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Emergency preparedness in Arctic oil and gas exploration

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Submission date: May 2013
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Preface

This paper is part of my master´s degree at the Norwegian University of Science and Technology, Department of Marine Technology. It was executed in the spring of 2013.

The subject of the thesis is "*Emergency preparedness in Arctic oil and gas exploration*". Working with this topic has been very interesting, and it has given me the opportunity to gain knowledge about the challenges that arise when performing oil and gas exploration in the northern part of the Barents Sea. I have also found it motivating that an increasing activity in the Barents Sea has been on the public agenda during the project period.

Trondheim, May 27, 2013

Bjarte Ims

Acknowledgements

I would like to thank my two supervisors, Jan Erik Vinnem at NTNU and Stine Albertsen Ranum at Safetec Nordic AS for patiently reading and giving good advice and feedback during the preparation of this report.

Many thanks to Hilde Færevik at SINTEF for answering my questions and giving me a better understanding of survival suits and accompanying tests and demonstrations. I would also like to thank Beate Kvamstad at MARINTEK for valuable input regarding the challenges that are related to communication coverage in the Barents Sea.

Abstract

Due to an increasing interest in oil and gas exploration in the Barents Sea, it is important to identify all the challenges related to petroleum activity in that area. The objective of this thesis is to examine conditions relevant to the evacuation and rescue of personnel from facilities operating in the Barents Sea. The report considers the Norwegian sector of the Barents Sea north of the Norwegian mainland, south of Bjørnøya, and extends towards the Norwegian/Russian border that came into effect in 2011.

A specific case was made to analyze the following three Defined situations of hazard and accident (DSHA):

- Personnel in the sea as a result of a helicopter accident (DSHA 2)
- Personnel in the sea during emergency evacuation (DSHA 3)
- Personnel injury/sickness requiring external assistance (DSHA 7)

Two scenarios were given: Scenario 1 and Scenario 2. The first scenario should have a SAR helicopter stationed on a production facility, while the other scenario should have the SAR helicopter stationed on a floating base (for instance a standby vessel).

The case study showed that land-based SAR helicopters would not fulfill the performance requirements regarding the three DSHAs mentioned above because the distances out to the actual facilities were too long. Having stationed a SAR helicopter offshore in a hangar is therefore a necessity, and placing the helicopter on a production facility is a better alternative than to station it on a floating base such as a standby vessel.

A SAR helicopter, with an operational speed of 140 knot and a 15 min. mobilization time, could in the event of a helicopter accident (DSHA 2) manage to cover 82 Nm. while rescuing 21 persons from the sea. In the event of a DSHA 7, time of response in emergency medicine, the range could be 100 Nm.

Long distances and a lack of infrastructure combined with the climatic conditions in the Barents Sea, lead to challenges that require special attention and management. Insufficient communication coverage around 70-75°N and further north cause an extra challenge in achieving a safe emergency preparedness. The poor communication coverage also has an influence on the quality of weather forecasts. A good reliable weather forecast is essential to maintain a safe and secure operation. This is however difficult to achieve today due to few

measuring points in the area. An increased activity in the Barents Sea will therefore improve the situation.

Ice accretion is an issue that requires attention particularly for standby vessels, lifeboats, MOB boats and facilities. Drifting sea ice and icebergs is also something that has to be taken into consideration when operating north in the Barents Sea.

Special attention has to be given to the use of free-fall lifeboats. If there is sea ice in the area around a facility, the drop of free-fall lifeboats cannot be carried through. Compensating measures then have to be taken into account.

The challenges related to oil and gas exploration in the Barents Sea are manageable, but they require attention and the provision of suitable resources in the area. No single secondary evacuation method is currently available for year-round operation when sea ice is present. Before all-year round petroleum activity can be possible everywhere in the Barents Sea, emergency preparedness must be given sufficient attention so that some critical challenges can be solved.

It seems to be a reasonable requirement that all producing fields in the Barents Sea, including exploration drilling, have an emergency preparedness standard that corresponds to the area-based emergency preparedness.

Sammendrag

Petroleumsnæringen møter spesielle utfordringer etterhvert som den forflytter seg lenger og lenger nord på sokkelen. Aktiviteten i Barentshavet preges av store avstander til land, manglende infrastruktur, lang mørketid, tøft klima og lave temperaturer. Hensikten med denne oppgaven er å undersøke forholdene tilknyttet evakuering og redning av personell fra innretninger som opererer i Barentshavet. Denne rapporten tar for seg den norske sektoren av Barentshavet nord for det norske fastlandet, opp til sørlige delen av Bjørnøya og strekker seg østover til den norsk/russiske grensen som ble bestemt i 2011.

Et spesifikt case, som innebefatter en produksjonsinnretning samt tre boreinnretninger, ble etablert for å analysere følgende tre definerte fare og ulykkeshendelser (DFU):

- Personell i sjøen som følge av helikopterulykke (DFU 2)
- Personell i sjøen ved nødevakuering (DFU 3)
- Personskade/sykdom med behov for ekstern assistanse (DFU 7)

Et landbasert SAR helikopter vil ikke kunne klare å oppfylle ytelseskravene tilknyttet de tre DFUene nevnt ovenfor, siden avstandene ut til de aktuelle innretningene var for stor.

To scenarioer ble laget, scenario 1 og scenario 2. Det første scenarioet skulle ha et SAR helikopter stasjonert på en produksjonsinnretning, mens i scenario 2 skulle SAR helikopteret være stasjonert på en flytende base (for eksempel et standbyfartøy).

Ved å ha et SAR helikopter stasjonert offshore, vil det være nødvendig med en hangar som vil beskytte helikopteret mot ising og annet hardt vær. Scenario 1 hadde best resultater, dermed vil det være å foretrekke å plassere et SAR helikopter på en produksjonsinnretning fremfor på en egen flytende SAR-base.

Med en helikopterhastighet på 140 knop og 15 minutter mobiliseringstid, vil et SAR helikopter kunne klare å redde 21 personer opp fra sjøen innenfor en rekkevidde på 82 nautiske mil (Nm) og allikevel oppfylle ytelseskravet innen 120 minutter. Angående DFU 7, akutt-medisinsk responstid, så vil rekkevidden være 100 Nm.

Et rimelig krav vil være at alle produksjonsinnretninger i Barentshavet inkludert boreinnretninger har en beredskapsstandard tilsvarende områdeberedskap, i.h.h.t. Norsk olje og gass 064. Det er ansett som ikke nødvendig å ha særskilte krav for beredskapen i nordområdene.

Mangelen på infrastruktur og store distanser kombinert med tøffe klimatiske forhold i Barentshavet medfører utfordringer som krever spesiell oppmerksomhet. Utilstrekkelig kommunikasjonsdekning fra 70°N-75°N og videre nordover medfører en ekstra utfordring knyttet til å ha en trygg beredskap. Den dårlige kommunikasjonsdekningen innebærer at også kvaliteten på værvarselet i området er begrenset. Det er essensielt å ha en god og tilgjengelig værvarslingstjeneste, for å sikre en trygg og god operasjon. Likevel er det vanskelig å oppnå dette per dags dato grunnet få målingsstasjoner i området. Økt petroleumsvirksomhet i Barentshavet vil bidra til å forbedre denne situasjonen.

Opphopning av is er et problem som krever oppmerksomhet, spesielt for standbyfartøy, livbåter, MOB båter og innretninger. Drivende sjøis og isfjell er også noe som må tas i betraktning ved petroleumsaktivitet i Barentshavet.

Bruken av fritt-fall livbåter kan bli problematisk hvis det er sjøis tilstede rundt innretningen. Dermed må kompenserende tiltak settes i verk, noe som igjen vil ha påvirkning av dimensjonerende antall personer i sjøen ved nødevakuering (DFU 3).

Utfordringene tilknyttet petroleumsvirksomhet i Barentshavet er håndterlige, men det vil være nødvendig med spesiell oppmerksomhet og tilstrekkelige ressurser i området. Per dags dato er ingen enkelt sekundær evakueringsløsning tilgjengelig for virksomhet året rundt når sjøis er tilstede. Før petroleumsvirksomhet vil være mulig året rundt i hele Barentshavet må noen kritiske utfordringer bli løst med tanke på beredskapen.

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1. Introduction

1.1 Background

The petroleum activity in the Barents Sea is characterized by large distances between the oilfields and the shore, a lack of infrastructure, darkness, rough environmental conditions and low temperatures /1/. Below are some statements that indicate the interest of oil and gas exploration in the Arctic.

Economic growth and rising standards of living will result in a more than a 30 % increase in global energy demand over the next thirty years. In order to replace existing production and meet increases in future demand, the world needs an "all of the above" energy strategy, one that includes the Arctic offshore resources. The Arctic continental shelf contains some of the least explored basins on Earth /2/.

The high oil prices of lately, and an increasing competition for new petroleum resources, have lead to a growing interest in offshore operation in the Arctic. It will be natural for Norway to explore the Arctic areas since 30 % of the world´s undiscovered petroleum resources are expected to be in the Barents Sea /3/.

Statoil recently made one of its most important oil discoveries in ten years when locating the Skrugard field in the Barents Sea. This field is currently the northernmost discovery on the Norwegian shelf. Due to the development of the Goliat field, NOFO (Norwegian Clean Seas Association For Operating Companies) is establishing a permanent oil spill emergency preparedness located in Finnmark. An increased drilling activity in the North is expected over the next two years. 11 operators there hold a total of 29 licenses with drilling commitments /4/.

Statoil started drilling in Nunatak in the Skrugard area in December 2012 and will drill and complete four wells in this area over a period of six months. The campaign will then continue with the drilling of two to three wells in the Hoop frontier exploration area further north in the Barents Sea in the summer of 2013. These will be the northernmost wells ever to be drilled in Norway /1/.

1.2 Purpose

Due to the increased interest in oil and gas exploration in the Arctic, it is important to identify all the challenges related to the petroleum activity in the Barents Sea so emergency preparedness is sufficient during oil and gas exploration.

The purpose of this thesis is to identify as many of these challenges as possible. As previously mentioned, large distances, poor infrastructure, bad conditions for communication and a harsh environment are some of the most critical challenges that must be taken into consideration before operating in the area. This thesis will therefore focus on these selected problems.

A case will be made with the purpose of analyzing an offshore production facility located far out in the Barents Sea. The focus will be on the evacuation of personnel, and problems regarding helicopter range, weather conditions, lifeboats and communication will be elaborated upon. This way the thesis will produce a specific example that may be used as guidance in other contexts.

A discussion in the end will further elaborate on the utmost challenges related to oil and gas exploration in the northern part of the Barents Sea.

1.3 Problem description

The thesis has, in total, four main parts that will be assessed:

- Theory concerning emergency preparedness analysis
- Special conditions that distinguish oil and gas exploration in the Arctic from the North Sea with regards to emergency preparedness
- Case from the Arctic where three Defined situations of hazard and accident (DSHA) related to the evacuation/rescue of personnel will be analyzed
- Discussion that will elaborate on the greatest challenges related to oil and gas exploration in the Barents Sea

The thesis will not consider whether the facility in question produces oil, gas, or both. Different export solutions will therefore not be discussed, nor will potential risks related to the export of oil and/or gas.

1.4 Limitations and scope

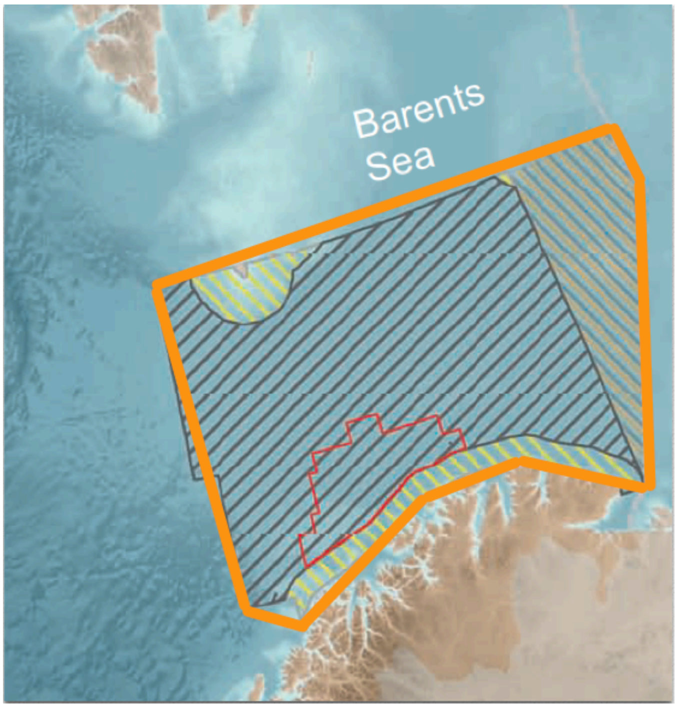

Figure 1 Area covered in the master thesis

The thesis will focus on the area within the orange line on the picture above. The illustration shows the Norwegian sector of the Barents Sea north of the Norwegian mainland and south of Bjørnøya, extending towards the Norwegian/Russian border that came into effect in 2011.

Main focus of the thesis will be on the challenges related to safety of personnel, and means of evacuation will be highlighted the most. Problems related to preventing oil spill will not be elaborated upon in the thesis.

Three selected Defined situations of hazard and accident will be focused on:

- DSHA 2 – Personnel in the sea following a helicopter accident
- DSHA 3 – Personnel in the sea following an emergency evacuation
- DSHA 7 – Illness/injury with need for external assistance

When trying to decide whether or not drifting icebergs should be considered as a DSHA, the DSHA 4 – Collision with drifting object will also be included.

Challenges will occur when completing the performance criteria of the three DSHAs presented above. The final discussion of the thesis will deal with these as well as with other challenges that come with operating in the Barents Sea.

1.5 Abbreviations

AIS	-	Automatic Identification System
ALARP	-	As low as reasonable practicable
AWSAR	-	All Weather Search and Rescue
DAE	-	Dimensioning accidental event
DRA	-	Design risk analysis
DSHA	-	Defined situations of hazard and accident
EER	-	Escape, evacuation and rescue
ENC	-	Electronic Navigational Chart
EPA	-	Emergency preparedness analysis
GEO	-	Geostationary
HEO	-	High Elliptic Orbit
H_S	-	Significant wave height
ISO	-	International Standards Organization
M-ADS	-	Modified Automatic Dependent Surveillance
MOB	-	Man Over Board
Nm	-	Nautical mile (1852 meters)
NOFO	-	Norwegian Clean Seas Association For Operating Companies
NRAO	-	Norwegian rescue responsibility area
OIM	-	Offshore installation manager
POB	-	Personnel On Board
PSA	-	Petroleum Safety Authority
QoS	-	Quality of service
QRA	-	Quantitative risk analysis
Skrugard/Havis	-	Johan Castberg
WCI	-	Wind chill index

1.6 Terms and definition

The following terms and definitions are expressed in NORSOK Z-013 /5/.

ALARP	Expresses that the risk shall be reduced to a level that is as low as reasonable practicable. In other words, risk shall be reduced until the cost of further risk reduction is grossly disproportional to the potential risk reducing effect achieved by implementing any additional measure.
DAE	Accidental events that serve as the basis for layout, dimensioning and use of installations and the activity at large.
DSHA	Selection of hazardous and accidental events that will be used for the dimensioning of the emergency preparedness for the activity.
Emergency preparedness	Technical, operational and organizational measures, including necessary equipment that are planned to be used under the management of the emergency organization in case hazardous or accidental situations occur, in order to protect human and environmental resources and assets.
Emergency preparedness analysis	Analysis that includes establishment of DSHA, including major DAEs, establishment of emergency response strategies and performance requirements for emergency preparedness measures, including environmental emergency and response measures.
Facility	Offshore or onshore petroleum installation, facility or plant for production of oil and gas.
Hazard	Potential source of harm. Harm may relate to loss of life, damage to health or the environment, or a combination of these.
Risk	Combination of the probability of occurrence of harm and the severity of that harm.
Risk acceptance criteria	Criteria that are used to express a risk level that is considered as

	the upper limit for the activity in question to be tolerable.
Risk analysis	Structured use of available information to identify hazards and to describe risk.
Risk assessment	Overall process of performing a risk assessment including: Establishment of the context, performance of the risk analysis, risk evaluation, and to assure that the communication and consultations, monitoring and review activities, performed prior to, during and after the analysis has been executed, are suitable and appropriate with respect to achieving the goals for the assessment.

Table 1 Terms and definitions /5/

2. Theory

This chapter presents relevant theory for the subjects discussed in the report.

2.1 Risk management process

Chapter 2.1 is mostly based on the guideline ISO 31000, Risk Management – Principles and guidelines. The risk management process should be /6/:

- An integral part of management
- Embedded in the culture and practices
- Tailored to the business processes of the organization

The risk management process is presented in Figure 2 below.

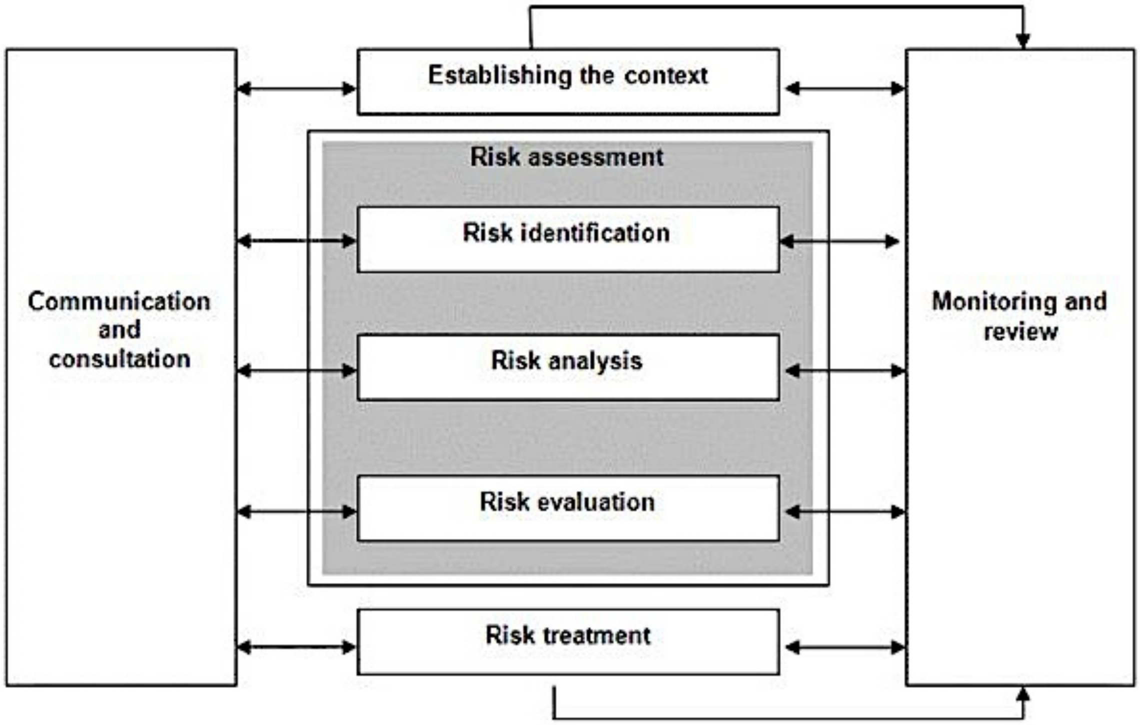

Figure 2 Risk management process /6/

2.1.1 Communication and consultation

The communication and consultation phase should take place during all stages of the risk management process and should address issues related to the risk itself, its causes, its consequences, and the measures taken to deal with it. Communication and consultation with stakeholders is very important as they make judgments about risks based on their perceptions of the risks. The stakeholders may have a significant impact on the decisions made /6/.

2.1.2 Establishing the context

When establishing the context, the organization coordinates its objectives, defines internal and external parameters and sets the scope and risk criteria for the remaining process. The external context is the external environment in which the organization seeks to achieve its objectives. The internal context, on the other hand, is the internal environment in which the organization seeks to achieve its objectives /6/.

2.1.3 Risk assessment

Risk assessment is the overall process of risk identification, risk analysis and risk evaluation. These three parts will be described in this section.

The aim for a risk identification is to generate a comprehensive list of risks based on those events that may create, enhance, prevent, degrade, accelerate or delay the achievement of objectives. This is a critical step in the risk management process. If a risk is not identified at this stage, it will not be included in the further analysis. Identification should include risks whose sources may or may not be under the control of the organization. The source or cause of the risk may also not be evident /6/.

A risk analysis provides input to risk evaluations, to decisions on whether risks need to be treated, and on the most appropriate risk treatment strategies and methods. It involves a consideration of the causes and sources of the risk, their positive and negative consequences, and the likelihood of those consequences occurring /6/.

The purpose of a risk evaluation is based on the outcomes of a risk analysis. It is meant to assist in the decision making when considering which risks need treatment and the priority for treatment implementation. The need for treatment is based on a comparison between the risks found in the analysis and the risk criteria established. The decision will be influenced by the organization's risk attitude and its established risk criteria /6/.

2.1.4 Risk treatment

In order to modify a risk, one has to select one or more options of modification and then implement them. Risk treatment involves a cyclical process of /6/:

- Assessing a risk treatment
- Deciding whether risk levels are tolerable
- If not tolerable, generate a new risk treatment
- Assessing the effectiveness of that treatment

The establishment of an emergency preparedness is a part of the risk treatment and not part of an emergency preparedness assessment /5/.

2.1.5 Monitoring and review

Monitoring and reviewing involves a regular check-up of surveillance and should be a part of the risk management process. It should include /6/:

- Ensuring that controls are effective and efficient in both design and operation
- Obtaining further information to improve risk assessment
- Analyzing and learning from events, changes, trends, successes and failures
- Detecting changes in external and internal context
- Identifying emerging risks

Figure 3 below has much of the same content as Figure 2. However, it is more detailed. The stages R3-R5 are specific for performing a risk assessment process, and stages EPA3-EPA5 are specific for performing an emergency preparedness assessment process.

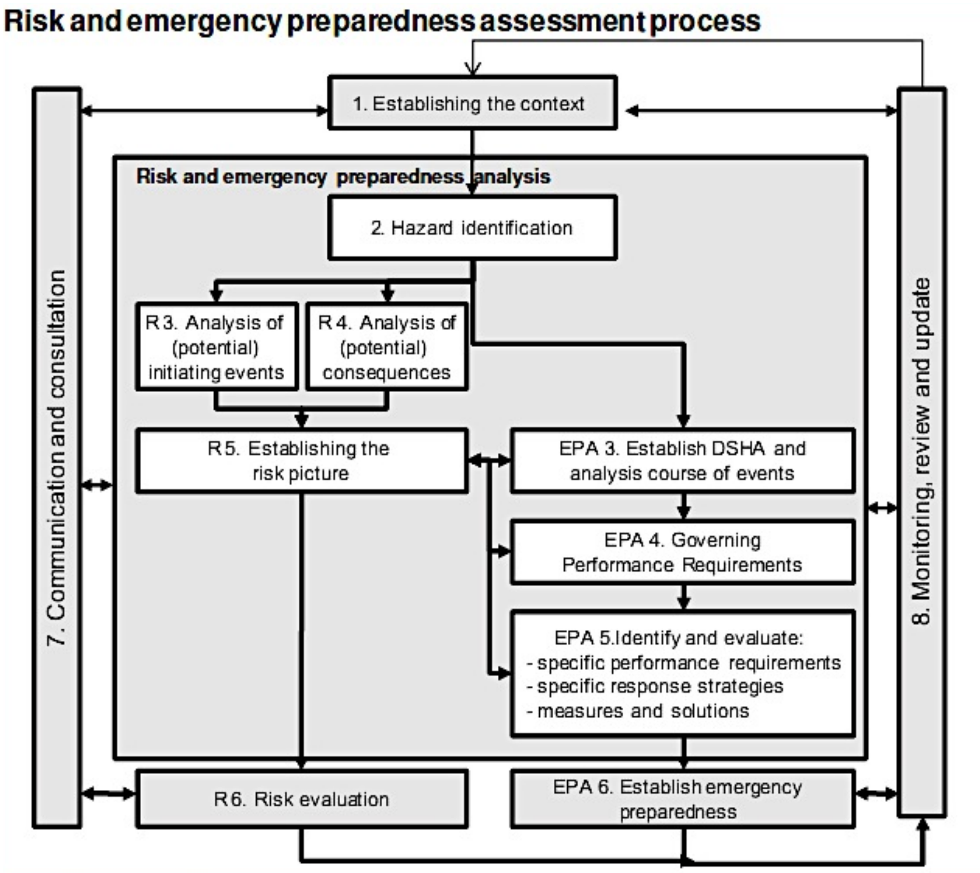

Figure 3 The process of performing a risk and emergency preparedness assessment /5/

2.2 Methodology for emergency preparedness analysis

In this chapter, the methodology used in an emergency preparedness analysis (EPA) will be described. The content of the chapter is based on an emergency preparedness analysis performed by Safetec Nordic AS and the standard NORSOK Z-013. The topics that will be discussed are:

- Establishment of DSHA
- Performance requirements

When a major accident occurs, or when the risk of a major accident increases, it is substantial that personnel has a possibility to arrive at the muster area. Primary working tasks of the emergency staff will here be to perform first aid on injured personnel. If the technical equipment does not have a sufficient capacity to handle the situation, evacuation will be the next option. It is important to emphasize that the primary goal of the emergency personnel is not to handle the situation, but to save exposed personnel /7/.

According to the definition given by the standard NORSOK Z-013, emergency preparedness analysis is defined as an /5/:

"*Analysis that includes establishment of DSHA, including major DAEs, establishment of emergency response strategies and performance requirements for emergency preparedness measures, including environmental emergency and response measures.*"

All relevant information and the results from a Quantitative risk analysis (QRA) should form parts of the EPA. Such information should include /5/:

- A description of the dimensioning accidental event (DAE) for which the organizational and operational measures should be established
- The time requirements that have to be satisfied
- The performance requirements of systems that form part of the emergency preparedness
- Assumptions on the success or suitability of the emergency preparedness measures

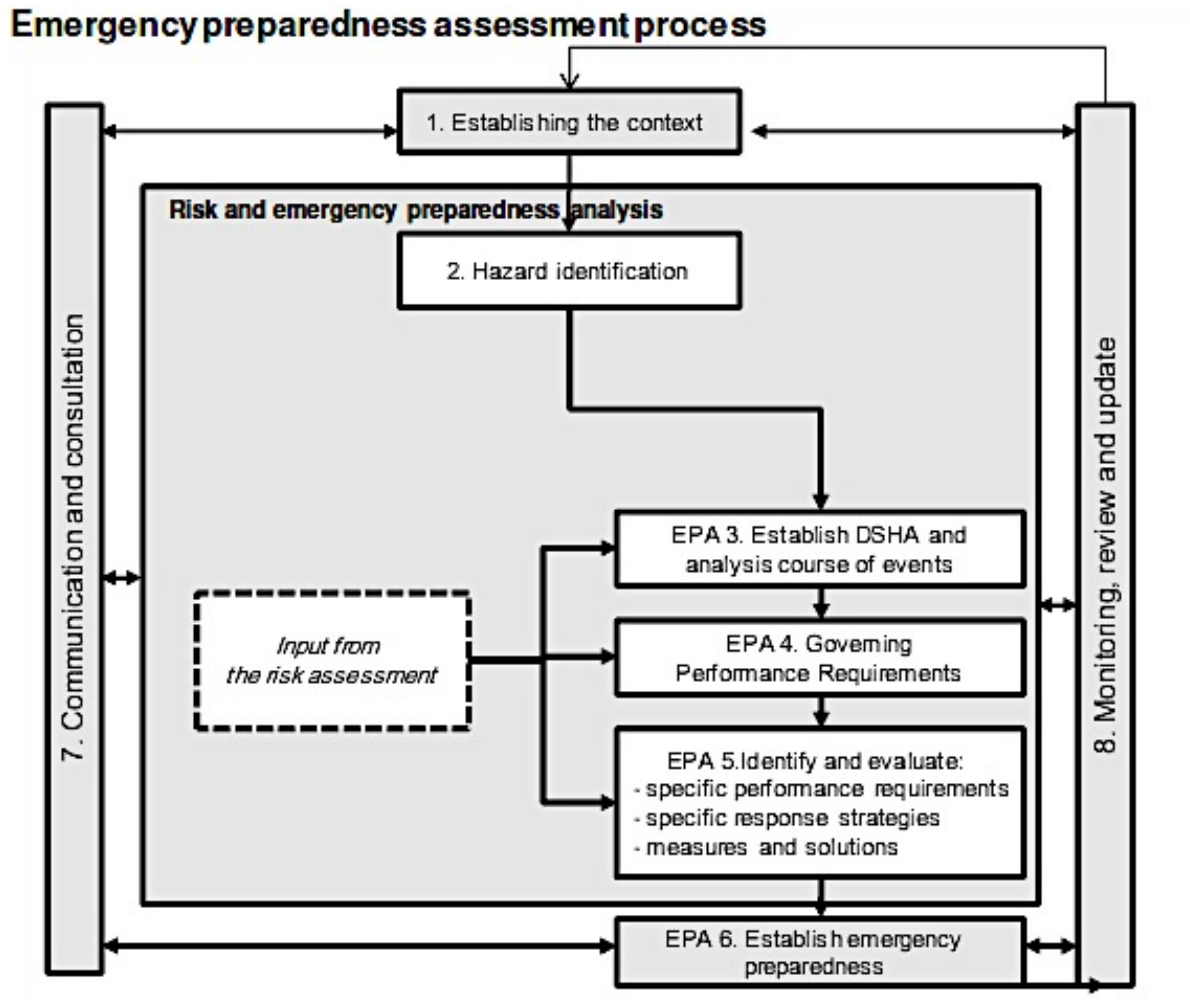

Figure 4 The process of performing an emergency preparedness assessment /5/

2.2.1 Establishment of DSHA

Here, the DSHAs that show the goal of the analysis and the operation/activity in question will be selected and described. The selection of the DSHAs includes /5/:

- Major accidents including the dimensioning accidental events described in the QRA
- Accidental events that appear in QRA without being identified as major accidents, as long as they represent separate challenges to the emergency preparedness
- Events that have been experienced in comparable activities
- Acute pollution
- Events for which emergency preparedness exists according to normal practice
- Temporary risk increase e.g. drifting objects, man over board, unstable well in connection with well intervention, and environmental conditions, etc.

In phase EPA3 it is also required to have a description of each DSHA. The selection of the DSHAs must be documented in a way that includes a description of the criteria for the selection /5/.

In the table presented below, a typical list of DSHAs with accompanying scenarios for an offshore facility is illustrated. Since this list is only meant as an example, all relevant scenarios will not be included. A complete list would be too comprehensive and specific.

DSHA	TITLE	SCENARIO
01	Oil and gas leak	01-01 Blowout on the rig 01-02 Subsea blowout 01-03 Leak during well testing
02	Acute oil spill	02-01 Acute oil spill to sea 02-02 Acute chemical spill
03	Fire or explosion	03-01 Ignited blowout on the rig 03-02 Ignited subsea blowout 03-03 Ignited leak during well testing 03-04 Fire/explosion in utility systems 03-05 Fire in LQ
04	Loss of well control	04-01 Loss of well control 04-02 Ignited well leak
05	Falling loads during lifting operations	05-01 Falling loads during lifting operations
06	Personnel injury or sickness	06-01 Personnel injury or sickness
07	Man overboard during work above sea	07-01 Man overboard during work above sea
08	Diving accident	08-01 Diving accident

09	Loss of stability	09-01 Structural failure 09-02 Failure in the ballast system/displacement of loads
10	Loss of position	10-01 Loss of position during drilling/well intervention
11	Lack of containment of radioactive source	11-01 Lack of containment of radioactive source
12	Danger of collision	12-01 Vessel on collision course 12-02 Drifting vessel/object on collision course 12-03 Collision with supply vessel
13	Helicopter accident	13-01 Helicopter accident on the rig 13-02 Helicopter ditching near the rig
14	Terror-/state of alert-situations	14-01 Terror-/state of alert-situations
15	Extreme weather conditions	15-01 Extreme weather conditions
16	Evacuation	16-01 Evacuation

Table 2 List of DSHA in a typical EPA /8/

As this table shows, there are sixteen different DSHAs. Each DSHA has up to several different scenarios. Each scenario has a specific number. The specific number connects the scenario directly to a given DSHA.

2.2.2 Establishment of performance requirements

The performance requirements are functional and do not provide suggestions to specified solutions. The reason for this is that one should be able to consider technological developments and not be bound by existing technology, operators and organizations. The establishment of performance requirements has come into place so that one can know which sets of requirements need to be met in an emergency preparedness. Performance requirements for an accident are formulated so that, when the requirement is met, it is expected that there is an adequate emergency preparedness for the DSHA for which the standard is established /9/.

According to the NORSOK Z-013, performance requirements should /5/:

- Express a functionality
- Be easy to understand
- Be explicit and measurable
- Be realistic

The performance requirements of an emergency preparedness organization are divided in different emergency preparedness phases according to the NORSOK Z-013. In Table 3 below they are presented:

Phase	Description
Detection and alert	Should ensure a fully effective mobilization of all the emergency preparedness resources.
Danger limitation	Should be implemented to prevent a hazardous situation from developing into an accident, and to reduce the consequences if an accidental situation has occurred.
Rescue	Should ensure that missing personnel are found and given necessary first aid treatment before being brought to a safe area for further help.
Escape and evacuation	Should be implemented in a safe and organized manner, both on and off of the installation, so that personnel can be brought to safety.
Normalization	Should ensure that personnel are brought onshore for treatment and care. The environment should be restored as far as possible to its normal condition and the ongoing situation that has damaged the installation should be stabilized.

Table 3 Emergency preparedness phases /9/

The Norwegian oil and gas 064 has established a list of DSHAs that are often being used as a basis for establishing the entire DSHA-table for a given facility. For each DSHA, the Norwegian oil and gas 064 has composed certain performance requirements. These requirements will be presented in Table 4 on the next page:

DSHA	Description	Performance requirements
01	Man over board when working above open sea	Persons that fall in the sea should be picked up within 8 minutes after the accident has been reported
02	Personnel in the sea as a result of a helicopter accident	In case of a helicopter accident into the sea within the safety zone, 21 persons can be rescued within 120 minutes
03	Personnel in the sea during evacuation	Given that everyone has access to a rescue suit, the number of persons given from the risk analysis should be rescued within 120 minutes
04	Risk of collision	The facility should be alerted as early as possible if a ship is on collision course, minimum 50 minutes before actual time of impact. A decision of evacuation must be taken 25 minutes at the latest before possible impact
05	Acute oil spill	Not considered in Norwegian oil and gas 064
06	Fire requiring external assistance	Time of response for external fire fighting is only required in those cases where ensuring personal safety/main safety functions demands fast mobilization of such capacity
07	Personal injury/sickness requiring external assistance	➢ Time of response in emergency medicine By the use of external resources, the time of response should not exceed one hour ➢ Time of transport in emergency medicine Time should not exceed three hours. This requirement is relevant for serious sickness and injury

Table 4 Performance requirements given by the Norwegian oil and gas 064 /11/

3. Special conditions in Barents Sea

This chapter will present some of the challenges related to oil and gas exploration in the Barents Sea. The following topics will be examined:

- Environmental conditions
- Ice conditions
- Communication
- Infrastructure
- Medical facilities and logistics
- Work environment
- Helicopter operations
- Evacuation and rescue
- Survival suits

Oil and gas exploration in the Arctic requires comprehensive planning and demand high costs. Noreco is a newly established oil and gas company that operates in the Barents Sea. Robert Farestveit, HSE leader in Noreco, has expressed the following /12/: "*Updated weather forecasts are important because of the limited infrastructure in the Barents Sea and a long line of communication onshore. We have to know which weather conditions we may experience*."

"*The platforms are designed to handle extreme weather conditions, but sudden icing may threaten the technical installations, rescue equipment and helicopters, which is something we can't tolerate*."

According to Farestveit, it is not an option to evacuate the crew if a polar low is forecasted. Instead, precautions must be taken, such as temporary production/activity shutdown. Early and more reliable forecasts for polar lows will build up the safety routines on the platforms. Ideally, at the platform everything should be predictable and go as planned /12/.

3.1 Environmental conditions in the Barents Sea

Operating companies which have been active both in the North Sea and in the southern part of the Barents Sea indicate that cold-related challenges experienced at Haltenbanken is at least as great as outside the coast of Finnmark. Experience has shown that the weather conditions are more stable throughout the year in the Barents Sea compared to in the North Sea /13/.

3.1.1 Wind

There is no significant difference in wind strength between the Barents Sea and the North Sea. The proportion of wind speeds above 6 on the Beufort scale (near gale) is highest for the Halten lighthouse. However, Bjørnøya has the highest measured wind speeds. The wind speeds decrease towards the east and north. During the winter, the wind direction is normally southwest except near the coast where the wind comes from the northeast /13/.

An example of maximum wind speeds in the Barents Sea is modeled based on wind data collected from 1958 to 2011. At Goliat, the maximum wind speed was 28 m/s. Further northeast in the Barents Sea (74°N/32,88°E) the maximum wind speed was 25 m/s. This may be compared to the maximum wind speed measured near Statfjord (61,2°N/1,86°E) which was 30,4 m/s /14/.

These data largely agree with the statement that the wind speed decreases towards the east and the north.

Based on wind data from the same time period (1958-2011), the significant wave height H_S [m] was modeled in the same three locations as mentioned above. The location furthest north (74°N/32,88°E) had a maximum wave height of 14 m. At Goliat the maximum wave height was 16,5 m, and at Statfjord the wave height was modeled to be 15,1 m /14/.

Figure 5 presented on the next page shows the percentage distribution of significant wave height Hs > 4 m in January. (Other weather data is to be found in Appendix A.)

The dark green area will include both the Goliat field and the location 74°N/32,88°E (point 5 given later in chapter 3.1.3) and indicate that between 20-25 % of the time the wave height is above 4 m. This percentage increases when the green color gets lighter and shifts to yellow and red. For instance, light green indicates a percentage of 30-35 % and yellow 35-40 %. As one may observe from the figure, the percentage increases further south in the Norwegian Sea and decreases northeastwards in the Barents Sea.

Based on Figure 5, one may observe and state that the percentage distribution of $H_S > 4$ m in January is a greater issue in the Norwegian Sea and the North Sea compared to in the Barents Sea. This will be discussed more in detail when dealing with operational restrictions in regards to the use of MOB boats when rescuing persons from sea.

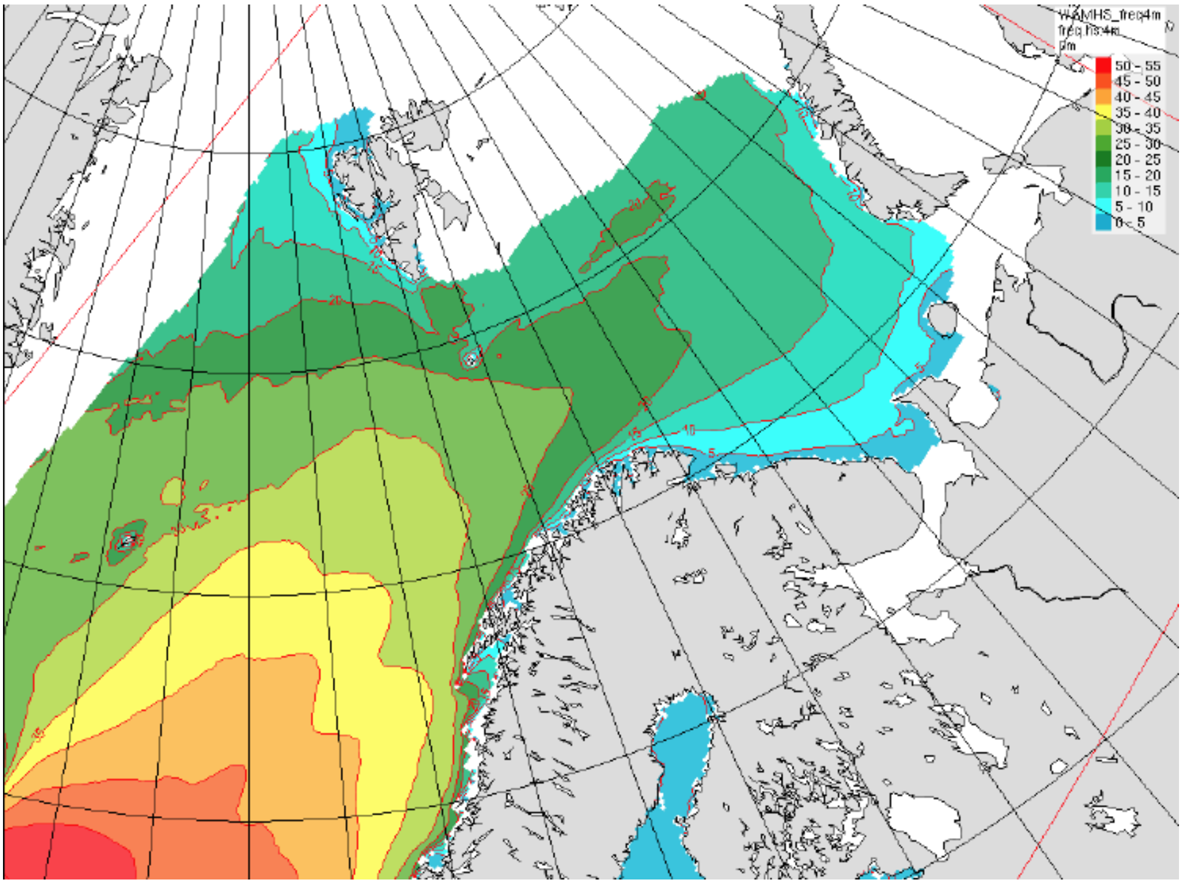

Figure 5 Percentage distribution of Hs > 4 m in January /14/

3.1.2 Polar lows

Polar lows are small, intense low depressions that form over cold open sea during the cold season within polar or Arctic air masses. They are most common between Bjørnøya and the northern part of Norway. Polar lows are characterized by sudden changes in wind direction, maximum wind speed of 70 knots, intense snowfall and icing. They are hard to detect and difficult to forecast /13/.

Normally polar lows result in strong gale, and 30 % of the time a storm around parts of the center will develop. It has been observed that the wave-height may increase up to 5 m in one hour. As mentioned above, polar lows are difficult to forecast since they occur in areas with few observation stations. In addition, they have a rather small scale compared with the observation coverage /14/.

The storm dies or dissipates when it moves over land because the driving force, the warm sea, no longer provides enough energy to sustain the wind system. A polar low normally has a typical diameter of 100 to 500 km, which makes it a relatively small weather system. The strong wind may create chaotic conditions on the sea even though there is not enough fetch to build up very large waves /15/.

Figure 6 presented below illustrates the monthly distribution of polar lows in the Norwegian Sea and the Barents Sea. As may be observed from the figure, the months January through March have most occurences of polar lows. The data is registered by the Norwegian Meteorological Institute between the year 2000 and 2012. The y-axis represents the number of polar low occurences that has been observed in that period.

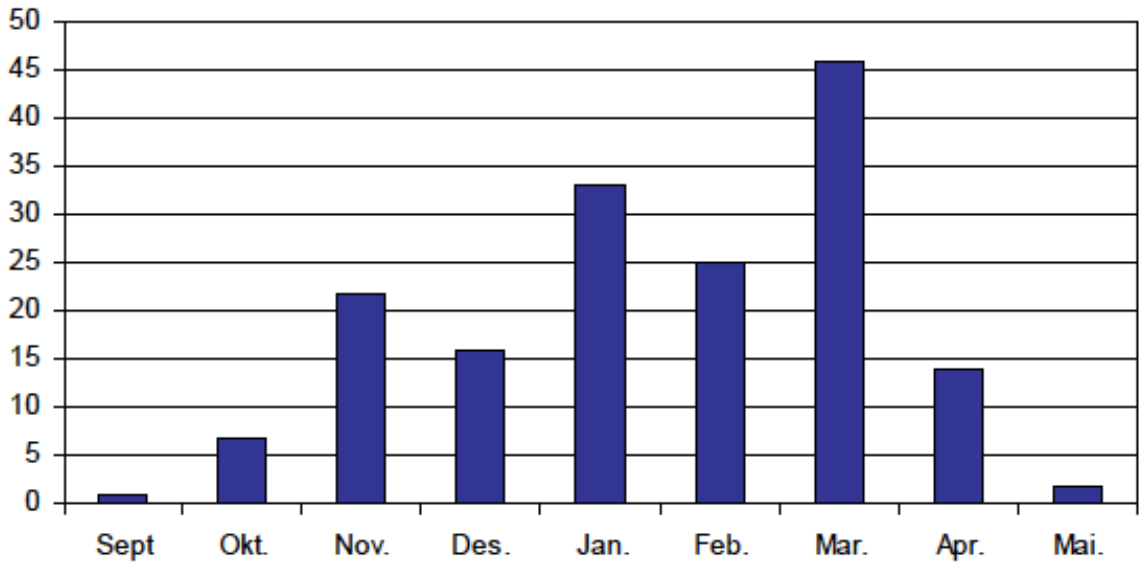

Figure 6 Monthly distributions of polar lows in the Norwegian Sea and the Barents Sea /14/

Figure 7, which is presented on the next page, shows an illustration of where the observed polar lows (166 occurences all in all) have taken place. The diagram presented above (Figure 6) is based on the same data.

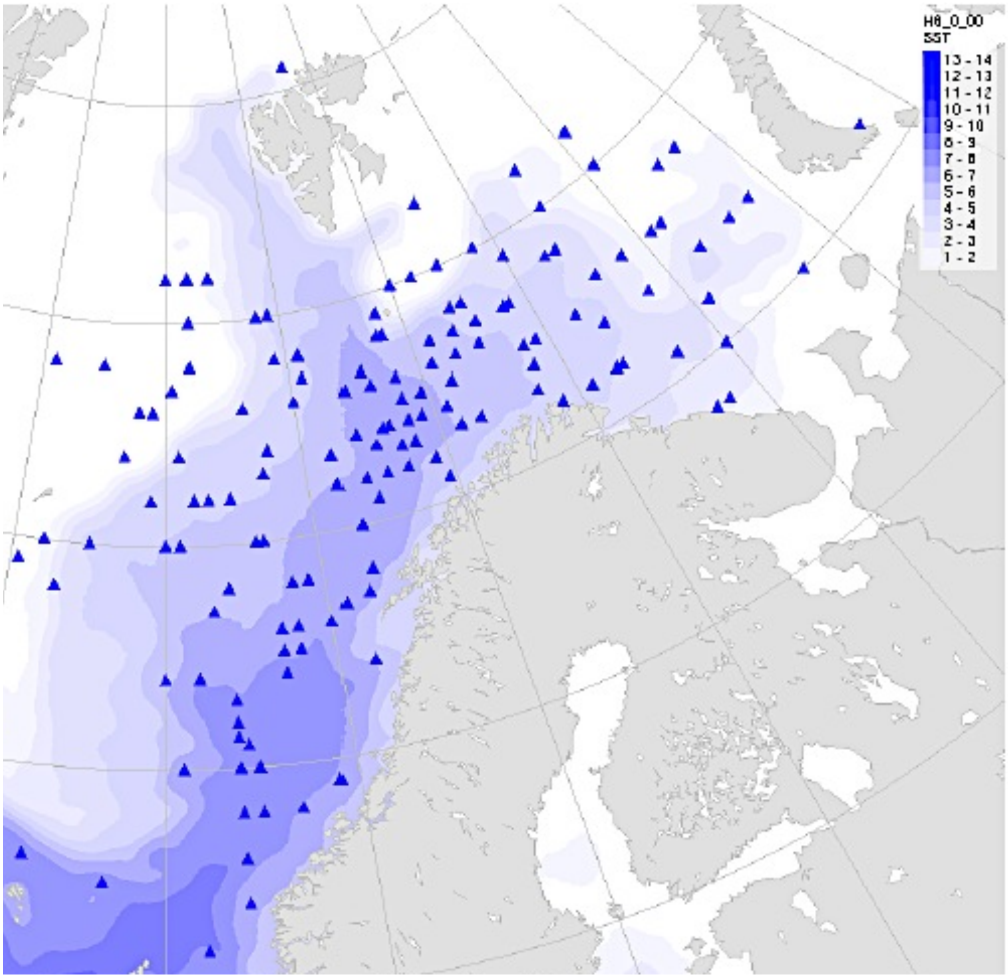

Figure 7 Area of growth for polar lows from year 2000 until 2012 /14/

As we can observe from the figure above (where each blue spot indicates the location of where the polar low was observed during this timespan), the amount of polar lows gradually decreases when moving further east in the Barents Sea. Nevertheless, the eastern part of the Barents Sea is rather close to the core area where most of the polar lows take form. Polar lows have only appeared four times in the southeastern part of the Barents Sea in the period between 2000 and 2012 /14/.

As a consequence of environmental changes, the frequency of polar lows may decrease. Temperature differences between sea and air in the Arctic will decrease in the winter as a consequence of increased global warming since the atmosphere has a shorter response time than the sea. This will then result in a more stable atmosphere and thereby give less favorable conditions for polar lows, which take form in unstable air masses /14/.

3.1.3 Temperature

This section will present data concerning air and sea temperatures in the Barents Sea southeast. Figure 8, presented below, illustrates five different measure points where sea and air temperatures have been measured. Table 5, also presented below, gives the associated coordinates to the five measuring points performed by Norwegian Meteorological Institute.

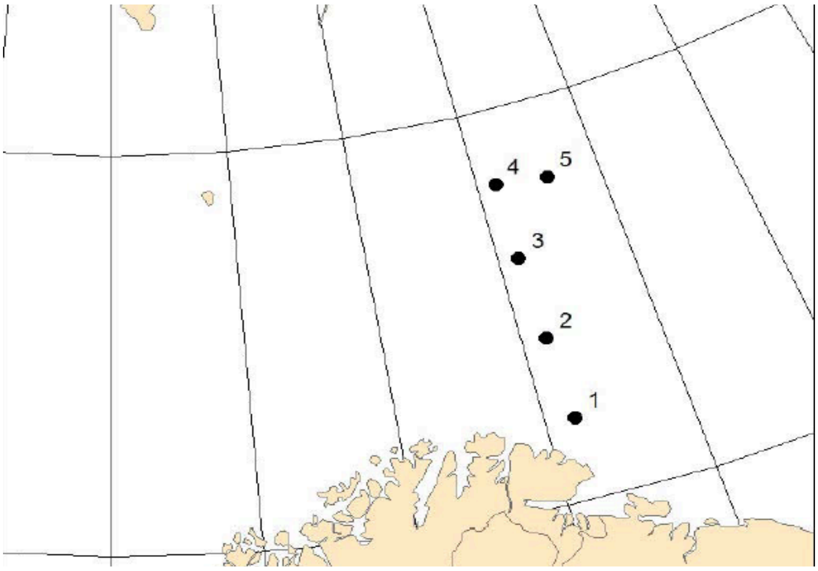

Figure 8 Positions of measuring points that were used in the Barents Sea southeast study /14/

Points	Coordinates
Point 1	71,04°N – 31,04°E
Point 2	72,07°N – 30,9°E
Point 3	73,11°N – 30,77°E
Point 4	74,07°N – 30,79°E
Point 5	74,00°N – 32,88°E

Table 5 Positions of measuring points /14/

The lowest sea and air temperatures normally occur between the end of winter season and the beginning of spring. Both sea and air temperatures seem to decrease when moving further north and east in the Barents Sea. Low temperatures are most frequent in the northern parts /13/. The numbers in Table 6 and Table 7 refer to the points located on the map in Figure 8, presented above, and give the maximum and minimum air (2 m above sea level) and sea surface temperatures at those particular points.

Position (Point)	Max (°C)	Min (°C)
1	14,8	-14,6
2	12,7	-16,6
3	11,6	-19,6
4	10,6	-24,9
5	10,8	-25,1

Table 6 Max and Min (°C) air temperature modeled in the period 1958-2011 /14/

Position (Point)	Max	Min
1	11,9	1,6
2	11,3	1,8
3	10,6	1,1
4	9,9	-0,7
5	11,3	1,8

Table 7 Max and Min (°C) sea surface temperatures modeled in the period 1958-2011 /14/

The difference between sea surface temperatures, when comparing point 1 through 5, is not very big for minimum and maximum temperatures. However, regarding the air temperatures, the differences between the five measuring points are greater. The minimum temperature at point 5 is approximately 10 °C lower than at point 1.

3.1.4 Icing

Icing is caused by sea spray, freezing rain, downpour and fog in combination with coldness. Sea spray is the most common cause of icing and also causes the most ice accumulation on ships. According to the Norwegian Meteorological Institute, icing caused by sea spray may occur when the air temperature is below 2 °C and the wind speed is above 11 m/s. In worst-case scenarios, icing may accumulate up to 4 cm/hour of ice on the surface of a facility/ship /13/.

There are different categories of icing:

- Mild icing < 0,7 cm/hour
- Moderate icing = 0,7-2,0 cm/hour
- Strong icing = 2,0-4,0 cm/hour
- Extreme icing > 4,0 cm/hour

In the two northernmost points in Figure 8 (point 4 and 5), where the probability of icing is the greatest, strong icing will occur 1,3 % of the time on a yearly basis. Mild icing will occur ca. 17 % of the time. For the three points further south (points 1-3) strong icing will occur 0,0-0,3 % of the time and mild icing 14-16 % /14/.

According to S. Jacobsen /15/, sea spray icing is mainly dependent on the following parameters:

- Air temperature: Ice will form if temp. is below freezing point
- Wind speed: Minimum 10,8 m/s (Beaufort force 6)
- Sea surface temperature: Seawater normally freezes at -1,9 °C
- Sea state: Beaufort force 6 corresponds to H_S=3 m
- Size and type of structure vessel: Usually does not occur over 25 m above sea level
- Course relative to waves and speed: Direct result of speed and angle into wave

The climate conditions in the Barents Sea are of such that icing on vessels normally can occur from October to May /16/.

DSHA - Icing on the facility

Icing of the facility may cause problems when operating in the Barents Sea, and could therefore be considered as a possible DSHA. When looking at Table 2 given in section 2.2.1, “Icing on the facility” may be related to point 15 (Extreme weather conditions) and could therefore be a possible scenario.

It is important to emphasize that the variation in the weather conditions is large when comparing the northern and the southern parts of the Barents Sea. Icing of rescue equipment, stairways and railings may increase the risk of having a personal injury. Therefore it will be important to have good procedures on how to handle these ice challenges by the use of proper anti-icing and de-icing systems. Design requirements in regards to icing on a facility will be discussed in chapter 3.6.1.

DSHA - Falling ice

Falling ice will be a consequence of icing on the facility, and since it may be a threat for personnel and equipment if not handled correctly, it may be seen as a possible DSHA. This hazard can injure personnel and may therefore be comparable with point 06 from the same table as mentioned earlier (Table 2). To prevent falling ice from injuring personnel and equipment, exposed areas have to be covered by roofs/plates.

3.1.5 Darkness and visibility

Fog and snowfall may impair the visibility, which then again might result in reduced availability of helicopter transport. Severe fog conditions may hinder helicopters from performing medical evacuation, precautionary evacuation or rescue operations. Impaired visibility may also have an impact on the operation of supply vessels in close proximity to the facility /15/.

At Fruholmen (50 km north of Hammerfest), the horizontal visibility is less than 1 000 m during 1,51 % of the year and less than 10 000 m for another 6,76 % of the year. At Bjørnøya, the horizontal visibility is less than 1 000 m for 8,58 % of the year and less than 10 000 m for as much as 31,76 % of the year /15/.

The sun is below the horizon all day for a given period of time during the winter. This results in a total darkness which is called the Polar night. Table 8, presented below, describes when the Polar night appears in different locations in the northern part of Norway and the Barents Sea.

Place	Whole sun up	Polar night from	Sun back again
Vardø	17. May – 26. July	23. Nov	19. Jan
Hammerfest	16. May - 27. July	22. Nov	20. Jan
Jan Mayen	14. May – 28. July	20. Nov	21. Jan
Bjørnøya	1. May – 10. Aug	7. Nov	4. Feb
Hopen	25. April – 17. Aug	31. Oct	10. Feb

Table 8 Polar night in the northern areas /17/

DSHA - Darkness

Darkness might be seen as an extra challenge since reduced visibility may cause a greater risk of personnel injuries. Therefore some may considered this to be a possible DSHA or a scenario in a DSHA-list when operating in the Barents Sea. However, darkness is something that occurs all over the Norwegian sector, it is just that during the winter season there is darkness day and night in the north. Challenges related to darkness should therefore be dimensioned in a proper way and taken seriously, but indicating that darkness should be a DSHA might be misleading. Darkness is in fact a weather phenomenon that can be compared to strong winds, rough sea conditions etc.

3.1.6 Emergency Escape, Evacuation and Rescue in the Barents Sea

As mentioned in the earlier chapters (3.1.1-3.1.5) a wide range of different weather conditions influence the potential consequences of an accident in the Barents Sea. Ice conditions, which will be described in chapter 3.2, will also have great influence on a potential Escape, Evacuation and Rescue (EER).

Some of the challenges that potentially are increasing the risks of an EER are /18/:

- The full range of weather conditions which may be encountered
- The logistics systems that may be available to support any required evacuations from an offshore structure or vessel, including a presence of helicopters and standby vessels
- The distances to support bases and other emergency facilities
- The capability of support vessels that may be called on for assistance with regards to their maneuvering and station-keeping abilities in icy waters
- The effects of cold temperatures on human physiology and psychology (described more in section 3.6)

Today there is no single solution that fits all the different conditions.

3.2 Ice conditions

The ice conditions vary in the Barents Sea, but they are uniform in each area. Figure 9, presented on the next page, illustrates how the Barents Sea is divided into different climatic zones by *The Arctic and Antarctic Research Institute of St. Petersburg*. Region II is generally ice free, region I usually have ice every winter, whereas regions V and VI are in between. An important distinguishing factor of the Barents Sea ice regime is that its surface area is never completely ice covered /19/.

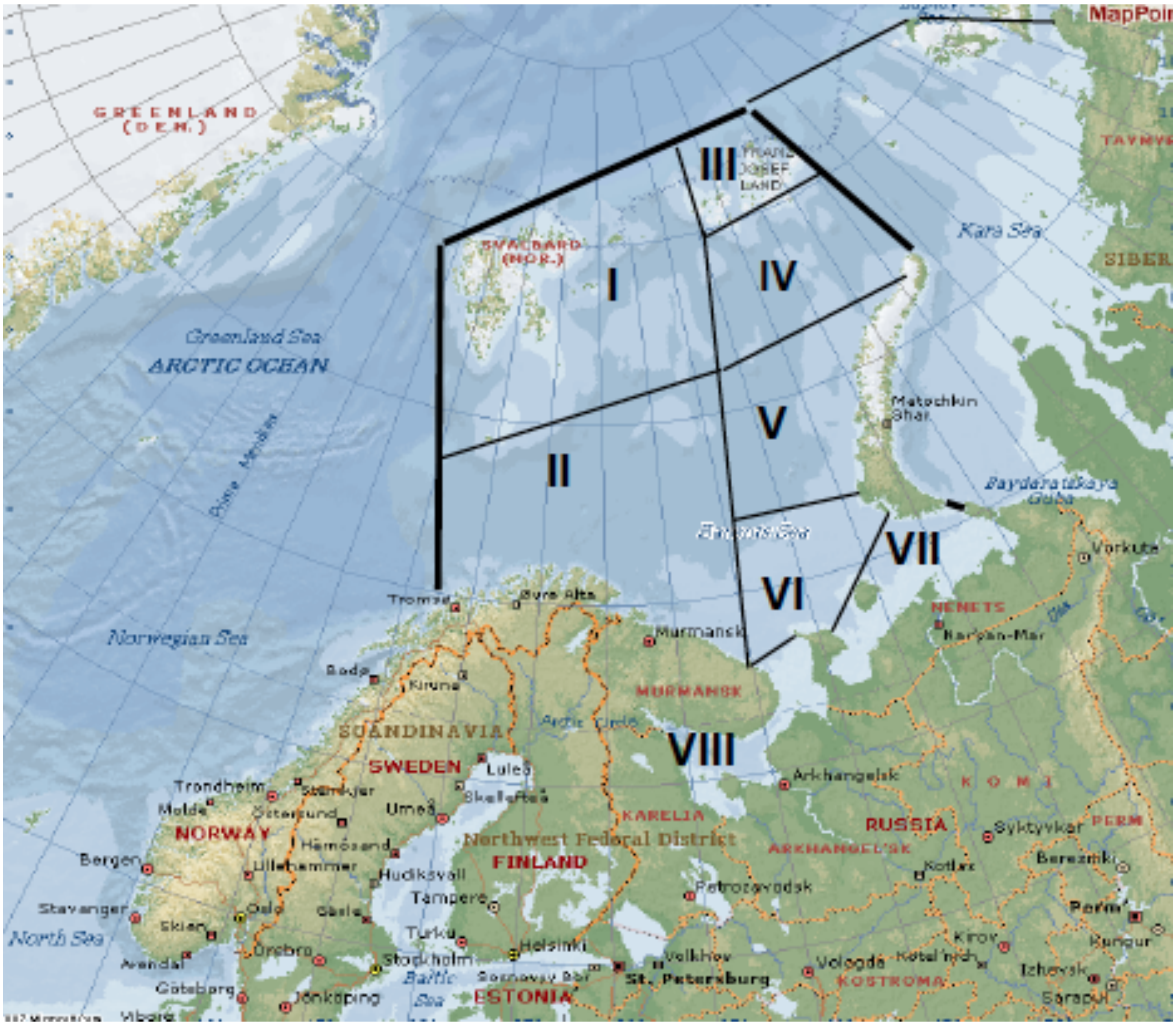

Figure 9 The Barents Sea divided into different zones /19/

The northern part of the Barents Sea might experience sea ice through some parts of the year. This ice will mainly be first-year ice that has drifted from the pole area. The sea ice is a major challenge for the dimensioning of both boats and installations. Ice concentration, thickness and ice pressure will have an impact on the vessels' speed when sailing through icy waters. Therefore it may be difficult to decide an actual arrival time in such waters. Experience has shown that dynamic positioning systems do not function properly when ice causes additional forces on the vessel. In such conditions, manual steering needs to be performed /20/.

Ice will be present for large parts of the year in most of what is defined as polar waters. This is the case both in terms of drifting ice and icing on equipment. Ice, snow, darkness and low temperatures will slow down and reduce the effectiveness of most operations. Navigating in ice, identifying the actual ice condition and finding the easiest way through the ice requires special competences as well as improved navigational equipment /18/.

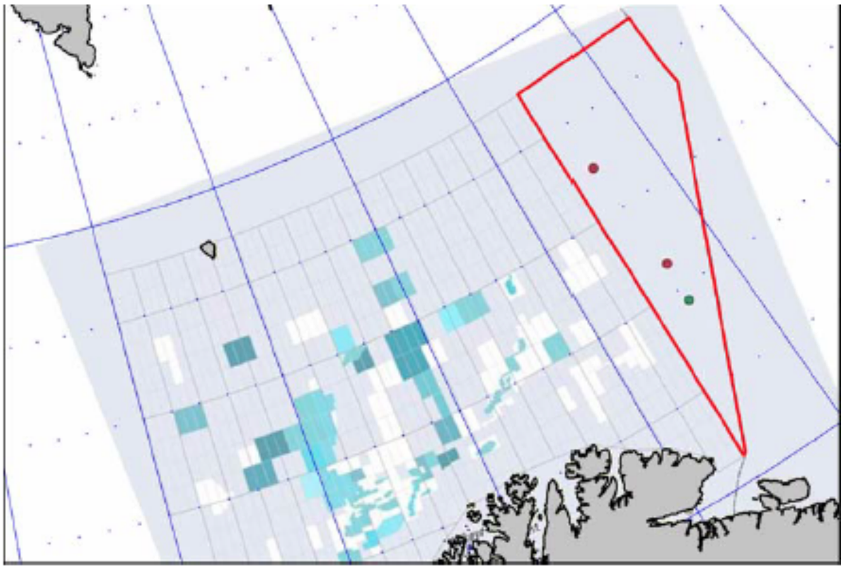

Figure 10 Area in the Barents Sea southeast /14/

The area marked by a red line in the picture above indicates the southeastern part of the Barents Sea. This area consists of a total area of 44 152 km^2. Figure 11 below indicates the amount of sea ice that is in the red area over a certain period of time.

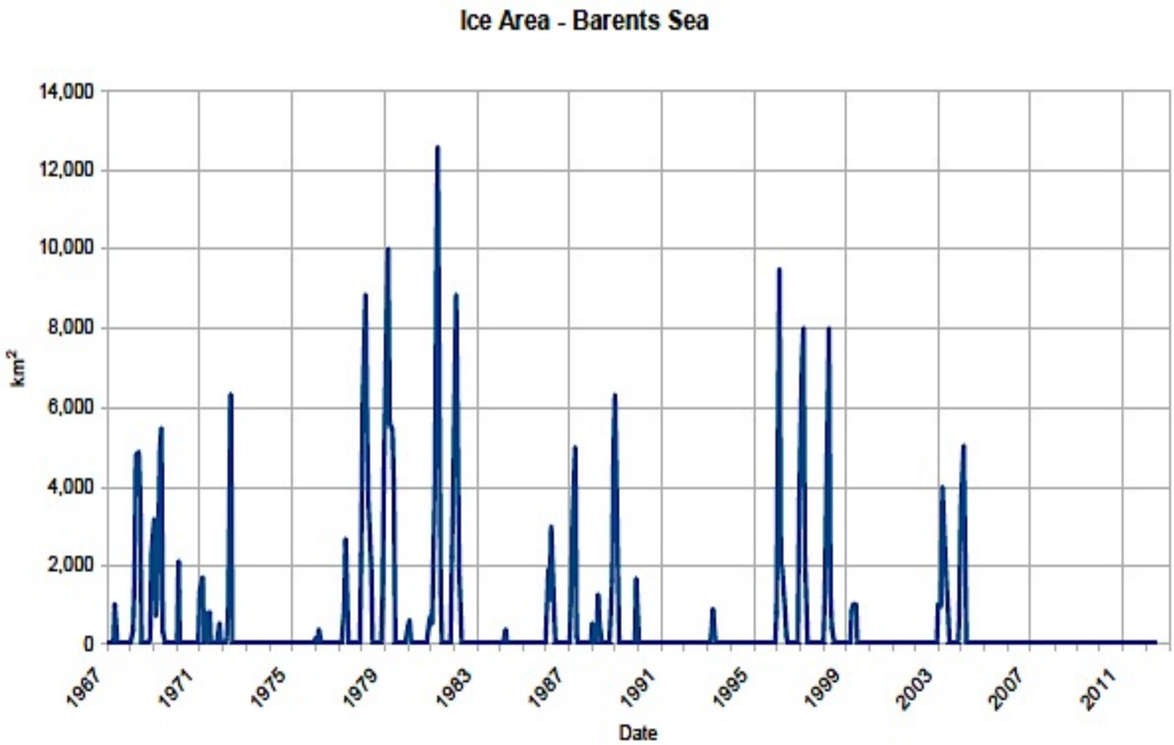

Figure 11 Ice area in the Barents Sea /14/

A general trend shows that the spread of sea ice in the Barents Sea is decreasing. The data observes that peaks appear approximately every ninth year, and these can be classified as larger or smaller. The two observed maximum peaks occurred with an interval of sixteen years, in 1982 and 1997. Two smaller peaks were reached in 1987 and 2003 with an interval of seventeen years. It is also worth mentioning that the last large peak to really stand out was measured in 1963. We may therefore expect a new peak of this kind in the time period between 2014 and 2016. Since the trend shows that the spread of sea ice is decreasing, this peak will probably be in the size order of 6 000-8 000 km^2 /14/.

Sea ice will have an impact on the detection of persons that are in the sea because these people will be partly hidden by the ice. The sea ice might also be a problem when trying to rescue people since vessels may be blocked and have reduced maneuverability. Experiences from facilities in other arctic areas, such as from the coast outside of Canada or the northern part of the USA (Alaska), show that the use of free-fall lifeboats is not a suitable solution /17/.

Figure 12 presented below show monthly graphs, which indicate the amount of sea ice in the Barents Sea southeast. The x-axis represents the time period between 1967 and 2007 and the y-axis represents numbers of 1 000 square meters.

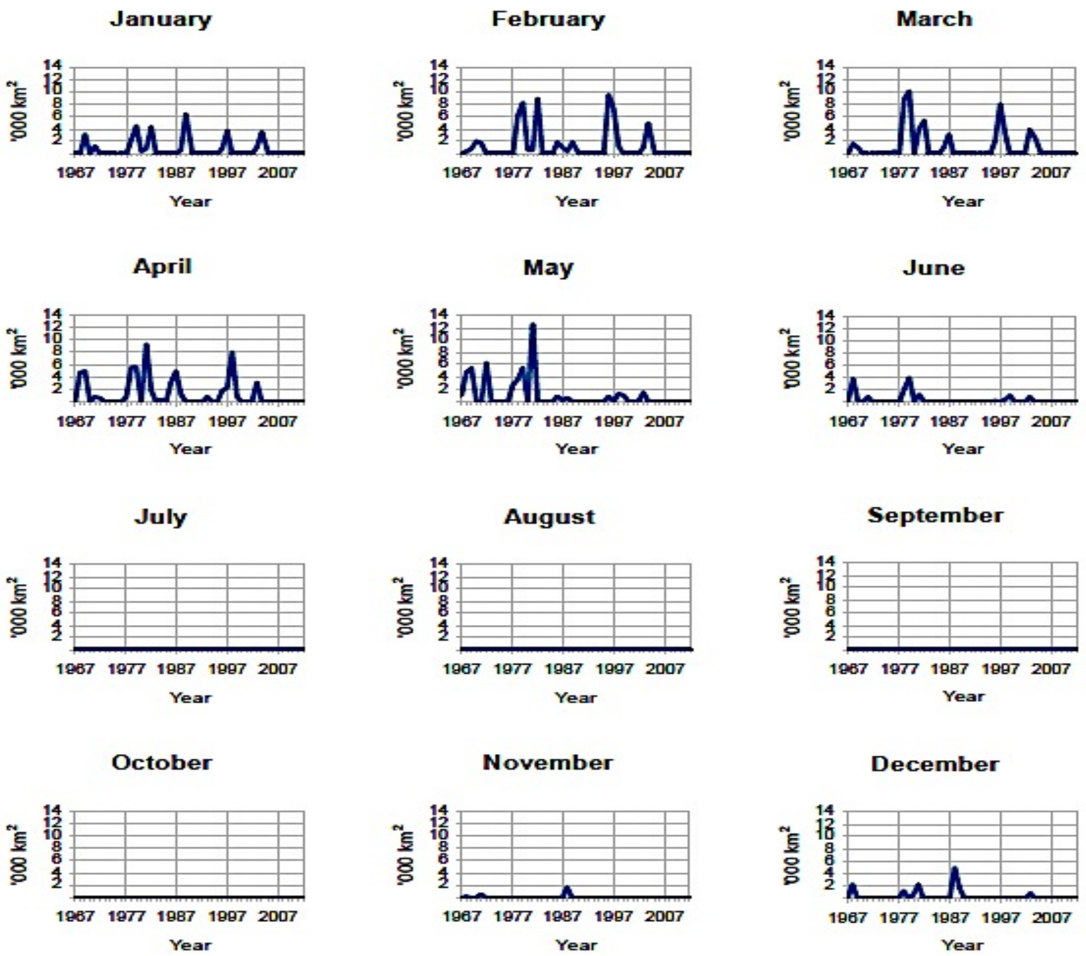

Figure 12 Spread of sea ice on a monthly basis during the time period 1967-2012 /14/

As may be observed from Figure 12, presented on the previous page, the Barents Sea southeast is normally entirely free of sea ice in the months of July through October.

The sea ice in the Barents Sea will generally be at its maximum southern extent in March and April and its minimum extent in September and October.

Figure 13, presented below, shows in which area of the Barents Sea southeast the maximum spread of sea ice occurred between 2001 and 2011 (blue color). The figure correlates with Figure 12, presented on the previous page, which means that the small picture at the top left represents January and the small picture at the bottom right represents December.

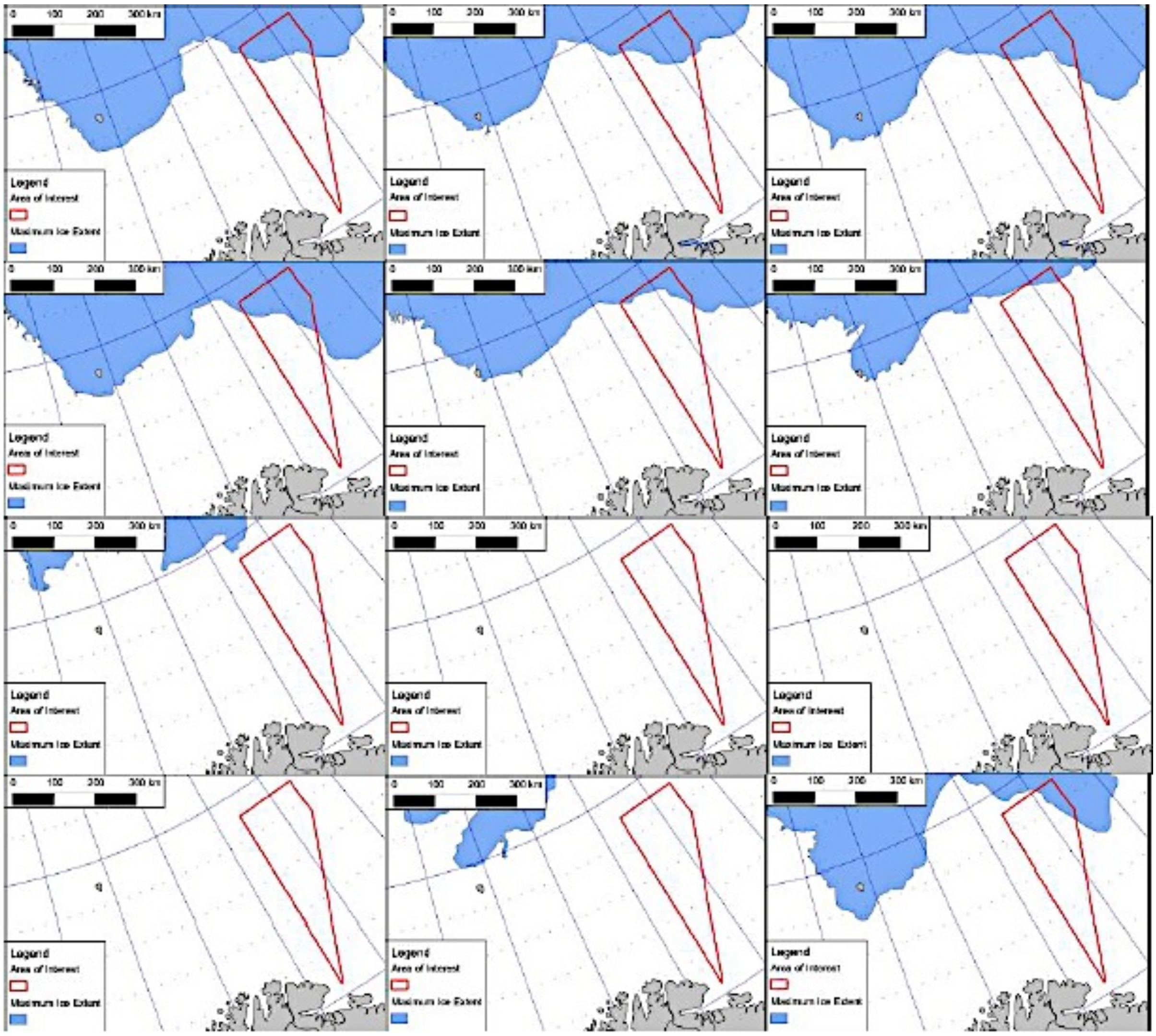

Figure 13 Maximum spread of sea ice in the time period 2001-2011, monthly /14/

As may be observed from the figure above, sea ice only occurs in the northern part of the Barents Sea southeast. Bjørnøya can also be observed (small white dot a bit left of the center) and is mostly surrounded by sea ice between December and June.

Grete Anita Landsvik (HSE Manager EXNC/IND at Statoil) gave the following answer concerning challenges that are related to drifting sea ice and icebergs /21/: Statoil has begun a metocean study using data related to the Hoop area. This study will include probabilities related to the spread of ice edge/drift ice/ice floe. The environmental risk analysis has already been started and will be finished in June 2013 at the earliest. The evaluation related to the whole emergency preparedness picture will be performed after the study is completed.

3.2.1 NORSOK N-003 – Sea ice and icebergs

Actions regarding sea ice and icebergs shall be taken into account when structures are located in parts of the Barents Sea. According to NORSOK N-003 /22/, the following information must be collected before activities are commenced in the actual areas:

- The possibility of icebergs and sea ice
- Type of sea ice (first-year ice, ice that is several years old)
- Sea ice thickness
- Size and shape of icebergs
- Velocity and direction of drifting sea ice and icebergs
- Mechanical properties of the ice

An emergency preparedness system, which will ensure safety in the event of ice, shall be established. In the event that the effects of sea ice or icebergs become unacceptable, solutions based on relocation of the installation may be chosen /22/.

The two pictures presented below (Figure 14) show the limits of sea ice (left picture) and collision with icebergs (right picture) in the Barents Sea. In both pictures, a solid line represents a probability of 10^{-2} and a dotted line a probability of 10^{-4} /22/.

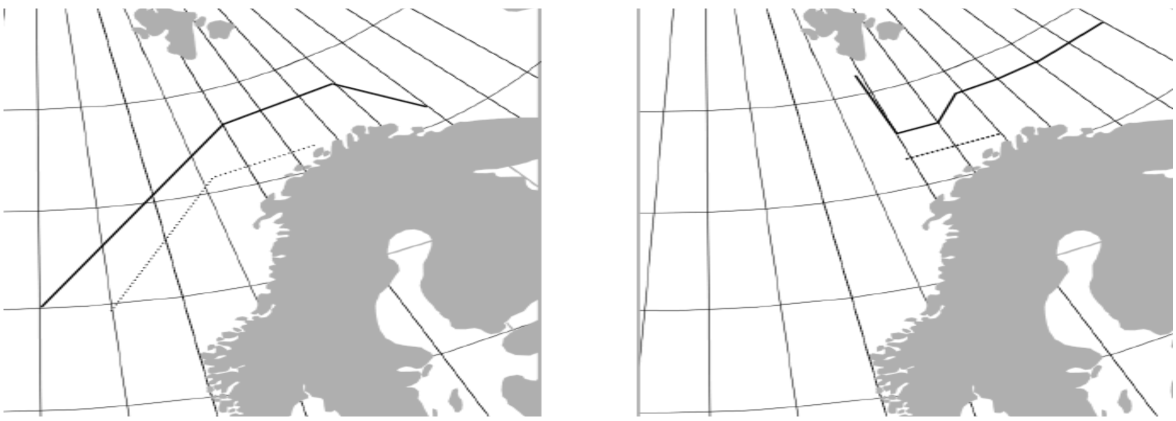

Figure 14 Limits of sea ice and collision with icebergs /22/

Sea ice with a return frequency of a hundred years normally only occurs north of 73°N and east of 31°E. The return frequency of sea ice increases to ca. ten years at 74°N and 33°E. The area which recently has been acquired for exploration after the border issue with Russia was resolved, has a greater probability of sea ice that the areas that are currently open for activity /16/.

3.2.2 Iceberg

Icebergs in the Barents Sea mainly originate from Franz Josef Land, which is a group of islands that is practically one hundred percent covered in ice. Icebergs are also produced by the glaciers of Novaya Zemlya, but are seldom released into open sea. This is because they are usually trapped in the fjords by prevailing sea currents and the shallow bathymetry. The icebergs are normally observed in the Barents Sea northwest /23/.

According to Arne Kvitrud, PSA, no platform or drilling rig located in the Barents Sea is currently constructed to withstand an impact with an iceberg. It is however possible to enable the facilities to do so. Through the use of helicopters/airplanes equipped with radars, it can be possible to detect icebergs on collision course. Satellites may also be used. That might however not always be the best solution /24/. In chapter 3.3 the communication coverage in the Barents Sea will be discussed.

The largest part of an iceberg is submerged below the sea surface. However, the ratio of height to draft depends greatly on the shape and density of the iceberg. The drift of an iceberg is difficult to predict. The forces acting on them are not as simple to analyze as, for instance, those acting on a floe of sea ice. The motion of an iceberg is generally determined by local sea currents in the top 100-200 m of the sea, but is also influenced by wind conditions. The iceberg velocity is about 1,5 times the current velocity at 15 m depth and twice the current velocity at a depth of 50 m. The existence of the Coriolis effect also imposes a transverse deflection on the motion of the icebergs, meaning that their movement frequently corresponds neither to wind nor current. Although the amount of ice released per year from the glaciers of the Arctic remains approximately constant in the long run, large annual and seasonable variations occur in the number of icebergs sighted while drifting freely in the oceans. Seasonal variations mainly occur because many icebergs are locked in landfast sea ice during the winter and suddenly become mobile during the summer months /23/.

S. Løset and T. Carstens did a study where they tracked icebergs in the Barents Sea /25/. In the study, two icebergs were equipped with positioning buoys. The average drift speed of the icebergs was 0,25 m/s and 0,28 m/s respectively. However, due to an atmospheric low, one of the icebergs increased its drifting speed to 1,13 m/s for a 31-hour period of time. This shows that the different shapes of an iceberg will have an influence on its drifting speed since the shapes will give the iceberg different drag coefficients /25/. In the Barents Sea and at the Grand Banks, the average ice drift speed is reported to be around 20 cm/s while it can be slightly higher than 1 m/s in more extreme situations (valid for both sea ice and icebergs) /26/.

Iceberg management

This section is based on the report "*An Assessment of Current Iceberg Management Capabilities*" written in association with National Research Council Canada /27/.

Iceberg management for the protection of offshore hydrocarbon facilities and operations involves detection, monitoring, decision making and response. The appropriate response to an iceberg threat may be a form of physical management and/or changes to the operational status of exploration or production activities. Iceberg management encompasses all operational procedures employed to minimize the risk of iceberg contact with offshore facilities.

Some of the current iceberg deflection techniques are: Synthetic line towing, dual vessel towing for medium to large icebergs, and prop wash and water canon deflection for smaller ice masses.

A current trend, which moves towards the use of floating production systems alongside the related need for high levels of operating efficiency, implies that iceberg management capabilities are a necessity. It is also important to be aware of the protection of wellheads, manifolds, pipelines and risers from deep-keeled icebergs.

Sea ice can disrupt both exploration and production activities. As an example, drilling rigs or floating production, storage and offloading vessels (FPSO), might have to suspend operations and move off of the location should sea ice occur. A shuttle tanker may be required to reduce speed, adjust transit routes, or delay oil-offloading activities when sea ice is present. However, the sea ice challenges are manageable and can be dealt with through appropriate design and/or operating procedures.

Icebergs are more problematic. Their large masses and unpredictable movements make them a significant threat to all engineered structures. To construct facilities that can withstand impacts from icebergs is in many cases difficult and always costly. Hibernia is one facility that is constructed to withstand such an impact, but the offshore loading system, as well as the shuttle tankers that export oil from that facility, is however not designed for impacts from large icebergs.

Typically, floating systems will be more vulnerable in the presence of icebergs and small ice masses than gravity based structures, such as Hibernia. Obviously, the production facilities will be required to remain on location with a minimum of downtime to maintain production operations, but will also have to avoid most icebergs for safety reasons.

Floating structures are not designed to withstand impacts from icebergs, which are likely to occur. Ice could cause damage to the structure itself, to its mooring and riser systems, and to associated subsea facilities. If deflection techniques are not effective, activities must be suspended and disconnect procedures may need to be initiated.

Comments from Pat Barron – MD Group

Pat Barron at MD Group works in Canada and has over thirty years of experience with iceberg management. For the thesis, he has answered questions concerning this topic. His answers follow below and are marked in italic /28/.

Tools for iceberg detection can be satellite imagery, dedicated reconnaissance fixed and/or rotor winged aircraft, and dedicated vessel of opportunity reports.

Ideally, icebergs are detected well upstream of the operations, days in advance. With that said, we are dealing with Mother Nature, and every once in a while an iceberg can sneak up on you. This can for example occur when you have had consecutive days of low visibility in fog.

Once you have established the size and shape of the iceberg, assessed the weather conditions and available time and management resources, the management technique is determined. Generally, the final decision regarding management procedure is usually a cooperation between the ice observer and the tow vessel Captain who has done the iceberg assessment.

Data is constantly being assessed to determine the ice threat, for example using 12, 24 and 48 hour drift forecasts, iceberg density and of course the resources available to manage the threat. As the icebergs get closer to the operations area (and they should still be miles away), vessels are instructed to manage the threatening icebergs to a position where their trajectory will no longer present a threat. The sooner your management operations commence, the better chance of success.

As the iceberg season draws closer, it is ensured that there are numerous vessels available to manage icebergs. Given individual tow operations, it depends on the size of the iceberg. Very large icebergs or ice islands for example may require two vessels to successfully deflect its course.

It really depends on the iceberg season (heavy or light) when determining the number of people involved. An example number for you to support one rig with observers and, say, three ice management supply vessels' crews could be forty people. Of course this does not include the aircraft reconnaissance crews nor the shore base support personnel. The area the vessels cover could be hundreds of square miles when conducting reconnaissance missions.

Hibernia

This section will describe the ice management at Hibernia, which is located 315 km east southeast of St. John's, New Foundland (Canada). The Hibernia oil field is the fifth largest oilfield ever discovered in Canada /29/.

The Hibernia platform is a gravity base platform and is designed to resist the impact of sea ice and icebergs. It can withstand the impact of a one million ton heavy iceberg with no damage and withstand a six million ton iceberg with reparable damage. The odds of large icebergs ever hitting the platform are extremely low since the Hibernia platform is located in relatively shallow water, just eighty meters deep /29/.

Icebergs that require intervention are tackled proactively while they are still twenty kilometers or more away from the platform. The platform support vessels encircle the iceberg with a long cable or rope and tow the iceberg into a different trajectory. The ice management is two-folded. Firstly, technology is used to prevent an iceberg collision. Such technology may be radar and satellite detection. Helicopters are also used to detect and locate iceberg positions. Secondly, the platform is designed to withstand such a collision /29/.

DSHA - Icebergs

A collision with drifting icebergs may cause great damage to a facility and is therefore considered to be a possible DSHA. Since the amount of sea ice in the Barents Sea vary a lot between the north and south, it will be important to gather considerable amounts of data so that exposed areas can be sufficiently protected by having a well-developed iceberg management system that prevents accidents from occurring. A discussion on this subject will be held in chapter 6.5.

3.3 Communication

Communication difficulties due to magnetic conditions, a lack of satellite coverage and language differences, are other large challenges that have been mentioned for operating in the Barents Sea. In this section, the communication situation in the Barents Sea today will be described. A description will also be given on what needs to be improved to achieve a satisfactory emergency preparedness situation.

Current maritime digital communication systems were not designed to cover the Arctic, and maritime operators lack sufficient knowledge and information about the real quality of service they can expect when they are operating in the far north /30/.

The level of communication services in the Arctic region is limited due to rather poor or non-existent geostationary satellite (GEO) coverage of latitudes beyond 75˚N and a lack of ground infrastructure. A study performed by the ArctiCOM project pointed out that in sub-Arctic areas below 75˚N, the satellite communication systems based on GEO satellites could meet the capacity demands. For complex offshore and marine operations however, this may after all not be sufficient. Some of these complex operations require a very high Quality of Service (QoS), such as high system reliability and low latency (for real time transfer of data/information). QoS can worsen due to harsh Arctic conditions that cause icing of equipment, salinity, high ionosphere activity and magnetic influence. Beyond 75˚N the coverage available today is not sufficient. Therefore, a new satellite system based on High Elliptical Orbit (HEO) satellite is a potential technological solution /31/.

Beate Kvamstad, who works at MARINTEK in Trondheim, indicates the following statement /32/: *"When we move further north than 70-75˚N, we observe that systems normally used for satellite communication are very unstable."*

The main reason for why the communication coverage is insufficient in the northern areas is that most of the satellites (GEO) circle in an orbit around equator. The satellite signals fade further north because the angle between the receive system and the satellite is too narrow. This will then cause problems with blind spots. High Elliptic Orbit (HEO) satellites may be a solution to this problem since they circle in an orbit above the poles /32/.

The theoretical limit for GEO systems is 81,3˚ north, but instability and signal dropouts can occur at latitudes as low as 70˚ north under certain conditions. Some of the factors that influence the QoS are /30/:

- Attenuation and depolarization of signals due to atmospheric dispersion, which is caused by rain and snow. The longer the path of transmission through the atmosphere, the more the signal is attenuated. This length increases at high latitudes.
- Heavy vessel movements can lead to antennas losing track of signals, or even tracking the wrong satellites

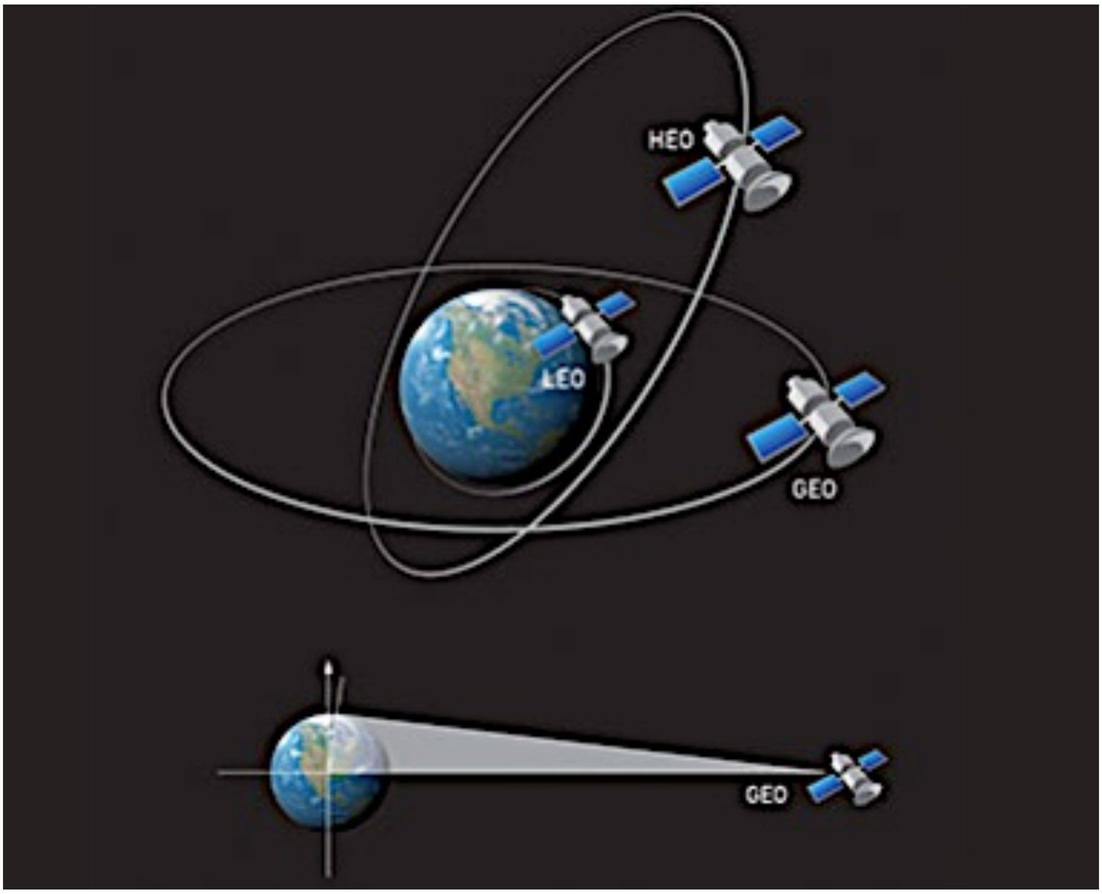

Figure 15 Types of satellites /30/

In the MarSafe North project /31/ there have made some findings that this thesis will present. The oil fields Snøhvit, Goliat, Skrugard and Havis are all in positions that range from 70˚N to 75˚N. These are areas where communication is a challenge under certain conditions. The findings from the MarSafe North project is given in a table on next page:

Area	Challenges
Navigation	Poor ENC (Electronic Navigational Chart) and information on weather and ice conditions with low quality
Positioning and DP operations	The need for ice management imposes the need for more advanced and energy demanding DP operations. Thrusters need more power due to extra ice load.
Data analysis	Increased exploration operations will lead to increased demands for data transfer from ships to data analysis on shore. This is not possible in many Arctic areas today due to a lack of proper communication infrastructure.
Gathering and analyzing environmental and metocean data	Oil and gas companies need to gather their own data in order to have sufficient decision support in their planning phase since the data quality on metocean data is very low in most part of the Arctic.
Supporting vessel navigation	Poor ENC, poor access to navigational information such as metocean.

Table 9 Challenges related to communication in the High North /31/

In Figure 16 on the next page, two pictures of the Earth are shown, respectively from two different satellite types, hence different coverage focus in the north. The picture to the left is from a GEO-satellite, which circles in an orbit around equator, while the picture to the right is from a HEO-satellite, which thereby gives a much better coverage of the northern areas.

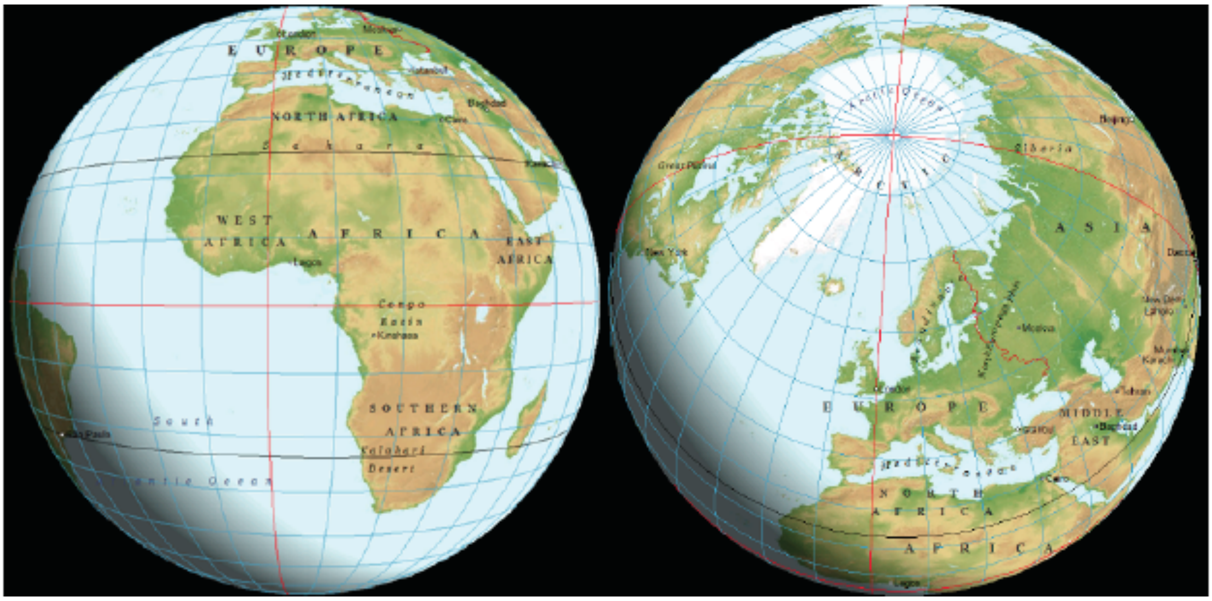

Figure 16 The Earth observed by respectively GEO (left) and HEO (right) satellite /31/

3.3.1 Sufficient communication coverage in the Barents Sea

This section is based on an interview with Beate Kvamstad (MARINTEK) where it was discussed which measures need to be taken to have sufficient communication coverage in the Barents Sea /33/.

To get sufficient communication coverage in latitudes up to 75 degrees north, one solution, and probably the most actual, is to send up two HEO-satellites. These two satellites have one long course above the northern hemisphere and a short course around the southern. That way the satellites spend a long time in the north and thereby give good coverage. If the two satellites are optimally adjusted to one another, the coverage will be sufficient since one can circle around the southern hemisphere while the other one is in the north (and opposite).

The investment of such a solution may be around 2-3 billion NOK. It must be evaluated who will pay these costs and what the usage will be (weather observation, communication etc.). Another method may be to improve the coverage of today's GEO-satellites. This may be done by the use of drones.

Today, an optical fiber cable is laid between the Norwegian mainland and Svalbard. Such cables are also laid out to offshore installations in the North Sea. Kvamstad therefore assumes that optical fiber cables will be laid between the mainland and out to all production installations. For that given installation, sufficient broadband capacity will become a reality. However, for the supply vessels and standby vessels around, the communication coverage will not have been improved. This may be solved by establishing a sort of wireless hub at the facility, which then shares the communication capacity with some vessels.

According to the plans that consider an establishment of the Skrugard field, it has been decided to lay an optical fiber cable between Skrugard and Melkøya /34/.

Eirik Holand, HSEQ Manager of District Operations in Eni Norge, indicates that there will be laid an optical fiber cable out to the Goliat field. The platform will then function as a wireless hub so supply/standby vessels and other nearby vessel will have sufficient communication coverage within a certain area /35/.

3.3.2 Automatic Identification System

The AIS is a system that makes it easier to keep surveillance of offshore operation traffic. Vessels equipped with AIS send out and share information about identity, position, speed, course, cargo, type of ship etc. Today there are forty land-based AIS stations spread around the Norwegian coast, and each station has a range of between 20-30 Nm. All registered ships above 300 gross ton must be equipped with such equipment for sending and receiving AIS-signals /20/.

3.3.3 Weather forecasting

Reliable weather forecasting is paramount for safe operation and activity at sea. Due to a low number of fixed observation stations in and around the Barents Sea, reliable weather forecasts are challenging. This is a great problem concerning Polar lows. As petroleum resources are developed in the area, valuable information will be gained through new fixed observation stations on the facilities /16/.

3.4 Infrastructure

The situation in the North Sea and in parts of the Norwegian Sea stands in contrast to the situation further north. The Northern areas, including the Barents Sea and the areas around Svalbard, are not considered to be developed petroleum regions and therefore have limited SAR resources. The large distances to available SAR resources, including land-based resources, is a special challenge. The traffic density is quite low, which results in fewer vessels being available to assist in search and rescue operations /36/.

The Snøhvit field was developed in 2002, with subsea installations connected by pipeline to an onshore LNG plant at Melkøya. In 2013 there are plans for the Goliat FPSO to be installed. Skrugard will be developed in the years to come and a facility installed in 2018. In addition to this, occasional drilling facilities are located in the area depending on the exploration and production drilling activity /15/.

In the next two years, an increased activity in the north is expected involving 11 operators with a total of 29 drilling obligation licenses /4/.

According to the project Barents 2020, the following challenges related to infrastructure were identified /19/:

- Lack of logistics systems and emergency response vessels to support an evacuation
- Long distances from potential emergency site to the support bases and other facilities
- Shortage of appropriately equipped vessels that may be called on for assistance

3.4.1 Supply bases

Activity currently receives support from the supply base in Hammerfest /15/. As a result of the developments of the Goliat field, the NOFO (Norwegian Clean Seas Association For Operating Companies) is going to establish a permanent oil spill preparedness located in Finnmark /4/.

3.4.2 SAR resources

There are two Sea King helicopters stationed in Banak, Finnmark, operated by the Royal Norwegian Air Force. During exploration or well maintenance activity in the Barents Sea, the petroleum industry operates a transport helicopter and an all-weather search and rescue (AWSAR) helicopter from Hammerfest /15/. According to the state budget for 2012, a post has been assigned for acquiring two new helicopters, AS332 L1 Super Puma, stationed at Svalbard Lufthavn within 2014 /37/.

3.5 Medical facilities and logistics

The rules and regulations regarding medical emergency preparedness in the Norwegian sector are still valid when operating in the Barents Sea.

There are hospitals located in Hammerfest and Kirkenes that provide health services to the inhabitants of Finnmark. The University Hospital of Tromsø is the largest hospital in the region, but Tromsø is located as far as 200 km southwest of Hammerfest. Remote medical diagnostics and telemedicine is provided from Tromsø. If it should be necessary to treat a large number of patients, all three hospitals mentioned above may be used, and Tromsø will be capable of dealing with the most serious injuries /15/.

According to the study Barents 2020 /38/, the following measures have to be taken into consideration in order to achieve a sufficient medical support:

- Qualified doctors placed at strategic locations
- Access to specialists outside the facility that can be used for consulting in difficult medical cases, in other treatments or in decision-making
- The facility must be equipped with sufficient medical gear so that both sudden and temporary treatment can be executed
- Effective system for transporting and handling of sick and injured personnel
- Effective communication with Government and service provider

The following points were presented in the baseline report for Norwegian oil and gas 064 /10/:

- Increase the medical competence on board
- Extra equipment on board (surveillance, medicine, intensive care equipment)
- Utilize the possibility for using telemedicine
- SAR helicopter stationed in the area, on the facility or on a standby vessel

In situations where it is not possible to perform a medevac, a measure to reduce the probability of a fatality offshore could be to have a medical doctor permanently employed on the facilities in the Barents Sea. An offshore doctor would require three persons per facility to fill an offshore rotation of two weeks on duty and four weeks off. However, it has been stated that: "*Even with a doctor on the installation there are limitations to what can be resolved locally*". Taking into account the scarcity of medical resources in the county of Finnmark, it may be argued that by increasing the availability of doctors in the area onshore rather than offshore, society could make better use of the medical resources /15/.

3.6 Work environment

The focus of the Barents 2020 Work Group 5 was: *Working environment and Human Factors* /38/. This section will reproduce some of their main findings.

As mentioned earlier, Arctic environmental conditions have a strong influence on the working environment and technical safety of offshore operations in the Barents Sea. To ensure that offshore facilities have sufficient integrity and operability requirements, the requirements of design need to be considered. The main objective is to provide adequate protection for personnel to ensure their health, safety performance and decision-making under the expected conditions. The main principle of such protection will be to enclose or shield working areas from the environmental elements. Areas that are not fully enclosed or protected may be exposed to ice and/or snow accumulation. Such areas should therefore be provided with anti-icing or de-icing arrangements /38/.

3.6.1 Design requirements

Anti-icing arrangements should have sufficient capacity to keep the area in question free of ice, snow or frost. De-icing arrangements must be sufficient to remove snow, ice or frost accumulations within a reasonable period of time. The study suggests as a minimum that anti-icing arrangements should be provided to:

- Escape routes
- Escape exits, including doors
- Emergency muster locations
- Access ways to lifeboats, life rafts, rescue boats and their associated launching and embarkation systems
- Stairways and their railings
- Decks, access ways, stairways and railings required for frequent daily use that are exposed to snow, ice or frost accretion
- Drainage systems
- Helicopter deck

3.6.2 Prevention and management of health problems

When operating in the Arctic, workers will be exposed to cold, windy and wet conditions. Working in the cold may cause several adverse effects on human performance and health, such as thermal discomfort, increased strain, decreased performance and cold-related injuries /38/.

Outdoor operations must be identified and reduced to a minimum on installations planned for use in areas with Arctic climate. Experiences from polar expeditions indicate that people commonly undergo psychological changes as a result of exposure to long periods of isolation and an extreme physical environment. To prevent pathogenic psychological outcomes, a psychological screening procedure to detect unsuitable candidates might be a good way to go.

On the next page, a table shows different categories of the wind chill index and recommended limits of how work under such conditions should take place.

Wind chill	Wind chill risk class		Recommended limits
Warmer than -10˚C	0	-	Normal work; emergency work; planned maintenance
-10˚C to -24˚C	1	Uncomfortably cold	Normal work (reduced work periods); emergency work
-25˚C to -34˚C	2	Very cold, risk of skin freezing	Normal work (reduced work periods); emergency work
-35˚C to -59˚C	3	Bitterly cold, exposed skin may freeze in 10 min	Emergency work only
-60˚C and colder	4	Extremely cold, exposed skin may freeze in 2 min	Emergency work only

Table 10 Suggested guideline in setting wind chill index /38/

3.7 Helicopter operations

This chapter is mostly based on the master thesis written by Sigurd R. Jacobsen /15/.

On behalf of the stakeholders in the industry, SINTEF has conducted three helicopter safety studies. The objective of these studies was to improve safety in helicopter transports of personnel. In the most recent report, the following recommendations and observations were found likely to have an effect on helicopter safety in the Barents Sea /15/:

- A reduced number of flights at night or in conditions of reduced visibility, especially when flying to moving helicopter decks.
- Requirements for improved weather observations, especially on remotely located facilities.
- Requirements for a hangar on offshore facilities where SAR helicopters can be stationed in order to improve the safety of operation.

Reducing the nightly flights might be difficult to accommodate during the winter season when Polar night occurs in the Barents Sea. In order to reduce the risk of landing, adjusted requirements on new helicopter decks were therefore implemented in Norway in 2008. The required size of a helicopter deck’s diameter is now 125 % of the entire length of a helicopter, including the rotor. Earlier, the required length was only 100 % /39/.

A study based on 147 operations performed with Sea King helicopters in the Barents Sea, showed that one third of the missions were performed in darkness /20/.

3.7.1 Operational limitations

Level of fuel is the limiting factor for the operational range of a helicopter. The decision on which fuel level to choose is based on the planned course out to the given destination as well as how long it will take to perform the approach. Also, the helicopter should be able to return to the original base, or to an alternative airport onshore, while still having sufficient fuel for thirty more minutes of flying time. A transport in current use carries fuel for ca. 3,5 hours of time in the air. Norwegian oil and gas – 066, additionally require that the alternative airport of landing cannot be on an offshore facility /15/.

The following meteorological factors are critical for helicopter operations:

- Lightning in a cumulonimbus cloud
- Air turbulence, wind speed on helideck
- Icing
- Poor visibility, fog, or dense snow
- Wind speed that significantly reduces or channels headway

The general rule is that a helicopter transport of personnel should not be carried out if the wind on the deck where the SAR helicopter is stationed exceeds 55 knots. The reason for this is that the SAR helicopter rotor might not start under such wind conditions.

3.7.2 Fuel requirements

Refueling on an offshore facility, and helicopter in flight refueling (HIFR), has inherent limitations. When relying on an offshore refueling through either one of these methods, the helicopter needs to reach the refueling facility before it has used more fuel than what is needed for it to return safely to its starting or alternative airport. Again, a thirty minutes fuel reserve is required. After successfully refueling, the helicopter should not fly further than for it to be able to return to an airport without a second additional refueling. This because the helicopter cannot be guaranteed that a second refueling operation will be neither possible nor successful. Hence, planning a flight that requires a second HIFR operation is not permitted /15/.

3.7.3 Coverage

Skrugard is expected to be in operation within 2018. The field is situated at a strategically important location about halfway between the Norwegian coast and Bjørnøya. Almost all areas of the western part of the Norwegian Barents Sea sector and the Norwegian mainland can be reached within one hour from Skrugard. Bjørnøya would be an alternative location where a SAR helicopter could be stationed, but Bjørnøya is much further from the mainland, and there are more challenges there related to fog. As petroleum activities move more towards the east, it will be necessary to establish bases for helicopter operations at airports like Berlevåg or Vardø /15/.

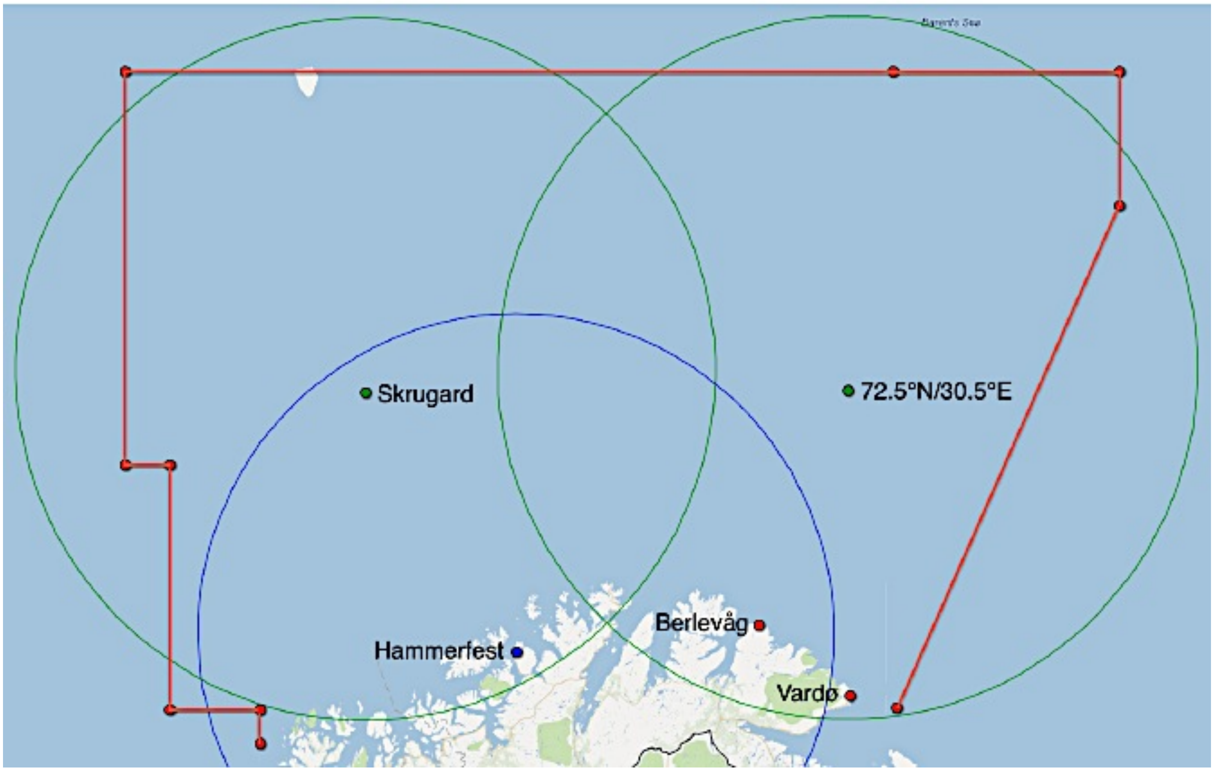

Figure 17 Helicopter coverage. Skrugard and a facility 72,5°N as offshore heliports /15/

The circles, in Figure 17 above, indicate the one-hour helicopter flying range from the center. The blue line indicates flying time from Hammerfest and the two green lines have their centers located at Skrugard and at a given coordinate point (72,5°N/30,5°E). The red line indicates the Norwegian part of the Barents Sea all the way up north to Bjørnøya.

3.7.4 Effects of wind on helicopter flights

The effects of wind on a flight from the coast to the destination 74,5°N/37°E are considered in this section and are based on the master thesis performed by S. R. Jacobsen /15/.

The distance one way is 260 Nm, which results in a total round trip of 520 Nm. The dimensional helicopter speed is 145 knots. Three hypothetical wind cases have been studied: No wind, side wind and head/tail wind with wind speeds between 20 and 50 knots.

The calculations show that in a constant head/tail wind situation, i.e. wind blowing along or in parallel with the route, approximately thirty minutes will be added to the round trip when the wind speed is 50 knots. In the case of side wind blowing across the route, about fifteen minutes will be added to the round trip in a wind speed of 50 knots.

Calculations were also made to illustrate the effect of head and tail wind one way. They are illustrated in the table below /15/. The time values are approximated:

Wind strength (knot)	Flight time Head (min)	Flight time Tail (min)
0	108	108
20	125	95
40	145	85
50	160	80

Table 11 Flight duration with head/tail winds between Berlevåg and 74,5°N/37°E /15/

These results show that wind has a significant impact on flight times. This is something to be aware of when dimensioning the emergency preparedness.

3.7.5 Rescue helicopter base at Banak

This section is based on information from the 330-squadron located at Banak /40/.

The 330-squadron does not have any sort of emergency preparedness cooperation with oil and gas companies. However, it uses offshore rigs for landing practice and performs pick-up exercises at standby vessels.

Today there are two Sea King helicopters stationed at Banak. One helicopter is always in emergency preparedness while the other is in for inspection. There are never two sets of crews on the station at the same time, which means that only one helicopter can be used.

The challenges of operating in the north are many. Poor visibility can be a huge problem, large wave heights may cause difficulties in pick-up operations, strong winds might result in the helicopter not being able to reach its destination on time, and icing on the helicopter itself can make flying impossible.

Operations conducted in darkness have other limitations than during daylight and are also more difficult. Therefore the crew is given stricter limitations in its operations, which means that it may not operate in quite as harsh conditions at night as they may in daylight.

Environmental conditions have an impact on the rescue time for pick-up operations. If the water is flat and the persons in the sea lie in a gathered group, a pick-up time of three minutes can easily be fulfilled. However, if the wave height is fifteen meters and the persons in the sea are spread from one another, the time might increase. Another factor that impacts such operations is how long the helicopter can stay in the air before it needs refueling.

3.8 Evacuation and rescue

In the Barents Sea there are currently few helicopter resources that can assist in both precautionary and emergency evacuations compared to in other areas, such as in the North Sea. The probability for lifeboats to be used for a precautionary in the Barents Sea might therefore be higher than in other areas on the NCS where a precautionary rather would be conducted with the use of helicopters.

It is a general fact that helicopters can operate and rescue persons from the sea in almost any weather condition except for in fog or low visibility. The capability and performance of a standby vessel is a lot more limited to weather conditions. Having a SAR helicopter stationed on an offshore facility causes challenges, especially if no hangar is available for the helicopter. This may expose the helicopter to icing, a phenomenon more closely described in chapter 3.1.4. Offshore SAR helicopters have been operated successfully for many years on facilities with a hangar. There is a general agreement that the SAR helicopters are a considerable strengthening of offshore emergency preparedness /15/.

Accidents where people end up in cold water (below 12 °C) may be life threatening. These kinds of accident can be divided into four stages /41/:

- Immediate temperature shock (duration of 1-2 min, uncontrolled breathing)
- Short time exposure to cold water (duration of 10-15 min, need of floating medium to prevent drowning)
- Long time exposure to cold water (duration of 15 min and up to several hours, the core temperature will decrease and will in the end lead to cardiac arrest)

- After rescuing (many fatalities – 20-25 % – happen after rescuing, mainly caused by swallowed seawater and disorder in circulation)

3.8.1 Lifeboats

Emergency preparedness equipment, such as lifeboats, must meet regulatory requirements that are normative to functional requirements. These regulations indicate which safety level must be reached, not how. Free-fall lifeboats, supplemented by rescue stockings and associated life rafts, should be used as means of evacuation for evacuation at sea /42/.

The owners of the lifeboats, i.e. the operator, have an overall responsibility for ensuring that the equipment in use is suited to its purpose and meets the functional regulatory requirements. It is also the operators responsibility to implement necessary compensation measures if there is uncertainty related to use of the lifeboats under given weather conditions /42/.

PSA still considers free-fall lifeboats to be the best currently available technology in the field of lifeboat evacuation on the Norwegian shelf. In comparison, more time is needed to launch conventional lifeboats, which are lowered down to the sea. In addition to this, only the conventional lifeboat's own engine power can move the lowered lifeboat away from the facility that is being evacuated /42/.

It must be noted that all experience with deploying free-fall lifeboats come from deployment during drills. There have been no actual incidents in the Norwegian sector where free-fall lifeboats have been involved /10/.

Over the past ten years or more, research has shown that where sea ice is present, no single secondary evacuation method is available for year-round (24/7) operations. There are many offshore Arctic facilities in operation that have applied performance-based approaches in order to assessing potential risks. This has lead to the establishment of lowest-risk emergency evacuation systems. All solutions that have been found, differ from one another due to various environments, facility design and related hazards, but regardless of location and facility type there are several principles that will still apply to all evacuation methods for operations in Arctic seas /19/.

- Stow and winterize the method
- Deploy the evacuation method from stowed position without damage during descent
- To launch the method with minimum risk

- To navigate unassisted through all possible sea states, ice and polar darkness conditions
- To sustain evacuees until rescued

The use of free-fall deployment systems needs to be considered carefully. To date, there are no free-fall evacuation systems known to be available for deployment into icy waters. Even with very small ice concentrations in the sea, it will be hazardous to utilize a free-fall system. A davit-launching alternative might then be an option since this alternative will maintain the craft's integrity and personnel safety during deployment. Launching into or onto ice with waves present and disconnecting safely are aspects that must receive very special attention /19/.

Statoil will use the rig West Hercules when performing exploration activity around Skrugard and in the Hoop area (Apollo/Atlantis). West Hercules is equipped with conventional free-fall lifeboats delivered by NORSAFE. A possible impact between free-fall lifeboats and drifting sea ice will however never be an issue here because the rig itself will disconnect from the location if the ice concentration around it is so comprehensive that lifeboats cannot be dropped /21/.

3.8.2 Escape chutes and life rafts

Escape chutes and life rafts have a limited operational window: They should not be used in conditions over Beaufort 8 (Gale, fresh gale. 17,2 – 20,7 m/s). The prevailing conditions in the winter and a polar low would probably disqualify the use of escape chutes and life rafts in the Barents Sea for considerable periods of time /16/.

3.8.3 Rescue

Once lifeboats or life rafts have been launched and come clear of the facility, the issue of rescuing survivors is paramount. If a helicopter or rescue vessel is unable to operate under the prevailing conditions, the survivors will have to ride out the weather and wait for an operational window that allows rescue. The time window will depend upon how severe the weather conditions are and how long it is since the rescue mission started /16/.

3.8.4 Emergency Response Vessel

Third generation rescue vessels are specially designed to launch and recover a fast rescue craft or daughter craft from a slipway in the stern. The sea trials of these vessels show that it is generally considered possible to operate in sea conditions up to $H_S \leq 9$ m. This corresponds to Beaufort 10 (storm, 24,5-28,4 m/s) if the wind has a short duration and Beaufort 9 (strong gale, 20,8-24,4 m/s) if the wind duration is long. A rescue made by conventional standby vessels on the other hand, requires the use of lifting equipment or a transfer of personnel from the lifeboat to a standby vessel through the use of a MOB boat, which is limited to Beaufort 6 (strong breeze, 10,8-13,8 m/s), or a Fast Rescue Craft limited to operate up to Beaufort 8 /16/.

3.8.5 Analysis of rescue operation near Bjørnøya

This chapter is based on a scientific article, "*Evacuation from Petroleum Facilities Operating in the Barents Sea*", written by Sigurd R. Jacobsen and Ove T. Gudmestad. The analysis is based on weather conditions observed during the first seven days of January 2009. The conditions were representative for the weather in the Barents Sea during the winter months of 2008 and 2009 /16/. This thesis will only include the analysis from Bjørnøya since it is the most relevant one to a case that will be presented in chapter 4.

The average air temperature found in the weather measurements was -12,6 °C. Wind speed was on average measured to 8,95 m/s, which is near Baufort 6 – the minimum for icing to start. The cold air temperature combined with the wind caused a considerable wind chill and provided the right temperature for considerable icing conditions, resulting in 3-5 cm/hour.

The wave height in the measured period was between 3 m$<H_S<$5 m, but for shorter periods of time, waves could grow as high as 10 m.

Visibility was mostly very good during the seven days of measurements. However, January is a dark month, and no daylight can be counted on due to the polar night.

A helicopter evacuation would be possible under the conditions presented above. The use of lifeboats could be a second choice. A use of escape chutes and life rafts would probably also lead to a successful evacuation under the given conditions. Low temperatures would however be of concern.

The main challenge when using lifeboats as a rescue option is the possibility of severe icing. If the lifeboat is not recovered from the sea within four to five hours, the effect of icing becomes noticeable through increased roll periods.

Awareness of the icing issue is of the utmost importance, and the maneuvering of all vessels should be done at a low speed in order to limit bow waves and sea spray.

Lifeboats are designed to have sufficient buoyancy and stability even in a damaged state where there is free water inside. They are, however, not evaluated for the combined effect of free water inside due to damage and icing. A slow roll caused by icing can result in the lifeboat developing a high angle of heel and thereby a lack of response to righting. Capsizing is not likely, but an unstable situation where the lifeboat potentially lies on its side and rolls slowly can be expected.

3.9 Survival suits

Survival suits used on the Norwegian Continental Shelf must be approved in accordance to the Norwegian Oil and Gas Guideline 094. This is the recommended guideline for requirement specifications for rescue and survival suits used on the Norwegian Continental Shelf. The suits must provide protection for six hours under standard testing conditions /10/.

SINTEF tested survival suits for the Barents Sea in 2010. The testing took place under quite different weather conditions than the ones that are used during standard testing. One result showed that the cooling of fingers and toes was more significant than previously believed. This is however not life threatening, according to SINTEF, but might lead to discomfort and reduced vigor /10/.

The ability of the suits to protect against drowning is difficult to measure specifically, but it is indirectly taken care of through the 50 % safety factor, an existing requirement in the guidelines. This means that the suits are designed to protect against hypothermia for 180 minutes. The maximum response time for saving 21 people from the sea is 120 minutes. The six hours requirement given from the Norwegian Oil and gas then gives a safety factor of 200 % /10/.

3.9.1 Short time effects of coldness

For a person located in cool water, swimming might be difficult because the cold temperature has an impact on muscles and nerves. The person might also experience uncontrolled ventilation. Reduced motor skills will however occur way before deep hypothermia and might make a person unable to take necessary measures to save him or herself, or others. This may eventually lead to drowning. It is important to point out that there are great individual differences between every potential person in the water. Examples of these are subcutaneous fat, nutrition, swimming skills, and the person’s physical and psychological condition. A good physical condition might lead to the person shivering less and hence having a longer endurance. Age also has an impact since the body's temperature regulation ability depreciates with increased age /43/.

Little scientific data on immersion hypothermia, cooling rates and immersion suits performance exists from rough sea conditions since these studies are often conducted in indoor laboratories with calm seas and no wind or wave action. In sea conditions where breaking waves occur, the primary problems are the maintenance of airway freeboard and the avoiding of drowning. Hypothermia is of secondary importance. The flushing of cold water over a suit and the leaking of cold water into a dry suit causes heat loss. It also becomes difficult to get into the right posture in the water when sea conditions are rough /43/.

3.9.2 Norwegian oil and gas 094 and ISO 15027

According to the guideline "Norwegian oil and gas 094" the following specifications concern the survival suits on the Norwegian Continental Shelf /44/.

All passengers must use Suit A during a helicopter transport. The suit will be distributed to the user on the heliport, and the same suit will also be used on the return flight back onshore.

During tests, the wind force should be at least 5 m/s and the front of the suit overflown with water (<2 °C) every ten minutes. The temperature measured in the neck should not decrease to less than 25 °C during the test. On hands and feet, the temperature should not go below 15 °C.

According to the regulation ISO 15027, the time of immersion, when performing a test for Suit A, is six hours with a water temperature of 2 °C. In this time, none of the six human test subjects' core temperature should fall more than 2 °C. Each human test subject's skin temperature can also not be lower than 10 °C for more than fifteen minutes. If one or both of the two requirements are not fulfilled, the suit system can be deemed to have failed /45/.

3.9.3 SeaAir immersion suit

This section is based on the master thesis written by Sigurd R. Jacobsen /15/.

During a course, "Enjoy the Cold", arranged by NTNU at Ny-Ålesund on Svalbard in March 2012, two participants (Person A and Person B) tested the HellyHansen SeaAir Immersion suit. The suit was tested according to the Norwegian oil and gas guideline 094 and the ISO 15027-3. The persons were equipped with temperature logging sensors and spent approximately ninety minutes in the sea. Sea temperature was 0,6 °C and the air temperature -4 °C. There was no wind or waves during the test.

Person A, female, wore an Aclima wool shirt and long pants, a thin jersey of synthetic material and a pair of woolen socks. She was in the water for about ninety minutes.

Person B, male, wore an Aclima wool shirt and long pants, cotton briefs and short cotton socks. He was in the water for hundred and five minutes.

Table 12, presented below, shows a comparison of the temperature changes that the two persons experienced during the test.

	Person A (difference)	Person B (difference)	Requirement
Armpit/upper arm	36°C to 33°C, (-3°C)	32°C to 28°C, (-4°C)	
Thigh	29°C to 24°C, (-5°C)	31°C to 22°C, (-9°C)	
Wrist	34°C to 22°C, (-8°C)	30°C to 15°C, (-15°C)	Min. allowed 15°C
Neck	33°C to 29°C, (-4°C)		Min. allowed 25°C
Chest		31°C to 28°C, (-3°C)	

Table 12 SeaAir immersion suit, comparison of temperature changes /15/

The two persons commented on their test experience:

Person A experienced coldness on hands, forearms, feet, and in the crotch. She did not move much while lying in the water in order to avoid water from flowing into leaky areas. The experience of lying in the water for ninety minutes was much better than she had expected and feared. She however assumed that it would be much more tiring in rough seas.

Person B experienced a general feeling of coldness. As opposed to Person A, Person B generated heat approximately every ten minutes through powerful movements because the cold feeling was too strong. He started feeling cold after thirty minutes, but was fully able to take care of his own safety and to help with the safety of others even after ninety minutes.

It may be concluded that it is wise to wear sufficient layered clothing under the immersion suit, and that some movement will improve the personal comfort.

3.9.4 SeaBarents suit demonstration

SINTEF and Hansen Protection have developed a new SeaBarents suit based on an initiative from Eni Norge. The suit is a further development of the helicopter suit SeaAir and includes improvements specifically made for arctic conditions and challenges in the Barents Sea, such as visibility and icing problems. The suit is simpler to use, grabbing things will be easier for the person inside the suit, and the visibility for the user has been increased. Additionally, there is more light on the suit, and the suit also has a better insulation for both hands and feet /46/.

The demonstration of the SeaBarents suit took place outside of Hammerfest on November 13-14, 2012. The weather conditions were as following: 0 °C in the air, 5 °C in the water and a wind force of 15 knot. Six persons were in the water between forty-five minutes and an hour and a half, and all six were satisfied when rescued. They were all dry after the demonstration and not especially cold. Their core temperatures were intact /46/. The suit has also been tested under controlled conditions at SINTEF SeaLab where the duration of the test in the water was two hours. The test was conducted under rougher conditions than regulations require /47/.

The thermal qualities in the SeaBarents suit are good, and the suit protects sufficiently against a hypothermic condition where the person's core temperature sinks below 35 °C. When wearing the suit in the Barents Sea, potential personnel in the sea will not even come close to reaching a core temperature below 35 °C in a time span of two hours /48/.

According to Hilde Færevik, SINTEF, drowning is a greater risk than hypothermia. In an accident where people end up in the sea, it is important for the rescue personnel to make the right decisions and to give the correct medical treatment in order to save as many people as possible. Experience shows that it takes time before the core temperature decreases below 35 °C. The core temperature will also continue to decrease for a while after being rescued /48/.

The regulations do not mention that temperatures should be measured on the participants' fingertips during testing. However, experience shows that fingertip temperatures are lower than on the wrists. During the test at SeaLab, the persons were picked up from the water after two hours, something that was planned beforehand. They were then a bit cold on their hands, but there was never any risk of them getting frost damages. The persons could probably have stayed in the water for an additional two to three hours. This was however not possible to carry through due to ethics regarding personal safety during trainings/drills /49/.

3.9.5 Effect of physical activity in water

This section is based on the report "Cold experiences" performed by Thelma /13/.

A general conclusion is that all physical activities performed in water when temperatures are below 25 °C will increase the drop in core temperature. The reason for this is because the physical activity disturbs the thermal layers in the water and thereby brings new cold water near the person's body. The temperature differences between the body area and the surrounding water increases. So does the heat loss from the human body.

Experiments have shown that by only moving the legs, the heat loss to the cold environment will be smaller than when moving the whole body. It is therefore recommended that a person lying in the water only uses the legs (if necessary) to generate heat.

How long a person may expect to survive in water is a question that typically comes up. Unfortunately it is not possible to give an exact answer because there are several factors that have an impact on the survival time. Some of these are:

- Individual differences between humans (morphological differences)
- Protective equipment used in the accidental situation
- Water break-through in the protective equipment
- Water temperature
- Water condition (waves, circulation, sea spray)

Even if limited data from experiments exists, one may assume with quite a certainty that a person's mental condition, such as if a person can keep calm in a critical situation and has the will to survive, will have great impact on an eventual survival.

3.9.6 Survival at sea

This chapter is based on information from Golden and Tipton's book "Essentials of Sea Survival", and it deals with hypothermia and sea survival /50/.

Hypothermia, unlike cold shock, is unlikely to be a problem within thirty minutes of head-out immersion for a fit, clothed adult, even in waters as cold as 5 °C. Under exceptional circumstances, however, rapid body cooling may occur if a person aspirates a large volume of water. Drowning will then pose a more serious threat than hypothermia.

As a rule of thumb: During head-out immersion under laboratory conditions the deep body temperature of an average young male adult wearing no specialized clothing will fall with 2

°C after approximately one hour in stirred 5 °C water. In water temperatures of 10 °C, the same decline in body temperature will occur in two hours, and in 15 °C water, in three to six.

A deep body temperature of about 35 °C is associated with the decline in useful consciousness onset. In temperatures under this, physical and mental capabilities progressively deteriorate and individuals become less able to help themselves. This deterioration will, as mentioned already, occur well before loss of consciousness from hypothermia.

Figure 18 below illustrates an empirical curve, which shows how the fall of body temperature corresponds time-wise with signs and symptoms experienced at each temperature.

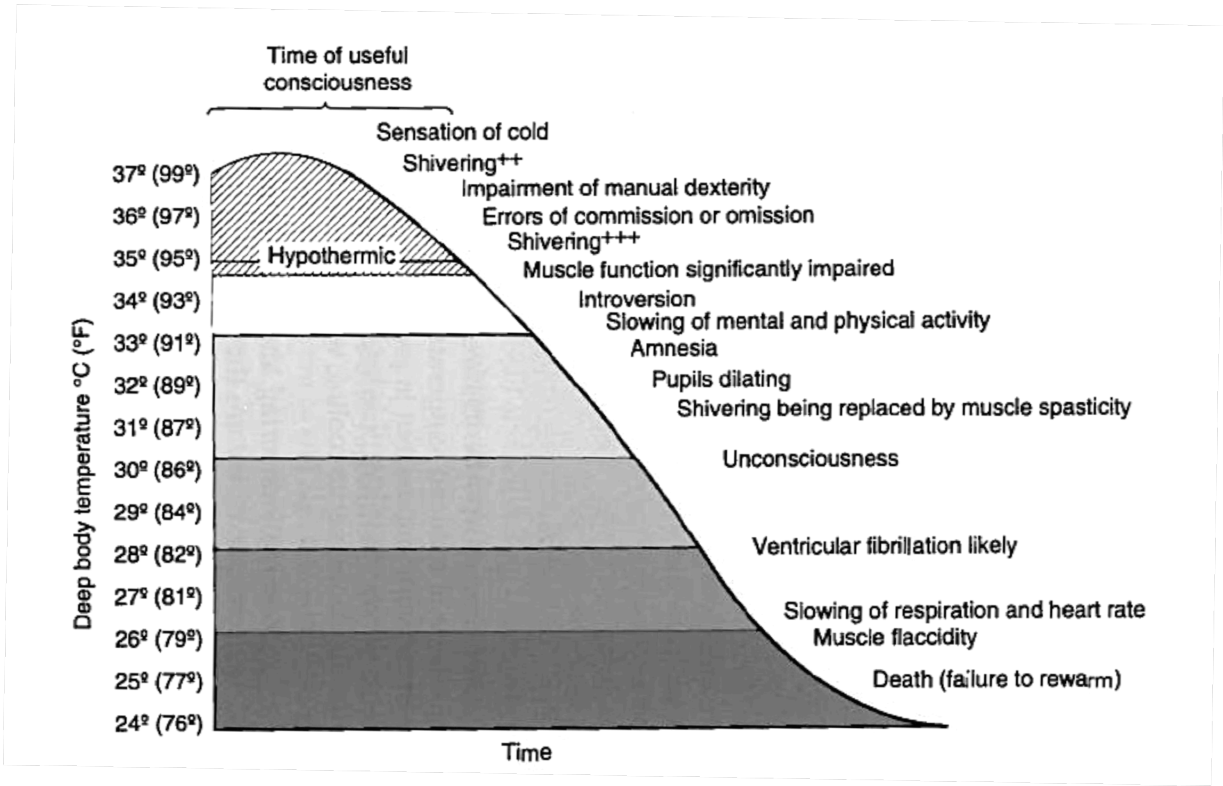

Figure 18 Empirical curve showing the fall of body temperature /50/

The two main sources of the information used to estimate survival times in cold waters, are reviews from actual emergencies as well as laboratory experimentation supplemented by mathematical manipulation and extrapolation. Whichever the source of data is, the various predictions tend to be closer to each other when considering very cold waters temperatures. As water temperatures increase, predictions vary more.

Existing predictive survival curves do little other than reminding us that survival time in cold water is limited. Guidelines based on the analysis of accidents, together with laboratory-based experimental evidence, show a clear correlation between water temperature, body cooling and survival times. Predicting survival times for immersion victims is however not a precise science. Search and rescue coordinators therefore have to make tough decisions based on the best information available, including a number of assumptions.

4. Case from the Barents Sea

This chapter will present a case where the challenges related to emergency preparedness on remote facilities in the Barents Sea will be discussed. The case is divided into two different scenarios. Each scenario has an area based emergency preparedness proposition and will analyze the following DSHAs:

- DSHA 2 - Personnel in the sea following a helicopter accident
- DSHA 3 - Personnel in the sea following emergency evacuation
- DSHA 7 - Illness/injury with need for external assistance

The analysis will respectively be performed in chapter 5.1 and 5.2.

4.1 Scenario description

In this scenario there are three drilling rigs in the Barents Sea in addition to the case facility. The three drilling rigs are noted as: Rig 7228, Rig 7325 and Rig 7432. The case facility, from here on noted as X or Facility X, is a floating production facility. Its location is marked with a blue spot on the map below.

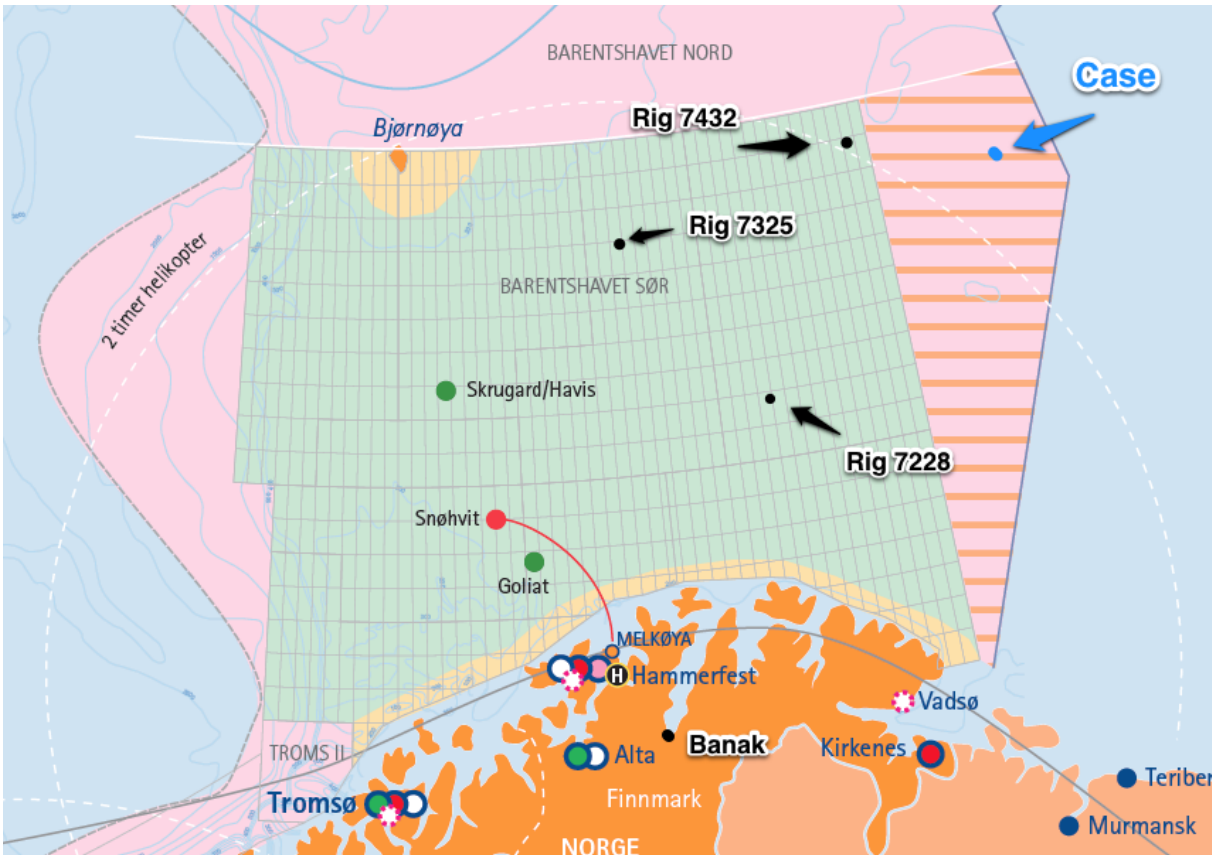

Figure 19 Case /51/.

X is located in the Barents Sea southeast (74°N and 35°E), and the opening process of this area has started (marked with orange stripes). The pink area north of Bjørnøya is not yet opened for petroleum activity. The green spots indicate oilfields (Goliat and Skrugard/Havis), and the red spot indicates a gas field (Snøhvit). The helicopter base is located in Hammerfest. There are also SAR-helicopters stationed at Banak, which are operated by the rescue coordination center (RCC) /51/.

4.1.1 Distances

The distances presented in the table below are not 100 % accurate. However, they give a good approximation and will be used in the case. The column to the right represents the helicopter flight time given a speed of 140 knot. Mobilization time is not included.

Hammerfest	Goliat	90 km	49 Nm	21 min
Hammerfest	Skrugard	240 km	130 Nm	56 min
Hammerfest	Bjørnøya	445 km	240 Nm	103 min
Hammerfest	Rig 7228	240 km	130 Nm	56 min
Hammerfest	Rig 7325	325 km	175 Nm	75 min
Hammerfest	Rig 7432	450 km	243 Nm	104 min
Hammerfest	Facility X	470 km	254 Nm	109 min
Hammerfest	Banak	81 km	44 Nm	19 min
Rig 7228	Facility X	245 km	132 Nm	57 min
Rig 7325	Facility X	320 km	173 Nm	74 min
Rig 7432	Facility X	133 km	72 Nm	31 min
Skrugard	Facility X	455 km	246 Nm	105 min

Table 13 Distances

4.2 General description of Facility X

The thesis does not consider if the facility produces oil, gas or both. This means that different export solutions will not be elaborated upon, and potential risks related to the export of oil and/or gas will not be a part of the thesis. A thesis presumption is that no production will be started in the area before an economic and safe export solution is ready.

The case assumes that Facility X is built as a middle thing between the Sevan 1000 FPSO and the Gjøa platform. The Sevan 1000 will be used on Goliat, and Skrugard will chose a facility that looks like the Gjøa platform, only larger. It is presumed that Facility X will be a winterized floating production facility that also has a helicopter deck with a hangar. In the thesis, the focus will not be on the facility itself, but on the emergency preparedness resources placed in the area around and on the facility such as helicopters, standby vessels and lifeboats. Personnel on board Facility X and on the three drilling rigs will be 120 persons per place. This number will be used later in the chapter 5 analysis. There, DSHA 3, "Personnel in the sea during emergency evacuation", will among other things be analyzed.

The Sevan 1000 concept is designed for operations under challenging conditions such as those encountered in the Barents Sea. Some of the things introduced by the concept, are new winterization systems. The Sevan 1000 is designed so that rain and snow naturally will be drained off of walls and roofs, and it is constructed to bear icing /52/.

Figure 20 The Sevan 1000 /52/


Figure 21 Gjøa platform /53/

4.3 Environmental conditions around Facility X

According to data provided by the Norwegian Meteorological Institute, the significant wave height is greater than five meters during 4,6 % of the year in the Barents Sea east (72,58°N and 33.1°E) /15/. This coordinate is near Facility X and will serve as a basis for what the significant wave height there could be like.

Point 5 in Figure 8, given in section 3.1.3, has the following given coordinates: 74°N and 32,88°E. This is fairly near Facility X and therefore provides a base for further weather assumptions. The maximum and minimum air temperatures are respectively 10,8 °C and -25,1 °C and the maximum and minimum sea surface temperatures 11,3 °C and 1,8 °C.

Polar nights will also occur. On Bjørnøya they start on November 7 and end on February 4. It is in this thesis presumed that this is a good approximation also for Facility X.

Polar lows will be a challenge on Facility X. Figure 7, given in section 3.1.2, indicates where the area of growth for polar lows is. By studying that figure one may see that Facility X lies in an area where polar lows occur.

4.4 Premises and technical assessments in Norwegian oil and gas 064

This chapter is based on the "Baseline report documenting premises and technical assessments in the Norwegian oil and gas 064" /10/, where the following DSHAs are discussed:

- DSHA 1 – Man overboard when working at sea
- DSHA 2 – Personnel in the sea following a helicopter accident
- DSHA 3 – Personnel in the sea following emergency evacuation
- DSHA 4 – Collision hazard
- DSHA 5 – Acute oil spill
- DSHA 6 – Fire with need for external assistance
- DSHA 7 – Illness/injury with need for external assistance

Today there are four areas that have area based emergency preparedness in the North Sea and the Norwegian Sea. They are respectively the Southern Fields, Troll/Oseberg, Tampen, and Halten Nordland. ConocoPhillips operates the Southern Fields in cooperation with BP and Talisman. Statoil operates the rest. BP and Shell have area based emergency preparedness at Halten Nordland together with Statoil. In addition to in these four areas, an AWSAR helicopter is placed onshore in Hammerfest when there is activity in the Barents Sea. When Goliat starts producing, Hammerfest will be a permanently operative helicopter base /10/.

As oil and gas activities are being expanded northwards in the Barents Sea, emergency medicine and survival at sea for those who are waiting for a helicopter rescue (DSHA 2 and DSHA 7) must be considered thoroughly. The following two sub-chapters (4.4.1 and 4.4.2) are almost completely based on the baseline report for the Norwegian oil and gas 064 and reproduce some of the report discussion around these two DSHAs /10/.

4.4.1 DSHA 2 – Personnel in the sea as the result of a helicopter accident

A premise for the guideline is that rescue of people from the sea will be carried out with SAR helicopters, if available. This is a more robust solution than using standby vessels since helicopters are less exposed to weather and operate faster. However, there are two conditions that make helicopters inapplicable for an evacuation:

- If the evacuation must take place quickly based on development of the accident situation

- If gas, smoke or fire on the facility, due to wind direction makes it impossible to use the helicopter deck.

After an AWSAR helicopter has managed to take off, it has practically no restrictions when it comes to rescuing personnel in the sea or from rafts. Experience from public rescue service has confirmed this. A rescue conducted in poor weather and dark conditions takes somewhat longer, but can still be carried out effectively. However, there are some weather limitations that can prevent the helicopter from taking off in the first place, such as high wind speeds or poor visibility.

A standby vessel can, in nearly all incidents, operate regardless of accident scenario. Heat, smoke or gas in the facility will not be a hinder. However, given a gas leak on the facility, the standby vessel will normally have to keep a safe distance since the vessel may be a possible ignition source /54/. The standby vessel may be used as a place of safety for personnel in lifeboats. When it comes to weather, standby vessels also have some weaknesses. The operational limitations when using a Man Over Board (MOB) boat are often H_S<4,5 m. Another standby vessel limitation is range. A typical operational speed for such a vessel is approximately 15 knots.

The main functions for a standby vessel in an emergency situation are normally /55/:

- Oil-pollution service
- Alert/sending away ship on collision course
- Search and rescue of personnel in the sea after a helicopter accident, in a man over board-situation, and in an emergency evacuation

Conceptual study for new rescue helicopters

This sub-chapter is based on the following document: Preparatory for new rescue helicopter capacity, Sub-document 1 of 5, Needs Assessment /56/.

The purpose of the study is to prepare for a well-documented and justified choice when current Sea King rescue helicopters will be replaced with new ones due to age. In subsection 5.3 of the study, Conclusion survival availability, a table (which Table 14 is based on) sums up the requirements on how quickly the efforts must be in place in order to ensure good survival ability.

Table 14, presented on the next page, shows the survival time until help arrives. Red color indicates that the outcome probably will be fatal, yellow that the possibility of survival is low, and green that there are good possibilities of surviving. In winter or under bad weather conditions, all categories move at least one step to the right in the table /56/. In potential Barents Sea incidents, this will be the case.

	Situation	Immediate response	Response within 30 min	Response within 1 hr	Response within 2 hrs	Response within 3 hrs	Response within 6 hrs	Response within 12 hrs
1	Unprotected in water	+	+/-	+/-	+/-	-	-	-
2	Protected in water	+	+	+	+	+/-	+/-	+/-
3	Unprotected in raft	+	+	+	+	+	+/-	+/-
4	Protected in raft	+	+	+	+	+	+	+
10	Acute heart attack	+	+	+/-	+/-	+/-	-	-
11	Acute stroke	+	+	+/-	+/-	+/-	-	-

Table 14 Response time requirements for new SAR helicopter needs analysis /56/

The following conclusion regarding rescue ambition levels is found in Sub-Document 2, Chapter 10: Overall strategy document /57/:

- After being notified of an accident, a Sea King helicopter should be able to, in one single operation, aid twenty people in distress within 150 nautical miles straight out from the baseline, and this within two hours.
- A Sea King should be able to carry out MEDEVAC for two people in distress as far out as to the outermost boundary of the NRAO (Norwegian rescue responsibility area), within 400 nautical miles from the baseline.
- A Sea King should also be able to aid those in distress at any point along the coast and the entire mainland, and bring those in distress to a safe location.

This shows that the ambition level of the public rescue service is more or less the same as the guideline Norwegian Oil and Gas - 064. The only difference is that the public rescue services must start relief efforts during the course of two hours while the guideline 064 indicates that aid should be carried out within two hours /10/.

4.4.2 DSHA 7 – Personal injury/illness with need for external assistance

Emergency medical response on the facility

The time requirement for emergency medical response on the facility is set to one hour. This entails thrombolytic equipment and doctoral expertise. Treatment of the most serious cardiovascular and brain diseases can only be done in a limited number of specialized hospitals /10/.

Transport of seriously injured and ill people to a hospital

The transport of a patient to a hospital is required to be carried out within three hours. It has been noted that there is no clear medical reason for this three-hour limit. It has also been expressed that an enhancement of the time gap to four hours would be desirable. That would make it easier to fulfill the time requirement when oil and gas activity moves further away from land in the Barents Sea. Pre-hospital thrombolytic treatment improves the chances of patients' survival and will be an important compensating measure in the event of a long transportation time to the hospital. If any change was to be made, it would be relevant to reduce the requirement to less than three hours /10/.

Special emergency preparedness requirements for the Barents Sea

Eni Norge will have a SAR helicopter stationed onshore in Hammerfest with a one hour mobilization time 24/7. For all shuttle flights, the mobilization time will be fifteen minutes. When the distance between facilities in the Barents Sea and Hammerfest is longer than 300 km (162 nm), it will be impossible to satisfy the requirements of medical evacuation. A one hour response time for external emergency medical assistance will not work out, nor will flying a patient to the hospital within three hours /10/.

If the time requirements cannot be satisfied, one needs to consider the possibility of implementing compensating measures /10/:

- Increase the medical expertise on board (doctor on facility, two nurses on board of which one has special expertise)

- Additional equipment on board (monitoring equipment, medication inventory) in combination with increased expertise
- Utilization of the possibility for telemedicine
- SAR helicopter in the area, on facility or vessel (adequate measure)

4.4.3 Operational restrictions

In the event of a helicopter accident within the safety zone, it has been common practice to set operational restrictions for helicopter transport services when an MOB boat is the primary means of rescue. A significant wave height of 4,5 Hs is a common restriction /10/.

Statoil's objective is that flights with a limited number of passengers may be allowed, based on available rescue capacity, when the following is taken into consideration:

- Increased mobilization time
- Changed flight time based on the helicopter's location on land
- Increased flight time based on wind conditions (direction and strength)

Changes can entail that it takes shorter or longer than hundred and twenty minutes to pick up the dimensioned number of people from the sea (21 persons if DSHA 2 is the dimensioning factor). When planning the helicopter shuttle service, a potential need for reducing the number of passengers on board should be taken into consideration so the rescue capacity will be sufficient enough to pick up the people in distress within the time limit /10/.

4.5 Calculations based on use of land-based SAR-helicopter to search and rescue

This section will contain calculations and examples to assess if the SAR-helicopters stationed at Hammerfest and Banak can fulfill the performance requirements given from the three different DSHAs presented in the beginning of chapter 4. The data given in Table 15 on the next page will be used.

Task	Parameter	Comment
Time of mobilization	15/30 min	SAR-helicopters have 15 min. time of mobilization when ordinary helicopter-traffic is in the area. Normally after 9 pm the time is 30 min.
Positioning	5 min	After the helicopter have arrived the scene of an accident, it needs approx. 5 minutes to get in position and lower the rescuer
Time of rescuing persons from sea	3 min	This is based upon that all personnel have a personal emergency beacon
Sustained speed	140 knot	It is assumed that it will take 2 min to reach sustained speed.

Table 15 Parameters used as basis in the helicopter calculations /55/

4.5.1 DSHA 2 - Personnel in the sea following a helicopter accident

As already mentioned, the performance requirement for a helicopter rescue is the pick-up of 21 persons within hundred and twenty minutes. Between Hammerfest and Facility X the distance is 254 Nm, and between Banak and Facility X 260 Nm.

The data presented in Table 15 above is used in the calculations:

When saving 21 persons, the time remaining to get out to the area where the accident has occurred is (120 min – 15 min – 2 min – 5 min – 21x3 min = 35 min). If the helicopter operates with a speed of 140 knots, it will only cover 82 Nm during those remaining thirty-five minutes. This means that the performance requirement for DSHA 2 cannot be fulfilled for Facility X with a SAR helicopter stationed in Hammerfest.

Given that two SAR helicopters are being sent from Hammerfest with a five minutes interval and each chopper rescues respectively eleven and ten persons from the sea, the scenario will look like this:

Helicopter 1: (120 min – 15 min – 2 min – 5 min – 11x3 min = 65 min) Range: 152 Nm

Helicopter 2: (120 min – 5 min – 15 min – 2 min – 5 min – 10x3 min = 63 min) Range: 147 Nm

The performance requirement cannot be fulfilled by the use of two helicopters either. This means that land-based SAR helicopters cannot be used as emergency preparedness resources when distances from the shore are this large.

4.5.2 DSHA 3 – Personnel in the sea during an emergency evacuation

DSHA 3, Personnel in the sea following emergency evacuation, will have much of the same conditions as a DSHA 2 when using a land based SAR helicopter. The only difference is the amount of persons needing assistance in the sea. Given that the dimensioning amount of personnel in the sea is less than for a DSHA 2, the performance requirement will be sufficient if the DSHA 2 is fulfilled. However, if the dimensioning amount of persons needing assistance is bigger than in the DSHA 2, the range of the helicopters will decrease.

4.5.3 DSHA 7 - Illness/injury with need for external assistance

This incident includes serious illness/injury for a person that needs emergency medicine treatment and/or transport to hospital.

In emergency medicine, the time of response by the use of external resources should not exceed one hour. Transportation time should not exceed three hours from when decision of disembarkation has been made to an arrival at a hospital /11/.

Because of the large distance between Hammerfest and Facility X (254 Nm), it is easy to see that it will be impossible for a SAR helicopter stationed in Hammerfest and operating at a speed of 140 knots to fulfill the performance requirement “Time of response within one hour”.

However, when looking at the “Time of transport within three hours”, will it then be possible to fulfill the performance requirements for a SAR helicopter stationed in Hammerfest? The total range the helicopter has to cover is 508 Nm, given that the person is sent to the hospital in Hammerfest. If the person has to be transported all the way to Tromsø, the total distance will be 616 Nm.

Given the helicopter speed of 140 knots, the fifteen minutes mobilization time, the two minutes the chopper needs before reaching full speed, and the five minutes it takes to place the injured person in the helicopter, the following can be concluded:

Hammerfest – Facility X – Hammerfest: (180 min – 15 min – 2x2 min – 5 min = 156 min). The helicopter will manage to cover a distance of 364 Nm, which is by far not enough. If the performance requirement should be fulfilled, the helicopter needs to cover a distance of 508

Nm. For the SAR helicopter to be able to fulfill the performance requirements, the time available must increase with 61 minutes.

4.5.4 Conclusion of land-based SAR-helicopter

For both the DSHA 2 and the DSHA 7, the performance requirements cannot be satisfied by the use of land-based SAR helicopters. DSHA 3 depends on the amount of people needing assistance. Therefore, a solution of having SAR helicopters permanently stationed offshore, close to Facility X, must be implemented to fulfill the performance requirements given in the Norwegian oil and gas 064.

5. Analysis and results

A presumption of the analysis is that the SAR helicopters are used only in emergency situations and not for shuttle traffic. The reason for this is that the large distances from the facilities to onshore areas result in small performance requirement margins.

The DSHAs 2, 3 and 7 will be analyzed into the two scenarios given in chapter 5.1 and 5.2. In regards to the DSHA 3, the thesis will analyze three different scenarios where personnel need rescue from sea:

- 21 persons (same as in the DSHA 2)
- 6 persons (which equals 5 % of a Personnel On Board (POB) limit of 120 people with emergency evacuation from independent facilities that have free-fall lifeboats)
- 30 persons (equaling 25 % of a 120 person POB with emergency evacuation from facilities with conventional lifeboats)

A simplification has however been done in the case of the rigs 7228, 7325 and 7432. In these cases it will be considered irrelevant if the drilling rigs are equipped with conventional lifeboats and not free-fall ones. The simplification has been done for two specific reasons.

Firstly, this comment from Grete Anita Landsvik in Statoil supports the decision /21/: "*West Hercules, a drilling rig that will operate in the Barents Sea, is equipped with free-fall lifeboats. If a risk of drifting ice occurs, West Hercules will disconnect and leave the area*".

Secondly, according to Activity regulation §77 and Facilities regulations § 44 it must be possible to evacuate personnel on a facility quickly and efficiently at all times and under all sorts of weather conditions. Free-fall lifeboats, supplemented by rescue chutes and associated life rafts, should be used as means of evacuation when evacuating to sea.

Therefore, in the case of Rig 7228, Rig 7325 and Rig 7432, the thesis assumes that they are all equipped with free-fall lifeboats only. Given a risk of sea ice near the areas of operation, the drilling rigs will simply disconnect and leave to a safe location.

Facility X, on the other hand, will be the object of a three case-analysis according to the list above (the DSHA 3 scenarios). It is presumed that Facility X will have a year-round operability because it is a production facility. Given that free-fall lifeboats are not always suitable for a potential rescue, the ones responsible of the facility have to come up with a solution that takes local conditions into account.

5.1 Scenario 1

Here, three SAR helicopters are involved. One is stationed onshore in Hammerfest, the two others offshore on Facility X and Skrugard. Facility X has an area based emergency preparedness-cooperation with Rig 7432. Skrugard cooperates with Goliat, Rig 7228 and Rig 7325. The scenario focus will be on area based emergency preparedness nearby Facility X.

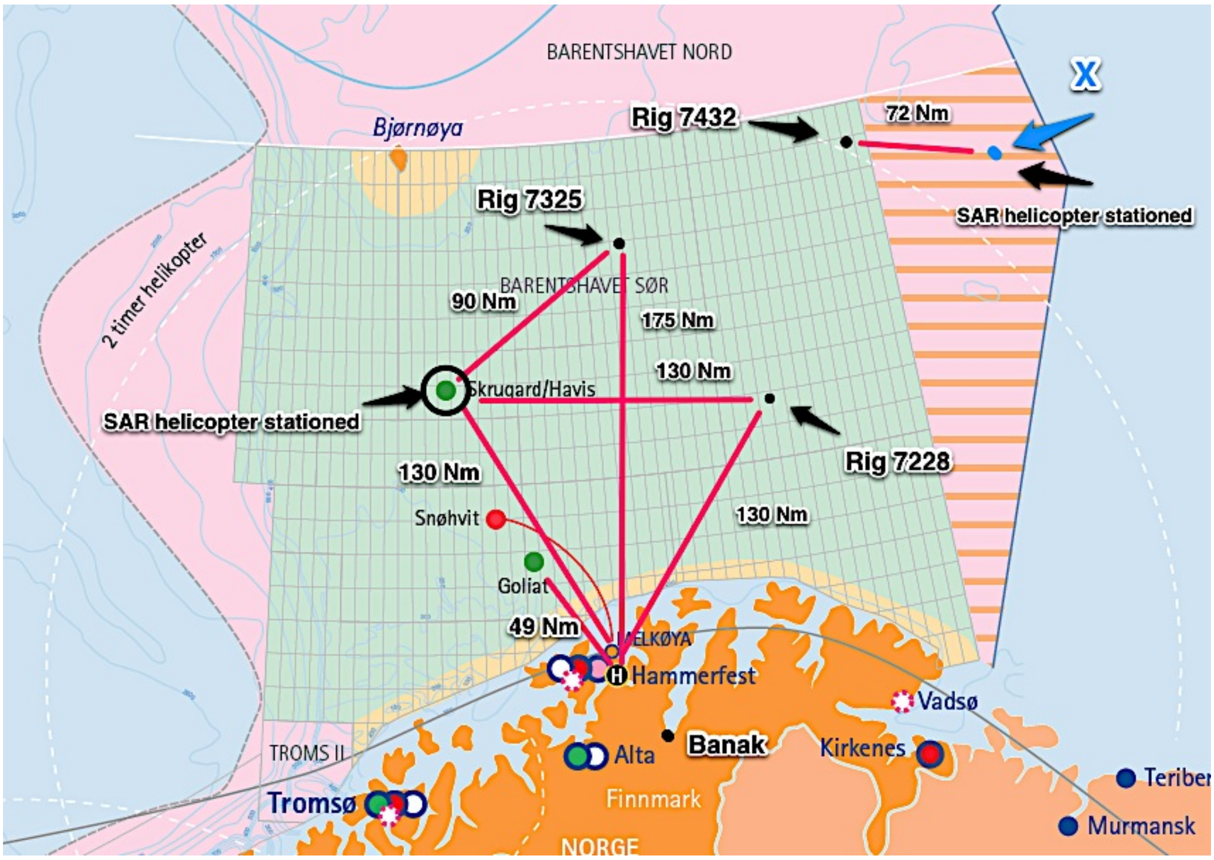

Figure 22 Scenario 1

Distances and SAR helicopter

X	-	Rig 7432	-	72 Nm
X	-	Rig 7325	-	173 Nm
X	-	Rig 7228	-	132 Nm
X	-	Hammerfest	-	254 Nm

The SAR helicopter stationed on Facility X is presumed to operate with a sustained speed of 140 knots and have a capacity of rescuing up to 21 persons per flight. The parameters used in the calculations for the analysis are given in Table 16 on the next page.

Task	Parameter
Time of mobilization	15 min
Positioning	5 min
Time of rescuing persons from sea	3 min
Sustained SAR helicopter speed	140 knots
Time until helicopter reaches 140 knots	2 min

Table 16 Parameters used in Scenario 1 as a basis for the helicopter calculations /55/

5.1.1 DSHA 2 - Personnel in the sea following a helicopter accident

The DSHA 2 concerns all facilities within a facility's 500 meters safety-zone. The dimensioning capacity for rescuing personnel in the sea following a helicopter accident is set to be 21 persons, including two pilots. The performance requirement indicates that all 21 persons should be rescued within 120 minutes after the accident has been alerted /11/.

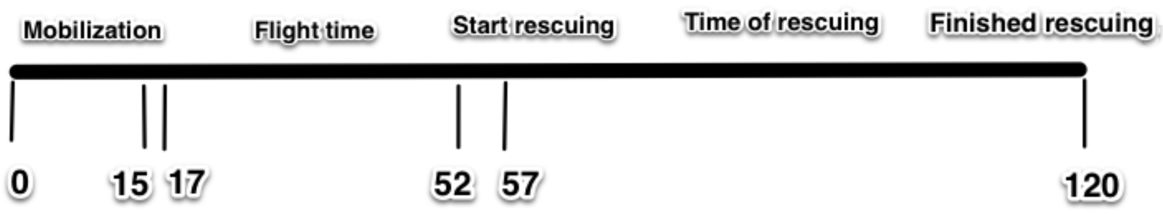

Figure 23 Time of rescuing personnel from sea after a helicopter accident

Figure 23 above presents a timeline of rescuing personnel from the sea after a helicopter accident. The numbers indicate minutes. 17 minutes after the alert the SAR helicopter should be in the air and will have reached a speed of 140 knots. If the helicopter should be able to fulfill its performance requirements, the rescuing of the first person has to start within 57 minutes. The SAR helicopter then has only 35 minutes left of flight time, which results in a rescuing radius of 82 Nm.

If a helicopter accident occurs within the safety-zone of Facility X, there will be no problem to fulfill the given requirements as long as the helicopter is able to take off. That the helicopter will be able to take off is here being assumed since calculating with two DSHAs occurring at the same time is not required, therefore not part of this thesis.

Rig 7432 is located 72 Nm west of Facility X. This is within the rescuing radius of 82 Nm. The previous calculations show that the performance requirement for the drilling rig can be fulfilled with a time margin of 4 minutes.

5.1.2 DSHA 3 - Personnel in the sea following an emergency evacuation

The DSHA 3 describes a situation where the personnel have to evacuate due to a hazardous situation on the facility. A given number of persons end up in the sea during the evacuation. Blocked escape routes or no available lifeboats might be the cause of such a scenario. Lifeboats, which take in water after having slammed into a platform leg on their way into the water, might be another factor. However, all personnel is presumed to be wearing survival suits when they end up in the sea /55/.

The performance requirement is that the number of persons determined by the risk analysis should be rescued within 120 minutes. It is a given that they all wear survival suits /11/.

As mentioned in chapter 5, three cases with various numbers of persons to be rescued from the sea is given for Facility X. For Rig 7432, scenarios for the rescue of only 6 and 21 persons are given. In chapter seven of the Norwegian oil and gas 064, a more detailed way of estimating the actual amount of people needing help during a rescue is given.

An alert will follow established procedures in an emergency preparedness plan. The event that causes the evacuation will often be alerted before the need of rescuing persons from the sea. That way the area emergency preparedness resources will get a head start with the DSHA since the resources will be alerted during the initial event /55/.

Given that the SAR helicopter stationed on Facility X can take off, the performance requirements are fulfilled both for Facility X and Rig 7432 in the cases of rescuing both 6 and 21 persons. The reason for this is that the performance requirements in the DSHA 2 were fulfilled; hence will the DSHA 3 requirements by implication also be fulfilled. However, if as many as 30 persons need rescue (25 % out of 120 persons) it will be more problematic to fulfill the performance requirements for Facility X.

Given that the emergency evacuation takes place on Facility X where the SAR helicopter itself is stationed, the helicopter will manage to rescue 21 persons within 83 minutes. A mobilization time of fifteen minutes and five minutes to prepare for rescue (lower down the rescuer into the sea) is included. After 21 persons are rescued, the SAR helicopter has to take the persons to a safe location and unload before flying back to rescue the remaining nine. If the weather conditions allow the SAR helicopter to land on a standby vessel, all thirty persons in the water will be rescued within 130 minutes. In the calculation it is presumed that it will take fifteen minutes to unload 21 persons from the helicopter and five further minutes before the SAR helicopter can begin picking up the remaining nine persons. The performance requirement of 120 minutes is thereby exceeded by ten minutes. However, if the weather conditions are so favorable that the SAR helicopter can land on a standby vessel, one might also presume that a MOB boat can participate in the rescue and save some persons from the sea. Thereby the performance requirement of 120 minutes can potentially still be fulfilled.

On the other hand, if the weather conditions are so harsh that a MOB boat cannot contribute in the rescue operations due to large waves and the SAR helicopter cannot deploy rescued persons onto a standby vessel, it is reasonable to presume that the performance requirement will be exceeded by even more than the ten minutes calculated above. Rig 7432 is situated closest to Facility X (31 min flying time, see Table 13), and as a second choice after a standby vessel, the platform will be the best place to unload rescued persons onto in the middle of the operation.

According to Table 13, SAR helicopters stationed in Hammerfest and on Skrugard will use 109 and 105 minutes of flight time to reach Facility X (mobilization time not included). Figure 24, presented below, illustrates how much time SAR helicopter assistance from Skrugard or Hammerfest requires. The performance requirement will be exceeded by 21 minutes. If the SAR helicopter stationed at Facility X has to rescue all thirty persons without assistance, it would need approximately 190 minutes. Therefore, assistance from Hammerfest and Skrugard is preferable even though the performance requirement is exceeded.

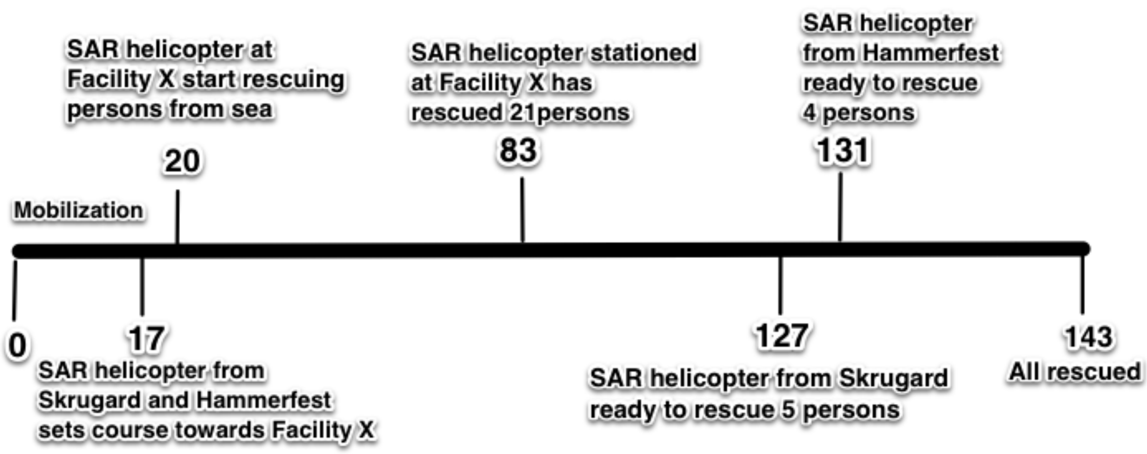

Figure 24 DSHA 3 - SAR helicopter assistance from Skrugard and Hammerfest

Below, Figure 25 illustrates how much time would be needed for rescuing all thirty persons from the sea with SAR helicopter assistance only from Skrugard. The calculations show that all thirty would be rescued within 152 minutes. This is 11 minutes more than in the case presented on the previous page where an additional SAR helicopter from Hammerfest also was used in the rescue operation.

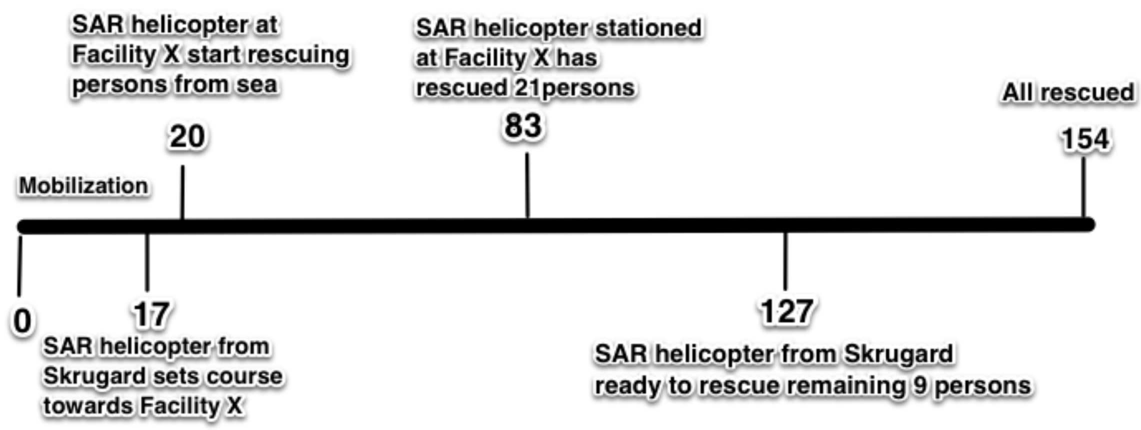

Figure 25 DSHA 3 - SAR helicopter assistance from Skrugard

Shown by the illustration above, it takes 44 minutes from when the first SAR helicopter leaves the scene of the accident with 21 rescued persons until the helicopter from Skrugard arrives. For the nine persons remaining in the sea, the wait can cause a mental challenge.

Standby vessel

A SAR helicopter stationed at Facility X cannot be used in a rescue operation if gas, smoke or fire in combination with an unfortunate wind direction makes it impossible to use the helicopter deck. A standby vessel can then be another option for rescue. Potentially, other SAR helicopters in the area also have to assist in the rescue operation.

Strong winds will have an impact on a vessel's cruising speed. A presumed cruising speed is 15 knots. The Norwegian oil and gas 064 indicates that 4,5 meters is the maximum significant wave height for the use of MOB boats /11/. A study performed by the shipping company Esvagt concludes that under conditions of H_S = 3,5 m, the pick-up time of people from the sea is less than one minute per person. During a training exercise at night where the standby vessel was located five hundred meters away from the accident scene, four persons were picked up within nine minutes after alert. This indicates that time used per person was around 1,5-2 minutes (including transport time out to the scene) /55/.

In this thesis it is being presumed that the time for rescuing persons from the sea by using a MOB-boat is 2,5 minutes in daylight and 4 minutes at night. The numbers are rather conservative, but it is then accounted for that the personnel operating the MOB-boat don't necessarily have a long experience in completing such missions /55/. The following parameters are used in the analysis:

Max wave height	4,5 m H_S	Given by the Norwegian oil and gas 064
Cruising speed	15 knots	-
Time spent on picking up each person	2,5 min (daylight) 4 min (darkness)	-
Time before first person can be picked up	8 min	Based on performance requirements for the DSHA 1

Table 17 Parameters used in standby vessel calculations for DSHA 3 /11,55/

When daylight conditions are a given, the following calculation can be made:

120 min = time to reach the scene of accident + 8 min + x*2,5 min

During darkness, the same formula as presented above is used, however, time spent on picking up each person is increased from 2,5 min to 4 minuets:

120 min = time to reach the scene of accident + 8 min + x*4 min

Number of persons needing rescue	Time of rescuing (darkness)	Time remain to arriving scene (darkness)
6 persons	20,5 min (28 min)	99,5 min (92 min)
21 persons	58 min (88 min)	62 min (32 min)
30 persons	80,5 min (124 min)	39,5 min (-4 min)

Table 18 Time of rescuing persons from sea with standby vessel

Harsh weather conditions resulting in operational restrictions when using a MOB boat

Given that the weather conditions are so harsh that a MOB-boat cannot be used in the rescue operation, SAR helicopters nearby (in Hammerfest or on Skrugard) have to assist. This scenario can only occur on Facility X since the thesis does not calculate for two DSHAs occurring at same time. If a MOB-boat is not operational, the thesis presumes that the SAR helicopters both from Hammerfest and Skrugard will assist in the rescue operation. The helicopter from Skrugard will be able to pick up its first person after 127 minutes while the one from Hammerfest will be ready to start its rescue four minutes later:

- 6 persons will be rescued within 139 minutes (Skrugard 4, Hammerfest 2)
- 21 persons will be rescued within 161 minutes (Skrugard 11, Hammerfest 10)
- 30 persons will be rescued within 175 minutes (Skrugard 16, Hammerfest 14)

5.1.3 DSHA 7 - Illness/injury with need for external assistance

The DSHA 7 concerns serious illness/injury for a person that needs paramedic treatment and/or quick transport to a hospital /55/.

The dimensioning capacity for the DSHA is /11/:

- Illness: 1 person with serious illness
- Injury: 2 persons where one has serious injuries and one less serious injuries

By the use of external resources, the time of response should not exceed one hour. Time of transport in emergency medicine should not exceed three hours.

Time of external medical response

A SAR helicopter is stationed on Facility X. This means that a medical emergency team is stationed there as well. A maximum response time of one hour will therefore not be difficult to achieve on Facility X.

Rig 7432 is located 72 Nm west of Facility X. When calculating the response time from Facility X to the rig, the parameters for SAR helicopter calculations given in Table 16, chapter 5.1, are used. In Figure 26 on the next page, where numbers indicate minutes, the time of response to Rig 7432 is 48 minutes. This is sufficient according to the requirements.

Figure 26 Timeline for DSHA 7, Time of external medical response

Time of transport in emergency medicine

In the scenario, it is presumed that the hospital onshore is in Hammerfest. The distance to Tromsø is too large compared to Hammerfest and will therefore not be considered.

There are 254 Nm between Facility X and Hammerfest. Between Hammerfest and Rig 7432 the distance is 243 Nm. The time needed to make a SAR helicopter ready for transporting injured personnel from Rig 7432 is set to five minutes.

Figure 27 and Figure 28 below show that the "time of transport in emergency medicine"-requirement both from Facility X and Rig 7432 to the hospital in Hammerfest will be fulfilled.

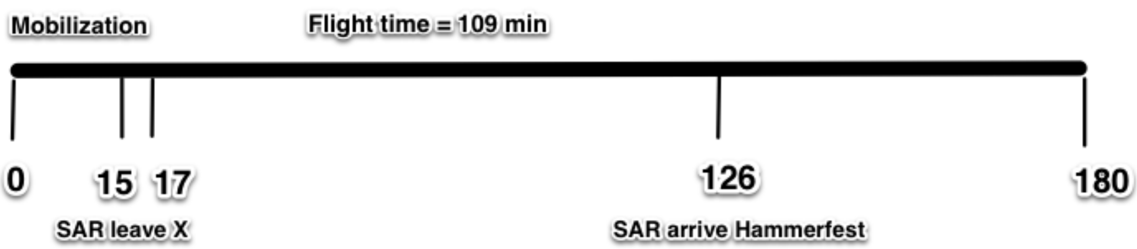

Figure 27 Transport of seriously injured and/or ill people to a hospital from Facility X

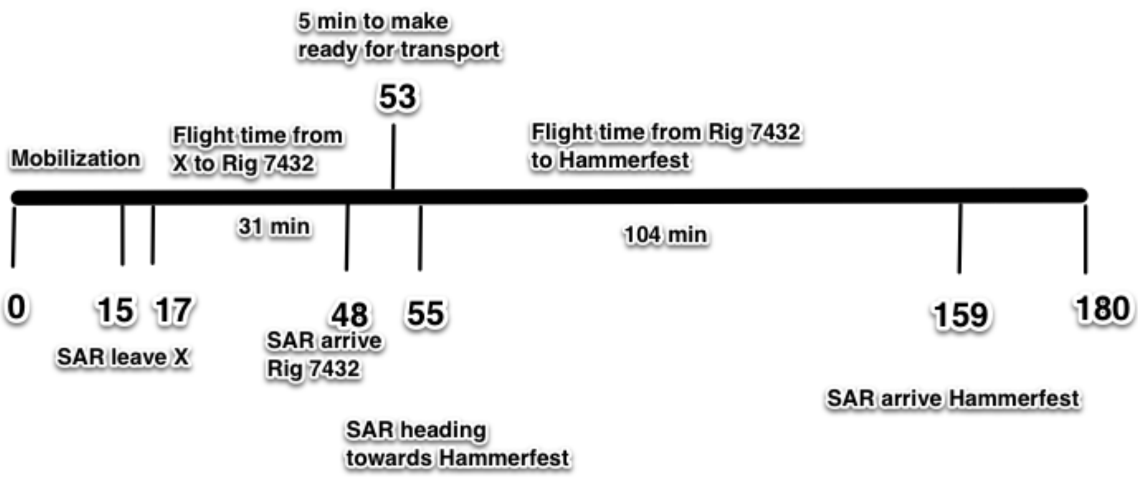

Figure 28 Transport of seriously injured and/or ill people to a hospital from Rig 7432

From Facility X (Figure 27), the time margin is 54 minutes. Rig 7432 (Figure 28) has a smaller time margin of 21 minutes since the SAR helicopter, if aiding personnel on Rig 7432, first needs to arrive from Facility X before it can pick up injured persons at Rig 7432 and set course towards Hammerfest.

Potentially, if the time of mobilization is increased from fifteen to thirty minutes, both cases will still fulfill the performance requirement of three hours.

5.1.4 Conclusion regarding Scenario 1

When considering a DSHA 2, the performance requirements are fulfilled for both Facility X and Rig 7432. However, by increasing the mobilization time to thirty minutes instead of fifteen, the performance requirements for Rig 7432 would not be fulfilled. Pick up time of persons from the water is set to be three minutes. In a three months period, from the beginning of November until early February, both facilities are exposed to polar nights and will have no daylight. This may have an impact on pick-up times.

Regarding the DSHA 3, the performance requirement can be fulfilled for Rig 7432 when 6 and 21 persons need to be rescued from the sea after an emergency evacuation. For Facility X the requirements will also be fulfilled as long as the SAR helicopter is able to take off. However, if thirty people are in the sea, the SAR helicopter from Facility X needs assistance from a MOB-boat in order to satisfy the time requirement.

The analysis dimensions the use of only one MOB-boat. If a standby vessel has two MOB-boats available, the range will naturally increase. Other nearby supply vessels may also be equipped with MOB-boats, which will help even further in the case of a rescue operation.

Finally, both performance requirements for a DSHA 7 in the scenario are fulfilled. The time for an external medical response can be satisfied within a range of 100 Nm of Facility X. This is given that the SAR helicopter has an operational speed of 140 knots and a mobilization time of fifteen minutes.

5.2 Scenario 2

In this scenario the SAR helicopter is not stationed on Facility X, but rather on a floating base stationed between Facility X, Rig 7228 and Rig 7432. The spot can be found in Figure 29 below, inside the black circle to the left. The SAR helicopter will have an area based emergency preparedness cooperation for Rig 7228, Rig 7432 and Facility X. A SAR helicopter will also be stationed at Skrugard, which then cooperates with Rig 7325 and Goliat. However, as in Scenario 1, the Skrugard area will not be analyzed in the thesis.

In the baseline report for Norwegian oil and gas 064 /10/, stationing a frigate as a station en route when drilling far north in the Barents Sea is mentioned as a cooperation possibility. Such a vessel would not have to stay in one position. It could move within a certain area, the report suggests, as long as it is within a pre-determined sector, which still lets it reach the drilling facilities quickly when necessary. Doubts have however been expressed that such an agreement, which would be with the Armed Forces, would not be possible.

Scenario 2 uses the same helicopter parameters as the first scenario. These parameters can be found in Table 16, chapter 5.1.

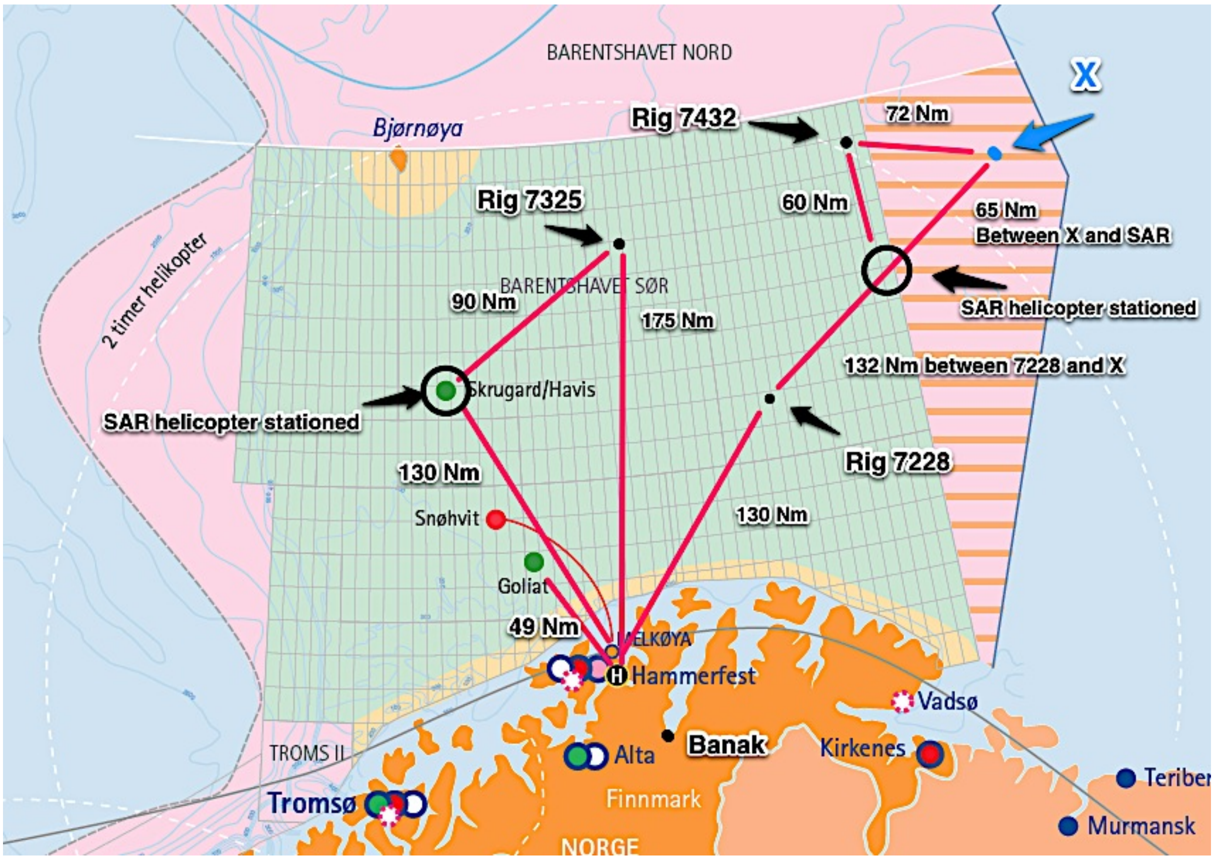

Figure 29 Scenario 2

Joacim Johannessen at Simon Møkster Shipping reacted as following to the suggestion of placing a SAR helicopter on a standby vessel /58/: "*It would be possible to place a hangar on a standby vessel where the SAR helicopter then could be stationed. This would however result in a very large and expensive ship. A ship is also much more vulnerable to the conditions of the sea than an offshore facility is, and a SAR helicopter would probably have more restrictions when taking off from a standby vessel than otherwise. Therefore, the availability and reliability of the helicopter is not likely to be as good as it would be on an offshore facility*".

Regarding the working situation on a standby vessel, Johannessen pointed out that the shifts often go for four weeks at a time. He assumed that pilots and paramedics would not always find these working conditions attractive.

Oskar Norderval at the Rescue helicopter service at Banak supposed, like Johannessen, that a SAR helicopter operability would be poorer if the helicopter is stationed on a vessel rather than on an offshore facility. This would be due to waves that have a greater impact on a vessel's movement than that of an offshore facility /59/.

Distances

SAR base	-	X	-	65 Nm
SAR base	-	Rig 7228	-	67 Nm
SAR base	-	Rig 7432	-	60 Nm
X	-	Hammerfest	-	254 Nm
Rig 7432	-	Hammerfest	-	243 Nm
Rig 7228	-	Hammerfest	-	130 Nm

5.2.1 DSHA 2 – Personnel in the sea following a helicopter accident

As already specified in Scenario 1, the DSHA 2 concerns all facilities within a facility's 500 meters safety-zone. The dimensioning capacity for rescuing personnel in the sea following a helicopter accident is still set to be 21 persons, including two pilots. The performance requirement indicates that all 21 persons should be rescued within 120 minutes after the accident has been alerted /11/.

Figure 23, presented in section 5.1.1, shows a timeline for rescuing personnel from sea after a helicopter accident. According to the figure, a flight time of only thirty-five minutes is possible from the SAR base and out to the actual scene. This results in a SAR helicopter radius of 82 Nm. Rig 7432, Rig 7228 and Facility X are all within this range, therefore the DSHA 2 performance requirement will be fulfilled.

5.2.2 DSHA 3 – Personnel in the sea following an emergency evacuation

Given that the SAR helicopter can lift off from the potential floating base, all three facilities will be within the range of 82 Nm. Personnel in the sea can in DSHA 3 thereby be rescued in time just like in the DSHA 2. However, if the dimensional amount of persons in the sea near Facility X is thirty persons, the SAR helicopter will, as in Scenario 1, not be able to rescue everyone in one operation.

To illustrate why it is difficult for one SAR helicopter to rescue as many as thirty people at a time, Figure 30 below shows a timeline where an attempt of this is made.

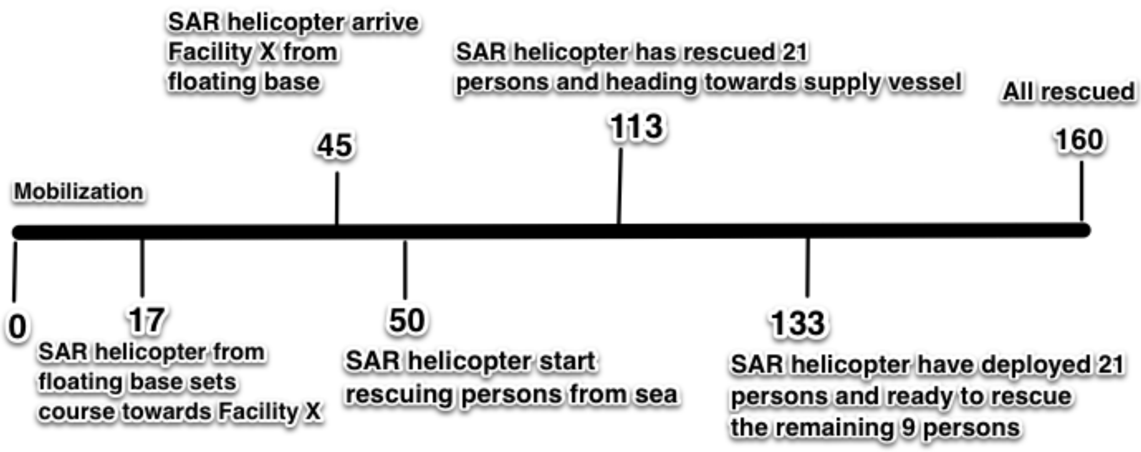

Figure 30 DSHA 3 - SAR helicopter stationed at floating base

The thesis presumes that a SAR helicopter only has the capacity to rescue 21 persons per flight. Therefore the helicopter needs to unload the first group of rescued people on a safe location before returning to the remaining nine in the water in this scenario. In Figure 30 above it is presumed that the rescued persons can be dropped off on a standby vessel located nearby Facility X. Such a standby vessel will presumably have the same landing restrictions as a floating SAR base. To assume that a floating SAR base will have good enough conditions for landing in the event of an accident is therefore risky, and a scenario where one SAR helicopter rescues thirty people can be considered unlikely given harsh weather conditions.

If the weather conditions do happen to be so favorable that the SAR helicopter safely can place the rescued on a standby vessel in the area, one may presume that the height of the waves is modest. Under the given circumstances, a MOB-boat can operate and rescue the remaining nine persons while the helicopter operates so the performance requirement can be fulfilled. However, if the weather restrictions keep a MOB-boat from participating in the rescue operation, assistance from a second SAR helicopter represents the next possible solution. This is illustrated in Figure 31 presented below. According to the timeline, all thirty persons are rescued from the sea within 154 minutes.

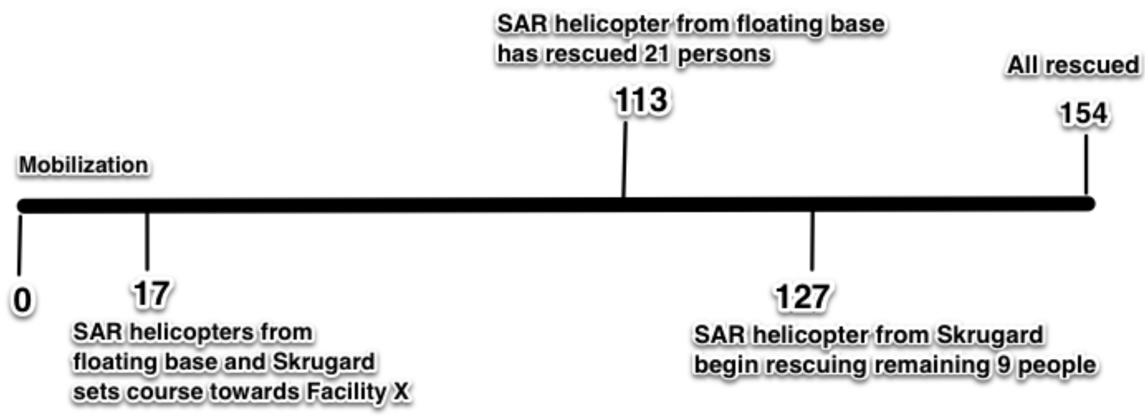

Figure 31 DSHA 3 - SAR helicopter assistance from both floating base and Skrugard

When compared to the limit of 120 minutes, this shows that the performance requirement can still not be fulfilled when SAR helicopter assistance is given only from Skrugard. The situation looks only slightly better when the SAR helicopter from Hammerfest is also used as a third helper in the rescue operation. Then all thirty can be rescued within 143 minutes (see Figure 24).

5.2.3 DSHA 7 – Illness/injury with need for external assistance

The DSHA 7 include serious illness/injury for a person that needs paramedic treatment and/or a quick transport to the hospital /55/.

By a use of external resources, the time of response should not exceed one hour. In emergency medicine, the time of transport should not exceed three.

Time of external medical response

The SAR helicopter is stationed on a floating base or vessel. The distances between the SAR helicopter and the actual facilities are given in section 5.2.1 where 67 Nm is the largest distance of the three facilities in question. In Scenario 1, the distance between Facility X and Rig 7432 was 72 Nm. The time of response was then 48 min, which was well within the performance requirement of one hour. It can therefore be reasonable to assess that the performance requirement for all three facilities will be fulfilled with sufficient margin also in Scenario 2.

Time of transport in emergency medicine

A premise of the scenario is that the hospital onshore is located in Hammerfest and not in Tromsø.

The range between the SAR helicopter base and Facility X is 65 Nm, and between Facility X and Hammerfest the distance is 254 Nm. The time needed to prepare the helicopter for an injured person transport from either Facility X, Rig 7432 or Rig 7228 is set to five minutes. The remaining parameters have been given in Table 15.

Figure 32 below shows that the SAR helicopter, when stationed on a floating base, fulfills the performance requirement for medical transport to a hospital with a time margin of nineteen minutes when rescuing personnel from Facility X and bringing them to Hammerfest.

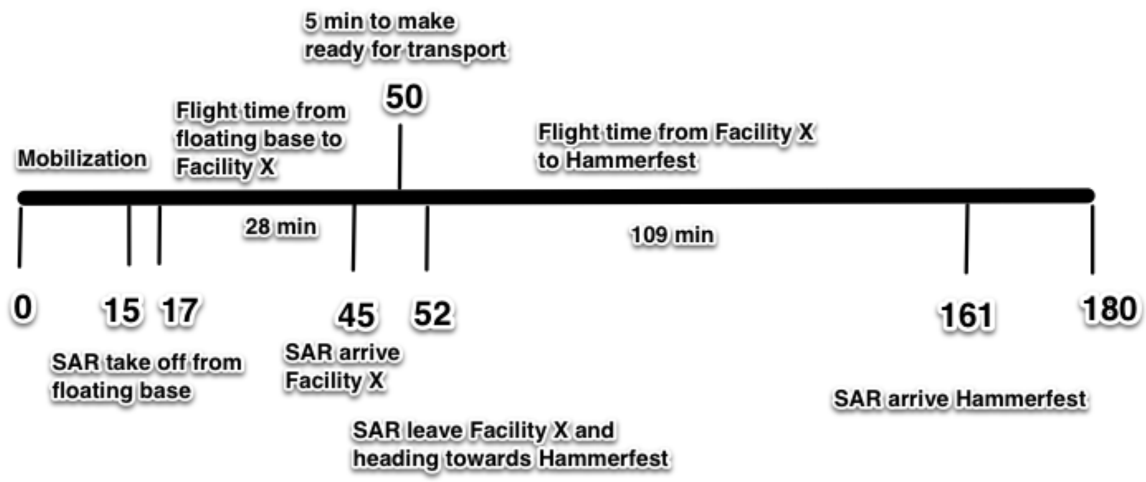

Figure 32 Timeline DSHA 7: SAR base - Facility X - Hammerfest

On this mission, the SAR helicopter covers 319 Nm (65 Nm + 254 Nm). Calculations show that the performance requirement for Rig 7432 and Rig 7228 also will be fulfilled since the total helicopter range in these two cases only will be 303 Nm and 197 Nm.

5.2.4 Conclusion regarding Scenario 2

The performance requirements are fulfilled for both the DSHA 2 and the DSHA 7, presuming that the SAR helicopter can take off from the floating base. In a rescue operation, the use of a standby vessel will be the second alternative.

In the case of a DSHA 3, the performance requirements for all three facilities are fulfilled when 6 or 21 persons are in the water. However, if thirty people are in the sea, something which in the thesis only can occur on Facility X, the performance requirements will not be met when rescuing with SAR helicopters, not even if assistance is given from Skrugard and/or Hammerfest. To fulfill the performance requirement of rescuing thirty persons within 120 minutes, a MOB-boat needs to rescue the nine persons who cannot be picked up on the helicopter's first run.

A major benefit of placing the SAR helicopter on a floating base rather than on Facility X is that the helicopter cannot become unavailable due to smoke or a gas leak on the platform. The SAR helicopter can therefore always assist in the event of a DSHA 3, and the assistance from a MOB-boat will not be necessary to uphold the performance requirement. However, the analysis shows that if the dimensional amount of persons in the water who need rescue is thirty, the SAR helicopters will not manage to rescue all persons within the performance requirements of 120 minutes.

5.3 Evaluation of Scenario 1 and Scenario 2

The following chapter contains four sub-chapters. A sensitivity analysis regarding the SAR helicopter speed will firstly be performed. In chapter 5.3.2 a further presentation of the results found in Scenario 1 and Scenario 2 will be given. Chapter 5.3.3 evaluates the results from the case-analysis, and finally the last sub-chapter discusses which of the two scenarios is the most preferable.

5.3.1 Sensitivity analysis SAR helicopter speed

The effect of reducing the SAR helicopter speed from 140 knots to 125 knots will here be highlighted. Again, the rest of the parameters used are the ones previously given in Table 16, chapter 4.5.

In the DSHA 2, a SAR helicopter with a speed of 140 knots can cover a maximum range of 82 Nm when fulfilling the performance requirement of a two-hour rescue. If the speed is reduced to 125 knots, the range will shrink to 73 Nm. A SAR helicopter speed of 125 knots will therefore be adequate to fulfill the performance requirement of 120 minutes in Scenario 1 and Scenario 2. The distance between the floating base where the SAR helicopter is stationed (Scenario 2) and out to the three nearby rigs, which is included in the area based emergency preparedness, are all shorter than 73 Nm.

When considering the DSHA 3, a decrease in SAR helicopter speed will naturally cause the performance requirements to be exceeded even more than before when rescuing thirty persons from the sea. The SAR helicopters from Skrugard and Hammerfest will see a thirteen minutes increase in flight time out to Facility X. If the number of persons in the sea is 6 or 21 however, the performance requirement can still be fulfilled by the use of one SAR helicopter stationed on either Facility X or the floating base.

There are two performance requirements that have to be satisfied when evaluating the DSHA 7. The first, the time of external medical response within one hour, will see a range reduction of 100 to 90 Nm when the SAR helicopter speed decreases from 140 to 125 knots. However, a range of 90 Nm will still be sufficient to fulfill the performance requirement for both Scenario 1 and 2. Secondly, the required emergency medicine transport time of maximum three hours is more sensitive to changes in the helicopter speed. In Scenario 1, (see Figure 28, section 5.1.3 for more information) the time margin was 21 minutes when a SAR helicopter stationed at Facility X transported injured personnel from Rig 7432 to Hammerfest. Figure 33 below shows that the margin is reduced to only four minutes due to a reduced SAR helicopter speed.

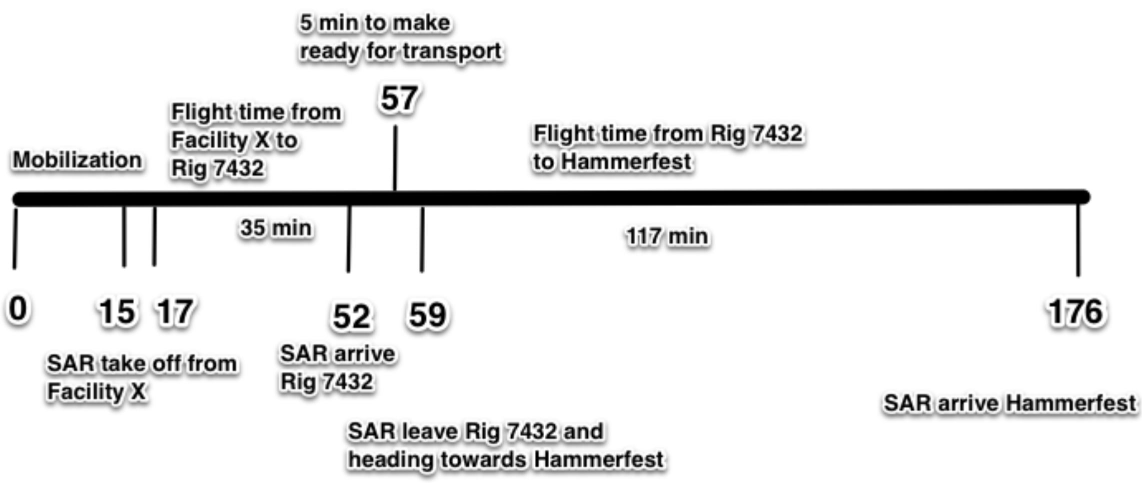

Figure 33 Timeline DSHA 7: Facility X - Rig 7432 - Hammerfest (125 knot)

In Scenario 2, the time margin will be reduced to a scarce two minutes, as Figure 34 on the next page shows.

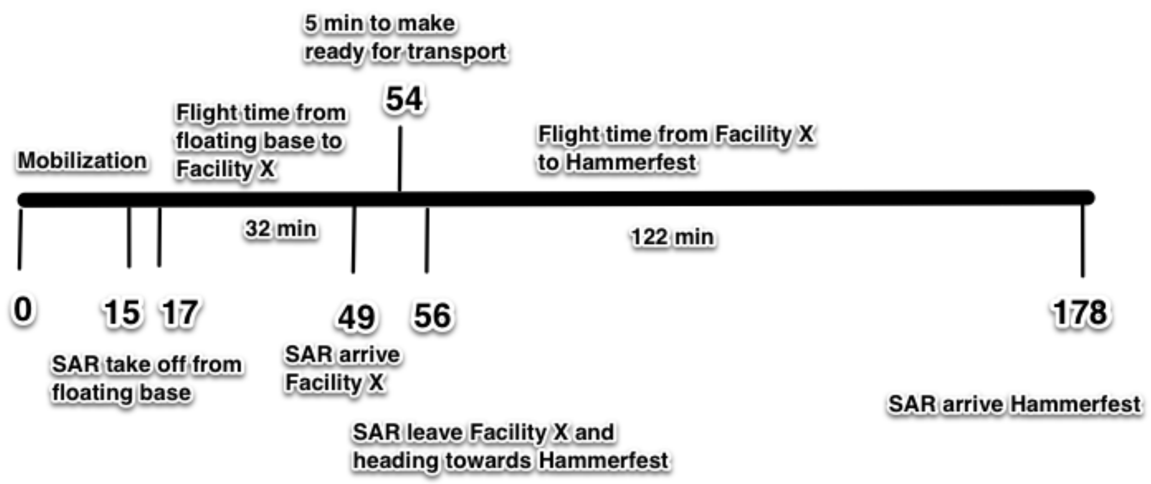

Figure 34 Timeline DSHA 7: SAR base - Facility X - Hammerfest (125 knot)

5.3.2 Comparing results from Scenario 1 and Scenario 2

Here a table comparing the results from the two scenarios is presented. The times given in the table indicate the time margin to the performance requirements for each DSHA. For the DSHA 3 in Scenario 1 two different times are given for standby vessels. The first one is the time margin of a rescue operation in daylight, the other one in darkness.

	Scenario 1	Scenario 2
DSHA 2	Worst case: 72 Nm 4 min	Worst case: 67 Nm 6 min
DSHA 3 • **6 persons** • **21 persons** • **30 persons**	**SAR helicopter** • 49 min • 4 min • Time limit exceeded (- 23 minutes)	**SAR helicopter** • 51 min • 6 min • Time limit exceeded (- 23 minutes)
• **6 persons** • **21 persons** • **30 persons**	**Standby vessel day/night** • 99,5 min / 92 min • 62 min / 32 min • 39,5 min / -4 min	**Standby vessel** Not needed since it is presumed that the SAR helicopter always can lift off from base

DSHA 7	**Medical response:**	**Medical response:**
• **External medical response**	Facility X: OK Rig 7432: 12 min	Facility X: 15 min Rig 7228: 14 min Rig 7432: 17 min
• **Transport in emergency medicine**	**Transport:** Facility X: 54 min Rig 7432: 21 min	**Transport:** Facility X: 19 min

Table 19 Comparing results from Scenario 1 and Scenario 2

5.3.3 Evaluation of results

As Table 19 above shows, the performance requirements were fulfilled for Scenario 1 and 2 with almost similar margins when evaluating the DSHA 2, personnel in the sea following a helicopter accident. The given factors for success are a mobilization time of fifteen minutes, a helicopter speed of 140 knots, and a SAR helicopter located within a distance of 82 Nm (more information in section 5.1.1).

The differences between the two scenarios are larger when considering a DSHA 3, personnel in the sea following an emergency evacuation. If gas, smoke or fire on the facility makes it impossible to use the helicopter deck on Facility X, the SAR helicopter stationed there will for example be unavailable for a given time-period. Therefore a standby vessel near Facility X or other SAR helicopters must be deployed.

Based on the information given in chapter 5, it is reasonable to presume that one or several MOB-boats will manage to rescue a dimensional amount of persons from the sea within the performance requirement of 120 minutes. In order for this presumption to work, the standby vessel must be located nearby the facility in question. The weather conditions must also allow the MOB-boats to operate without limitations.

Leiv Eiriksson, a drilling rig that will be operating in the Norvarg 2 area (7225/3-2), will have two dedicated supply vessels on standby at all times (Viking Lady and Viking Athene) /60/.

Based on the calculations and scenarios presented in the thesis, one can recommend that every facility operating in the Barents Sea follows the example of the Leiv Eriksson rig and has at least one standby vessel available nearby.

In Scenario 2 it is presumed that the SAR helicopter can lift off from the floating base at all times and thereby fulfill the performance requirements for rescuing 6 and 21 persons from the sea. If the number of people needing rescue is thirty, the SAR helicopter will need assistance from a standby vessel to make it within two hours.

A SAR helicopter stationed on a vessel will have a lower operability than if it were placed on an offshore facility. This is because the motion of the vessel caused by waves is much greater compared to on an offshore facility. It is therefore possible that a SAR helicopter is unavailable when needed in an emergency situation because the movement of the floating base is too extensive for the helicopter to lift off. In such conditions, MOB-boats or other SAR helicopters must be used.

Harsh weather conditions may not only have an impact of SAR helicopter availability, but also on the use of MOB-boats. The Norwegian oil and gas 064 has set a limitation of significant wave height when using a MOB boat to H_S<4,5 m. If waves are higher than this, MOB-boats cannot operate responsibly and effectively in a rescue operation.

In scenarios when this is the case and thirty people find themselves in the water, other SAR helicopters must assist. The choppers located on Skrugard and in Hammerfest have nearly the same distance out to Facility X. Calculations in the thesis show that the performance requirement of two hours will be exceeded regardless of which location the assistance is given from. The alternative that exceeds the time limit the least in any given situation should therefore be chosen. SAR helicopter assistance from both locations, Skrugard and Hammerfest, should be deployed in a DSHA 3 when:

- The SAR helicopter stationed at Facility X has rescued 21 persons (the two assisting SAR helicopters will be responsible for the remaining nine)
- The SAR helicopter is unable to lift off from Facility X (the two assisting helicopters will have to rescue all thirty persons in the water)
- The SAR helicopter stationed on a floating base has rescued 21 persons from Facility X (the two assisting SARs will rescue the remaining nine)

When evaluating the DSHA 7, illness/injury with need of external assistance, the performance requirement is fulfilled in both scenarios. For an external medicine response, time of mobilization must not exceed fifteen minutes, two minutes are calculated for the helicopter to reach the desired operational speed of 140 knots, and the helicopter can fly for 43 minutes before arriving the facility. If these requirements are fulfilled, the time limit of one hour will not be broken in a rescue operation and the helicopter will be able to cover a range of 100 Nm. When evaluating the use of time in emergency medicine transport, the situation also looks good for both Scenario 1 (Rig 7432) and Scenario 2 (Facility X). In a worst-case scenario, a SAR helicopter will have respectively 21 and 19 minutes left on the three-hour time limit.

Situation near Skrugard

Emergency preparedness with a SAR helicopter stationed at Skrugard will not be analyzed in the thesis. This has been clarified both in section 5.1 and 5.2. However, a comment on the findings made in Scenario 1 and 2 will here be made in relation to the Skrugard area. Appendix A3 shows the results from the analysis performed.

In a DSHA 2, the SAR helicopter has to be within 82 Nm of the accidental scene. Figure 22 in chapter 5.1 shows that the distance between Skrugard, where the SAR helicopter is stationed, and out to Rig 7325, is 90 Nm. The performance requirement is thereby exceeded by a few minutes. A SAR helicopter in Hammerfest may also assist in rescue operations close to Rig 7325 and will need 75 minutes of flight time to cover a distance of 175 Nm.

Between Skrugard and Rig 7228 there are 130 Nm. The same distance is found between Hammerfest and Rig 7228. One single SAR helicopter stationed at Skrugard will only be able to rescue fourteen people in the water within a time limit of two hours. The requirement of 21 persons can in other words not be fulfilled. If the Hammerfest SAR helicopter contributes, however, all persons will be rescued within the deadline.

Given that Rig 7325 and Rig 7228 both have their own standby vessel nearby, one can presume that one or more MOB-boats will already have rescued a number of persons before a SAR helicopter arrives. Yet, it is important to be aware of the recommended weather restrictions of H_S<4,5 m when using MOB-boats.

In a DSHA 3, a SAR helicopter on Skrugard might experience difficulties taking off from the facility due to smoke or a gas leak on the facility. The Hammerfest SAR chopper is presumed to be able to assist at all times. In case of a gas leak at Skrugard, the helicopter from Hammerfest will be able to rescue fourteen people within two hours. A MOB boat must be deployed to save the remaining seven within the given time frame. A case where thirty people need rescue from the water around Skrugard is not likely since drifting ice is not a problem there. Free-fall lifeboats can be used all year long.

In the event of a DSHA 7, time of medical external response, the time requirement of one hour for Rig 7228 will be difficult to fulfill. The rig is located 130 Nm from both Skrugard and Hammerfest. As the thesis calculations show, a facility must be within 100 Nm from a SAR helicopter in order to manage the performance requirement. For Rig 7228 two options remain: The rig either needs to be equipped with sufficient medical personnel and instruments, or it must be accepted that the performance requirement will be exceeded. The final option is not likely to be accepted amongst labor unions or authorities, and an expanded dimensioning of safety measures onboard the rig can therefore be recommended.

However, in the thesis' Scenario 2, Rig 7228 is not included in the area based emergency preparedness for Skrugard. For Skrugard to have its own SAR helicopter base (Scenario 2) would potentially only influence the area's emergency preparedness to a minor extent. Rig 7228 is however included in Facility X's emergency preparedness. Still, it is difficult to decide which scenario is the most favorable for Skrugard – Rig 7228 being part of the area based emergency preparedness for the platform or not.

Is it possible to have a dimensioning mobilization time of thirty minutes when operating so far from the shore?

In the case of a DSHA 2, the range of a SAR helicopter would decrease from 82 to 47 Nm if the mobilization time changes from fifteen to thirty minutes. The result would be that the performance requirements in Scenario 1 and 2 could no longer be fulfilled. In the Polar night period in the Barents Sea, between November and February, persons in the sea are more likely to experience a tough psychological strain when being stranded in total darkness. It would therefore be of extra importance to keep the mobilization time down to a minimum, fifteen minutes, in the winter.

If the mobilization time is increased to thirty minutes in a DSHA 7, the time of external medical response will no longer satisfy the performance requirements. In Scenario 1, for instance, the time margin was originally only 12 minutes. Compensating measures could therefore be implemented, such as an increase in the medical expertise on board. It is however worth noting that having a doctor and two nurses (one with special expertise) on each facility would presumably cost more than to uphold a mobilization time of fifteen minutes.

When considering the deadline of three hours in emergency medicine transportation, the time margins in Scenario 1 and 2 were originally 21 and 19 minutes in the two worst-case scenarios. By a fifteen minutes mobilization time increase, the margins will be reduced to only 6 and 4 minutes.

The three-hour requirement of an emergency medicine transport is not a critical upper limit. The probability of survival will however gradually decrease the longer it takes for the helicopter to reach a hospital. For a cerebral infarction, an adequate treatment must for example be given in a hospital within three to four hours after the patient had the stroke /60/. When considering emergency medicine transportation, it is more difficult to calculate time restrictions and operational limits than in DSHA 2 transport flights because an emergency medicine flight is likely to occur under more unstable circumstances. To have estimates is still important, and to have a time buffer in the calculation might also be a good idea since the DSHAs are dimensioned for weather conditions that may reduce the operational speed of a chopper. This will be further discussed in chapter 6.7.

Based on the information given above, it will not be recommendable to increase the mobilization time from fifteen to thirty minutes in either a DSHA 2 or 7 because performance requirements then cannot be fulfilled. If one still decides to do so, other compensating measures must be implemented. Concerning DSHA 3, the performance requirement when rescuing 30 persons from sea are already exceeded with a mobilization time of 15 minutes (given that a MOB boat cannot assist in the rescue operation). To increase the mobilization time to 30 minuets would therefore be difficult to support and recommend.

SAR helicopter operational speed of 125 knots

Results from the sensitivity analysis (5.3.1) show that the performance requirements for a DSHA 2, 3 and 7 can still be fulfilled if a SAR helicopter reduces its speed from 140 to 125 knots. However, the time margins will naturally be smaller.

When covering distances up to 100 Nm, the speed of the SAR is only of minor relevance since the picking up of persons from the water takes up a greater part of the total time available than what the flying time does. An example is the DSHA 2 in Scenario 1 (see section 5.1.1 and 5.3.1). Here it took four minutes longer to reach Rig 7432 from Facility X (72 Nm) due to reduced helicopter speed.

When a SAR helicopter covers larger distances of 200 Nm or more, however, the helicopter speed has a big impact on how much time will be available for an actual rescue within the performance requirements. Flying from Facility X to Hammerfest (254 Nm) will take 13 minutes more – an increase in flight time from 109 to 122 minutes – if the helicopter speed is reduced. In a DSHA 2 and 3, the reduced speed will result in three to five minutes extra spent on flying time. The time of transportation in emergency transport during a DSHA 7 will be sixteen to eighteen minutes longer than otherwise when helicopter speed is reduced.

Interestingly, the times pointed out above show that an increased mobilization time might be considered to have a more negative impact on a rescue operation than a reduction of SAR helicopter speed.

5.3.4 Comparison between Scenario 1 and Scenario 2

Which one of the two scenarios is the most preferable?

Performance requirement margins in Scenario 1 and 2 are quite similar regarding a DSHA 2 and a DSHA 7. In the event of a DSHA 3, however, the two scenarios are the most different. As already pointed out, a SAR helicopter stationed on Facility X (Scenario 1) may not be able to take off if there is smoke around the helideck or if there is a gas leak and the wind blows from the leakage area towards the helideck. As also mentioned already, a Scenario 2 floating base in the shape of a vessel will more likely be affected by large waves than an offshore facility will. This may prevent a SAR helicopter from lifting off. If the unavailability of a SAR helicopter is greater when placed on a floating base than when based on Facility X, Scenario 1 seems to be the best solution in the event of a DSHA 3.

If a floating base should be an actual alternative to place a SAR helicopter on, it seems reasonable to presume that it would also be used for other purposes, such as a refueling station and a reliable landing station for SAR helicopters participating in other emergency missions. However, if helicopters are unable to land on the floating base due to large waves, it is not a reliable landing station. When operating that far from land, it is extremely important that the landing alternatives are reliable since other options are limited. Scenario 2 does not give a considerably better result than Scenario 1 in this case. A standby vessel equipped with a SAR helicopter hangar would also be costly due to its large dimensions. Therefore it is difficult to stand up for a potential choice of having a SAR helicopter stationed on a floating base. Placing a SAR helicopter on Facility X rather seems to be the better alternative.

Is a fifteen-minute mobilization time realistic?

As to mobilization time there are some differences on how this is practiced on the Norwegian Continental Shelf. The organization of the helicopters is the crucial factor /10/.

On the Southern Fields, the mobilization time is fifteen minutes in the day and thirty minutes in the night. At Oseberg, Tampen and Halten Nordland the daytime limit is the same as on the Southern Fields, but the nighttime mobilization time only twenty minutes. Hammerfest has a mobilization time set to fifteen minutes in the event of a transport flight and one hour otherwise. As a precept, Eni Norge uses forty minutes as a dimensioning mobilization time.

In the baseline report for Norwegian oil and gas 064 it is being stated that the mobilization time is set, as a point of departure, to thirty minutes after 9pm. Maintaining a fifteen minutes mobilization time during late hours would have a negative impact on the pilots' breaks. From the tower, air traffic is controlled in such a way that in the event of late flights, available standby vessels are ordered out to cover for the longer helicopter mobilization time. If the weather conditions make the use of standby vessels unfavorable, the tower will consider two possible options: Cancelling the flight, or maintaining a fifteen minutes mobilization time for the SAR helicopter and rather accepting a delay in shuttle traffic until pilots have completed their breaks /10/.

The emergency preparedness arrangements for the Air Force 330 Squadron require that a crew should be ready for immediate departure 24/7, year round. Immediate departure in this case means a response time of approximately fifteen minutes /36/.

Having a fifteen-minute mobilization time in the Barents Sea should, based on the information presented above, not be a problem.

Helicopter operational speed of 140 or 125 knots?

According to the "Pre-study of new SAR helicopter capacity, Sub document 2 of 5 - Overall strategy document" /57/, most of the new medium rescue helicopters will have a practical operational speed limit of about 150 knots. However, such high velocity will result in large fuel consumption. Oskar Norderval at the Rescue Coordination Center at Banak suggested that 140 knots would be a reasonable operational speed for new rescue helicopters. This is considering that their top speed is 150 to 160 knots, depending on the model. The Sea King helicopters, which are used today, have a dimensional speed of 125 knots. They are quite old, and it is therefore reasonable to assume that new and improved helicopters will manage to operate with a higher velocity than the Sea Kings. After having included the operational restrictions detailed in chapter 4.4.3, one can state that 140 knots will be a reasonable operational speed for new SAR helicopters.

Harsh wind and weather conditions, that might have an impact on the speed, will then also have been taken into consideration. Strong headwinds will for example slow a helicopter down. However, the loss of speed might be made up for on a potential return flight. Based on the sensitivity analysis performed in section 5.3.1, performance requirements can still be fulfilled when a SAR helicopter speed is reduced from 140 to 125 knots.

An implementation of new rescue AWSAR helicopters is planned to begin by 2020. These helicopters will operate better in all weather conditions, have a higher operational speed and a much greater range than the Sea King helicopters operating today /36/. New calculations and assessments for emergency preparedness in Arctic oil and gas exploration will then have to be made. For the time being, a SAR helicopter speed of 140 knots seems to be a reasonable assessment based on the information given above.

6. Discussion

6.1 Evaluating the purpose of the thesis

The goal of the thesis is to identify special emergency preparedness conditions that distinguish oil and gas exploration in the Barents Sea from that in the North Sea. The identification process has taken place in chapter 3. There are, however, still uncertainties concerning which security measures need to be taken into account when considering a sufficient evacuation of personnel. This is because petroleum activities in the Barents Sea still are in the start-up phase. For this reason, the thesis does not suggest specific solutions to how the emergency preparedness can be handled sufficiently. Instead, challenges that the operators carefully need to consider before starting to operate in the area are being pointed out.

The thesis analysis in chapter 5 could potentially have been more extensive. The simplicity has however been intentionally chosen to make the analysis more lucid and specific. The main intention of choosing a floating SAR helicopter base in Scenario 2 has been to see if such an arrangement can help fulfilling DSHA 2, 3 and 7 performance requirements better than when the helicopter is stationed on a production facility like in Scenario 1. Therefore it has been considered irrelevant whether the floating base is a standby vessel/coastguard vessel/jacket.

The Facility X location 74°N/35°E has been chosen because it is likely one of the most remote locations that can be considered for exploration in the near future. Also, the safety challenges there regarding infrastructure, sea ice/icebergs and communication coverage are potentially some of the most difficult ones in the area. A sufficient dimensioning of the emergency preparedness challenges when it comes to evacuating personnel on Facility X will therefore cover most of the challenges concerning oil and gas exploration in the Barents Sea as a whole.

Despite the simplifications made in the analysis, the thesis specifically points out which areas need special attention when it comes to emergency preparedness. Perhaps this can serve as a helpful indicator for future developers. It remains to be seen how the development in the Barents Sea will actually degenerate and what kind of emergency preparedness solutions will be implemented.

6.2 Uncertainties in the analysis

In the chapter 5 analysis, the parameters used in the SAR helicopter calculations are based on the Safetec Nordic AS report ST-04516. Two minutes were added to make up for the time a SAR helicopter needs to reach 140 knots. The calculations in the analysis, however, have not taken into account the lower SAR helicopter speed the first two minutes of the mission. Indirectly, the extra two minutes mean that the total mobilization time would be seventeen minutes in a DSHA 2, 3 and 7 (time of transport in medical response). The time of transport in emergency medicine would indirectly increase to nineteen minutes since the two-minute time slot has to be added both times the helicopter takes off. Given that an average SAR helicopter speed the first two minutes after takeoff is 90 knots, the helicopter could manage to cover an additional range of 3 Nm.

The effect that wind has on helicopter flights is not fully taken into consideration in the analysis. Section 3.7.4, however, presents results from S. Jacobsen's master thesis where wind effects are included. These show that given a 50 knots headwind, the flying time over a distance of 260 Nm would increase with approximately fifty minutes. However, if the helicopter is expected to make a round trip it will have tailwind on its way back. The increased flight time for 520 Nm would then be thirty minutes.

To achieve a better base for deciding where a SAR helicopter should be stationed, a more detailed analysis should be performed when it comes to the possibilities of landing a SAR helicopter on a standby vessel versus on an offshore facility. The uncertainties are large when considering the helicopter's availability on a standby vessel. Data on SAR helicopter landings on standby vessels and offshore facilities should therefore be collected, and weather conditions should be a crucial factor of the measurements. If this is done, it will be easier to decide which alternative is more suitable.

In the analysis, problems related to fuel requirements are not assessed. The same goes for alternative landing sites that are mandatory for helicopter transport.

The three-minute pick-up time when rescuing persons from the sea has been based on the baseline report for Norwegian oil and gas 064. In the report, an increased rescue time in the event of sea ice or icebergs is not taken into consideration.

6.3 Training and drills

All DSHAs in connection with area based emergency preparedness, with the exception of a DSHA 7, are rare incidents. A potential verification through incidents that have occurred is therefore much too random and insufficient. Verification must rather be found through exercises and, to a certain degree, analyses /10/.

To provide the best possible qualifications for the crew, it is desirable that training and exercises take place under as realistic conditions as possible. At the same time it is an established principle on the Norwegian Continental Shelf that one should not expose crew and live markers to unnecessary risk during training and exercises. This sets clear restrictions as to how realistic the conditions can actually be. As a result, weather restrictions during training and exercises are often stricter than what one could expect the emergency preparedness resources to operate efficiently under. This is to avoid unnecessary risk exposure for the people involved in the drill; if the conditions are close to the weather expected in real life, the risk exposure for the involved is considered to be unnecessarily high. However, if the gap between training conditions and the weather conditions that occur in the Barents Sea is too large, the training will not have its desired effect. A verification through exercises will also not be possible /10/.

It is therefore essential that exercises are carried out under marginal conditions. Such conditions include wind strength, wave circumstances, sea temperature, daylight/darkness, etc. Under the most marginal conditions it will be wise not to use live markers. When collecting verification data on which requirements can be met, two situations must be considered: When a SAR helicopter is the primary emergency preparedness resource, and when a standby vessel is either the primary resource or, under certain conditions, the only resource available /10/.

The Danish company Esvagt provides a good example for training under realistic conditions. When the company changes crew on its standby vessel, a MOB-boat under the prevailing weather conditions is used. As a result, the company’s crews are trained in maneuvering the MOB-boat and implementing personnel transfers under realistic weather conditions /10/.

Survival suit

In the SeaAir immersion suit demonstration presented in section 3.9, these were the important findings:

- An intermediate layer of clothing would normally enhance heat conservation
- Both test persons expected that their situation would be more challenging under more realistic conditions at sea

Exercises on how to perform emergency procedures and how to use rescue equipment are carried through in controlled situations so personnel should not be unnecessarily exposed to risk. This may however also result in drills that lack realistic challenges, and test persons may be deluded in regards to what they may experience in real-life emergency situations.

Some might state that the average Norwegian offshore worker is often unlike the people used as testers when evaluating emergency equipment and procedures. Theoretically, if a typical offshore worker is an overweight person of high age who smokes and is in poor physical condition, it is essential to observe and document how low temperatures, cold waters and icing will affect such a person. A representative selection of offshore workers should therefore be chosen for such tests because overly fit testers, who do not represent the majority of offshore workers, will provide irrelevant data.

Another point to consider is the following: Given that an unfit person can survive in Arctic waters only half as long as a fit person can, restrictions on the health state of offshore workers operating in Arctic waters need to be evaluated thoroughly.

A good way of training personnel for out-to-sea emergency situations could be to offer voluntary courses where the participants are exposed to cold water, experience the effect of this, and become familiar with their own reactions to such conditions.

6.4 Icing around facility

According to Activity regulation §77 and Facilities regulations § 44, personnel on a facility should be evacuated quickly and efficiently at all times under all weather conditions. Free-fall lifeboats supplemented by rescue chutes and associated life rafts should be used as means of evacuation to sea.

Onboard each facility, alternative solutions that consider specific local conditions must be developed in case free-fall lifeboats cannot be used. According to the Management regulations section 4 and 5, "*the solutions and barriers that have the greatest risk-reducing effect should be chosen based on an individual as well as an overall evaluation. Collective measures should be preferred over protective measures aimed at individuals. Barriers should be established that:*

- *Reduce the probability of failures and the development of hazard and accidental situations*
- *Limit possible harm and disadvantages*

The responsible party should implement the necessary measures to remedy or compensate for missing or impaired barriers."

A use of free-fall deployment systems would need to be considered carefully. To this date there are no free-fall evacuation systems known to deploy into icy waters. Even with very small ice concentrations it will be hazardous to utilize a free-fall system. Davit launching could maintain the craft's integrity and personnel safety during deployment, but launching into or onto ice with waves present and a safe disconnection are aspects that should receive special attention.

As seen through the arguments presented above, a responsible part on each facility needs to display necessary evacuation options that are especially sculpted for the location in question. A natural part of this task would be to also evaluate other options that can supplement or compensate a potential use of free-fall lifeboats.

When looking at the occurrence of sea ice in the Barents Sea, statistics show that sea ice in the area north of 73°N and east of 31°E usually has a return frequency of 100 years. The return frequency increases to ca. 10 years at 74°N and 33°E. Facility X, analyzed in chapter 5, is located 74°N and 35°E. Although the amount of sea ice in the Barents Sea generally seems to be decreasing, it seems reasonable to presume that a presence of sea ice will occur every ten years around Facility X.

Chapter 5 has considered DSHA 3 rescue scenarios with 6, 21 and 30 persons in the water. It has been presumed that sea ice will not cause a problem for the use of free-fall lifeboats from drilling rigs. If the opposite is the case, the drilling rig will simply disconnect and move to a safe location until the sea ice is gone. However, Facility X is an offshore production facility and not a drilling rig. It is therefore expected to operate all year long. To disconnect and leave location due to drifting sea ice seems to be an expensive solution. Alternative lifeboat options, such as conventional lifeboats or other available rescue concepts, should therefore be introduced.

The number of thirty people in the water who needs rescue has been chosen for the DSHA 3 in the thesis because it causes vital challenges. As the analysis has shown, one single SAR helicopter cannot rescue thirty people within the time limit of two hours. Assistance from a MOB-boat would be necessary. Sea ice around Facility X might however cause problems for a potential MOB-boat or a standby vessel during a rescue operation, and having a second or third helicopter intervene could then be another option. However, the analysis has also shown that SAR helicopters stationed on Skrugard or in Hammerfest would be too far away from Facility X to potentially assist within the given time frame. A possible solution to the problem could be to place a helicopter closer to Facility X, for instance on Rig 7228, during the winter months when the spread of sea ice is at its maximum. Such a helicopter would increase the emergency preparedness in the area by being able to assist in a thirty-person rescue operation within the time limit of two hours.

As mentioned in chapter 3.8.1, PSA considers free-fall lifeboats to be the best currently available technology in the field of lifeboat evacuation on the Norwegian Continental Shelf. Equipping Facility X with both free-fall and conventional lifeboats could be a solution that would increase safety onboard. The lifeboats would take up much space on the facility, something which potentially could cause higher costs when building the rig because it must have an increased size. This problem is however not considered in the thesis.

6.5 Icebergs treated as a DSHA

The baseline report for Norwegian oil and gas 064 discusses whether or not ash clouds should be considered a DSHA.

As a repetition: A DSHA is defined as a "*selection of hazardous and accidental events that can be used for the dimensioning of the emergency preparedness for an activity*".

In spring of 2010, a large ash cloud from the Eyjafjöll eruption stopped air traffic in large parts of Europe. The duration of the shutdown was however not significantly longer than most of the longer periods of shutdown due to fog. Fog is not treated as a separate DSHA. The report concluded that this should be the case also for ash clouds. However, ash cloud conditions would entail a need to operate offshore facilities in another manner, which would indirectly have an effect on the area based emergency preparedness.

The ash cloud case above also describes the situation regarding icebergs: The baseline report, similarly to ash clouds, does not consider icebergs to be a DSHA. Still, icebergs need to be carefully considered when developing an area based emergency preparedness in the Barents Sea because they do occur in the area.

An argument for treating icebergs as a DSHA is the demands of operating efficiency on the offshore facilities. It is a current trend that the efficiency level increases, and production downtime caused by a drifting iceberg on collision course, forcing the facility to disconnect, would be highly unfortunate. The costs of having sufficient iceberg management might therefore be lower than the cost of potential downtime.

Pat Barron in the MD Group has said: "*Ideally, an iceberg should be detected days in advance.*" To be able to do this one needs proper tools. In contrast to ash clouds, icebergs can be dealt with through the use of emergency preparedness resources such as standby vessels. Given sufficient weather forecasts and detection systems, icebergs can also be detected at an early point. In contrast to icebergs, emergency preparedness resources cannot prevent ash clouds. Still, if an ash cloud hits an offshore facility, it will indirectly have an impact on the emergency preparedness: The facility will have to be operated in a different manner than usual.

When looking more closely at the characteristics of icebergs, section 3.2.2 specified that the average drift speed of two icebergs observed in the Barents Sea were measured to 0,25 m/s and 0,28 m/s. Due to an atmospheric low, one of the icebergs increased its drifting speed to 1,13 m/s for a 31-hour period. A drifting speed of 1 m/s equals approximately two knots and is a good dimensional presumption for an iceberg's drift speed. The section that dealt with Hibernia in chapter 3.2.2 showed that icebergs requiring intervention were tackled proactively while they were still twenty kilometers or more away from the platform. Given an iceberg drift speed of 1 m/s, the iceberg would use 5,5 hours to drift those twenty kilometers.

Since drifting icebergs, as mentioned, are not considered to be a DSHA in the guideline Norwegian oil and gas 064, it might be problematic to develop reasonable performance requirements for facilities in areas where icebergs might appear. However, one may compare the event of an iceberg with a DSHA 4 for collision hazard described in the baseline report. A DSHA 4 typically concerns the following two cases:

- Ship on collision course
- Drifting vessel/object

A drifting vessel/object could in this case be descriptive of an iceberg. The time requirement for a notification of a vessel on collision course is fifty minutes. The requirement is based on the possibility of making a decision regarding evacuation twenty-five minutes before potential collision time. The remaining time should be sufficient to evacuate all personnel into lifeboats with a certain time margin. However, recent information indicates that fifty minutes is too little time for facilities with a high number of people on board to evacuate sufficiently, especially if free-fall lifeboats are installed parallel to one other. For facilities that only require one or two lifeboats for the evacuation, or are equipped with multiple lifeboats that point in different directions, the fifty-minute time frame is sufficient. It is up to each facility to make sure that the performance requirements for emergency preparedness solutions fit the facility's risk picture and specific conditions. If it is necessary the emergency preparedness requirements must be adjusted locally /10/.

Ships and drifting objects, such as facilities and rigs, have all installed an Automatic Identification System (AIS). This makes them easy to spot through the use of surveillance equipment. The equipment can detect AIS signals from large vessels within 20 Nm of the facility. From smaller vessels the range is 12 Nm /11/. An iceberg will of course not be equipped with such a system. Spotting it in time will therefore be more difficult.

Chapter 3.2.2 specifies that an icebergs' drifting course will be dependent upon factors such as sea current, wind direction and the Coriolis effect. A combination of these factors leads to unpredictable iceberg movements. This poses a signification threat to offshore facilities. Even on Hibernia, which unlike Facility X is a gravity-based platform constructed to withstand impact from an iceberg, a comprehensive iceberg management system is still in use to prevent collisions from occurring because it is difficult to predict the outcome of such accidents.

Pat Barron in the MD Group states that vessels used in iceberg management operations in addition can function as standby vessels and/or supply vessels. If a standby vessel is to cover other facilities or to be part of ice monitoring or ice management tasks, this might however have an impact on the vessel's response time in case of a rescue emergency situation: The vessel might not be as quickly in position to rescue personnel or to retrieve a MOB-boat as it would otherwise.

Common practice does not require a facility to be equipped for two simultaneously occurring DSHAs. One can therefore presume that if a standby vessel is on an iceberg management mission, there will be no extra standby vessel located near the facility for emergency preparedness in the event of another emergency incident. If the standby vessel will be unavailable for assistance to the offshore facility for a long time, however, another standby vessel might be required to fill in.

When a drifting iceberg and a facility is on collision course, all available vessels, in reality often only one, will assist and participate in the towing operation /62/. As the iceberg gets closer to the area of oil and gas operation, the standby vessel will be instructed to direct it into a position where its trajectory can no longer be a threat. At this point it is likely that the iceberg is still miles and hours away from the facility in question. Chances of success increase the sooner such a directing operation can commence.

A remaining question in an iceberg impact scenario is what will happen to a facility after having been evacuated due to an iceberg threat. The Norwegian oil and gas 064 implicitly indicates that the answer would be to “sacrifice” the facility. Personnel will close up wells and shut down production before evacuating. How the scenario then will develop depends on forces and energy. If the drifting iceberg approaches the facility at full speed – 0,25 m/s, 0,28 m/s or up to as much as 1,13 m/s according to the numbers in section 3.2.2 – the facility will probably not be able to withstand an impact /62/.

Though not defined as a DSHA in the guideline Norwegian oil and gas 064, the information above and in section 3.2.2 shows that drifting icebergs theoretically can be compared to a DSHA 4. The thesis discussion shows that there must be a critical time limit in which an instruction of evacuation and/or a disconnection of the facility must be performed. Further, the discussion shows that it is possible to develop iceberg management systems that keep drifting icebergs from colliding with offshore facilities. However, to uphold such an emergency preparedness will require large resources.

Therefore it is important to identify the frequency of drifting icebergs around 74 °N in the Barents Sea. How big a threat do they actually pose? In order to answer this, considerable data must be collected and analyzed. When parameters such as size and shape of the icebergs, weather conditions, and available time and management resources on the facilities in question have been established, techniques for how to deal with the iceberg challenge can be developed. It is highly recommendable to invest in such a mapping. If an iceberg management system does not succeed in handling a potential hazard, it might result in an impact between facility and iceberg. This can have major consequences and cause enormous damages.

6.6 Weather conditions

Is it reason to believe that exploratory activity and oil and gas production will take place all year long in the Barents Sea?

Chapter 3.1 dealt with environmental conditions in the Barents Sea. Figure 5 in chapter 3.1.1 illustrated a percentage distribution of significant wave height above four meters. According to the figure, the percentage decreases further northeast in the Barents Sea and increases when moving further south in the Norwegian Sea. MOB-boats have a recommended operational restriction if the significant wave height is above 4,5 meters. Figure 5 supports that non-operable MOB-boats will be a bigger problem in the North Sea and the Norwegian Sea than in the Barents Sea.

Severe fog conditions might keep helicopters from performing medical evacuations, precautionary evacuations or rescue operations. Chapter 3.1.5 shows that the visibility on Bjørnøya is less than 1000 meters during 8,58 % of the year. This may result in operational restrictions for the facility.

Polar nights will appear from November to February. The result is total darkness in the Barents Sea, also during daytime. A SeaBarents survival suit will be equipped with more light than a SeaAir survival suit and therefore be more visible in the darkness.

Section 3.2 looked into ice conditions. A general trend shows that the spread of sea ice in the Barents Sea is decreasing. In Figure 11, data illustrates how peaks appear every nine years and how they can be classified as larger or smaller. Considering that the latest large peak occurred in 1997, one might presume that the next will appear between 2014 and 2016. Sea ice in the Barents Sea can be expected the months of December through May. It remains to be seen whether or not the trend of sea ice really is decreasing. If it is, a larger area of the Barents Sea can be expected to be free of sea ice for at least a shorter period of time each the year.

Sea ice is one major Barents Sea challenge. Icing is another. The latter will have a negative impact on standby vessels and MOB-boats as well as facilities and persons in the sea. Equipment and facilities therefore need to be properly winterized before being deployed for use in the Barents Sea.

Polar lows represent a particular challenge when operating in the North. They mainly appear between October and April, and from January to March their occurrences can be expected to be the most frequent. Polar lows are hard to detect and difficult to forecast. This makes them difficult to handle. To evacuate personnel from a facility due to a polar low is presumably not an option. Instead, precautions should be made such as a temporary production or activity shutdown. As a consequence of environmental changes that lead to higher temperatures, the frequency of polar lows might decrease.

Year-round operations in the Norwegian sector of the Barents Sea are likely to face difficult challenges. Such operations will however still be manageable if appropriate risk analyses are conducted and sufficient risk reduction measures are put into place. Precise weather forecasts will be essential to warn the facilities in time if operational restrictions are necessary to maintain a secure production. The thesis has already showed that drilling rigs most likely will disconnect if sea ice is present. As a result of this, exploratory activity is likely to only take place when the sea is ice-free. In practice, this would mean during the summer months for the northern part of the Barents Sea. Production facilities such as Facility X will on the other hand be likely to operate year-round because it will be non-profitable to stop production for weeks or months due to sea ice. Here, other safety measures must be implemented instead.

As the thesis shows, the challenges related to oil and gas exploration in the Barents Sea are manageable. Still, they require attention and the provision of suitable resources. When considering emergency preparedness, sufficient attention must be given and solutions for certain critical challenges pointed out in the thesis must be solved before an all-year round petroleum activity can be possible everywhere in the Barents Sea.

How to act if weather conditions are too rough for MOB-boats to operate

As the weather data in section 3.1.1 shows, the wind conditions are stronger in the Norwegian Sea and North Sea than in the Barents Sea. The use of MOB-boats will pose greater challenges there than in the Barents Sea. Drifting sea ice in the Barents might however make the MOB-boat and standby vessel use there more difficult after all.

Given that there is a polar low close to a facility, all operations on the facility are likely to be stopped until the polar low has passed. This is to avoid unwanted accidents. The probability of having a major accident resulting in an emergency evacuation simultaneously with a polar low therefore seems small. This will however be up to the local risk analysis to decide, and will not be further discussed in the thesis.

If a DSHA 3 emergency evacuation has taken place, rescuing survivors is paramount. In the event that the helicopter or standby vessel is unable to operate under the prevailing conditions, the people in the sea will have to ride out the storm in wait of an operational window that allows rescue.

If weather conditions are so rough in the event of a DSHA 2 that MOB-boats cannot operate, a helicopter transport of personnel is also likely to see certain operational restrictions so an emergency preparedness can still be sufficient. One such restriction could be that transport helicopters only should be able to fly with 15 instead of 21 passengers in wintertime. If wind on the helideck exceeds 55 knots, it will be difficult to start the helicopter rotor. Under such conditions, no helicopter transport of personnel should be performed.

6.7 Should a higher level of emergency preparedness be required?

The question of whether or not special emergency preparedness requirements for the Barents Sea should be introduced, is asked in chapter 11.3 of the baseline report for Norwegian oil and gas 064 /10/

Here follows a summary of the main points in the chapter:

"*It is considered to be a reasonable requirement that all production fields in the Barents Sea with permanent facilities should have emergency preparedness standards that correspond to the area based emergency preparedness. It is not considered reasonable to introduce stricter requirements than on the rest of the shelf.*"

"*It will likely also be a reasonable requirement that explorative drilling in the Barents Sea has an emergency preparedness standard corresponding to area based emergency preparedness, but for exploration drilling it would be more natural to accept compensating measures*."

"*There are strong objectives against giving a permission of increased rescue time from the sea beyond 120 minutes even though suits that can withstand sea and air temperature, wind/icing, etc. can be acquired.*"

The thesis analysis uses a given mobilization time of fifteen minutes (further discussed in chapter 5.3.4). This should be sufficient regarding transport flights and in the event of a DSHA 7. To keep the mobilization time at a minimum is particularly important when the distance between two facilities is large. If the distance is too large, other measures must be implemented so the emergency preparedness still is sufficiently dimensioned.

As promised in chapter 5.3.3, a further discussion of the time buffer for the different DSHAs will here be executed:

When considering a DSHA 7 it might be difficult to get acceptance for stricter performance requirements than those existing today. There are also no technical arguments that speak to the advantage of stricter requirements. For a DSHA 2 and 3, the reasons might be more heavy-weighing, yet difficult to implement due to the lack of infrastructure in the area /60/.

Given that a time buffer regarding the performance requirements should be implemented, it is reason to assume that this would be stated in the Norwegian oil and gas 064. It would be a weakness in the guideline if such a buffer was excluded when it still should be considered when dimensioning the emergency preparedness. Therefore we can presume that the emergency preparedness is sufficiently dimensioned if the performance requirement is fulfilled.

A certain margin to the performance requirement will however strengthen the emergency preparedness and make the solution more robust. Such a time margin will take into account unforeseen things that might occur and result in more time to handle the hazardous situation. It is important to emphasize that even if the performance requirement is satisfied, this does not guarantee that the outcome of an emergency situation will be successful. Therefore it is important to carry out emergency preparedness as efficiently as possible at all times.

Given that the amount of persons onboard a transport helicopter is reduced from 21 to 15 persons, it will be easier to fulfill the performance requirement of a DSHA 2. However, this represents an operational limitation rather than a buffer.

Table 14 in chapter 4.4.1 illustrates survival time until help arrives. Given an acute heart attack or an acute stroke, the possibilities for survival are low if rescue is given one to three hours after the incident. A response within six hours will probably have a fatal outcome. When considering the three-hour limit of emergency medicine transport, the 180 minutes represent a given line. Whether treatment is given after 175 or 185 minutes might however not have a big impact on the outcome, and to state that treatment after 175 minutes is a success while treatment after 185 minutes is a fiasco would be misleading. However, three hours, 180 minutes, is in the case of emergency medicine transport the limit that has been drawn.

The same Table 14 shows that a person lying in water while wearing a survival suit will have good possibilities of surviving if rescue response arrives within two hours. If response is given in three to twelve hours, survival chances are low. Three to twelve hours is however a long timespan, and it is difficult to indicate exactly where the survival limit should be drawn. Individual factors also play a role in the calculation. Survival suit demonstrations show that there are personal differences as to how long someone can stay in water before getting cold.

Despite different possible interpretations, the thesis presume that the given performance requirement is sufficient. Therefore no extra time buffer should be required.

A particular challenge in the Barents Sea is the large distances to available SAR resources including those based on land. The traffic density in the area is also low compared to that of the North Sea. The result is fewer vessels available in search and rescue operations. Therefore it is of the utmost importance to prevent accidents from occurring in the northern Barents Sea. The consequences of an accident are likely to be greater in the northern areas than elsewhere. The factors of time, distance and climate will sometimes make it impossible to carry out operations, and not even the amount of resources available in the rescue operation can help change this fact /36/.

Given below the baseline report for Norwegian oil and gas had another statement concerning stricter requirements for the Barents Sea /10/:

"*The dimensioning minimum temperature near the Goliat field is around -20 °C. It is expected that the requirements for suits can be considerably more extreme if dimensioning towards minimum temperatures of -30 or -40 °C. On the other hand, some are skeptic to ending up with several suit types, which would complicate logistics substantially. Additional requirements must also be fixed with requirements for undergarments.*"

Chapter 3.9 deals with survival suits and how SINTEF and Hansen Protection have developed the new SeaBarents suit on initiative from Eni Norge. The thermal qualities for that suit are very good and give sufficient protection against reaching a hypothermic condition. Persons lying in the Barents Sea while wearing the suit would not even get close to reaching a core temperature of less than 35 °C within two hours. When temperatures are very low, however, extremities such as arms and legs would be affected. If temperatures reach zero degrees, frost damages on the extremities in the shape of ice crystals on skin tissue could occur. As chapter 6.3 points out, it is not allowed to try out such conditions during tests since test-persons should not be exposed to unnecessary risks. Therefore it seems difficult to give a good estimate on when life-threatening conditions in the water occur and to describe how much worse it is to float in the sea if the surrounding temperature is -40 rather than -10 °C. One thing is however sure: It should be focused more on wearing proper-layered clothing under the immersion suit. This would presumably elongate the time until a person starts to freeze.

The baseline report for Norwegian oil and gas also give the following statement:

"*If it is possible to implement measures that increase the probability of people in the sea getting onto a raft, this will have a very good effect on the probability of surviving for a longer period. Such measures could be good ALARP measures.*"

A vessel in distress in the Arctic is likely to face additional hazards from rapidly changing ice conditions. Ice fields and ridges can impose extreme pressure against a vessel's hull. A several-hour power blackout in open waters does not normally represent extreme danger, but if this happens in ice it might lead to damage of the hull or equipment located in heated areas /18/.

Again, the challenges of operating in the Barents Sea are many, but manageable. It is important that the responsible party develops the necessary evacuation options suitable to each location in question. Challenges regarding environmental conditions, ice conditions, communication, infrastructure, evacuation and rescue, and survival suits must be solved on each facility so the emergency preparedness is sufficiently dimensioned and the personnel working offshore can operate safely.

7. Conclusion

There are certain area-specific emergency preparedness challenges related to the rescue and evacuation of personnel that occur during oil and gas exploration in the Barents Sea. Icing, drifting sea ice/icebergs, poor communication coverage, a challenging climate, darkness, long distances, and poor infrastructure must be evaluated in particular in order to uphold a sufficient emergency preparedness in the area.

The Barents Sea is currently an undeveloped petroleum province with little infrastructure and large distances to the nearest SAR resources. As fields are being discovered and resources are being spent on development, the situation is likely to improve.

When considering the evacuation of a facility, certain issues require special attention. Scarce helicopter resources and an impossible drop of free-fall lifeboats into the sea when sea ice is present are two causes for major concern. Having reliable weather data is crucial when deciding how a facility should be equipped in regards to evacuation safety.

As of today, resources available for rescue operations in the Barents Sea are few. They are also situated far apart from one another and can only provide limited service compared to that available in the North Sea. The use of a land-based SAR helicopter based in Hammerfest is not sufficient when operating as far as 74°N. Instead, helicopters stationed offshore in hangars are a necessity when performing oil and gas exploration so far from land. Offshore helicopters can contribute to fulfilling performance requirements regarding the rescue of persons from the sea in the case of a helicopter incident (DSHA 2), persons in the sea due to an emergency evacuation (DSHA 3) and external medical assistance (DSHA 7). As the thesis shows, placing a SAR helicopter on an offshore production facility seems to be a better solution than having one stationed on a standby vessel or a floating base.

The challenges related to oil and gas exploration in the Barents Sea are manageable, but they require attention and sufficient economic resources in order to be solved. There is for instance no single secondary evacuation method currently available for year-round operations when sea ice is present. This, and certain other critical challenges such as sufficient weather forecast, communication coverage, sea ice and iceberg management, infrastructure, etc., needs to be solved before an all year round petroleum activity can be possible everywhere in the Barents Sea.

Finally, it seems to be a reasonable requirement that all producing fields in the Barents Sea, also those working with explorative drilling, has an emergency preparedness standard that corresponds to the area based emergency preparedness.

7.1 Further work

- A reliable weather forecast is essential for safe petroleum activities. More measuring points would improve the forecast, which would further increase the safety concerning petroleum activities. Valuable information could be gained through new fixed observation stations on the facilities when petroleum resources are being developed in the Barents Sea.
- Establish solid and reliable data coverage in the Barents Sea areas, which informs where and when icebergs most probably will occur.
- A reliable communication system is the key to success in a rescue operation. It is essential that the communication coverage in the Barents Sea will be improved. The use of an extra satellite (HEO) and/or optical fiber cable out to all facilities is an option.
- Analyze the use of free-fall lifeboats in areas where sea ice can be expected.
- The effect of ice accretion on stability and performance needs to be studied for both vessels and lifeboats deployed for activities in the Barents Sea.
- Actions of sea ice and icebergs for design loads.
- Operational strategies for structures, vessels and evacuation means must be considered.
- Requirements regarding a minimal standard of clothing underneath the survival suit need to be considered when operating in the Barents Sea since there is not much to gain by improving the SeaBarents suit anymore. Special attention to the issue should also ensure that personnel uses correctly sized immersion suits.
- A detailed study of which impact weather conditions (wind, darkness, snow, etc.) have on a SAR helicopter’s speed. It will be important to identify how big an influence the weather factors actually have in a rescue operation because the helicopter must calculate with the extra time spent.

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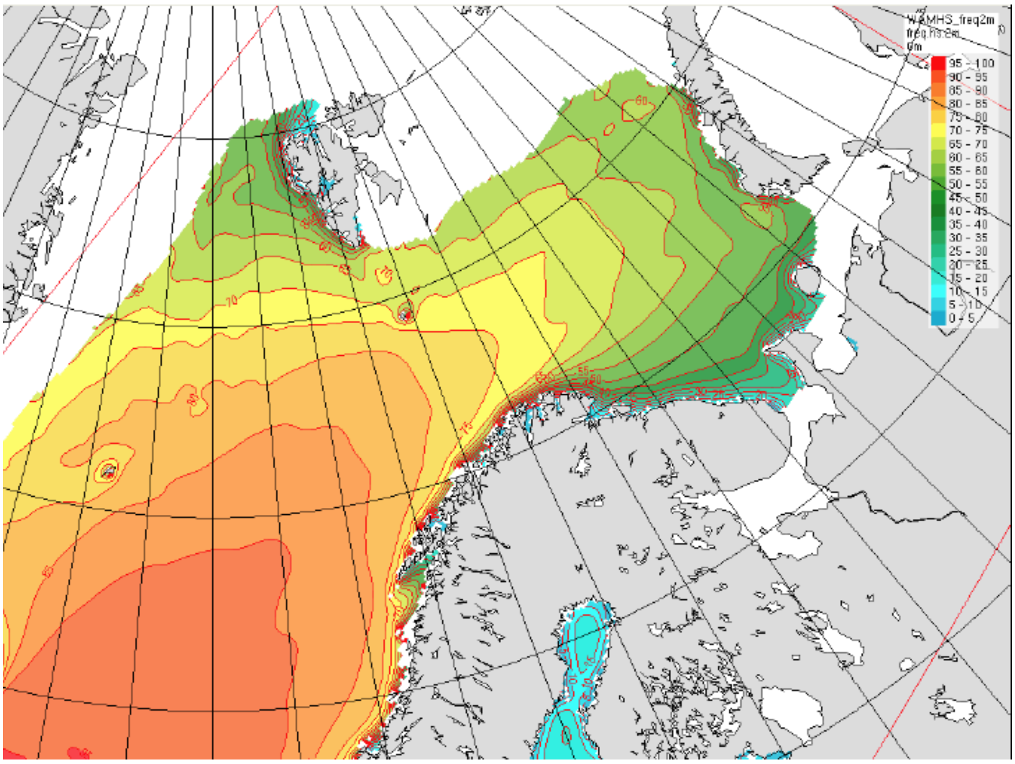
Appendices

A1 – Weather data

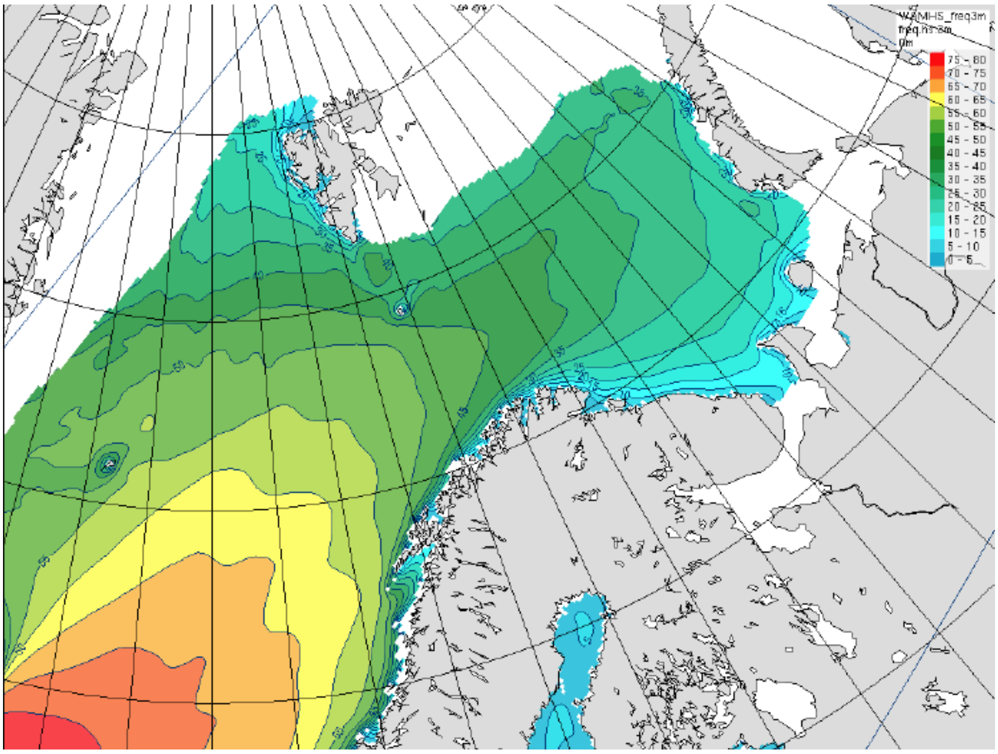
This section will present some figures related to environmental conditions in the Barents Sea. All these figures are taken from the study: “Vær, is og andre fysiske utfordringer ved Barentshavet sørøst” – Meteorologisk institutt /14/.

Percentage distribution of Hs > 2m in January /14/



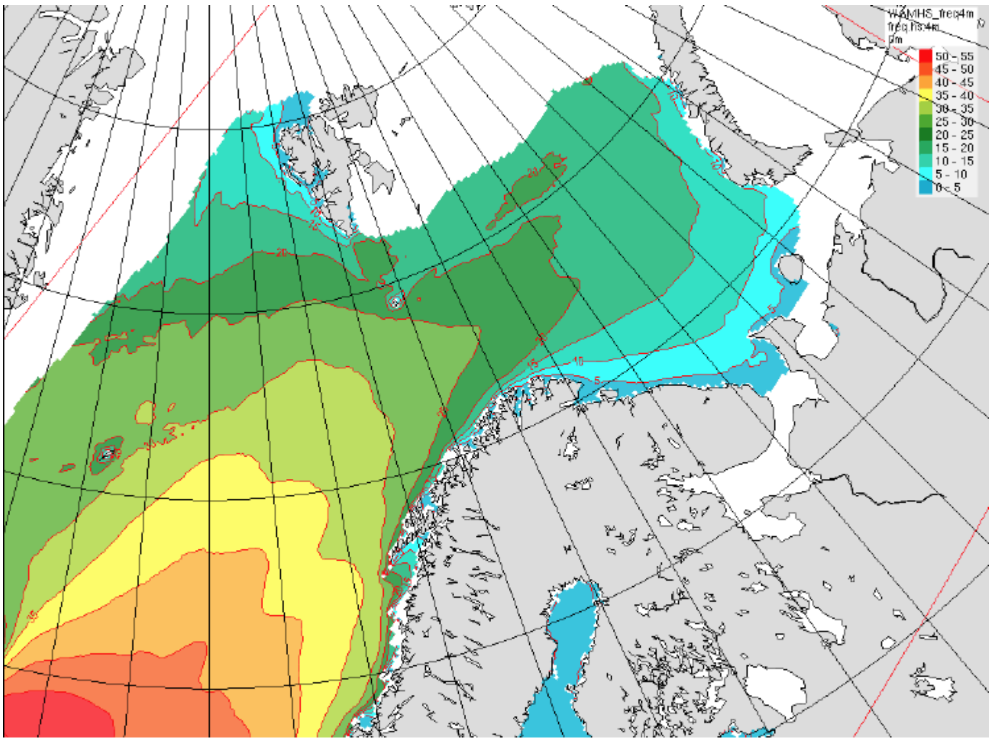
Yellow color indicates a percentage distribution of 70-75 %. Dark green is 40-45 %, orange is 80-85 %.

Percentage distribution of Hs > 3m in January /14/



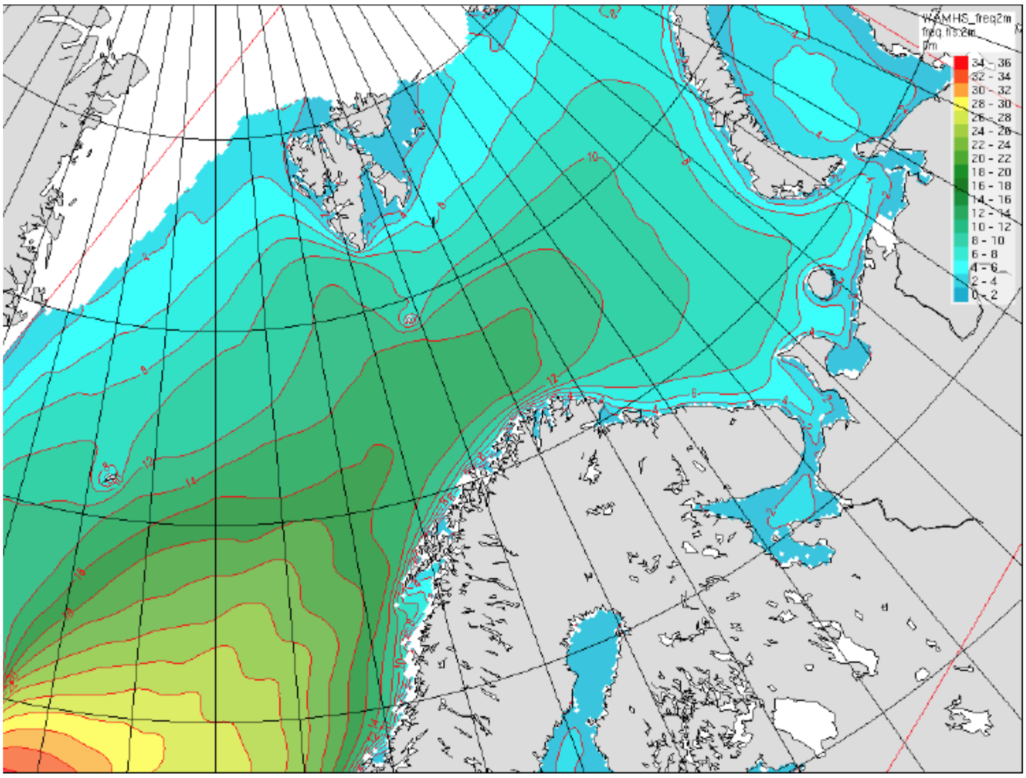
Dark green is 40-45 %, yellow is 60-65 %, and light blue is 10-15 %.

Percentage distribution of Hs > 4m in January /14/



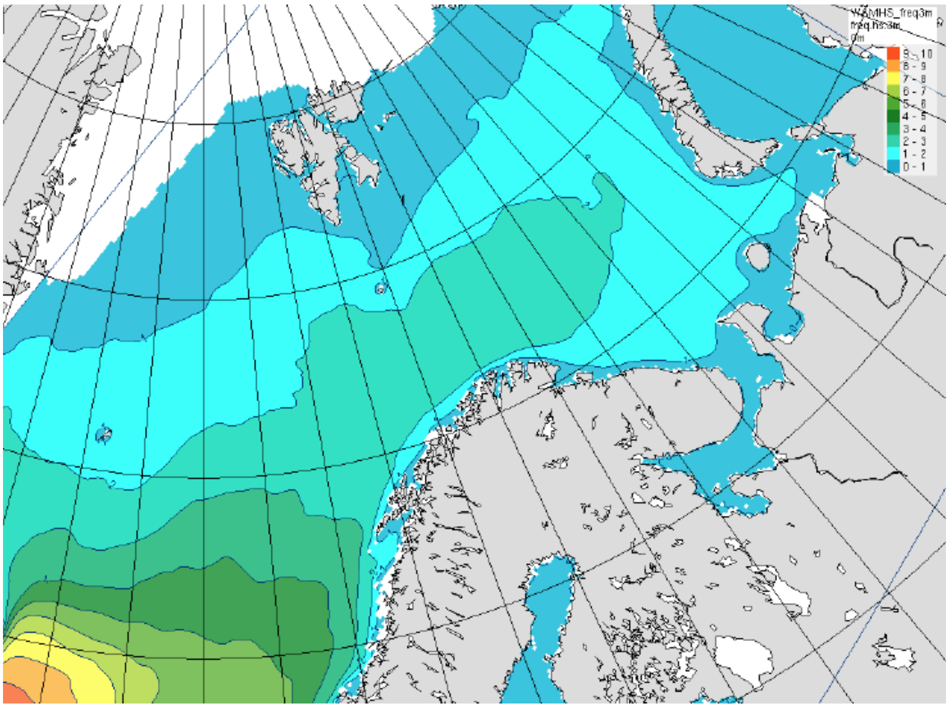
Dark green is 20-25 %, yellow is 35-40 %, and light blue is 5-10 %.

Percentage distribution of Hs > 2m in July /14/



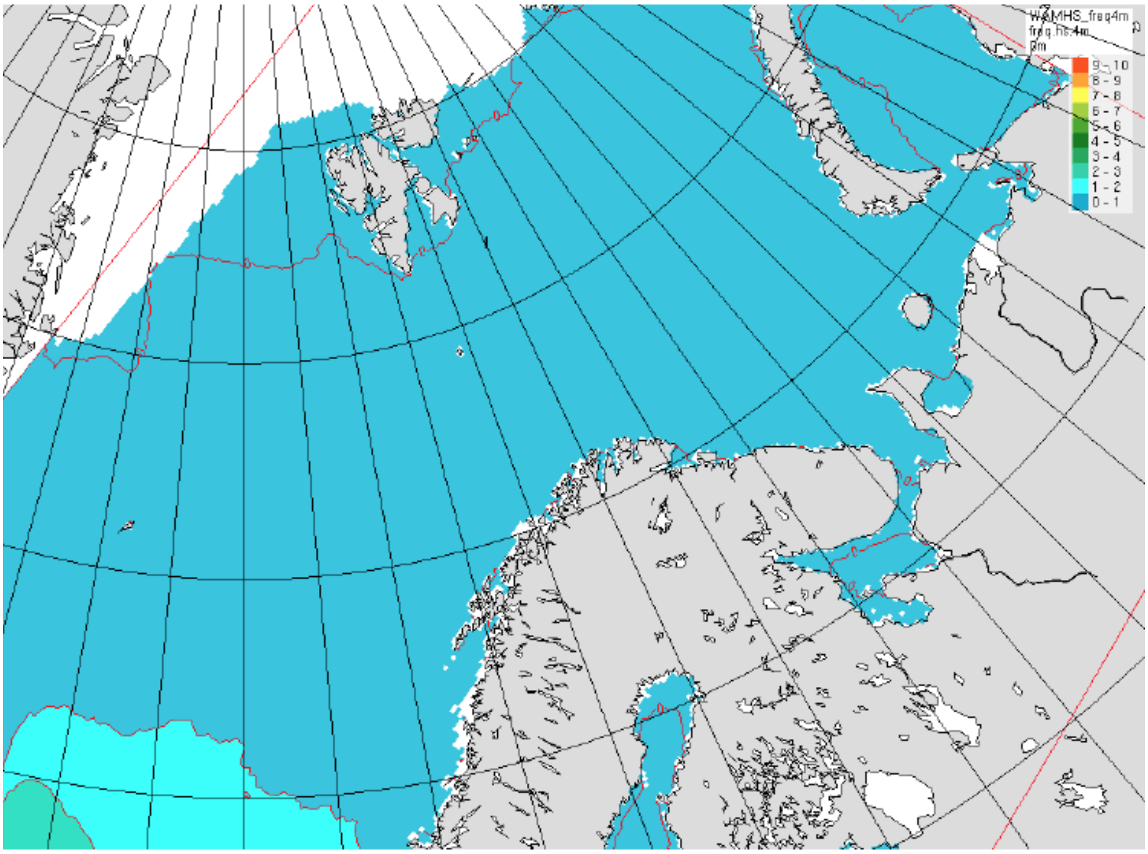
Dark green is 16-18 %, yellow is 28-30 % and light blue is 4-6 %.

Percentage distribution of Hs > 3m in July /14/



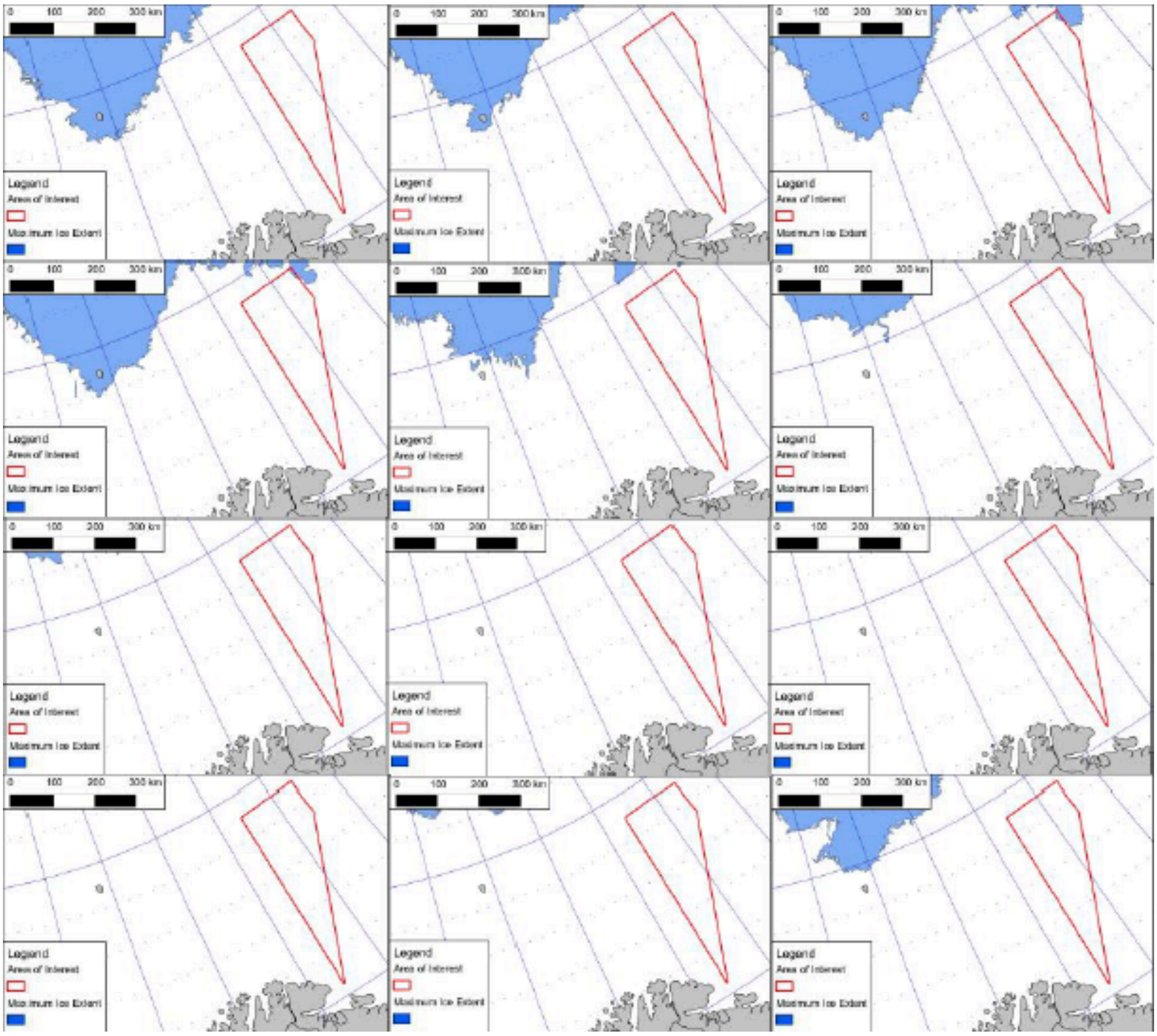
Dark green is 4-5 %, yellow is 7-8 % and light blue is 1-2 %.

Percentage distribution of Hs > 4m in July /14/

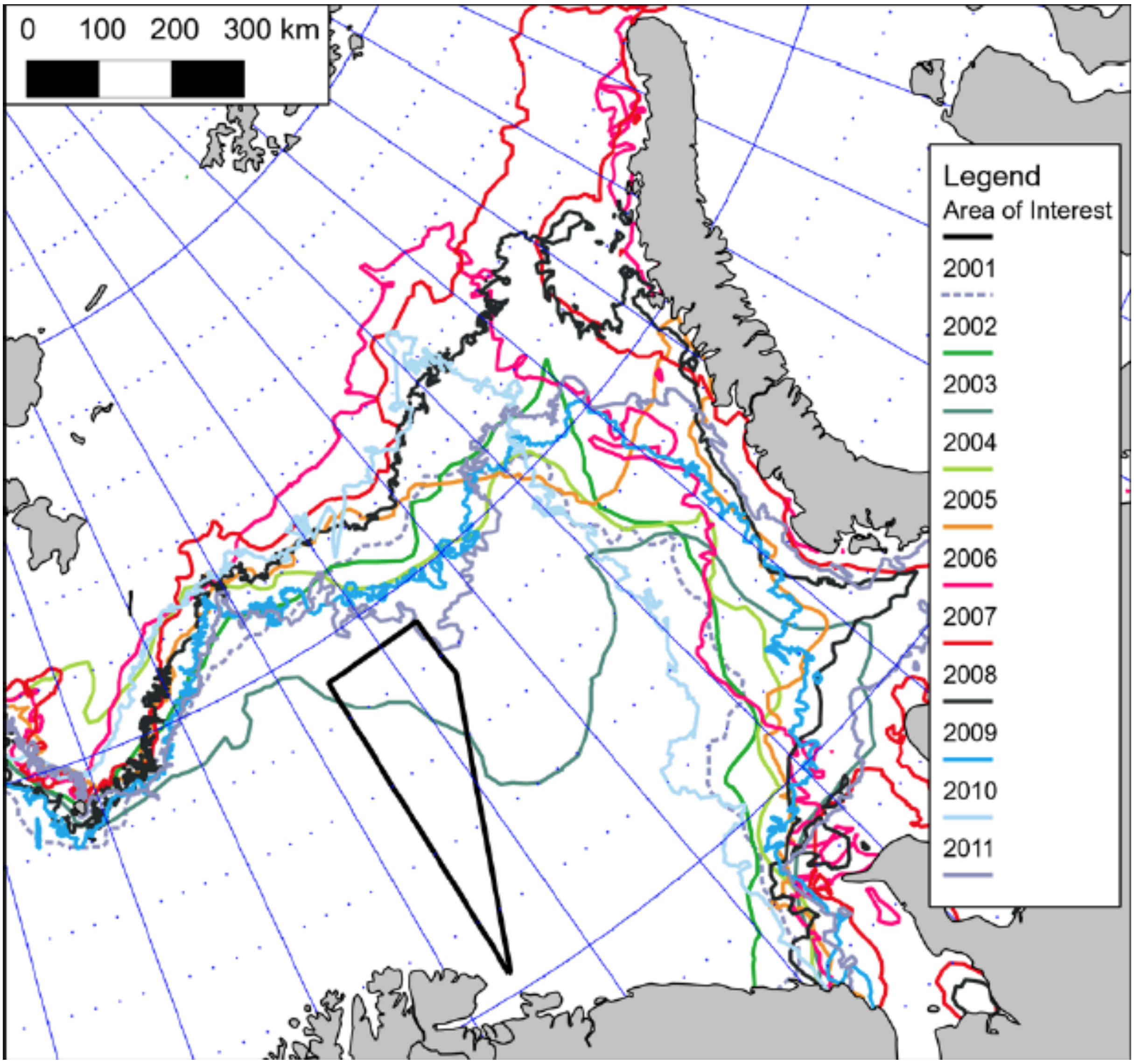


Blue is 0-1 %.

Maximum spread of ice in period 2009-2011, monthly /14/



Annually maximum spread of sea ice between year 2001-2011 /14/



As may be observed from the figure presented above, the spread if sea ice in the period between 2001-2011 was at its greatest in year 2003.

A2 – Prestudy of new SAR helicopter capacity

The range when picking up 20 persons for todays Sea King helicopters are 53 Nm straight out from the baseline. The requirement that will be valid in the future is 150 Nm. In Figure 35 illustrated below one can observe the NARO-area (red line). The yellow line shows the coverage area for saving 20 persons for a Sea King helicopter, and the green line indicates the future range that will be required for a rescue helicopter.

Figure 35 The future rescue helicopters /63/

In the process of renewing new rescue helicopters, there are today four actual candidates. These helicopters are: Eurocopter Super Puma EC225, NH Industries NH 90 TTH, Sikorsky S92A and Augusta Westland AW101 Merlin.

In the table presented on the next page, the specification of the different helicopter-types is given. Osprey V-22 is also included in that list, even though it might not an actual alternative since it will probably be too expensive.

	NH 90 TTH	Eurocopter Super Puma EC225	Augusta Westland AW-101	Sikorsky S-92	Osprey V-22
Basic weight (kg)	6400	5300	10500	7000	15000
Max weight (kg)	10600	11000	15600	12000	27400
Speed (nm/h)	162	175	150	150	240
Range (nm)	530	533	500	539	880
Passengers	20	24	30	19	24
Crew	2	2	2	2	4

Table 20 Helicopter specifications /63/

Conceptual study for new rescue helicopters – Alternative-analysis

This section will present the best concepts composed by the Sub-document 4 of 5, Alternative-analysis, in the conceptual study for new rescue helicopters /64/.

There are today six locations in addition to Svalbard where rescue helicopters are stationed in Norway: Banak, Bodø, Ørland, Florø, Sola and Rygge. The station in Banak lies farthest in the Porsangerfjord, about 70 Nm from the baseline. The base in Bodø is stationed 45 Nm from the baseline. During rescue operations at sea, a lot of time is spent in transport from the base and out to the baseline.

According to the pre-study, it is considered the most practical to purchase a uniform fleet of large rescue helicopters, class D and E (10-20 tons), that is fitted for rescue operations at sea and on the mainland.

3d1 – Six bases plus Svalbard

New rescue helicopters will be acquired at Svalbard. At the mainland there will be a uniform fleet with 16 new large rescue helicopters of class D or E spread out on six stations. Svalbard will then get an emergency rescue capacity more equal to that on the mainland. The northern areas, especially in the Barents Sea and around Svalbard, will be more robust.

3e – Seven bases plus Svalbard

This alternative will be quite similar to 3d1. The only difference is that one additional base is stationed in the north. To account for increased shipping and petroleum activity in the Barents Sea, this will be a good measure. In the north, rescue helicopters are more unique resources since there are fewer alternative parties in the area.

3f – Five bases plus Svalbard

By purchasing new large helicopters with increased range, compared with today´s Sea King helicopters, this concepts looks at the possibility of remove one of the bases stationed in the southern part of Norway. The preparedness at Svalbard will be strengthening in the same way as alternative 3d1 and 3e.

Very large helicopters – Class F

Very large helicopters are categorized in class F, and the weight is generally above 20 tons. This class is normally characterized by a large loading capacity and range. One negative factor by using such kind of helicopters is that the rotor may cause large wind-effects that may be undesirable in situations where persons are rescued from a rescue fleet. This kind of helicopters require also more maintenance compared to helicopters from class D and E.

One helicopter-type that is suitable to rescue operations far from shore is tilt rotor helicopters. Osprey V-22 is such a helicopter-type. This kind of helicopter can land and take off as a normal helicopter, but can move as a plane when tilting the rotor and thereby cover great distances since the speed can be up to 240 knots. This concept is not yet tested in a rescue-context, but is developed based on military missions. It may be very costly to develop an alternative that is adjusted for only SAR operations.

Conclusion of best solution

The identified concepts are evaluated according to the requirements given by the Overall Strategy Document /57/. Next page will present a table containing 15 points that were used in the evaluation.

	Description	3d1	3e	3f
1.	Rescue helicopters should be able to relieve 2 persons for MEDEVAC at the outer edge of NRAO and return to place to be treated			
2.	Rescue helicopters should within 2 hours after alert reach 150 Nm straight out from the baseline and start rescuing 20 persons, and then return to shore.			
3.	Should be able to reach the entire coastline and mainland, and save 20 persons and return to a safe location at the mainland			
4.	All helicopter-bases should uphold a 15 minutes preparedness 100% of the time			
5.	The rescue helicopter capacity should support the fire service during rescue operations at sea			
6.	Rescue helicopters should be suited for an adjusted search and localization of object			
7.	Rescue helicopters should be suited for rescue operations during harsh conditions			
8.	Rescue helicopters should be suited for mountain rescuing under harsh conditions			
9.	Rescue helicopter should safely operate and protect crew and passengers			
10.	Rescue helicopters should provide medical assistance and treatment equivalent to “Luftambulansetjenesten” during operations			
11.	Rescue helicopters should be equipped with sufficient communication tools			
12.	Rescue helicopters should be robust and available when needed and supported by effective logistics and maintenance solutions			
13.	Rescue helicopters and equipment should be updated during entire lifetime when required			
14.	The capacity of the rescue helicopters should be as good as or better than todays’ alternative			
15.	The alternative should include educating and training of personnel to secure high competence for all critical functions			

Table 21 Alternative concepts in choice of new rescue helicopters purchase /64/

Green indicates that the requirements are fulfilled while yellow indicates that only a few of the concepts fulfill the requirements. Red indicates that the requirements are not fulfilled. Alternative 3e will be the one that fulfills all the requirements, but it might also be the most expensive choice of the three candidates. 3f will not satisfy the requirement of quick response time and robustness.

The concept that the alternative-analyses recommended was 3d1. That alternative was around 3-4 billions NOK cheaper than 3e.

A3 – Analysis Scenario 1 and Scenario 2

Area based emergency preparedness cooperation near Facility X

Scenario 1			Scenario 2		
SAR helicopter			**SAR helicopter**		
Mobilization	15	min	Mobilization	15	min
Time until reach 140 knot	2	min	Time until reach 140 knot	2	min
Time to prepare for rescue	5	min	Time to prepare for rescue	5	min
Pick-up time	3	min	Pick-up time	3	min
Speed	140	knot	Speed	140	knot
Standby vessel			**Standby vessel**		
Speed	15	knot	Speed	15	knot
Pick-up time (day)	2,5	min	Pick-up time (day)	2,5	min
Pick-up time (night)	4	min	Pick-up time (night)	4	min
Time picking up first person	8	min	Time picking up first person	8	min
Mobilization time	0	min	Mobilization time	0	min
Distances			**Distances**		
Facility X - Hammerfest	254	Nm	Facility X - Hammerfest	254	Nm
Facility X - Rig 7432	72	Nm	Facility X - Rig 7432	72	Nm
Rig 7432 - Hammerfest	243	Nm	Facility X - SAR base	65	Nm
			Rig 7432 - SAR base	60	Nm
			Rig 7432 - Hammerfest	243	Nm
			Rig 7228 - Hammerfest	130	Nm
			Rig 7228 - SAR base	67	Nm

DSHA 2			DSHA 2		
Dimensional amount	21	persons	Dimensional amount	21	persons
Performance requirement	120	min	Performance requirement	120	min
Facility X	35	min margin	Facility X	7,1	min margin
Rig 7432	4,1	min margin	Rig 7432	9,3	min margin
			Rig 7228	6,3	min margin

DSHA 3		
Dimensional amount	6	persons
Performance requirement	120	min
Facility X (SAR helicopter)	80	min margin
Facility X (Standby vessel day)	99,5	min margin
Facility X (Standby vessel night)	92	min margin
Rig 7432	49,1	min margin
Dimensional amount	21	persons
Performance requirement	120	min
Facility X (SAR helicopter)	35	min margin
Facility X (Standby vessel day)	62	min margin
Facility X (Standby vessel night)	32	min margin
Rig 7432	4,1	min margin
Dimensional amount	30	persons
Performance requirement	120	min
Facility X (SAR helicopter, Skru. + Hamm.)	-23	min (exceeded)
Facility X (Standby vessel night)	-4	min (exceeded)
Facility X (SAR helicopter + standby vessel)	35	min margin

DSHA 3		
Dimensional amount	6	persons
Performance requirement	120	min
Facility X	52,1	min margin
Rig 7228	54,3	min margin
Rig 7432	51,3	min margin
Dimensional amount	21	persons
Performance requirement	120	min
Facility X	7,1	min margin
Rig 7228	9,3	min margin
Rig 7432	6,3	min margin
Dimensional amount	30	persons
Performance requirement	120	min
Facility X (SAR helicopter, Skru. + Hamm.)	-23	min (exceeded)
Facility X (Standby vessel night)	-4	min (exceeded)
Facility X (SAR helicopter + standby vessel)	7,1	min margin

DSHA 7		
Time of external medical response	60	min
Facility X	OK	OK
Rig 7432	12,1	min margin
Time of transport in emergency medicine	180	min
Facility X	54,1	min margin
Rig 7432	21	min margin

DSHA 7		
Time of external medical response	60	min
Facility X	15,1	min margin
Rig 7432	17,3	min margin
Rig 7228	14,3	min margin
Time of transport in emergency medicine	180	min
Facility X	19,3	min margin
Rig 7432	26,1	min margin
Rig 7228	71,6	min margin

Area based emergency preparedness near Skrugard

Scenario 1			Scenario 2		
SAR helicopter			**SAR helicopter**		
Mobilization	15	min	Mobilization	15	min
Time until reach 140 knot	2	min	Time until reach 140 knot	2	min
Time to prepare for rescue	5	min	Time to prepare for rescue	5	min
Pick-up time	3	min	Pick-up time	3	min
Speed	140	knot	Speed	140	knot
Standby vessel			**Standby vessel**		
Speed	15	knot	Speed	15	knot
Pick-up time (day)	2,5	min	Pick-up time (day)	2,5	min
Pick-up time (night)	4	min	Pick-up time (night)	4	min
Time picking up first person	8	min	Time picking up first person	8	min
Mobilization time	0	min	Mobilization time	0	min
Distances			**Distances**		
Skrugard - Hammerfest	130	Nm	Skrugard - Hammerfest	130	Nm
Skrugard - Rig 7325	90	Nm	Skrugard - Rig 7325	90	Nm
Skrugard - Rig 7228	130	Nm	Rig 7325 - Hammerfest	175	Nm
Rig 7325 - Hammerfest	175	Nm			
Rig 7228 - Hammerfest	130	Nm			

DSHA 2			DSHA 2		
Dimensional amount	21	persons	Dimensional amount	21	persons
Performance requirement	120	min	Performance requirement	120	min
Skrugard	35	min margin	Skrugard	35	min margin
Rig 7432 (Only Skrugard SAR helicopter)	-3,6	min exceeded	Rig 7432 (Only Skrugard SAR helicopter)	-3,6	min exceeded
Rig 7228 (Only Skrugard SAR helicopter)	-20,7	min exceeded			

DSHA 3			DSHA 3		
Dimensional amount	6	persons	Dimensional amount	6	persons
Performance requirement	120	min	Performance requirement	120	min
Skrugard (SAR helicopter)	80	min margin	Skrugard (SAR helicopter)	80	min margin
Skrugard (Standby vessel day)	99,5	min margin	Skrugard (Standby vessel day)	99,5	min margin
Skrugard (Standby vessel night)	92	min margin	Skrugard (Standby vessel night)	92	min margin
Rig 7325	41,4	min margin	Rig 7325	41,4	min margin
Rig 7228	24,3	min margin			
Dimensional amount	21	persons	Dimensional amount	21	persons
Performance requirement	120	min	Performance requirement	120	min
Skrugard (SAR helicopter)	35	min margin	Skrugard (SAR helicopter)	35	min margin
Skrugard (Standby vessel day)	62	min margin	Skrugard (Standby vessel day)	62	min margin
Skrugard (Standby vessel night)	32	min margin	Skrugard (Standby vessel night)	32	min margin
Rig 7325	-3,6	min exceeded	Rig 7325	-3,6	min exceeded
Rig 7228	-20,7	min exceeded			
DSHA 7			**DSHA 7**		
Time of external medical response	60	min	***Time of external medical response***	60	min
Skrugard	OK	OK	Skrugard	OK	OK
Rig 7325	4,4	min margin	Rig 7325	4,4	min margin
Rig 7228	-12,7	min eceeded	Rig 7228	-32,0	min eceeded
Time of transport in emergency medicine	180	min	***Time of transport in emergency medicine***	180	min
Skrugard	107,3	min margin	Skrugard	107,3	min margin
Rig 7325	42,4	min margin	Rig 7325	42,4	min margin
Rig 7228	44,6	min margin			