</th></tr>
<tr><td rowspan="2">1</td><td>Standby system</td><td>0</td><td>2</td></tr>
<tr><td>Goliat</td><td>567</td><td>26</td></tr>
<tr><td rowspan="2">2</td><td>Hammerfest 1</td><td>588</td><td>34</td></tr>
<tr><td>Hammerfest 2</td><td>588</td><td>54</td></tr>
</table>

The location for this particular example is north east in the suggested new oil field, close to the ice edge.

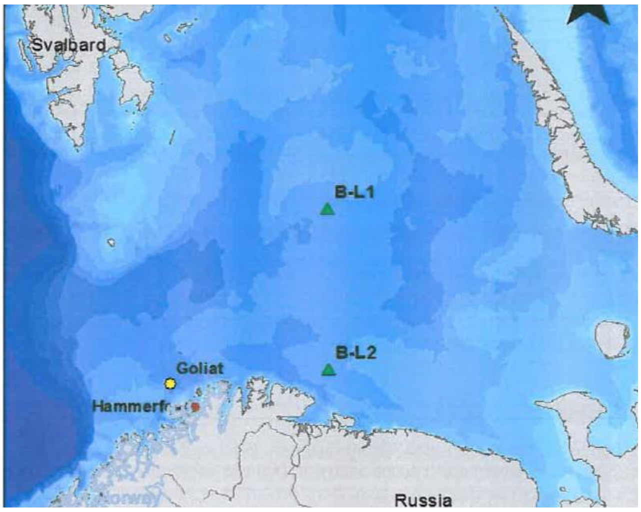

Figure 30 Location of oil spill example, B-L1 (25)

The OR-vessels involved in the clean-up process have a tank capacity of 1000 m^3. The time to empty the tanks is estimated to be 4 hours. The resultant distribution of the oil spill is shown in Figure 31.

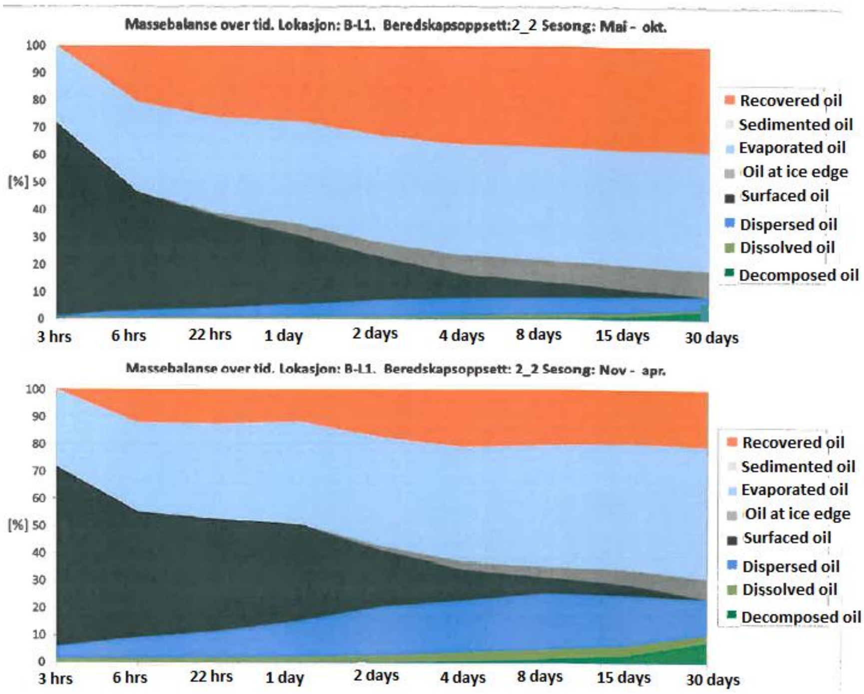

Figure 31 Oil spill scenario the Barents Sea South East: Mass balance over time (25)

As the figure suggests the majority of the oil will be recovered within two days of the oil spill starting. Therefore it is important that the appropriate resources are available as quick as possible in case of an oil spill happening. If a tanker is not able to be present before after 72 hours it can slow the whole operation down. As already mentioned the NOFO OR-vessels have a tank capacity of 1000-2000 m^3. In this particular case 40 % recovered oil represents

8234 m^3 assuming that the oil has a density of 0.87 ton/m^3. Which means that the 4 OR-vessels used in this particular case has to be emptied once each if they were to recover pure oil. They most likely have to be emptied more often as the mass balance of recovered oil only covers pure oil. In reality a much larger total mass has been recovered as the oil will emulsify and mix with water. This can in many cases result in a total mass many times larger than the mass of the oil originally spilled.

The scenario presented is calculated with a relatively small oil spill amount. For instance the Deepwater Horizon accident resulted in a total oil spill of 780 000 m^3. This was a very unique incident in many aspects. To avoid this kind of extreme scenario there should be focus on preventive measures, as dimensioning emergency preparedness with respect to an oil spill catastrophe of this calibre is not practical. But accidents like this are a reminder that safety is very important in the petroleum business and the necessary measures should be taken.

2.3 Regulations

Over the last years the interest in the Arctic has increased regarding marine and offshore activities. A problem to be addressed regarding this is the access to relevant regulations and technical standards, especially for offshore projects. The current technical standards puts much of the responsibility on the operators as they have to adapt these standards to a new climate and therefore have to rely on field specific functional requirements set by individual operators. DNV concludes in their project *Barents 2020 Assessment of International Standards for Safe Exploration, Production and Transportation of Oil and Gas in the Barents Sea* that it is necessary to supplement the existing technical standards in order to ensure an acceptable level of safety in the Arctic. In this report DNV also compared the metocean conditions in the Barents Sea and related them to the existing offshore codes.

Table 11 Summary of present state of ice and metocean conditions with respect to Standards and data background (5)

Hazard	**Additional challenge in the Barents Sea**	**Implication**	**Mitigation**	**Addressed in code**	**Need for change**
Metocean					
Wind	No	None except when combined with low temperature	None but better spatial data coverage needed	NORSOK N-002 and N-003, ISO 19901-1, DNV-RP-C205	No, but more data is needed
Waves	No	None except when combined with ice and global features			
Current	No	None			
Weather forecast	Yes, more demanding due to less data and smaller scale	Few observations from open ocean give less reliable forecasts. Particularly relevant for Polar lows	Increased observation network, automated stations at sea, higher resolution models	Mentioned in NORSOK N-003	Yes, see mitigation
Visibility (not incl. darkness)	No, but somewhat worse conditions	Hamper operations incl. ice management	Procedures more data		Probably not
Temperature	Yes	Wind chill, tougher working conditions, icing	Limit exposure, enclosures, procedures, ventilation, choice of materials	NORSOK S-002 and N-003	Yes, see mitigation

Icing	Yes	Change dimensions, freezing valves and other process equipment, block escape routes, slippery gangways, falling loads, reduced gas detection, reduced effectiveness of radars and communication	Ice removal manually, by chemical de-icing, choice of coatings and materials, heat tracing (electric heating cable), steam and salt	NORSOK S-002 and N-003, old and uncertain table	Yes, more knowledge, more data and improved prediction models. Should be included in standard
Sea ice					
Level Ice	Yes	Extra loads, hampering operations, complicates rescue and spill response, complicates maintenance and inspection	Design ice management	In ISO 19906-1 (Draft), API, CSA, DNV	Yes, more data and less spread in load predictions in standards
Level ridges	Yes				
Icebergs	Yes				
Combined loads and metocean	Yes	Extra loads, hampering operations, complicates rescue and spill response, complicates maintenance and inspection	NORSOK N-002 and N-003. ISO 19901-01	Not propoerlyin any	Yes, should be included in any standard for the Arctic, incl. the Barents Sea

Regarding shipping and marine operations there is a complete set of regulations and rules internationally, but also here there is a lack of specifications for Polar Regions and there are currently discussions on how to translate and develop the existing framework so that it can be applied to polar areas.

2.3.1 IMO Polar Code

The International Maritime Organization (IMO) is currently developing a code which is to be followed by vessels sailing in Polar waters. The code is expected to come into force in 2015[9]. The code is being developed to protect the Antarctic and the Arctic regions from maritime risks. When the code is completed it will address certification, design, equipment, systems, operations, environmental protection and some manning and training.

> *The goal of this Code is to provide for safe ship operation and the protection of the Polar environment in by addressing risks specific for the Polar regions and not explicitly considered by other instruments of the Organization* (26)

In 2010 the IMO agreed on the principles for the Polar Code where they stated that the code should ensure the same level of safety for persons, the environment and the ships as in other waters. They also decided that the Polar Code should be an extension on already existing IMO codes with added requirements that are caused by the conditions in the Polar waters. The Polar Code is risk based and consists of functional requirements. In the Arctic the Polar Code is applicable to all areas above 60° North with some exceptions.

[9] Stange, Rolf, IMO: polar code not before 2015 (http://www.spitsbergen-svalbard.com/2012/03/01/imo-polar-code-not-before-2015.html)

Figure 32 Areas where the Polar Code is to be applicable[10] (26)

> *1.3 [Arctic waters means those waters which are located north of a line from the latitude 58º00΄0 N and longitude 042º00΄0 W to latitude 64°37΄0 N, longitude 035°27΄0 W and thence by a rhumb line to latitude 67º03΄9 N, longitude 026º33΄4 W and thence by a rhumb line to Sørkapp, Jan Mayen and by the southern shore of Jan Mayen to the Island of Bear Island, and thence by a great circle line from the Island of Bear Island to Cap Kanin Nos and hence by the northern shore of the Asian Continent eastward to the Bering Strait and thence from the Bering Strait westward to latitude 60º N as far as Il'pyrskiy and following the 60th North parallel eastward as far as and including Etolin Strait and thence by the northern shore of the North American continent as far south as latitude 60º N and thence eastward along parallel of latitude 60º N, to longitude 56º37΄1 W and thence to the latitude 58º00΄0 N, longitude 042º00΄0 W* (27)

To separate the different conditions met in the Polar waters, the IMO has divided the ships into three different categories. Since the code is not complete yet the categories are considered as preliminary.

[10] The division of the applicable areas is a suggestion from IMO, it has not yet been verified.

Table 12 Preliminary ship categories in the Polar Code (26)

	Category	Description	
A	Polar ice covered	Ships that may operate in ice-covered waters with 10% or more of ice	Polar class or equivalent
B	Polar open water	Ships that may operate in ice-covered waters with less than 10% ice, where it may pose a structural risk	Assessment/ice-strengthening or other mitigating measures
C	Polar open water including ice-free waters	Ships that may operate in waters with zero to 10% ice cover, where it does not pose a structural risk	No ice-strengthening

Other topics that are also still under discussion are the geographical limitations, the additional risks and requirements related to Polar waters. The group working with the Polar Code has requested that the code should be made mandatory as fast as possible.

The Polar Code will when verified give functional requirements and regulations regarding

- Structural integrity for ship structure and deck machinery
- Stability
- Watertight and weather tight integrity
- Anchoring arrangements
- Habitability
- Fire safety/protection
- Life-saving appliances and arrangements
- Navigation
- Communication
- Crewing and manning
- Emergency control
- Environmental protection

2.3.2 Other regulations applicable to the Barents Sea

The main laws and guidelines that are applicable for the Barents Sea are:

- The Port and Fairway Act
- The Pilot Act
- The Planning and Building Act
- The Pollution Act
- MARPOL
- The Seaworthiness Act

2.3.2.1 The Port and Fairway Act

The main intention with this act is to establish a legal framework that contributes in making the ports logistical junctures, in addition to ensure safe and effective transport by sea that with its environmental superiority is competitive with other means of transportation. The law was changed in 2009 and the new version came into force in 2010. The act is not applicable to Svalbard, but the King of Norway can decide to what extent the act should apply for the island. The act covers areas such as maximum allowed speed, areas that the vessel is allowed to enter when carrying dangerous cargo, areas that are prohibited to enter when there is fog and/or ice present. Most of these regulations are applicable to the Norwegian coastline to hinder accidents.

2.3.2.2 The Pilot Act

The Pilot Act states that it is mandatory for vessels above 500 GT to use a pilot hired by the state inside the sea boundary. There are exceptions to this rule, for instance if it is domestic shipping the vessel can navigate inside the sea boundary by itself if the responsible for operating the bridge has a certain amount of years sea experience. If it is foreign shipping there are also some exceptions, the people responsible for operating the bridge then needs to have a fairway certificate that states that he or she is qualified to sail without a pilot. The act is not applicable to Svalbard, but the King of Norway can decide to what extent the act should apply for the island.

2.3.2.3 The Seaworthiness Act

The Seaworthiness Act is not an act that is applicable to certain areas in the Norwegian seas. The act is applicable to all Norwegian vessels sailing all over the world. For foreign vessels the law comes into act when the vessels are sailing inside Norwegian Sea territory. It is also applicable to foreign installations positioned on the Norwegian continental shelf, but for foreign vessels and installations in the waters outside Svalbard this act does not apply. To be able to control that the foreign vessels sailing into Norwegian seas are seaworthy they have to be able to document that they satisfy the demands given in relevant international rules and regulations about safety, protection of the environment and health and work environment on board. If the vessels do not satisfy these regulations they will not be able to go into any Norwegian ports.

2.3.2.4 The Pollution Act

The main intention of the act is to protect the external environment against pollution, to reduce existing pollution and to reduce the amount of waste and to encourage a better handling of waste. To prevent pollution from happening and to reduce it the technology that is available and that gives the best results shall be used. The law is applicable to sources of pollution that are inside the Norwegian economic zone or that threaten to hit the Norwegian zone. This act does not apply to Svalbard. When it comes to pollution from each unique vessel the specifications in the Seaworthiness Act and the Port Act among others apply.

2.3.2.5 The Svalbard Environmental Protection Act

The government in Norway has decided that Svalbard shall have one of the world’s best administrated wild life territories, and that protection of the environment comes first when there is a conflict with other interests in the area. On Svalbard 87% of the territorial waters and 65% of the land areas are preserved as natural reserves and national parks. The Svalbard Environmental Protection Act is the most important policy instrument when it comes to protecting the wilderness on Svalbard. From 2015 the use of heavy fuel oil as fuel will not be allowed in the protected areas on Svalbard.

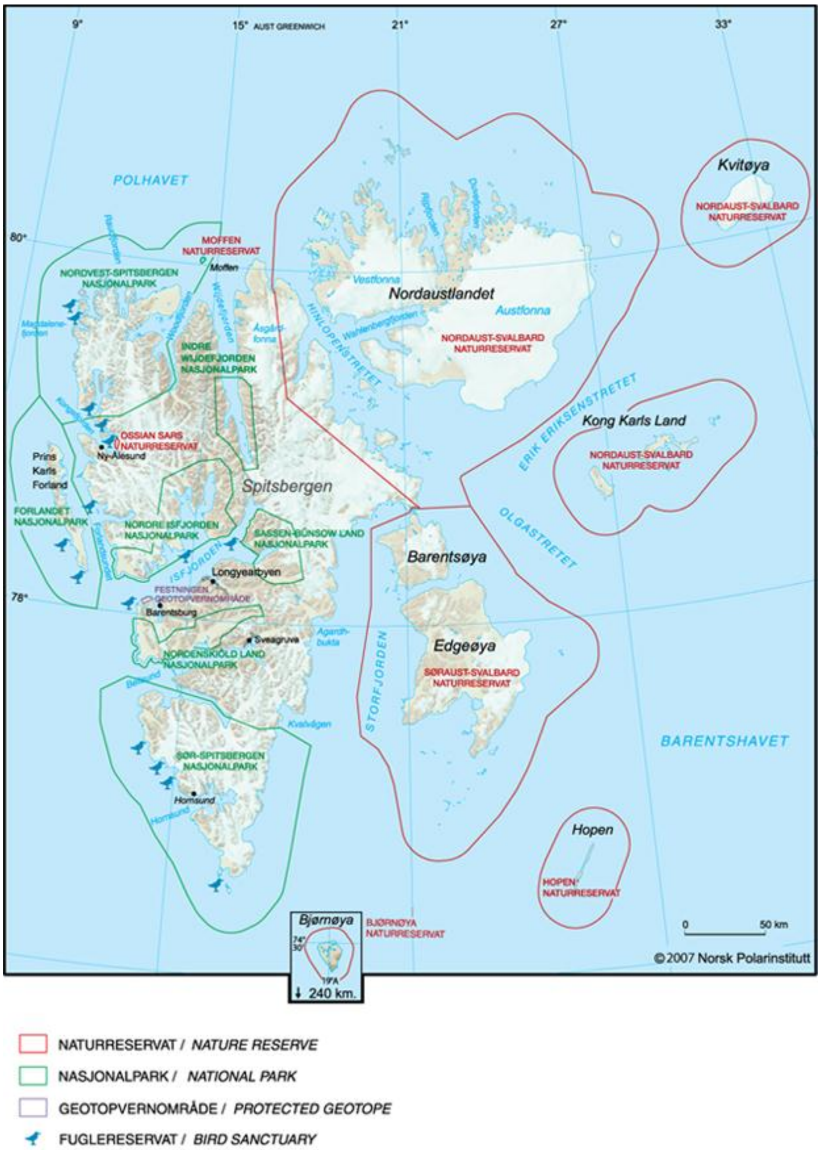

Figure 33 Svalbard's protected areas (28)

2.3.2.6 Trading Area Regulations

This regulation is applicable to Norwegian ships and has its legal basis in the Seaworthiness Act. A trading area is defined as an area where there can be shipping and the regulation then regulates special demands for design, manning and equipment for that area. The ship will have to get a certificate from the authorities over where it is allowed to operate and sail.

2.3.2.7 Regulations Regarding Protected Areas around Bear Island

The entire island is a protected nature area and motorized vessels larger than 16 feet are not allowed to sail within 4 nm of the island.

2.3.2.8 SOLAS

SOLAS, or Safety of Life at Sea, is an international convention which gives regulations to ensure safety for people at sea and their regulations are applicable for all passenger ships with more than 12 passengers and for cargo ships larger than 600 GT that sails in international waters. It is the flag state that has the responsibility to ensure that the regulations set in

SOLAS are followed. The flag state also has the legislative, executive and judicial power over the vessel, with the exception from some rights that the coastal state has regarding possible environmental damages to its coasts.

2.3.3 Classification of vessels operating in cold climates

It is mandatory for vessels to be classified. The classification of a vessel describes the

- Hull strength
- Corrosion
- Coating
- Machinery

The choice of ice class for a vessel is based on what type of vessel it is, what area it is to be operating in, the ice conditions and temperatures that are valid for that area and the possible encountered ice impacts. In addition the level of needed operational support from icebreakers and tugs, charterer requirements, and the future flexibility of operations are also factors that are to be determined when deciding upon a suitable ice class.

DNV is one classification company and in Figure 34 its class notations for vessels operating in an arctic climate is shown.

DNV Class Notations	Equivalent Baltic Ice class	Vessel Type	Ice Conditions	Impact Limits
ICE-C		- All ship types	Very light ice condition	No ramming
			- First year ice and **broken channel**	
ICE-1C	1C		0.4 m ice thickness	
ICE-1B	1B		0.6 m ice thickness	
ICE-1A	1A		0.8 m ice thickness	
ICE-1A*	1A Super		1.0 m ice thickness	
ICE-1A*F			1.0 m ice thickness	
ICE-05 ICE-10 ICE-15		- Vessels intended for ice breaking - Built for another main purpose	First year ice with pressure ridges	
POLAR-10 POLAR-20 POLAR-30			Multi year ice with glacial inclusions	Accidental ramming
ICEBREAKER		Icebreaking is main purpose		Repeated ramming

Figure 34 DNV Class Notations for vessels operating in an arctic climate (29)

The Baltic rules issued by DNV are applicable to ships which are operating in channels of broken first-year ice made by ice-breakers or in open waters where small ice floes can be encountered. In the Baltic rules the rules issued by Finnish and Swedish Authorities are included. When operating further North in the Arctic regions it is the Arctic Ice Class which is applicable. All the Arctic ice classes are used for vessels that can break their own way in winter ice, but it is separated between icebreakers and vessels mainly intended for other purposes.

When a vessel is classified according to the Baltic or the Arctic Ice Class there are additional requirements to

- Ice strengthening
    - Rudder/stock
    - Hull
    - Propeller/shaft
- Main engine output
- Sea chest arrangement
- Anti-freezing for ballast water

The exact specifications regarding these requirements depend on the classification. Vessels in cold climates are also to be winterized according to class. The type of winterization is divided into three:

1. Winterized Arctic (vessels built to ARCTIC or ICEBREAKER class)
   Relevant for vessels operating in cold climate environments for longer periods.
    a. Requirements to controlled pitch propeller or diesel/electric system
    b. Requirements to the type of propeller material
    c. Requires two engine rooms for power, auxiliary equipment and heating equipment
    d. Requires that OPP-F[11] and oil outflow index is less than 0.01
    e. Requirements to the helicopter landing facilities
    f. Requires lifesaving and navigation equipment certified for low temperatures
2. Winterized Cold (vessels built to Baltic ICE-1C or higher)
   The purpose of this ice class notation is to maintain the safety of the ship and its personnel during winter conditions. Relevant for vessels operating in cold climate environments for longer periods.
    a. Important equipment is to be built-in against the cold or to be heated/protected
    b. Propulsion system must have a controllable pitch propeller or an electrically driven propeller
    c. Requirements to the type of steel used
        i. Low temperature materials for the hull
        ii. Low temperature materials for the equipment on-board
        iii. The propeller material
3. Winterized Basic
   Meant for ships operating in cold climate for short periods and not necessarily in ice covered waters.
    a. Arrangements for anti-icing and de-icing
    b. Heating of spaces that have important equipment
    c. Arrangements and location of generator capacity

[11] Class notation for Oil Pollution Prevention for Fuel oil tanks

Another important factor addressed in the classification of vessels operating in the High North is the human factor. This is a very important matter as the human factor is considered to be one of the most important risk factors when operating in cold climates. The human factor addresses noise, vibration and indoor climate. What separates operations in icy waters is for instance that the noise levels increase to 20-30dB above levels which are usually experienced in open waters, this together with the extreme temperatures that may be experienced puts a significant strain on the people on-board. Therefore DNV recommends building the vessel in accordance to Comfort Class which addresses these elements.

2.4 Summary

The metocean data of the Barents Sea show that the wind and wave conditions are generally better than what is experienced in other areas, for instance in the Norwegian Sea. The general trend is that the annual significant wave heights and the annual wind speeds become lower further north and further east. What can be an issue for the Barents Sea are the occurrences of polar lows, the polar lows also occur further south in the Norwegian Sea, but the difference is that the weather forecasting is not fully developed in the Barents Sea yet. Since the polar lows are accompanied with snow, fog and heavy wind speeds they create challenging situations for marine and offshore activities. The polar lows are most frequent in the area between Bear Island and Northern Norway.

Another issue for the Barents Sea is poor visibility. The main reasons for poor visibility is fog and snowfall, but also the polar night which is experienced in the High North. Polar lows and poor visibility often accompany each other which cause more challenges when operating. In case of difficult marine operations or helicopter services during the winter half of the year. For instance the actors operating in the Barents Sea have no option to wait for daytime to execute the operation. This is also a challenge that needs to be addressed when designing vessels or offshore installations for the Barents Sea. The polar night can also affect the people working in this area in other areas than just making the operations more difficult to execute. Experiencing long periods without any daylight is proven to have a negative effect on people. Therefore it is important to have extensive lighting arrangements both inside and outside to ensure the health and wellbeing of the people working there.

Another issue that affects both the vessel or installation itself and the people working there are the low temperatures. The low temperatures can cause important equipment to freeze and may also cause issues for gangways used for evacuation for instance. To avoid this problem proper winterisation is important. Escape ways should for instance be built-in in addition to the heating for equipment and pipelines. Also the inside working areas need to have an appropriate temperature, and the people working need proper working gear. Regarding the low temperatures it is also important to choose the appropriate materials which can endure the lowest temperatures that can be expected. Icing can also cause the same negative effects that the low temperatures do directly and it can create stability issues for the vessel or installation if not accounted for. The amount of icing that can be experienced in the Barents Sea depends on the location of the vessel or installation. It is proven that the worst icing conditions are experienced on the open sea. Throughout the year the highest rate of icing is between October and May, where the highest chance of experiencing severe icing is in January and February.

The seagoing vessels are normally more prone to icing because they are affected by both atmospheric icing and icing because of sea spray. Icing 15 meters above sea level is relatively rare. To avoid severe situations caused by icing, winterisation and general design of the vessel or installation is important. The issue of sea ice is also present in the High North. Regarding ice covered waters the Norwegian part of the Barents Sea can be divided in two, the Barents Sea North and the Barents Sea South. Where the North experiences varying ice coverage during the winter, the South is in general ice free. There is also a need for ice management regarding icebergs. The strength and size of icebergs are of such a magnitude that if there is a collision with vessels or installations this is often fatal and will cause serious damages at a minimum. Therefore implementing ice management where surveillance, tracking, forecasting and mitigation of icebergs and sea ice are covered is important in the Barents Sea. Also, having the ability to either move the vessel or installation or tow the ice berg away from the danger zone is crucial. The ice berg monitoring throughout the years have not been done to a completely satisfactorily level, but according to the sightings that have been recorded it is not likely to encounter ice bergs below 74°N. The ice bergs are especially a danger to petroleum installations as a collision can create especially dangerous situations both to the people working on board the installation and to the environment in case of severe oil spill situations.

The shipping traffic in the Arctic has increased in the later years due to the decrease in ice covered waters which has caused an increase in shipping traffic going through the Northern Sea Route and the Northwest Passage. The relative increase has been significant, but compared to the amount of vessels using other solutions than sailing thru the Arctic Ocean the absolute increase is small. In the Barents Sea specifically, the main source of ship traffic is the fishing vessels which take up 60% of the total traffic. The expectation in the following years is that there will be a 3% increase of shipping traffic in the Barents Sea. The main reason for this is more traffic related to the oil- and gas activities in the Barents Sea.

The communication possibilities in the Arctic are still at an unsatisfactorily level. This is an important issue as the ability to communicate is very important when at sea. One of the main reasons for this is that the Barents Sea and the Arctic in total is very close to the North Pole whereas the geomagnetic storms affects radio and satellite signals. Another reason is that the infrastructure in the High North is not fully developed and there are limited possibilities in relation to broadband for instance. When new installations are being built this can be solved by laying cables from the installation to the shore. This will not solve the problem completely and does not help the vessels sailing in the Barents Sea and the Arctic in general. The AIS system has been developed for the Barents Sea. The AIS system increases the safety level in the Barents Sea as the authorities are able to track the vessels and installations that are present in the area.

Another important safety issue in the Barents Sea is the emergency preparedness coverage. If petroleum activities are moved further north it will be very difficult to fulfil the SAR-regulations that apply to the petroleum business. To solve these issues alternative solutions should be considered such as offering extended medical services and stationing SAR-capable helicopters offshore. In regards to emergency preparedness in case of oil spill there are also challenges, mainly because of the vast distances. Regarding the oil emergency preparedness the petroleum companies themselves have the main responsibility for providing the adequate amount of emergency preparedness. When the petroleum activities are moved further north and further into remote areas, alternative solutions to emergency oil spill preparedness needs to be evaluated. The first two days of an oil recovery operation may be critical regarding the total amount of oil that is recovered in an emergency. When there are vast distances, the time before OR-vessels and tug vessels stationed at the different bases along the coast increases. This calls for a better standby system and increased access to oil recovery equipment closer to the area where the risk of oil spill is present. At present time the response time for tankers acting in an oil preparedness operation in the Barents Sea is within 75 hours.This may hinder the effectiveness of the oil recovery operation.

The increased interest in the High North and the Arctic has brought forward the need for adequate regulations liable for that area. At present time the petroleum operators have the main responsibility to interpret the technical standards such that they apply to the conditions met in the High North. This may cause safety hazards as it is more difficult to verify that the installations are suited for the challenges that are met so far north. Regarding shipping the IMO is currently developing a Polar Code in order to protect the Arctic regions from maritime risks. The code is to be made mandatory as fast as possible, but is not fully developed yet. Because of the presence of ice the vessels intended for the High North need to be classified accordingly. There are different classification companies, presented in this paper are the DNV classification rules. The final choice of ice class and application of winterization depends on the final location in which the vessel or installation is to be operating

3 Offshore Supply Base

Some of the main issues that are present in the development of the High North are the vast distances and the missing infrastructure. The main possibilities that are being looked at, especially for the Barents Sea, is the possibilities of extracting petroleum. The increased interest in the Barents Sea raises many issues especially regarding safety, both in respect to the safety of the increased number of people that will be working there and in respect to the environmental risks that accompany petroleum activities. There has also been an increased interest in the Arctic in respect to shipping possibilities as the ice coverage is decreasing and shipping lanes are open longer periods of the year. In the Norwegian part of the Barents Sea the expected increase in shipping is mostly related to the new petroleum activities. Because of this increased interest, combined with the already mentioned vast distances in the Barents Sea alternative solutions regarding SAR-operations and possibilities of extended medical services offered offshore should be considered. Also, as mentioned, petroleum activities increase the risk of major environmental catastrophes, e.g. if there is an accident which causes an oil tanker to spill oil or if there is an oil well blow-out. Therefore, to improve the situation, having an OSB stationed in the Barents Sea which can offer services that improve the safety issues should be considered.

To make the appropriate choice for the type of structure the OSB will be, several traditionally petroleum based installations have to be considered. Because the OSB is to be placed in the Barents Sea the decided location will influence the choice of structure. It depends on whether or not it should be placed in an area where sea ice is an issue. The final decision of appropriate structure also depends on the services that the OSB will provide. Far north the main challenge is the presence of ice, and the type of structure has to be chosen and designed accordingly. The type of ice also influences the risk that the chosen vessel or structure is exposed to. There may be possibilities of encountering first year or multi-year level ice in addition to ice ridges and icebergs. Traditionally the structures that have been permanently deployed in ice-infested waters have been fixed structures such as caissons and jacket platforms, in addition to ice capable vessels that are used for shipping. In a presentation made by the Petroleum Safety Authority Norway at the Barents Sea Convention which was held April 24th 2012, it was concluded that the floating installations available today are not suitable in case of collisions with icebergs or when encountering ice covered waters. If these scenarios happen the installations have to be moved from their original position. Because of the increased interest in the Arctic region there is research going on to develop capable floating concepts that may be permanently placed in ice-infested waters. That will open up possibilities of operating on deep waters that are currently ice-infested.

In the Barents Sea South which is normally ice free and also where the likelihood of encountering icebergs is very low, the choice of structure is more open as it can be both fixed and floating. But also here measures should be taken to avoid the risk of collisions with icebergs or ice ridges and as this is placed in open water icing is a more severe problem than in ice covered waters.

3.1 Offshore Structures

Below some suggestions for offshore structures that may be a feasible option for the OSB are presented.

3.1.1 Fixed structures

Fixed platforms are designed for long-term use as they are built on concrete or steel legs that are anchored directly onto the seabed and are immobile. They can be designed with storage tanks below the sea surface, which again works as flotation devices. The structure of the platform varies as it can be steel jackets, concrete caissons, floating steel and floating concrete. It is rendered economically feasible for installations in water depths up to 520 m.

3.1.1.1 Jacket

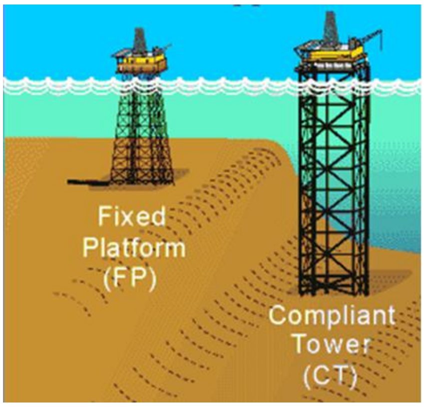

Figure 35 Jacket platform (30)

The jacket has a tubular space frame where the near vertical legs are supported by a bracing system. The jacket is traditionally used for drilling, production and accommodation. The advantage of the jacket is that they are common and well proven. The disadvantage is that they cannot be used for storage and are limited to about 100 m water depth. In greater water depths a tower or a compliant tower can be used. The tower has the same functional capabilities as the jacket, but can be extended to 400 m water depth. The compliant tower can be used in water depth reaching as deep as 1000 m, but weight and initial cost become challenging when water depths increase.

3.1.1.2 Gravity Structure

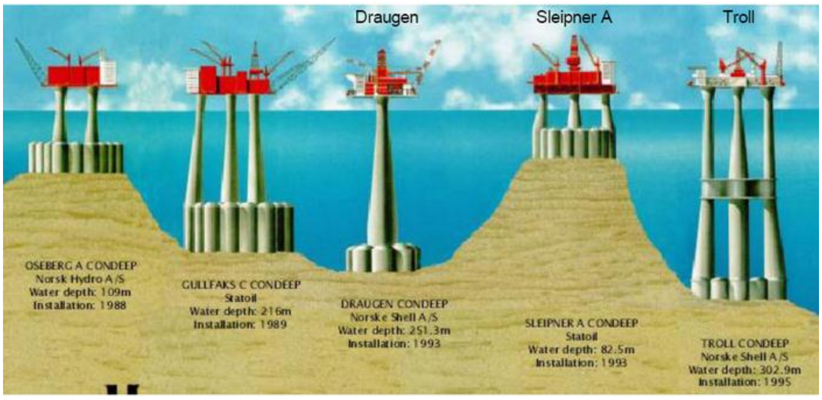

Figure 36 Gravity based structure (31)

The gravity structure is a type of fixed structure that is held in-place by its own weight and any contained ballast. The gravity structure is typically constructed of concrete. The functional qualities of the gravity structure are similar to that of the jacket and towers, but it also has the advantage of having storage tanks. The later years the gravity structures have fallen out of favour due to its relatively high construction costs.

Although gravity structures have a high construction cost, when used for petroleum production in remote ice-infested regions they are often favourable compared to other fixed structures. The main reasons for this is that in remote areas onshore facilities might be limited and if the petroleum field is far from the shore ensuring the safety of pipelines becomes challenging such that having the option of storing produced oil on board becomes a major advantage. Some floating structures also have storage options, but designing the mooring system and the risers such that they can withstand the environmental loads from ice have traditionally proven to be quite challenging, the ice loads also impact the design of the structure.

3.1.2 Floating structures

3.1.2.1 Jack-up rigs

Figure 37 Jack-up rig (32)

Jack-up rigs are barges fitted with movable legs that can be extended above or below the hull, they are self-elevating. The barges are towed to the location, then the legs are lowered onto the seabed which anchors the rig, the barge itself is then placed well above the waves. One of the disadvantages with a jack-up rig is that they can only be used in relatively shallow waters, they are usually used in water depths less than 120 m, but there is also one class of jack-ups that are called premium or ultra-premium jack-up rigs that operate in water depths ranging from 150 m to 190 m. This is still too shallow for most of the Barents Sea as the average depth is 230 m.

3.1.2.2 Semi-submersible platform

Figure 38 Semi-submersible platform (33)

The semi-submersible platforms are rendered to have good stability and sea keeping characteristics. These floating platforms are kept sufficiently buoyant by the design of their hull using columns and pontoons. The pontoons are located underneath the sea surface and away from the influence of waves. The operating deck can also be placed high and away from the waves. Because they are floating they are movable and can also be ballasted up or down.

Since the structure of the platform can be submerged at a deep draft they are less affected by wave loads than normal ships, but they also have a relatively small water plane area which makes it more sensitive to load changes and more attention has to be paid to trimming of the vessel to ensure that sufficient stability is withheld. They are anchored up using chains or wire rope, etc. They can also be equipped with dynamic positioning. Semi-submersibles can be used in a range of water depths going from 60 m to 3000 m. The semi sub-submersible is primarily used for drilling, production and/or accommodation. They do not have storage space for petroleum. The semi-submersibles are usually not used in ice-infested waters as there might be problems with strengthening the traditionally vertical columns so that they can withstand ice loads. Also, ice accumulation between the legs and breathings for traditional semi-submersibles is a critical factor.

3.1.2.3 Tension-leg platform

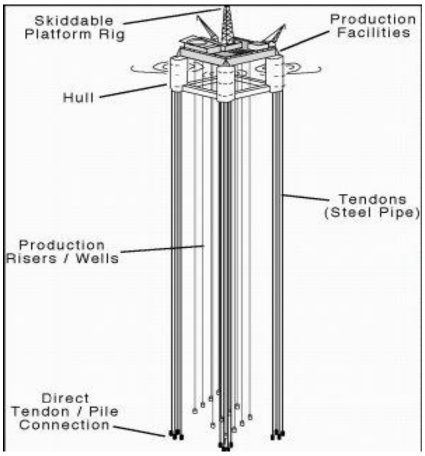

Figure 39 Tension-leg platform (33)

The conventional version of a tension-leg platform (TLP) looks similar to a semi-submersible. The TLPs can be used in water depth ranges of 180 m to 1300 m. One of the main features of a TLP is that they have low vertical motions as they are tethered to the seabed in a way that prevents most of these motions. They are primarily used for production and have accommodation facilities, but no storage tanks.

3.1.2.4 Spar Platforms

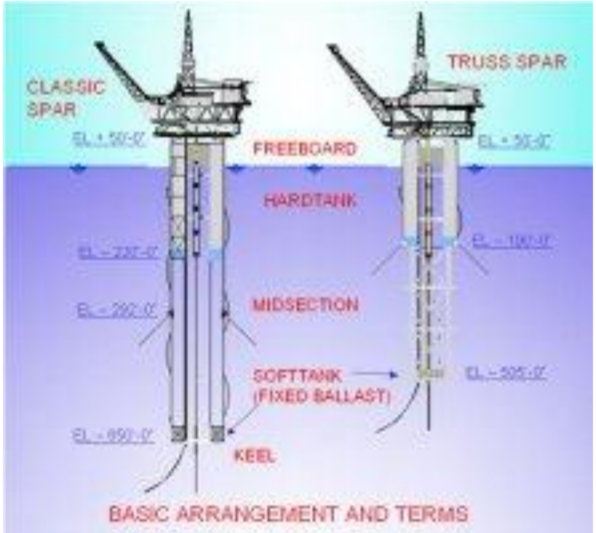

Figure 40 Spar platform (33)

The spar platform is normally used for deep water operations and can be used in water depths up to 3000 m. It is made up by a deep-draft floating caisson, with about 90% of the total structure underwater, which gives it favourable motion characteristics compared to other floating concepts. The four major systems on a spar platform are the hull, moorings, topsides and risers. To maintain its position the spar platform is moored. The spar platform is traditionally used for production and drilling purposes, it has very little storage space.

3.1.2.5 Monohull

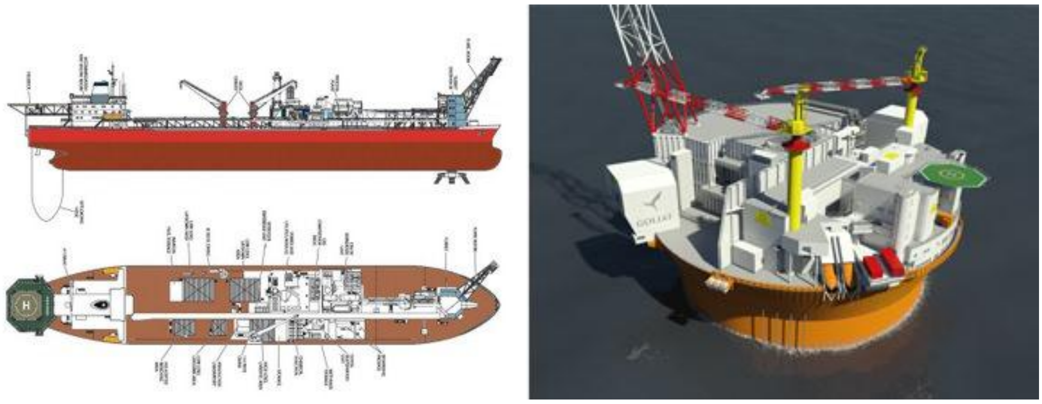

Figure 41 Ship-shaped monohull (33) and circular monohull (17)

The monohull consists of a single continuous buoyant hull and is typically a ship shaped vessel with configurations that are similar to tankers or barges for instance, but the hull can also be circular. The Floating, Production, Storage and Offloading (FPSO) unit built for the new Goliat field in the Barents Sea is a circular monohull. The advantage of the circular monohull in respect to oil production is that there is no need for a turret. In respect to metocan conditions the circular design has the advantage of not having a bow or stern which means that it will not be turning in relation to weather and wind which increases the safety zone around the vessel. The advantage of monohulls used in petroleum production is that they have a significant storage capacity and a large deck area which also enables to offer significant variations in payload.

3.1.3 Constraints

In addition to the location the purpose of the OSB will also influence the choice of structure. The main purpose of the OSB should be to improve human and environmental safety, and it should be able to provide logistical services. For instance, the OSB can have storage space for spare parts for the operators stationed in the Barents Sea and/or have extended work shop possibilities. The OSB should be able to improve the emergency preparedness situation in the Barents Sea. For the OSB to able to this it should be able to provide these services:

- Permanently placed SAR-helicopter to improve the coverage area in the Barents Sea today
    - Extended hospital services which enable the OSB to fulfil the 3 hour SAR-limit regulation for offshore operators.
- Storage tanks which enable the OSB to receive recovered oil during emergency oil spill preparedness operations.

If the OSB is to provide these services it should be located at a position where these services are needed. The majority of the activities going on in the Barents Sea today are located in the Barents Sea South, but there are also currently activities in the Barents Sea North where the marine traffic mainly consists of fishing vessels, cruise ships, research vessels and general cargo vessels going to and from Svalbard. The petroleum activities today are only situated in the Barents Sea South. In total the Norwegian continental shelf stretches above 80°N and into the Arctic Ocean which opens up to the possibility that there will be increased activities in the Barents Sea North, also north of Svalbard into the Arctic Ocean. It is not certain when this will happen. If the petroleum activities are to be extended further north it is more likely that they will happen in the Barents Sea North before the Arctic Ocean, where the ice conditions become more severe. In chapter 2.2.4.5 Future Possible Offshore Activities scenarios presented by the Norwegian Government were shown. The future scenarios presented oil finds east and south of Svalbard in addition to findings in the Barents Sea South East area where the opening process has already started. Because the other areas of the Barents Sea which are already opened for petroleum activities are within SAR-coverage the OSB should be placed such that these areas also are within the 3 hour limit. In regards to emergency oil spill preparedness the OSB should be able to improve the situation for the entire Norwegian part of the Barents Sea. Because the conditions are very different in the Barents Sea North and the Barents Sea South Concept 1 will represent an OSB stationed in the south and Concept 2 will represent an OSB stationed in the north.

3.2 Concept 1: The Barents Sea South

The main focus of an OSB placed in the Barents Sea South will be to reassure that the new possible oil field will have complete SAR-coverage and to improve the emergency oil spill preparedness for the entire area. If this oil field is in fact opened for the extraction of petroleum the SAR-resources available today will not cover the entire new area within the 3 hour SAR-limit as shown in chapter 2.2.5 Emergency Preparedness. Even if the SAR resources are extended onshore it will be very difficult for the most northern part of the area. Also the practical maximum SAR-coverage area, given as 220 nm by the 330 squadron, leaves uncovered areas in the Barents Sea. Areas outside this coverage area will require the SAR-helicopters to refuel, which is possible to do at Hopen or Bear Island, but this also means that the time frame of the SAR-operation will be extended, which can be critical in the harsh environment that is experienced in the Barents Sea. Therefore, the placement of the OSB should be in a location such that the possible new oilfield is covered by a SAR-helicopter operating from the base. A proposition for the placement of the OSB is shown in Figure 42.

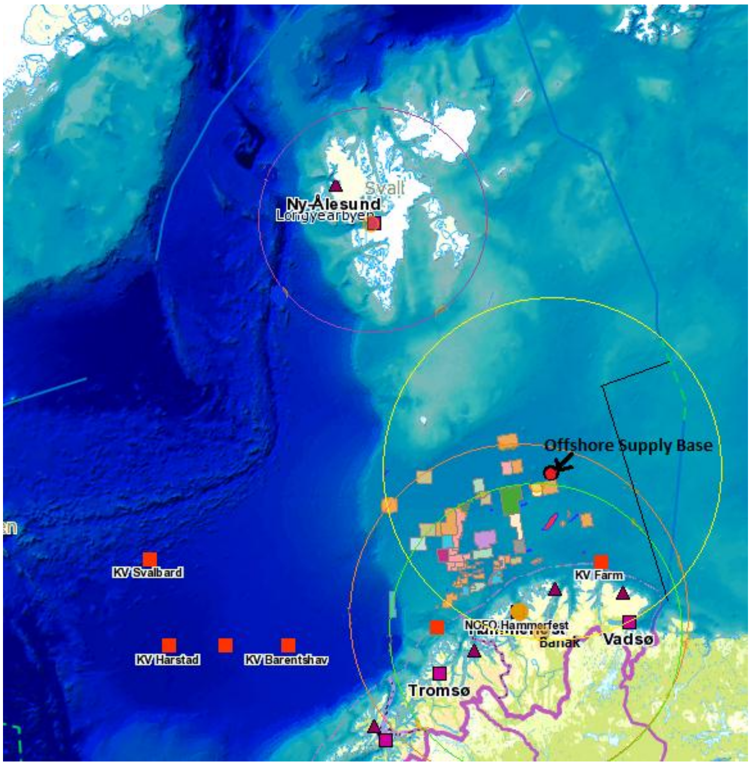

Figure 42 Location of OSB in the Barents Sea South with 3 hour helicopter range

As the figure shows a placement of an OSB at this location will cover the entire new petroleum area and will also extend the SAR-coverage for other marine activities that are present between Svalbard and the Norwegian coastline, for instance shipping and fishing activities. If the SAR requirement is to be fulfilled the OSB must be able to give extended hospital services to the people that have been rescued. As the figure also show, placing an OSB in this location will allow for helicopter services from Hammerfest to reach the base within 3 hours, this opens up for the possibility of bringing hospital personnel from the mainland to the base. This way there is no need for permanent placing of advanced hospital personnel at the base itself. Also, when the base is placed within reasonable reach of the shore it will improve the safety of the people that will be working on the OSB.

The suggested location of the OSB is at approximately 73.1N 27.1E. The metocean conditions for approximately this position are shown in Table 13, Table 14, Table 15 and Table 16.

Light icing	< 0.7 cm/h
Moderate icing	= 0.7-2.0 cm/h
Heavy icing	= 2.0-4.0 cm/h
Extreme icing	> 4 cm/h

Table 13 Icing and sea ice at 73.11N 30.77E 1958-2011

Icing and sea ice at 73.11N 30.77E 1958-2011			
January-March		**April-June**	
Light icing, in % of time	31.51	Light icing, in % of time	13.27
Moderate icing, in % of time	9.44	Moderate icing, in % of time	1.03
Heavy icing, in % of time	0.99	Heavy icing, in % of time	0.01
Extreme, in % of time	0.08	Extreme, in % of time	0.00
Sea Ice, in % of time	0.00	Sea Ice, in % of time	0.00
July-September		**October-December**	
Light icing, in % of time	0.01	Light icing, in % of time	18.61
Moderate icing, in % of time	0.00	Moderate icing, in % of time	2.27
Heavy icing, in % of time	0.00	Heavy icing, in % of time	0.13
Extreme, in % of time	0.00	Extreme, in % of time	0.01
Sea Ice, in % of time	0.00	Sea Ice, in % of time	0.00

Table 14 Average air and sea temperatures 73.11N 30.77E (3)

Average temperatures 73.11N 30.77E 1958-2011		
	Max	**Min**
2 m air temp	11.6	-19.6
Avg. Sea temp	10.6	1.1

Table 15 Maximum significant wave height (3)

Maximum significant wave height (Hs) 1958-2010			
	1 year	**10 years**	**100 years**
73.11N 30.77E	8.7	11.6	14.5
71.23N 22.12E (Goliat)	9.8	13.2	16.6
65.36N 07.14E (Heidrun)	10.5	13.3	16.0

Table 16 Maximum wind speed (3)

Maximum wind speed and appurtenant direction 1958-2010		
	Max.	Direction
73.11N 30.77E	26.2	18
71.23N 22.12E (Goliat)	28.0	260
65.36N 07.14E (Heidrun)	28.4	250
61.20N 01.86E (Statfjord)	30.4	255

The position which the metocean data is collected from is slightly further east than the suggested position for the OSB. This may indicate that the conditions are slightly different for the suggested position for the OSB. The maximum wind speeds and significant wave heights have a tendency to be lower as one move further east or north, the temperatures have a tendency to be lower and there is a greater possibility of encountering sea ice. But since the distance is not to extensive and the final location of the OSB is not fixed the data presented will be rendered as representative for the suggested position.

The data shows that the wind and wave conditions are less severe than what is experienced in the Norwegian Sea and North Sea and further south-west in the Barents Sea. The data also show that there is no expectance of experiencing sea ice, but some icing is to be expected. Since there is no sea ice to be expected the structure chosen for the OSB may be either fixed or floating. One of the functional requirements that were set for the OSB was that it should have storage tanks such that it is able to receive recovered oil spill in case of an emergency oil spill preparedness operation. The structures that are applicable then are:

Fixed Structures

- Gravity based structure

Advantages
- Stable
- No mooring required
- Able to support large deck loads

Disadvantages
- Cost increases exponentially with depth
- Subject to seafloor scour
- Not movable

Floating Structures

- Spar platform

Advantages
- Applicable to extreme water depths
- Favourable motion characteristics compared to other floating concepts.
- Movable

Disadvantages
- Little storage space
- Requires mooring
- Relatively complicated hull structure, new build required

- Circular monohull

Advantages
- Applicable to extreme water depths
- Large storage opportunities
- Large deck space
- Good weather vaning capabilities
- Movable

Disadvantages
- Requires mooring
- Large motions vertically, horizontally depends on mooring
- New concepts, requires new-build

- Ship-shaped monohull

Advantages
- Applicable to extreme water depths
- Large storage opportunities
- Large deck space
- Possible to upgrade existing vessels to necessary functions and classifications
- Movable
- Good weather vaning capabilities

Disadvantages
- Requires mooring
- Large motions vertically, horizontally depends on mooring

The water depth in the area where the suggested position lies is between 270 and 400 meters, which is a feasible depth for all the structures, but is a disadvantage for the gravity based structure. This type of offshore structure is rendered economically feasible in water depths only up to 350 meters when used for petroleum purposes. The deciding factor for which concept to choose will be its capability of providing storage tanks for oil spill. Therefore the

Spar structure will not be selected. Because of the vast distances in the Barents Sea the OSB should also be movable in order for it to provide the advantage of having oil spill storage tanks available. The OR-vessels typically have a cruising speed of 14 knots, if they have to move back and forth between the OSB and the area of the oil spill this can waste crucial time. As an example the distances and transit times between the OSB and selected oil fields in the Barents Sea are shown in Table 17.

Table 17 Distances and time in transit OSB location 1

	Location 1 [nm]	**Location 1 time in transit (14 kn) [hr]**
Snow White	143	10
Goliat	144	10
Havis	126	9
Skrugard	124	9
Possible new oilfield South East		
74.25N 35.65E	162	12
73.27N 34.08E	124	9
72.32N 32.70E	109	8
71.37N 32.04E	138	10
Possible new oilfield Svalbard East		
78.97N 35.08E	373	27
78.12N 34.43E	320	23
Possible new oilfield Svalbard South		
76.20N 26.00E	184	13
75.75N 22.54E	173	12

This in addition to the economical disadvantages rules out using a gravity based structure for the OSB. Both the circular and the ship-shaped monohulls are moveable. However, a NOFO-tanker is expected to have a cruising speed of minimum 15 knots, this indicates that a traditional ship-shaped monohull is preferable. Also, choosing a ship-shaped vessel enables the possibility of redesigning existing vessels such that it is applicable for use in the Barents Sea, in many cases this can be an economical advantage. Therefore, for concept 1 a ship-shaped monohull is chosen. When using the vessel as a NOFO-tanker it will be able to cover the entire Barents Sea within 24 hours.

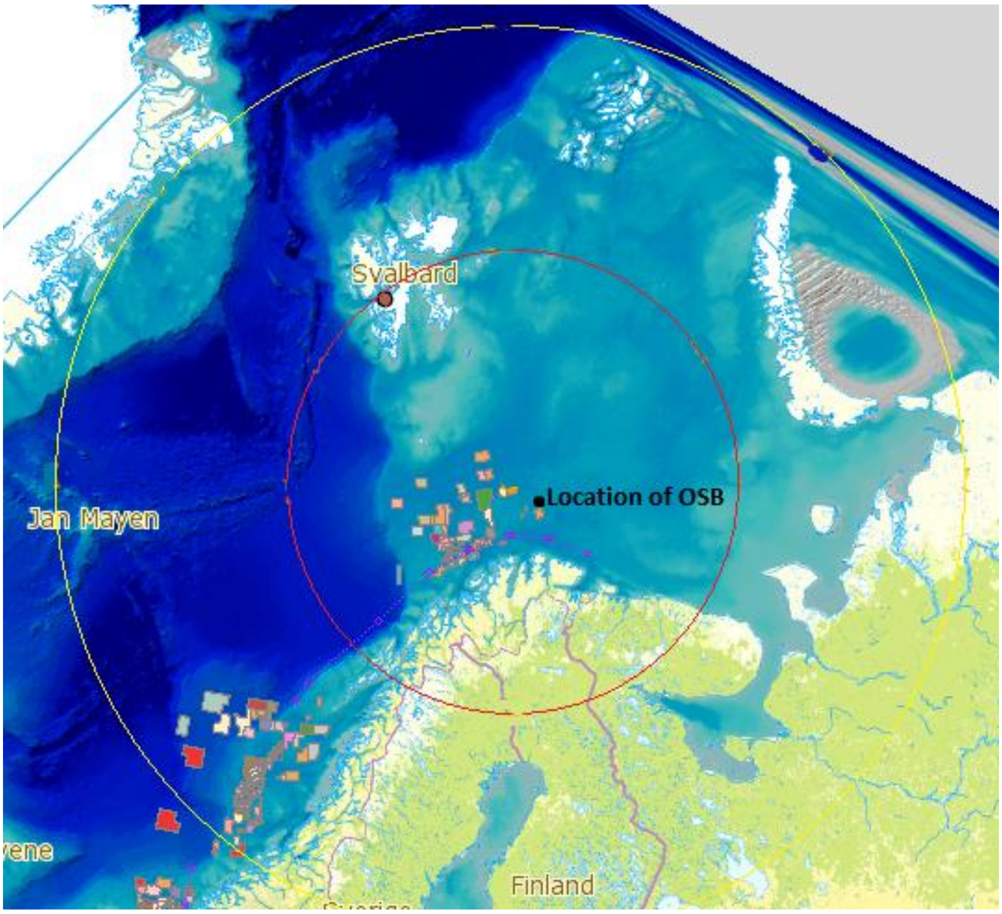

Figure 43 NOFO-tanker range [15kn]. Red line 24 h range, yellow line 48 h range

To enable the OSB to function as a NOFO-tanker it should be equipped with a quick release mooring system. In addition the mooring should have floaters connected to it such that the vessel may be re-moored. A quick release mooring system is also a safety function against icebergs. Although it is highly unlikely that icebergs will travel as far south as the area where the base is placed, the consequences from iceberg collisions are so devastating measures should be undertaken to avoid the risk.

The OSB should be of such a size that it has tank capacity for the minimum amount of oil spill recovered that the petroleum companies have dimensioned their emergency oil spill preparedness to. The Goliat platform which is planned to start oil production in 2014 has dimensioned the emergency preparedness such that is able to recover 30% oil of a total oil spill of 31 050 m^3 pure oil. This only adds up to a total amount of 9315 m^3 oil which does not require a very large tanker, but it should also be kept in mind that the oil recovered will be mixed with water and the oil spill scenario that the Goliat has prepared for is not the worst case scenario. The worst case scenario of the Goliat field is an oil spill daily rate of 20 729 m^3 for 45 days, which is a highly unlikely scenario that would require much more oil spill emergency preparedness than what is available in the Barents Sea today. It is not necessary to dimension the OSB to be able to handle such extreme scenarios, but it indicates that there should be possibilities of the tanker to handle more extensive oil spills than what the Goliat emergency preparedness is dimensioned for. Using a larger vessel also means that there will be more deck space and opportunities to have a larger superstructure which opens up to more possibilities for the OSB outside the emergency preparedness elements. The hull of the vessel should be based on the hull of a tank ship. Typical tank ships used to ship crude oil are the Aframax and Suezmax vessels. The Aframax tank vessel is a mid-sized tanker which has a deadweight that lies between 80,000 and 120,000 tons. The Aframax is considered to have a favourable size as it is able to access most ports around the world. The Suezmax has its name from its size which is a term for the largest ship measurements that may pass thru the Suez Canal. The deadweight of the Suezmax vessel lies between 120,000 and 200,000 tons and it typically has a beam of 50 meters. The Suezmax vessels are also of a size that gives them access to most ports around the world. The main ports in Finnmark, Norway are both deep and wide, and the only limitation is for the port in Hammerfest where the maximum ship length is set to 200 meters.

The OSB is located in ice free waters, but it should be able to navigate in some ice conditions in case of an oil spill emergency in ice covered waters. Therefore the vessel should, as a minimum, have a classification equivalent to DNVs ICE-1C Winterized (design temperature) classification and it should be equipped such that it follows IMO Polar Codes requirements for vessels category B.

> *Category B: Ships that may operate in ice-covered waters with less than 10% ice, where it may pose a structural risk* (26)

Vessels classed according to ICE-1C will be able to navigate in broken channels of 1^{st}-year ice made by ice breakers or open waters with small ice floes, the maximum height of the ice is $h_0 = 0.4$ meters. This particular class is equivalent to the Finnish Swedish Ice Class 1c which was developed for ships sailing in the northern Baltic waters. The classification rules give requirements to the following parts of the vessel:

Hull – ice belt

DNV defines in their classification rules for vessels navigating in ice that the vessel needs to be strengthened, in this relation they have defined an ice belt region where the strengthened plates are to be applied.

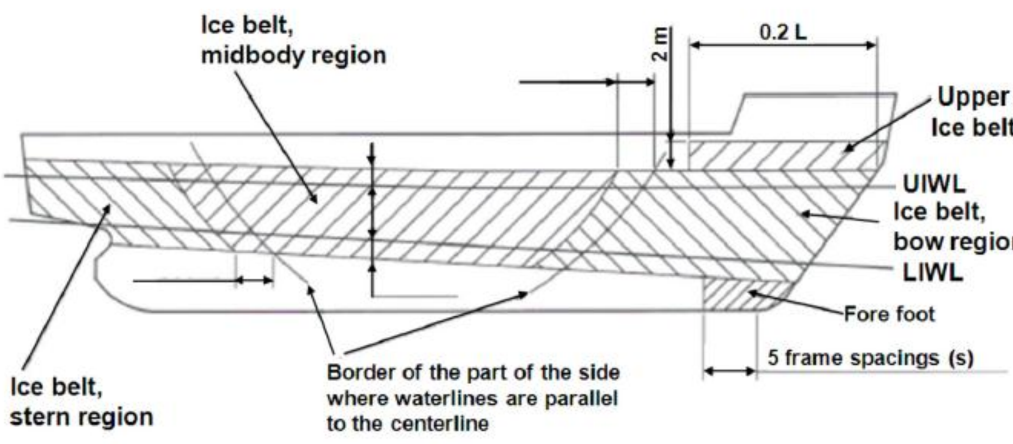

Figure 44 Ice belt regions (34)

Machinery output

The maximum machinery output is to be calculated for the Upper Ice Waterlines (UIWL) and Lower Ice Waterlines (LIWL). For ice class ICE-1C the design requirement is that the vessel should be able to maintain a minimum speed of 5 knots in a brash ice channel where the thickness of the brash ice in mid channel is 0.6 meters.

Shaft – System and propeller

Regulations to the strengthening of shafts and propellers in accordance to the expected ice load that the propeller will experience. For ice class Ice-1C the propeller is to be able to endure ice blocks with the maximum thickness of 1.0 meters entering the propeller. If the vessel is fitted with azimuth thrusters or podded propellers to improve the manoeuvrability of the vessel the stern area will also experience increased ice loading which needs to be considered. In addition to avoid high loads on propellers and blade tips the distance between the propeller and hull should be more than the maximum height of the ice, which in this case is 0.4 meters.

Heating of ballast tanks

The ballasting tanks need to be heated to avoid ballast water from freezing.

Sea chest

For the cooling water system the vessel shall have a sea chest arrangement. It needs to be designed in such a way that it is not blocked. The sea inlet is to be placed aft in the ship and close to the centre line. The volume of the sea chest should be at least 1 m^3 for every 750 kW engine output. When a vessel is in ballast condition it may be useful to use a ballast water arrangement for cooling purposes, but this cannot be viewed as a substitute of the sea chest cooling system.

The vessel also needs winterisation. The vessel shall have the classification Winterized (design temperature °C) which is needed for vessels that are placed in cold environments for long periods at a time. The design temperature is a reflection of the lowest mean daily average temperature which in this case is -19.6°C. For the choice of materials for the structure and equipment and for heat balance calculations for ventilated spaces an extreme temperature of 20°C below the design temperature should be used. The winterization rules set demands to the ship arrangement and requires that some of the equipment shall be protected by deck houses or be partly enclosed such that it is protected from sea spray and icing is avoided. The winterization has divided the needed measures in two categories, where category 1 represents equipment and systems that are to be kept free from ice at all times. Category 1 applies to:

- Navigation systems
- Steering installations
- Propulsion system
- Anchoring system
- Lifesaving/escape routes

Category 2 is applied to equipment that is required to have de-icing arrangements which enables the system to be ice free within a reasonable amount of time. Category 2 applies to:

- Decks and superstructures
- Helicopter decks
- Railings
- Cargo deck area

In addition the navigation bridge wings needs to be fully enclosed and engine rooms and spaces which contains important equipment needs to be fitted with a proper heating arrangements. Regarding power and machinery the emergency generators should be located and arranged in such a way that they are able to operate at the extreme design temperature, that is -39.6°C in this case. The machinery should be able to start from a black out within 30 minutes at the temperature drop it will experience at the extreme design temperature.

This classification requires a minimum heating capacity 450 W/m^2 for open deck areas, helicopter decks, gangways, stairways, etc. The superstructures are required to have a heating power of minimum 200 W/m^2 while railings with inside heating shall have a minimum of 50 W/m.

Another issue to be considered is that the vessel will need an extensive amount of ballasting because the tank which is intended for recovered oil spill will be empty most of the time. Because of this, the OSB should be fitted with a ballast water cleaning system. In the Norwegian regulation regarding ballast water[12] it is stated that the vessels that are going to dispose of ballasting water, which is from areas outside the region the ship is operating in, have to either

- Replace the ballast water at special disposing areas
- Clean the ballast water before discharging it
- Deliver the ballast water to special reception facilities

According to the regulation discharging of untreated ballast water is allowed at water depths exceeding 200 meters when the ship in question is more than 200 nm from the nearest land, or if this is not possible at water depths exceeding 200 meters at a minimum distance of 50 nm from land. The regulation therefore opens up for the possibility of not having a ballast water cleaning system. The Polar Code, which is not finalized yet, suggests that ice covered waters or ice shelves should also be considered as “land” which limits the possibility of discharging untreated ballast water, especially during the winter. The Polar Code have also suggested that in order to discharge ballast water it should be mandatory for the vessel to have an approved ballast water treatment system or, if not, it is mandatory for the vessel to deliver ballast water to onshore reception facilities. Therefore, assuming that all regulations in the Polar Code will be ratified, the OSB will need a ballast water cleaning system.

[12] FOR 2009-07-07 nr 992: Norwegian regulation regarding prevention of dispersion of alien organisms through ballast water and sediments from ships (http://www.lovdata.no/cgi-wift/ldles?doc=/sf/sf/sf-20090707-0992.html)

3.3 Concept 2: The Barents Sea North

As mentioned there are future possibilities of increased shipping traffic and oil fields being opened further north as well, the second concept alternative will therefore be an OSB placed in the Barents Sea North. The functional criteria are the same as for concept 1, the OSB should be able offer SAR-services and storage for oil recovered in emergency oil spill preparedness operations. The future scenarios presented by the Norwegian Government pictured possible oil fields just east of Svalbard. Therefore the location of the OSB will be in relation to this possible oil field. The location chosen together with the 3 hour helicopter range from the base is showed in Figure 45.

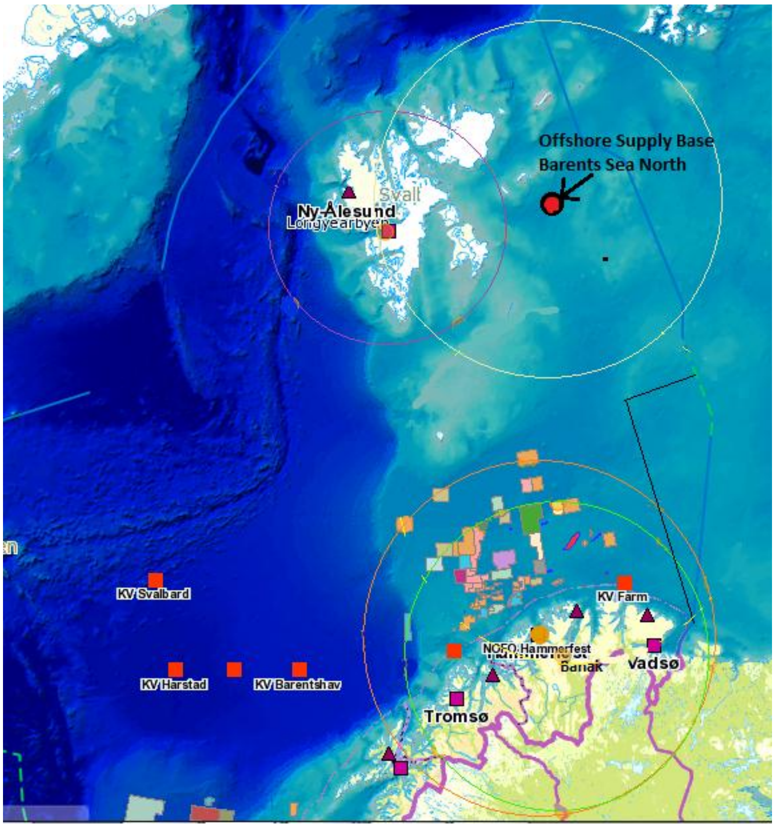

Figure 45 Location of OSB in the Barents Sea North with 3 hour helicopter range

The OSB is placed at approximately 78.3N 29.8E, the water depth in this area lies between 280-300 meters. Because the location is further north the metocean conditions are different from location 1. The average temperatures, expected icing and sea ice coverage throughout the year at 78.05N 27.57E is shown in Table 18.

Table 18 Temperature, sea ice and icing at 78.05N 27.57E 1958-2009

Temperature, sea ice and icing at 78.05N 27.57E 1958-2009			
January-March		**April-June**	
Avg. sea surface temp	-1.77	Avg. sea surface temp	-1.81
2m air temp	-15.86	2m air temp	-4.74
Light icing, in % of time	0.19	Light icing, in % of time	0.32
Moderate icing, in % of time	0.05	Moderate icing, in % of time	0
Heavy icing, in % of time	0.06	Heavy icing, in % of time	0
Extreme , in % of time	0.05	Extreme , in % of time	0
Sea Ice, in % of time	99.55	Sea Ice, in % of time	94.3
July-September		**October-December**	
Avg. sea surface temp	-0.97	Avg. sea surface temp	-1.57
2m air temp	-0.6	2m air temp	-12.62
Light icing, in % of time	4.79	Light icing, in % of time	5.15
Moderate icing, in % of time	0.76	Moderate icing, in % of time	2.99
Heavy icing, in % of time	0.26	Heavy icing, in % of time	1.47
Extreme , in % of time	0.1	Extreme , in % of time	1.11
Sea Ice, in % of time	52.81	Sea Ice, in % of time	84.04

As can be seen from the data sea ice can be expected throughout most of the year, the ice that is found around Svalbard is mainly first-year ice and the thickness is usually less than 2 meters. The presence of sea ice limits the choice of structure for the OSB. As mentioned earlier there are no appropriate floating structures that may be permanently placed in ice covered waters available today. Therefore, the only appropriate choice is a gravity based structure. The gravity based structure has storage space and may be dimensioned to endure ice loads.

Because the gravity based structure is permanently fixed to the location the OR-vessels have to sail to the OSB in order to empty their tanks. The transit time for an OR-vessel from selected oil fields to the OSB is shown in Table 19.

Table 19 Distances and time in transit OSB location 2

	Location 2 [nm]	**Location 2 time in transit (14 kn)[hr]**
Snow White	435	31
Goliat	446	32
Havis	388	28
Skrugard	375	27
Possible new oilfield South East		
74.25N 35.65E	146	10
73.27N 34.08E	320	23
72.32N 32.70E	373	27
71.37N 32.04E	433	31
Possible new oilfield Svalbard East		
78.97N 35.08E	71	5
78.12N 34.43E	64	5
Possible new oilfield Svalbard South		
76.20N 26.00E	140	10
75.75N 22.54E	186	13

As can be seen in the table the transit times becomes quite long which makes it a poor alternative in regards to emergency oil spill preparedness. Location 2 is also away from the main shipping lanes that are used today. This means that it will not be able to offer any advantages for the marine activities except to fishing vessels and possibly cruise ships and research vessels that are sailing around Svalbard. If more ships are starting to sail thru the Polar Ocean as the ice retracts and more oil fields are opened further North it is also possible that solutions have been worked out to make floating structures feasible to use in waters that are permanently or occasionally covered with ice. This opens up to the possibility of using concept 1 as a solution also for location 2, only with a higher ice classification.

3.4 SWOT Analysis

To investigate the advantages and disadvantages of the two OSB-concept solutions a SWOT analysis has been executed. The SWOT analysis is a way to analyse and evaluate the Strengths, Weaknesses, Opportunities and Threats that are present in a project.

SWOT Analysis ___SHIP-SHAPED OFFSHORE SUPPLY BASE STATIONED IN THE BARENTS SEA SOUTH___	
Strengths - Improves SAR-coverage - Movable - Self-propelled - Able to be used as NOFO-tanker - Emergency oil spill preparedness equipment stored on board - Dispersion chemicals stored on board - Large deck space - Versatile - Good weather vaning capabilities - Symmetrical shape - Re-build of existing vessels possible - Location close to majority of marine and offshore activities in the Barents Sea - Initial costs - Possible to upgrade vessel to high ice class - Possible to design as a double acting ship - Easy to decommission - May be used as an emergency harbour for smaller vessels - Life-cycle possibilities, be moved and reused other locations/used for other purposes	**Weaknesses** - Ship motions may make it challenging to provide necessary medical services - Needs mooring and/or DP - Operating costs - Icing - Necessary to have personnel trained for ice navigation if OSB is needed in ice covered waters - More challenging to land helicopters on ships than on fixed structures - If ship is to be used in the Barents Sea North high ice classification is necessary

Opportunities
- Usable as a maintenance and storage hub
- Bunkering opportunities for vessels operating in the Barents Sea
- Modula based
- Possible to change modules depending on what is most needed, e.g. search phase, drilling phase, production phase
- Large superstructure with extended crew capacity
- Able to receive evacuated people, for instance
- Workshops
- Extra clean workshops for turbines/compressors
- Calibration
- Welding possibilities
- Pre-fabrication of pipes
- Equipment for BOP-testing
- Research base
- Information hub
	Threats
	- Extensive operation to change modules, onshore offshore?
	- Ship motions may be challenging for some work shop features
	- More features requires large diesel storage capacity
	    o Heating of living quarters and workshops etc.
	    o Aux. equipment
	    o Heat tracing of equipment
	    o Testing and overhauling of equipment (turbines etc)
	- The OSB itself poses a threat to the environment as collisions may occur
	- Increased shipping traffic because of it

SWOT Analysis

__GRAVITY BASED OFFSHORE SUPPLY BASE IN THE BARENTS SEA NORTH__

Strengths

- Fixed to seabed
- Stable
- Improves SAR-coverage
- Storage tanks for recovered oil spill
- Emergency oil spill preparedness equipment stored on board
- Dispersion chemicals stored on board
- May be permanently connected to network by fiber optic cables
- Supports large deck loads
- No mooring required
- Able endure sea ice
- Operating costs
- May be used as a emergency port for smaller vessels
- Connection to gas-lines possible

Weaknesses

- Not movable
  - Not practical to use as NOFO-tanker if oil spill is at distant oil fields
  - Iceberg encounterings
- Initial costs
  - Cost increases exponentially with depth
- Seafloor scour
- Distant to majority of the current marine and offshore activities in the Barents Sea
- Distant to current shipping lanes
- Outside current 3 hour helicopter range
- Difficult to decommission
- According to the Norwegian Government there are no plans for opening oil fields in the Barents Sea North

Opportunities

- Usable as a maintenance and storage hub
- Bunkering opportunities for vessels operating in the Barents Sea
- Large superstructure with extended crew capacity
- Workshops
  - Extra clean workshops for turbines/compressors
  - Calibration
  - Welding possibilities
  - Pre-fabrication of pipes
  - Equipment for BOP-testing
- Research base
- Information hub

Threats

- Distant to majority of the current marine and offshore activities in the Barents Sea
- Distant to current shipping lanes
- Outside current 3 hour helicopter range
- According to the Norwegian Government there are no plans for opening oil fields in the Barents Sea North

3.5 Resulting concept in the Barents Sea South

The resulting concept is a multipurpose ship placed at approximately 73.1N 27.1E where the main purpose is to provide SAR helicopter service and increase emergency oil spill preparedness for the Barents Sea. In addition it should be able to function as a storage and maintenance hub. The vessel shall be moored with a quick-release mooring system.

The vessel shall have an ice class equivalent to DNV's ICE-1C Winterized (-19.6°C) and be equipped such that it follows the IMO Polar Code's requirements for vessels category B. The service speed of the vessel shall be minimum 15 [kn]. The hull of the vessel will be based on the hull of a tanker where the hull shall be double bottomed and have double skin with coated cargo tanks to minimize the risk of oil spill. The ballast water tanks shall be equipped with a ballast water cleaning system. The OSB shall as a minimum have cargo tanks of such a size that it is able to assist in emergency oil spill preparedness operations that the oil field operators in the Barents Sea have dimensioned their emergency preparedness for. The OSB shall also be equipped with one dispersion chemical tank. The main deck of the OSB shall as a minimum be fitted with:

- One helicopter hangar with permanently based SAR-helicopter,
- One helideck
- Storage space for NOFO equipment
- Superstructure with hospital

The everyday use of the helideck will primarily be for crew changes, but a more important feature of it is that it enables fast transfer of people rescued by the SAR-helicopter. This indicates that the helideck should be in connection with the superstructure and that it should be possible to transport patients which are on stretchers directly from the helicopter and in to the hospital area. The hospital area should preferably be placed on a low level of the superstructure to reduce motions as much as possible, while the helideck should be placed in connection with the top of superstructure. This is to free as much space on deck as possible and to minimize icing on helideck. For fast and safe transfer from helideck to hospital area there should be an elevator. Additional areas that should be found in the superstructure are:

- Navigational bridge with enclosed bridge wings
- Extended living cabin arrangements with room for
  - Crew
  - Possible research crew
  - Cabin solutions such that it is possible to accommodate people that have been evacuated from installations or vessels
  - Galley, common area etc.
- Research lab/calibration lab
- Small workshop

In addition to enable the OSB to function as a storage and maintenance hub the main deck should be fitted with:

- Winterized workshop and storage area
- Container based storage area
- One A-frame crane with capacity to move containers and NOFO equipment
- One high capacity offshore crane to lift equipment on/off OSB

It is also possible to equip the vessel such that it is able to provide extended services. Possible opportunities were presented in the SWOT-analysis. The final size of the vessel will therefore depend on the amount of oil spill the OSB shall be able to receive and the services it will be able to provide. This decision will have to be made through a conceptual business plan where the demand for the different services is considered.

One possible solution could be an OSB that is based on an Aframax or Suezmax vessel. Because these are typical sizes for a tank vessels it opens up to the possibility of buying an old vessel and rebuilding it such that it is fit to purpose. This is very common to do when building FPSOs for instance. Another design aspect which can be taken from the building of FPSOs is that they are very often module based, where the topside for instance is divided into different modules which are built separately and delivered to the vessel as whole building blocks that are pieced together. This is also an approach that can be used when designing the OSB, where the SAR-helicopter with hangar, hospital area, oil-spill receiving tanks and helideck are fixed elements while the other service directed modules are more flexible in terms of what they should be able to provide and of what size they should be. To illustrate a possible OSB-solution a simple sketch is shown in Figure 46.

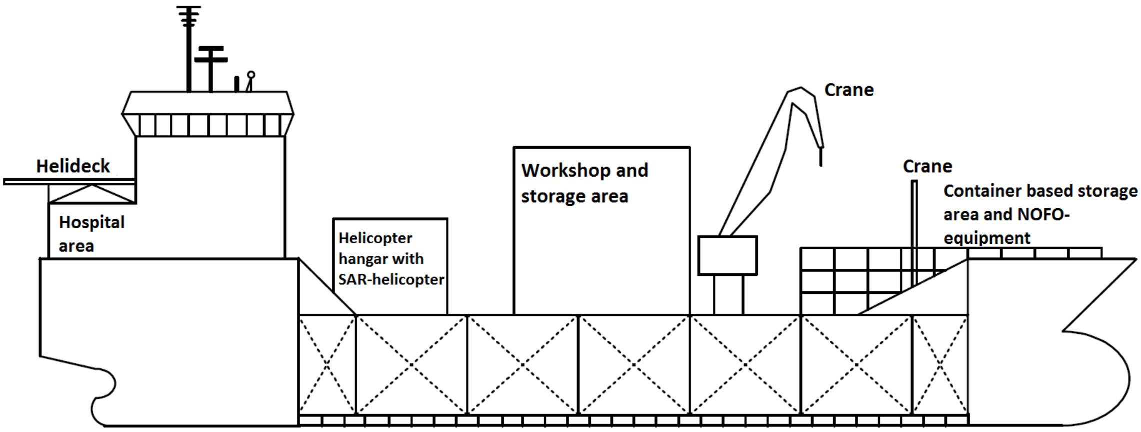

Figure 46 Sketch of possible OSB solution

The areas assigned to the different elements of the OSB are suggestive and not a final solution. It is also possible to design the cargo tank in such a manner that the OSB is able to provide different services. Once the amount of oil spill the OSB should be able to receive is fixed the available tanks can be arranged such that they are able to provide other services. For instance

- Bunkering possibilities for vessels operating in the Barents Sea
- Reception tanks for
    - Grey water
    - Sewage water
    - Ballasting water
    - Oily water

The final tank arrangement is also an issue that has to be resolved through a conceptual business plan.

Whether or not the OSB will be a new-build or a conversion of an existing tank vessel the OSB needs to be modified such that it is fitted for operation in the Barents Sea.

4 Conclusion

The Barents Sea is a remote area with harsh weather conditions which is lacking sufficient infrastructure to ensure safe development of oil fields further north. The remoteness and lack of infrastructure also makes it difficult to ensure economically feasible operations in the Barents Sea. The SAR-helicopter coverage which exists today does not cover oil field developments further north than what exists today within the mandatory 3 hour limit which petroleum actors are subject to. The current oil spill emergency preparedness is also limited as the actors operating in the Barents Sea are not guaranteed a tank ship before 75 hours. Placing an OSB in the Barents Sea will ensure that the SAR-coverage is extended further north. In addition, if the OSB is a ship-shaped monohull vessel with storage opportunities which has a minimum service speed of 15 kn, it will be able to cover the entire Barents Sea within 24 hours in case of an oil spill emergency. Extending the services provided by the OSB to also include workshop and storage possibilities for instance, will improve the logistical challenges related to the vast distances which are found in the Barents Sea. This could possibly be an aid to ensure economically feasibility of operations in the Barents Sea.

4.1 Recommendations for further work

To investigate the OSB solution further it is recommended that a risk analysis is conducted to determine the preferable volume of the oil spill recovery tanks. To conduct a conceptual business analysis to identify the logistical services that the OSB should provide and to determine the area of the OSB they should take up. Lastly it is recommended to investigate the resulting OSB concept by conducting a case study. ‘

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