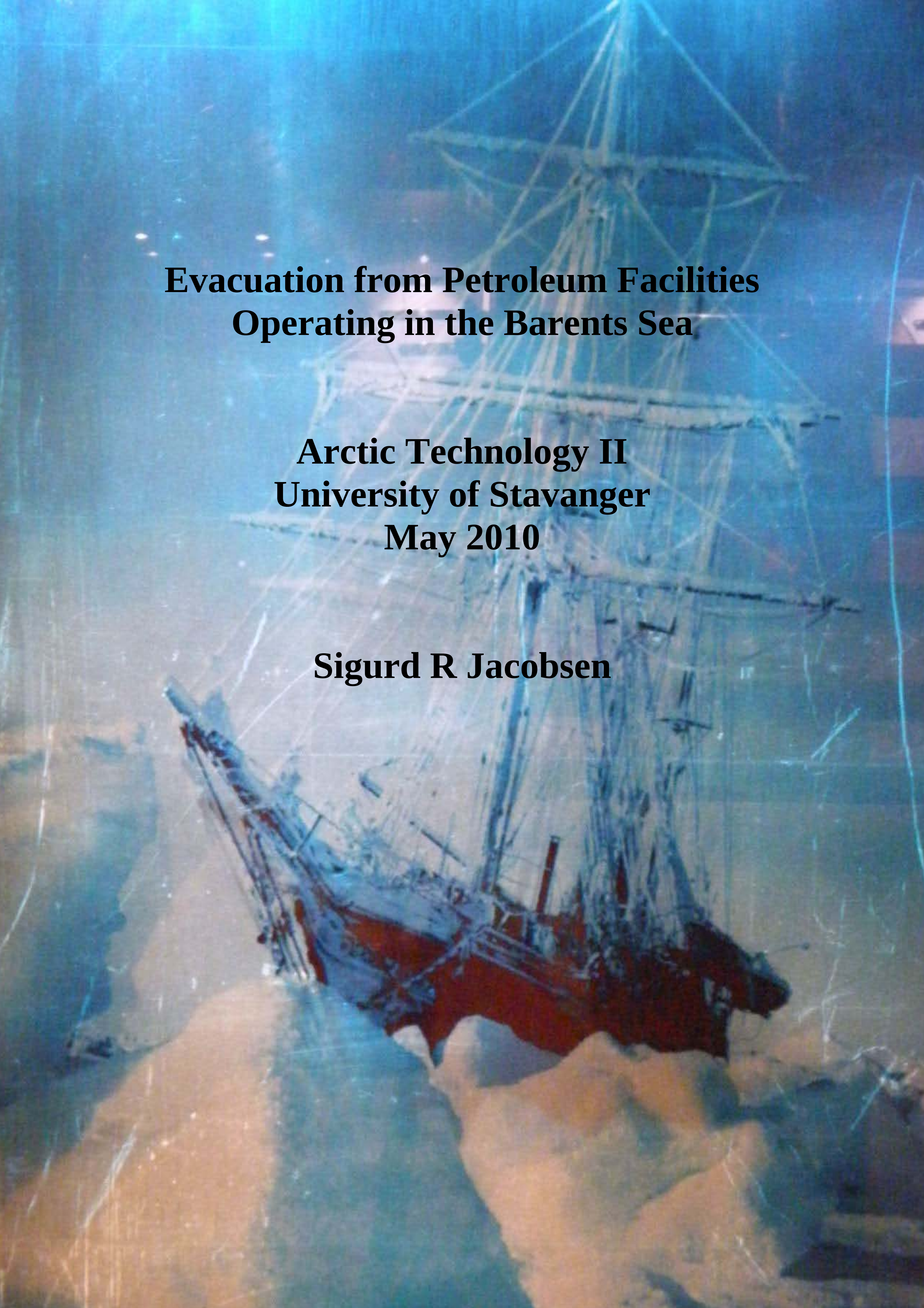

Evacuation from Petroleum Facilities Operating in the Barents Sea

Arctic Technology II
University of Stavanger
May 2010

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1 PREFACE

1.1 The purpose of the report

Norwegian petroleum regulations require that the personnel on a facility can be quickly and efficiently evacuated to a safe area at all times (Activity regulation § 68 litera d) and in all weather conditions (Facilities regulation § 43).

The aim of this report is to:

a.) Investigate historical meteorological conditions in order to identify conditions where it would be challenging or potentially not possible to evacuate personnel utilising current technology,
b.) Investigate the affect of ice accretion on lifeboat stability,
c.) Identify requirements for new solutions and regulations.

1.2 Major contents of the report

The report considers the area from the Norwegian coast to Bjørnøya in the north and the new border with Russia in the east. Background information on the climate conditions in the Norwegian sector of the Barents Sea is covered. Special features of the area are also presented.

Meteorological observations for 2008 and 2009 are used as a basis to discuss the suitability of evacuation and rescue system that are common in the petroleum industry. Information on the most commonly available evacuation and rescue systems is discussed briefly. A simplified model is used to evaluate the effect of ice accretion on the stability of lifeboats.

Note: /#/ in this report indicates a document listed in the reference list in section 8.

2 ACKNOWLEDGEMENTS

2.1 *Thanks to others who have assisted and contributed*

Arne Kvitrud, principal engineer, Petroleum Safety Authority, for assistance with collecting pertinent meteorological data and guidance on issues related to stability.
Gerhard Ersdal, principal engineer, Petroleum Safety Authority, for assistance with collecting pertinent meteorological data and guidance on issues related to stability.
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Erik Hamremoen, Statoil, for information related to helicopter operations in the Barents Sea and rescue operations performed by the Norwegian rescue service, 330 squadron.

2.2 *Thanks to supervisor*

Professor Ove Tobias Gudmestad, University of Stavanger, who has eagerly shared and imparted knowledge on the issues of operating in the Arctic with his students. Thank you for the abundance of information you have shared with us. This will provide useful reference documents for our future work on issues related to the petroleum industry in the Arctic. Thank you also for being a demanding tutor as this greatly increased the effort I have put into the course and thereby enhanced what I have got in return.

2.3 *Thanks to sponsors*

The Norwegian Petroleum Safety Authority who have sponsored my participation in the Arctic Technology II course at the University of Stavanger.

2.4 *Cover illustration*

The cover page illustration is from a photographic installation on glass by the artist, David Buckland (b. 1949, British), displayed onboard Brilliance of the Seas, a cruise ship belonging to Royal Caribbean Cruise Line. The photograph depicts the vessel, Endurance, lodged in the ice in Antartica. The vessel was used by the polar explorer, Ernest Shackleton, (1874-1922), during his Imperial Trans-Antarctic Expedition of 1914–17. The vessel was subsequently crushed by the ice and lost. Ernest Shackleton led all of his men to safety in one of the most dramatic survival stories ever. (/5/Sturridge, C. 2008) Their evacuation from the ice floes of the Weddel Sea to Elephant Island and on to South Georgia was made under extreme conditions in small open boats. The original photograph was taken by Frank Hurley, (1885-1962), the Australian photographer accompanying Shackleton on the ill-fated expedition. I have chosen to use this illustration as the cover page because it is a tribute to people who have real experience in an evacuation under harsh conditions with clothing and equipment that we today would declare as totally inadequate. Their expedition, loss of their vessel and evacuation illustrates very well both the conditions and remoteness of the polar region. Today we have better suited equipment and the speed at which we can travel across the polar region is greatly improved. However, we should ensure that we have a humble respect for the conditions we will experience in the Barents Sea and respect the memory of the many who have perished in this area.

3 ABSTRACT

3.1 A briefing on the purpose of the work

The purpose of this report is to examine conditions relevant to evacuation and rescue of personnel from facilities operating in the Barents Sea.

3.2 Information about the limits of the examinations

The report considers the area from the Norwegian coast to Bjørnøya in the north and the new border with Russia in the east. This corresponds roughly to the area that is open for exploration and exploitation of petroleum resources in the Norwegian sector of the Barents Sea.

The combined probability of an evacuation and rescue being necessary at the same time as inclement weather at the facility is not treated in this report. This is deemed allowable because actual weather conditions are used and the regulations stipulate a requirement for quick and efficient evacuation at all times and in all weather conditions.

The report does not consider issues related to winterization of a facility as these are considered to be in place as a prerequisite for evacuation.

Protection against ice accretion on vessels and structures is not discussed in this report. It is a major topic that designers need to give due consideration.

3.3 A briefing of the methods that are used

Pertinent meteorological observation data is collected from the Norwegian Meteorological institute using eKlima. The data is used to evaluate evacuation and rescue under the observed conditions. The probability and effect of ice accretion on vessels, in particular lifeboats, is considered in the report. A simplified mathematical model of a lifeboat is used to examine the effects of ice accretion on the stability and the roll period.

3.4 Information about the quality/certainty of the given information

The meteorological observations are collected from the Norwegian Meteorological institute and are considered reliable. Information on the accuracy of the measurements can be found together with the data in eklima/24/.

The stability calculations use a very simplified and rudimentary model of a lifeboat. They should NOT be used as exact information on the scale of the issue of ice accretion. They are only intended to illustrate that the issue should be given due consideration by all responsible parties, i.e. designers, owners and authorities.

3.5 The most important results

Meteorological conditions in the Barents Sea are such that existing equipment like life rafts, escape chutes, davit launch lifeboats and 1st and 2nd generation standby vessels may not be appropriate for the prevailing conditions during winter. Ice accretion on lifeboats is possible and could threaten stability if the lifeboat has to ride off inclement weather conditions while waiting for an operational weather window that allows rescue of the passengers. The issue of ice accretion is also of concern for standby and rescue vessels.

3.6 Major findings and conclusions

All year operation in the Norwegian sector of the Barents Sea is possible when appropriate risk analysis and risk reduction measures are put in place.

The analysis of the meteorological data for stations around the Barents Sea coincide with what can be expected from literature and norms for the area. The meteorological data and the stability calculations indicate that stability of lifeboats could be impaired due to ice accretion. This is an issue that the designers and producers of lifeboats are aware of, but has not been investigated in any detail. The effect of ice accretion must be investigated for each lifeboat model that are intended to be used on facilities operating in the Barents Sea.

Access to reliable weather forecasts is paramount for operating in the Barents Sea. Responsible personnel onboard facilities operating in the Barents Sea should be competent in the interpretation and understanding of weather forecasts and the implications the conditions may have in an evacuation and rescue situation.

Awareness to potential ice conditions is important as activity moves to the north or the east towards the borderline with Russia.

Equipment available for evacuation can encounter conditions that render them inappropriate. The limitations of existing evacuation and rescue systems are generally understood/2/.

Third generation rapid response rescue vessels are recommended as standby vessels in the Barents Sea. Their rescue capacity and ability is by far the best that is currently available/29/.

The currents regulations are functional and risk based. They are considered sufficient to regulate safe evacuation and rescue in the Barents Sea. The guidelines to the regulations should be complemented with references to standards like ISO-19906. Specific requirements to the use of third generation rapid response rescue vessels should also be considered enforced.

3.7 Recommendations for further work

The affect of ice accretion on lifeboat stability must be investigated for each lifeboat model that is intended for use on facilities operating in the Barents Sea.

The affect of ice accretion on standby and rescue vessels should also be investigated for each vessel that is intended for operation as a support vessel to any petroleum facility.

Appropriate standards and norms should be identified and included either in the regulations or in the guidelines to the regulations. This is work that should be aligned with the Barents 2020 project involving Norway and Russia/1/.

4 INTRODUCTION

4.1 Regulatory requirements

There are two direct requirements given in Norwegian HSE legislation regarding evacuation from facilities used in petroleum activities. They are stated in the Activities regulation § 68 litera d and in the Facilities regulation § 43. The main content is given below;

Activities regulation § 68 Handling of situations of hazard and accident /32/
The party responsible shall ensure that necessary actions are taken as quickly as possible in the event of situations of hazard and accident so that
d) the personnel on the facility can be quickly and efficiently evacuated at all times, cf. also the Facilities Regulations Section 43 on means of evacuation,

Facilities regulation § 43 Means of evacuation /33/
It shall be possible to carry out quick and effective evacuation of personnel on facilities to a safe area in all weather conditions, cf. the Activities Regulations Section 68 on handling of situations of hazard and accident litera d.

The regulatory requirement is to be able to evacuate quickly and effectively at all times and under all weather conditions. The regulatory requirement does not stipulate a probability for success of an evacuation. Means of safe evacuation shall always be available for use by all personnel onboard the facility. If these conditions cannot be met under certain weather conditions, necessary compensating measures shall be put in place to ensure the safety of the personnel involved in the petroleum activity. Examples of compensating measures may be:

a.) Personnel leave the facility before the weather situation arises that precludes safe evacuation using available evacuation means. Return of personnel to the facility can only take place when the weather conditions have returned to a level that allows safe evacuation and renders existing evacuation systems available for use.
b.) Activities involving risk or threatening the safety of the facility, for example hot work or well intervention, are not performed immediately prior to or during the weather situation.

4.2 A brief description of the methods

Pertinent meteorological data has been collected for 4 stations around the Barents Sea, ie on the coast of northern Norway and Bjørnøya. The data is gathered from the Norwegian Meteorological Institute and eKlima /24/.

Based on the interpretation of the regulatory requirement, actual weather conditions that have been observed are evaluated for the prospect of a successful evacuation under those given conditions. The data is used in a deterministic evaluation of conditions on given days in 2008 and 2009. These years have been chosen in order to avoid a discussion regarding the relevance of this work regarding issues related to climate change or global warming.

The result of the analysis of the meteorological data is used to consider what effect these may have on an evacuation under the given conditions. The main focus is on lifeboat evacuation and the effect of icing. Some consideration is also given to how long the lifeboat may be exposed to these conditions due to difficulty in retrieving either the persons onboard or the whole lifeboat onto another vessel. Retrieval may be difficult due to wind and sea conditions.

A simplified model of a lifeboat is used to calculate static stability conditions with regard to metacentric height and the roll period. The model is described in detail in section 4 of this report.

4.3 The limitations of the report

4.3.1 Probability of inclement weather and an accident

It is not the aim of this report to consider the probability of an accident occurring simultaneously with the examined weather conditions. A probabilistic approach to the simultaneous occurrence of inclement weather conditions and an accident requiring evacuation from the facility is not considered as applicable within the interpretation of the regulatory requirement. Evacuation shall be possible under all weather conditions independently of the probability of the accident. This equates to being able to evacuate at the design metocean conditions of the area where the facility is being operated.

4.3.2 Winterisation

Issues related to winterisation of the facility will not be discussed in this report. It is acknowledged that there are numerous challenges that need to be overcome to ensure that the lifeboats and other means of evacuation are always accessible and ready for use. In this report, winterisation of a facility is considered to be in place as a prerequisite for evacuation.

4.3.3 Ice protection

Methods for protecting vessels and structures against ice accretion and for the removal of ice are not discussed in this report. For further information on this subject reference is made to the paper "Assessment of Superstructure ice protection as Applied to Offshore Oil Operations Safety", Charles Ryerson, April 2009, US Army Corp of Engineers, ERDC/CRREL, TR-09-4.

4.3.4 Geographical area

This report concentrates on the area currently opened for exploration and exploitation of petroleum resources in the Norwegian sector of the Barents Sea. This is basically the area from ca. 15° E to 31° E and 70° N to 74,5° corresponding to the area between the coast of northern Norway and Bjørnøya. This area is shown on the map in figure 1. The map is an excerpt from the Norwegian Petroleum Directorate continental shelf map, /21/.

The border between Norway and Russia from the coast through the Barents Sea to the North Pole, has been disputed by the two countries for approximately 40 years. In April 2010 the border dispute between Norway and Russia was resolved. The newly agreed border is shown in figure 2, /22/.

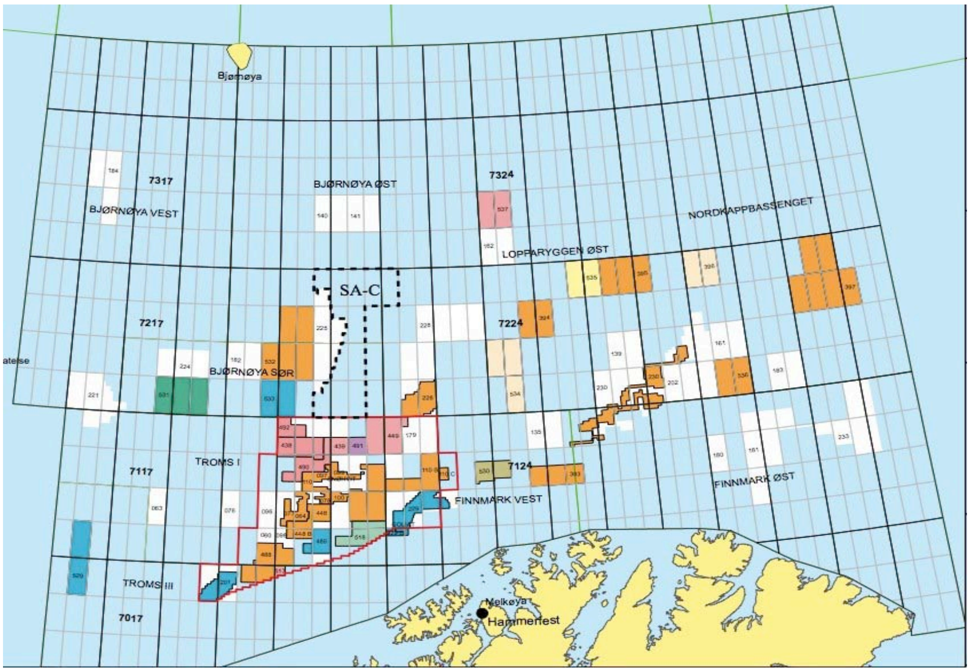

Figure 1, Map of the blocks in the Norwegian part of the Barents Sea /21/

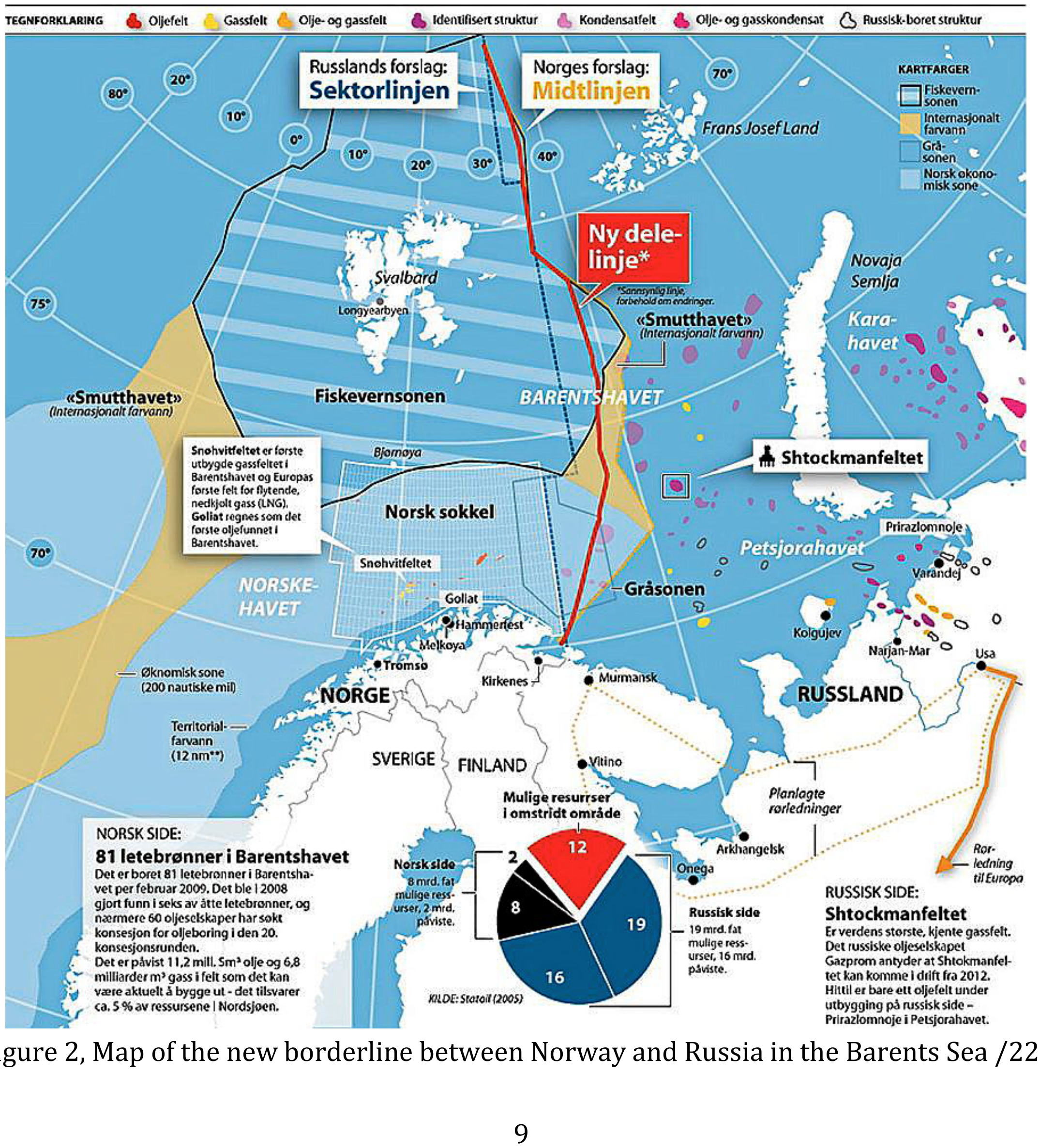

Figure 2, Map of the new borderline between Norway and Russia in the Barents Sea /22/

5 MATERIALS AND METHODS

5.1 *Barents Sea Climate*

There are numerous sources of information regarding the climate of the Arctic. The main sources used in this report are ISO/FDIS 19906:2009(E), /17/, and Norsok N-003 Edition 2, /20/, September 2007. In addition, course material (Gudmestad, O.T. 2009) is taken into account and used as background information. The area of the Barents Sea opened for Norwegian petroleum activity corresponds to the southern half of area 1, Western Region in ISO 19906. This area is described as having a winter climate all year. The following climatic issues have been identified as pertinent to operations in the Barents Sea.

5.1.1 Air temperature

The maximum average air temperature is +4,4 °C with the annual range between +2,0 to +7,0. The maximum air temperature that can be expected in the southwest, near Goliat and Snøhvit, is in the range of 20°C to 25°C. Towards the north and east, the maximum temperature decreases to the range of 15°C to 20°C.

The minimum average air temperature is -7,7 °C with an annual range between -6,0 to -9,0. The minimum air temperatures that can be expected in the southwest are in the range of -15°C to -20°C. Towards the north and east, the temperatures decrease to the range of -20°C to -30°C. /17 & 20/

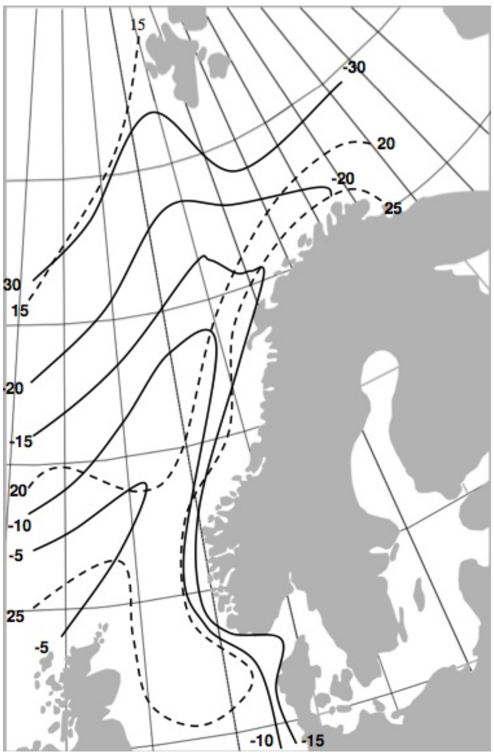

Figure 3 - Highest and lowest air temperature with an annual probability of exceedance of 10-2 (the temperatures are given in °C) /20/

5.1.2 Sea temperature

The maximum average sea temperature is +7,0 °C with the annual range between +5,0 to +9,0. The maximum sea temperatures that can be expected in the southwest are in the range of 10°C to 12,5°C. Moving towards the north and east, the maximum temperatures decrease to the range of 5°C to 10°C.

The minimum sea temperature that can be expected in the southwest is in the range of +2°C to +4°C. Towards the north and east, temperatures decrease to the range of +2°C to -2°C. /17 & 20/

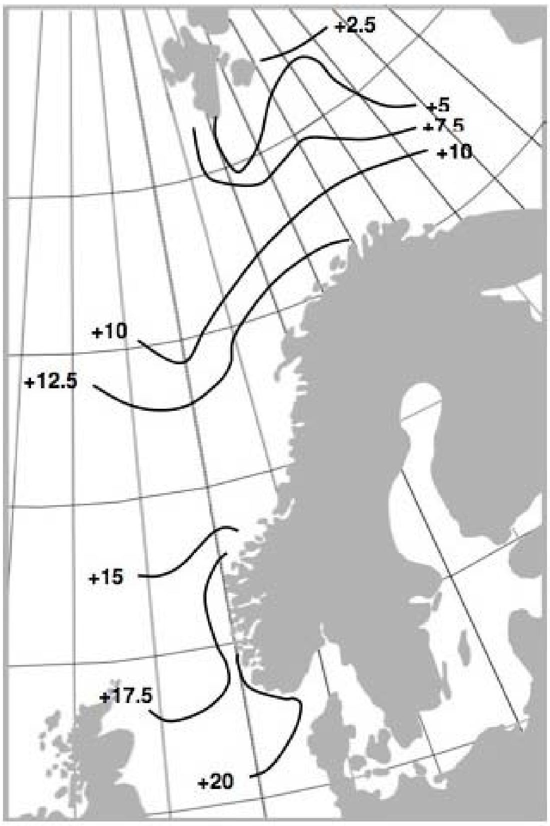

Figure 4 - Highest surface temperature in the sea with an annual probability of exceedance of 10-2 (the temperatures are given in °C) /20/

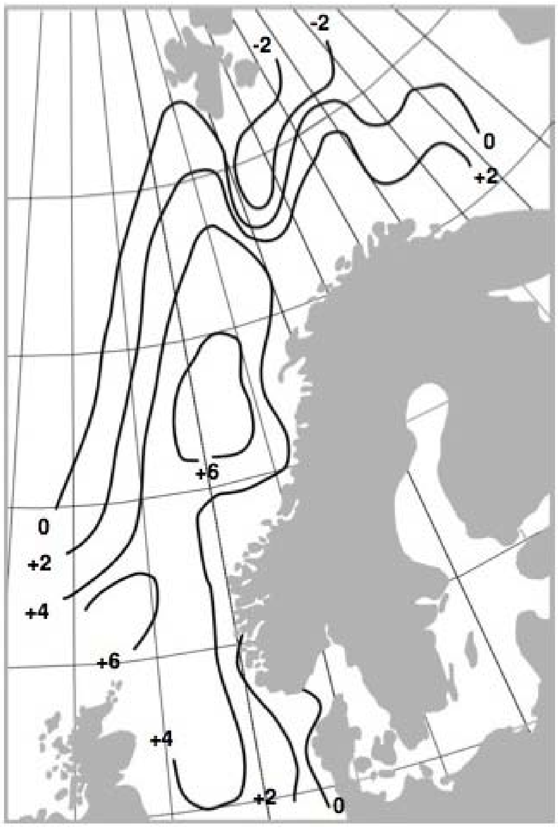

Figure 5 - Lowest surface temperature in the sea with an annual probability of exceedance of 10-2 (the temperatures are given in °C)/20/

5.1.3 Visibility

Visibility can be impaired both by fog and snowfall. Statistically this can occur for a large number of days during the year. Typically there 64 days per year with visibility below 2km due to snow and 76 days per year with visibility below 1km due to fog. Reduced visibility is a lesser threat to safety as there is a very low probability of icebergs in the area. Measures have been taken to establish internationally agreed fixed shipping lanes lying 30nm off the coast from the Russian border to Røst, thereby reducing the probability of collision with passing ships. Fog and snowfall that impairs visibility will be an operational issue reducing the availability of helicopter transport and potentially disturbing operation of supply vessels in close proximity to the facility. Severe fog conditions can hinder helicopters performing medical evacuation, precautionary evacuation or rescue operations. /7, 17 & 20/

5.1.4 Sea conditions

The significant wave height that can be expected in the southwest is 15 m decreasing to 14 m when moving to the north and the east. Storms can create violent sea and wave conditions disrupting activities and hinder evacuation or survival on the sea. /20/

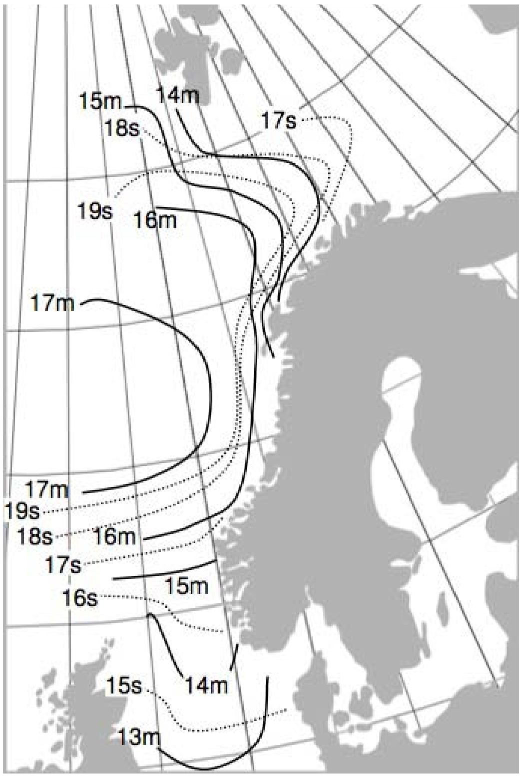

Figure 6 - Significant wave height Hs and related maximum peak period TP with annual probability of exceedance of 10-2 for sea-states of 3 h duration. ISO-curves for wave heights are indicated with solid lines while wave period lines are dotted.

5.1.5 Wind

The 10 minutes average maximum wind speed at 10 m above sea level is 26,6 m/s with the annual range of 25 m/s to 28 m/s. The dominant wind direction during the summer is from the west. The dominant wind direction during the winter is from the northeast. Extreme wind speeds can occur during polar low and polar front conditions. /17/

5.1.6 Polar Lows

Polar lows are weather phenomena that are well known from the Norwegian and Barents Sea. The storm or polar low occurs in the season from autumn to winter with a frequency of 2 to 4 per month. Polar lows are a potential threat to all activity in the Barents Sea due to their nature and suddenness with which they develop. (/13/ Noer, G & /14/ Sætre, Ø)

The polar lows develop in a short space of time and have a short lifespan. Typically, polar lows have durations of 6 to 48 hours. They develop swiftly when cold wind blows from the ice covered regions in the north over areas with relatively warm sea. The storm dies or dissipates when it move over land because the driving force, the warm sea, no longer provides the energy to sustain the wind system. A polar low has a typical diameter of ca. 100 to 500 km in diameter making it a relatively small weather system. Typically, a polar low can travel at ca. 15 to 25 knots with the highest observed speed of 52 knots. Winds speeds are typically up to Beaufort force 10 or storm with wind speeds up to 28,4 m/s. Hurricane wind speeds have been observed but are more seldom.

The wind is strongest to the west of the centre. The wind decreases in speed to the east of the centre. It is not uncommon that the polar low is accompanied by heavy snowfall. The strong and variable winds can create chaotic conditions on the sea even though there is not enough fetch to build up very large waves. The combination of wind, snow and sea spray can increase the danger of icing on vessels and structures.

Polar lows are difficult to forecast due to the fact that there are few meteorological observation stations in the Barents Sea. Satellite surveillance is necessary to provide reliable forecasts. The coverage provided by satellites is currently not on a full 24 hour basis because the polar orbit only brings the satellite over the area for a limited period each day.

5.1.7 Sea ice and icebergs

Normally the seawater in the Barents Sea will freeze when the water temperature is -1,7°C to -1,9°C dependent on the salinity of the water. Sea ice will normally only occur north 73°N and to the east of 31°E with a return frequency of 100 years. The return frequency for sea ice increases to ca. 10 years at 74°N and ~33°E. It is interesting to note that the area now acquired for potential exploration due to resolving the border issue with Russia, has a greater probability for sea ice than the areas that are currently opened for activity. (/17/ & /20/)

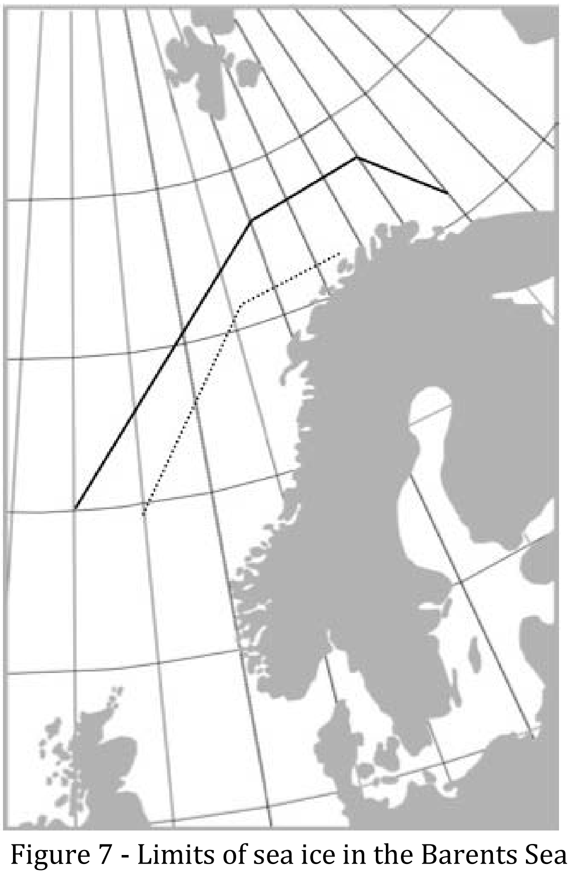

Figure 7 - Limits of sea ice in the Barents Sea with annual probability of exceedance of 10-2 (solid line) and 10-4 (dotted line) /20/

Figure 8 - Limit for collision with icebergs with a probability of exceedance of 10-2 (solid line) and 10-4 (dotted line) /20/

5.2 Other specific features of the Barents Sea

5.2.1 Icing on vessels

The climate conditions in the Barents Sea are such that icing on vessels can normally occur from October to May. There are two types of icing that need to be taken into consideration for the Barents Sea, atmospheric and sea spray icing. Atmospheric icing occurs in conjunction with low air temperature and precipitation. This form of icing normally leads to smaller amounts of ice developing on structures than sea spray ice accretion. Atmospheric ice has normally a higher density than sea spray ice (/2/ Løset et.al. 2006). I will only discuss the effects of sea spray ice accretion as this is the dominant source of ice on structures and vessels.

Sea spray icing is dependent mainly on the following parameters /11 & 12/:

- Air temperature: as the air temperature decreases below the freezing point of the seawater, ice will be deposited if sea spray occurs.
- Wind speed: increasing wind speed leads to more sea spray and more water in the air to freeze onto the vessel. Beaufort force 6 equivalent to 10,8 m/s is normally considered as the minimum wind speed to start ice accretion.
- Sea surface temperature: as the sea surface temperature decreases towards the freezing point, icing can increase dramatically as there is less energy that needs to be removed from the sea spray. Seawater has normally got a freezing temperature of -1,9°C in the Barents Sea. The freezing point is determined by the salinity of the water and less salt in the water leads to a higher freezing point.
- Sea state: as the sea state gets more severe as the wind increases and drives waves that can release sea spray either when breaking or when a vessel sails into the waves. The bow wave then creates the spray. Beaufort force 6 corresponds to waves of Hs=~3m with maximum waves of ~4m.
- Size and type of structure or vessel: ice accretion due to sea spray does not normally occur over 25m above sea level. Sea spray is generally not carried higher than 25m. It is not uncommon for small fishing vessels to experience icing. These fishing vessels are comparable in size to lifeboats. It is therefore considered relevant to look into the issue of icing on lifeboats.
- Course relative to the waves and speed: the amount of sea spray developed is a direct result of the speed of the vessel and the angle that the vessels heads into the waves. Icing can be reduced by decreasing vessel speed and optimising the vessel heading into the waves.

A formula has been developed to predict the rate of ice accretion due to sea spray /2/. The formula takes into account the wind speed (Ua), the freezing point of seawater (Tf), the sea surface temperature (Tw) and the air temperature (Ta). The ice accretion predictor (PR) has been developed by the National Oceanic and Atmospheric Administration (NOAA). The relationship between the predictor and the ice accretion rate is illustrated in the figure below.

$$PR = Ua(Tf-Ta)/(1+0,4(Tw-Tf))$$

	Light	Moderate	Heavy	Extreme
Icing rate cm/hr	< 0.7	0.7 to 2.0	> 2.0	> 5.0
Predictor	< 20.6	20.6 to 45.2	> 45.2	> 70

Table 1, Relationship between icing predictor and rate of ice growth /2/

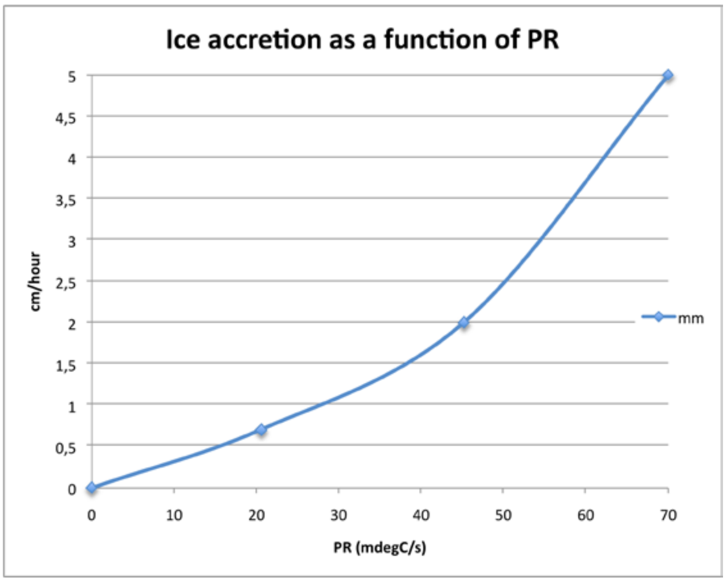

Figure 9, Ice accretion in cm/hour as a function of icing index, PR

The two figures below illustrate the relationship between two parameters that are used in the ice accretion predictor. The wind speed in each chart corresponds to the lower limit for Beaufort force 6 to 12, ie fresh breeze to hurricane. Fixed air temperatures of -5 deg C and -10 deg C are used to illustrate the effect of decreasing air temperatures. It can clearly be seen that the predictor increases dramatically as the seawater temperature approaches the freezing point. The yellow, orange and red horizontal lines are used to denote an ice growth rate of 0,7cm/h, 2cm/h and 5cm/h respectively.

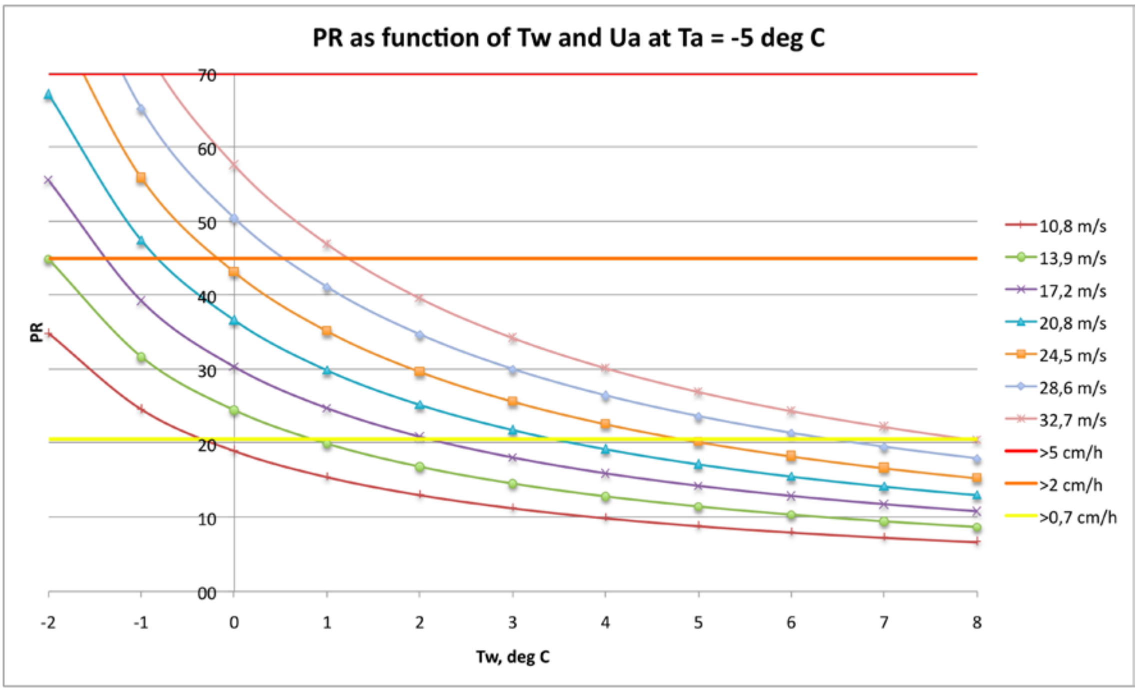

Figure 10, Icing index as a function of seawater temperature (Tw) and the wind speed (Ua) at a air temperature of -5 deg C.

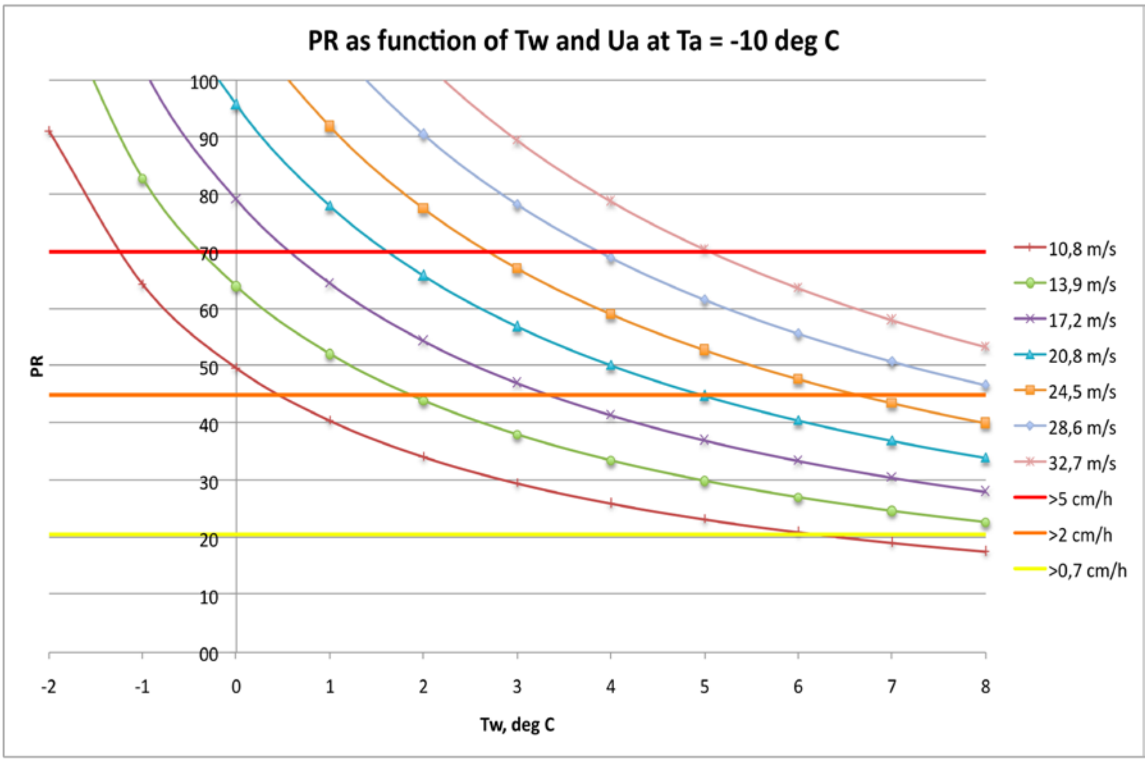

Figure 11, Icing index as a function of seawater temperature (Tw) and the wind speed (Ua) at a fixed air temperature of -10 deg C.

5.2.2 Darkness

The sun is below the horizon for a given period during the winter. This results in total darkness, called polar night, in the middle of the winter. There are limited periods of twilight during the day until the sun returns. The length of the daylight period decreases rapidly from the autumn equinox until the sun leaves. Similarly the daylight period increases rapidly from the return of the sun until the spring equinox /25, 26 & 27/. A twilight chart can be found in appendix 9.4.

Location	Sun leaves	Sun returns
Vardø	23. November	19. January
Hammerfest (Fruholmen)	22. November	20. January
Nordkapp	20. November	22. January
Bjørnøya	07. November	04. February
Longyearbyen	26. October	16. February
North Pole	25. September	18. March

Table 2, Dates for the sun below the horizon /26/

5.2.3 Weather forecasting

Reliable weather forecasting is paramount for safe operation and activity at sea. Due to the low number of fixed observation stations in and around the Barents Sea, reliable weather forecasts are challenging, especially with regard to forecasting polar lows. As petroleum resources are developed in this area, valuable information will be gained through new fixed observation stations on the facilities. (/16/ Wergeland, S. 2005)

5.3 Meteorological data

5.3.1 Observation data used in the report

Meteorological measurements are limited in the Norwegian sector of the Barents Sea. I have chosen to use information readily available from the Norwegian Meteorological Institute in eKlima/24/. I have selected the four stations listed in the table below. The stations all lie on the outer edge of the geographical area covered in this report. The table also shows the type of observations that have been used for analysis in this report.

	Longitude	Latitude	TA	TW	TD	DD	FF	FG	FG_1	HL	VV
Bjørnøya	74,5167	19,0167	X	X	X	X	X	X		X	X
Fruholmenfyr	71,0933	23,995	X		X	X	X		X		
Slettnesfyr	71,084	28,2178	X		X	X	X		X		
Vardø Radio	70,3707	31,099	X		X	X	X		X	X	X

Table 3, Meteorological observations available at selected locations /24/

TA: Air temperature, °C	DD: Wind direction	HL: Cloud base, m
TW: Sea temperature, °C	FF: Wind speed at 10 meter, m/s	VV: Visibility, m
TD: Dew point, °C	FG_1: Maximum gust last hour	FG:Maximum gust

The observation data has been loaded into an Excel spreadsheet. A value for the icing index, PR has been calculated /2/. The difference between the air temperature and the dew point has been calculated as an indication of the likelihood of fog developing /7/. Conditional formatting of the spreadsheet has been used to highlight the analysis of the observation data. The following limits have been used in the spreadsheet.

TA, air temperature below -10 °C, cell is yellow
TA, air temperature below -15 °C, cell is orange
TA, air temperature below -20 °C, cell is red
HL, cloudbase =< 200m, cell is yellow, minimum for normal helicopter transport
VV, visibility =< 1000m, cell is yellow, defined as fog
FF, FG, FG_1, wind speed and gust >= 24,5 m/s, cell is red, Beaufort 10, storm
FF, FG, FG_1, wind speed and gust >= 17,2 m/s, cell is orange, Beaufort 8, gale
FF, FG, FG_1, wind speed and gust >= 10,8 m/s, cell is yellow, Beaufort 6, strong breeze
PR, icing index, >= 45,2, cell is red, ice accretion over 2 cm/h
PR, icing index, >= 20,6, cell is orange, ice accretion between 0,7 and 2 cm/h
PR, icing index, > 0, cell is yellow ice accretion may begin

5.4 Lifeboat stability

5.4.1 Stability requirements

Stability requirements for lifeboats can be found in IMO Life Saving Appliances (LSA) Code and Det Norske Veritas Offshore Standard DNV-OS-E406, April 2009. An excerpt of the DNV standard can be found in appendix 9.2. Some of the main requirements are listed below:

- The lifeboat shall have inherent buoyancy.
- The lifeboat shall have self-righting ability.

- Lifeboats that become fully submerged after water entry shall be stable and have a positive righting moment.
- The lifeboat shall be stable and have a positive metacentric height when loaded with 50% of maximum occupants placed one side of the centreline.
- The stability and the self-righting ability are dependent on the passengers being strapped in their seats.

5.4.2 Lifeboat model

Description of the model

A simplified model of a lifeboat is used in this report. The lifeboat cross section is described as a triangle below the waterline and a rectangle above the waterline. The triangle is dimensioned such that the height of the triangle is equal to the draught of the lifeboat when empty. Any additional weight added to the lifeboat, people and ice, will start submerging the rectangle. This cross section is used for the entire length of the lifeboat. This model is chosen to allow simple calculations with the purpose of illustrating the effect of ice on the lifeboat. It is not intended to be an exact model and correct calculation of real stability of any particular make of lifeboat. As the lifeboat model is simplified, the resulting GM and T_{roll} must not be taken literally. The amount of ice that any particular lifeboat can tolerate before losing stability must be investigated for each type of lifeboat. These calculations are only intended to illustrate a potential problem.

In the case of a real lifeboat experiencing icing, the ice will spread more evenly and the centre of gravity will probably be lower than used in the spreadsheets. This is due to icing on the sides of the lifeboat as well as the top. The lifeboat is a small vessel with limited height and any waves or green sea washing over the lifeboat could melt away ice and reduce the problem. When performing such a rudimentary calculation as is done in this report, it is intended that these calculation shall not be identified with any existing lifeboat on the market. The dimensions of the lifeboat used on the model are selected as an “average” of lifeboats available on the market.

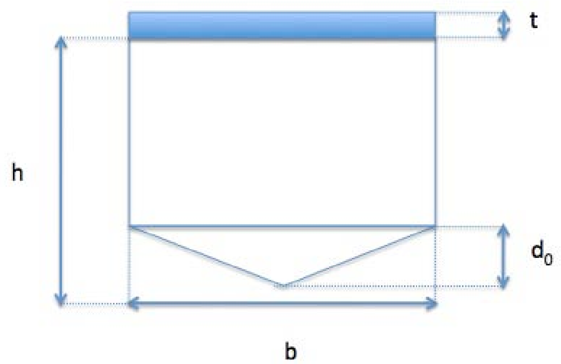

Figure 12, Simplified model of the lifeboat

Errors arising due to the selected model

The underwater volume is greater than what is realistic for a lifeboat of the given dimensions. Curvature of the hull towards the bow and stern are not taken into account. This gives a smaller initial draught than is the case in a real lifeboat.

The way the model is used gives the full beam of the lifeboat as the waterline breadth already from the empty boat case. The beam of the lifeboat model does not increase as it is loaded with people or ice. This gives a high initial moment of inertia that remains constant for all subsequent loads on the lifeboat model. The result of this is a higher initial metacentric height, GM, than can be expected in a real lifeboat. As a real lifeboat is loaded the beam will increase as the draught increases. In a real lifeboat, this leads to an increase in the moment of inertia resulting in a higher GM than the chosen model predicts, i.e. the model predicts a quicker degradation of GM than will be observed in real life.

The load from icing on the lifeboat is only distributed across the top of a flat surface on the top of the lifeboat. In a real situation ice would form along the sides as well as the top. The model uses a centre of gravity (CoG) for the ice that is higher than what may be observed in a real situation. The total ice load in the model is probably higher than may be observed in a real situation.

In total it is considered acceptable to proceed with the selected model and method of calculation because the results are intended only as an illustration of how the ice will effect the stability of the lifeboat and give an easy method for detecting icing by observing the change in the roll period of the lifeboat.

5.4.3 Stability calculation method

The following method and formulae are used in the attached Excel spreadsheets for calculating GM, the metacentric height and T_{roll}, the period of roll in each case.

The following parameters are used in the calculations:
M_b: initial mass of lifeboat
M_{pax}: mass of the passengers
M_i: mass of the ice
ρ_{sw}: density of sea water
ρ_i: density of ice
l: length of the lifeboat
b: beam or width of the lifeboat
h: height of the lifeboat
t: thickness of the ice
CoG_b: initial centre of gravity of the empty lifeboat (30% to 45% of the height of the lifeboat)
CoG_{pax}: centre of gravity of the passengers (30% to 60% of the height of the lifeboat)
CoG_i: centre of gravity of the ice (1/2 of the thickness of the ice plus the height of the lifeboat)
Other parameters are defined the first time they are used in the method description below.

<u>Step1:</u> Calculate the combined centre of gravity for lifeboat, passengers and the ice:

$$CoG_{bpax}=(M_b * CoG_b + M_{pax} * CoG_{pax})/(M_b + M_{pax})$$

$$CoG_{total}=(M_{bpax} * CoG_{bpax} + M_i * CoG_i)/(M_{bpax} + M_i)$$

CoG_{bpax}: centre of gravity of the lifeboat with passengers
CoG_{total}: centre of gravity of lifeboat with passengers and ice
M_{bpax}: mass of the lifeboat with passengers

Step 2: Calculate the volume of the displaced seawater:

$$\nabla = M/\rho_{sw}$$

∇: volume of the displaced seawater
M: mass of the lifeboat, passengers and ice as relevant in each case

Step 3: Calculate the draught of the lifeboat

Calculate the initial draught of the empty lifeboat according to the model description in the previous section, i.e. the triangular section of the lifeboat is submerged.

$$d_0=2*\nabla/l*b$$

d_0: initial draught of the empty lifeboat

Subsequent calculations of the draught consider the rectangular section becoming submerged in addition to the triangular section. The volume of the seawater displaced by the additional mass, i.e. passengers and ice.

$$d_{add}=\nabla_{add}/l*b$$

d_{add}: the additional draft resulting from the mass of the passengers and the ice
∇_{add}: the additional volume of seawater resulting from the mass of the passengers and the ice

The total draught of the lifeboat is then:

$$d_{tot}= d_0+d_{add}$$

d_{tot}: the total or actual draught of the lifeboat model

Step 4: Calculate the centre of buoyancy

Centre of buoyancy for the triangular section:

$$B_{tri}=2/3* d_0$$

B_{tri}: Distance from the keel to the centre of buoyancy of the triangular section

Calculate the centre of buoyancy for the rectangular section:

$$B_{rec}=1/2* d_{add}+ d_0$$

B_{rec}: distance from the keel to the centre of buoyancy of the rectangular

Calculate the combined centre of buoyancy of the two sections

$$CoB_{tot}=(V_{tri}* CoB_{tri} + V_{rec}* CoB_{rec})/(V_{tri} + V_{rec})$$

CoB_{tot}: centre of buoyancy of the lifeboat with passengers
CoB_{tri}: centre of buoyancy of the triangular section, measured from the keel
CoB_{rec}: centre of buoyancy of the rectangular section, measured from the keel
V_{tri}: volume of the triangular section
V_{rec}: volume of the rectangular section

<u>Step 5:</u> Calculate the inertia at the waterline plane:

$I_w=(l*b^3)/12$

I_w: inertia at the waterplane

<u>Step 6:</u> Calculation of metacentric height

The distance between B, centre of buoyancy, and M, the metacentre:

$BM=I/\nabla$

Calculation of metacentric height, GM:

$GM = KB + BM – KG$

KB: distance between the keel and the centre of buoyancy
BM: distance between the centre of buoyancy and the metacentre
KG: distance between the keel and the centre of gravity
GM: metacentric height

<u>Step 7:</u> Calculation of ice load

Mass of the ice:

$M_i = \rho_i*l*b*h$

The centre of gravity of the ice is half of the thickness of the ice because the vertical plane of the evenly distributed ice is considered to be rectangular. This distance is added to the height of the lifeboat in order to get the actual CoG of the ice.

<u>Step 8:</u> Calculation of the roll period

T_{roll} is calculated by:

$T_{roll} = 0,8*b/\sqrt{GM}$

5.5 Evacuation

In 1998 the Norwegian Petroleum Directorate (NPD) engaged Det Norske Veritas (DNV) to prepare a technical report on evacuation and rescue means. The report is titled Evacuation and Rescue Means, Strength Weaknesses and Operational Constraints, YA-795, Norwegian Petroleum Directorate 1998 December /3/. The following information on weather limitations for different means of evacuation are taken from the report and used in this report.

Type of evacuation means	Documented performance	Uncertain performance
Davit launched life rafts	6	8
Escape chute	6	8
Davit launched lifeboats	7	10
Free fall lifeboats	12	12

Table 4, Performance of evacuation means defined by Beaufort force /3/

5.5.1 Helicopter evacuation

Helicopter evacuation is considered the preferred method of dry evacuation from a facility. The performance or availability of helicopters is governed mainly by visibility. Under normal operations, a minimum cloud base of 200 to 300 meters is necessary and a horizontal visibility of 0,5 nautical mile. Helicopters do not normally operate on a helicopter deck in winds over 55 to 60 knots, Beaufort 10. Normal flying to installations may be performed at wind speeds with gusts up to 60 knots. (/18/ OGP 2005 & /19/ OLF 2010)

5.5.2 Lifeboat evacuation

Lifeboat evacuation by freefall lifeboat is considered the most reliable. The NPD/DNV report /3/ was made prior to the discovery of weaknesses related to free lifeboats in 2005 and subsequent years. The Norwegian Oil Industry Association (OLF) has performed extensive work related to issues with freefall lifeboats. The OLF work has resulted in many improvements and the new DNV-OS-E406 for freefall lifeboats. The Norwegian Shipowners' Association (NR) has performed studies of the issues related to davit launch lifeboats. The NR work has resulted in recommendations for improved competence, training and maintenance.

5.5.3 Escape chutes and life rafts

Escape chutes and life rafts have a limited operational window /3/. They generally cannot be used in conditions over Beaufort 8. 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 the year. The issue of protection from the cold will need to be looked into specifically.

5.5.4 Survival suits

Personal survival suits are required for all persons working on a facility, cf. facility regulation § 44, Survival suits and life jackets etc. /34/. In the Barents Sea high priority should be given to dry escape /1 & 10/. The main goal of a survival suit should be to keep a person warm and dry. Entry into the water during winter should be avoided as far as possible especially in temperature conditions where the air temperature is below 0°C and the sea temperature is low. Currently available survival suits need to be proven adequate for the winter conditions in the Barents Sea or replaced by more suitable models.

5.6 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 required to ride out a particular condition will depend on how severe the weather is and how long it is since it started. The tables below illustrate that there is a potential to have to stay onboard a lifeboat for a considerable length of time. It is therefore relevant to study the effects of icing on a lifeboat during this time span. The tables are taken from the NPD 1998 report, YA-795, /3/. The information regarding the rapid response rescue vessel is new information that is added to the table. This vessel is discussed in 5.6.2 Standby vessels.

Type of rescue means	Documented performance	Uncertain performance
Rescue basket	5	7
Rescue zone with net	6	8
Dacon scoop	6	8
MOB boat	6	8
Sealift	7	11
Fast recovery craft	8	11
Rapid response rescue vessels	9	
Helicopter	10	12

Table 5, Performance of rescue means defined by Beaufort force /3/

Beaufort	Mean duration (hours)	Maximum duration (hours)
6	20 to 25	
7	15	60
8	12	30
9, 10, 11	8 to 10	

Table 6, Mean and maximum duration of wind conditions /3/

5.6.1 Helicopter

In an emergency situation the operational limits can be exceeded at the discretion of the pilot /19/. The success of an operation in adverse weather conditions will be dependent on wind speed, visibility, fog or snow and the pilot's ability to operate under the prevailing conditions. The transport helicopters are the main resource for evacuating people in an emergency situation. The Norwegian rescue service, 330 squadron, has an excellent record in rescue operations under adverse conditions. The capacity of the rescue service is limited relative to the large number of people who can be onboard a facility operating in the Barents Sea.

5.6.2 Standby vessel

Custom designed third generation rapid response rescue vessels are now available /29, 30 & 31/. They are specially designed to launch and recover a fast rescue craft or daughter craft from a slipway in the stern. The slipway can also be used to recover a lifeboat from the sea. The sea trials of these vessels are promising and it is generally considered possible to operate in sea conditions up to Hs=< 9m /31/, corresponding to Beaufort 10 if the wind has had a short duration. If the wind has had a long duration and the sea has had time to build up, Hs=< 9m is reached already at Beaufort 9. Rescue to conventional standby vessels require the use of lifting equipment or the transfer of personnel from the lifeboat to the standby vessel by MOB boat, limited to Beaufort 6, or Fast Rescue Craft limited to operate up to Beaufort 8 or less respectively. There is therefore good reason to consider the possibility of survivors in the lifeboats having to ride off weather conditions.

6 RESULTS & ANALYSIS

6.1 Meteorological observations

I have chosen to discuss the weather conditions observed during the first 7 days of January in 2009. These conditions are representative for the weather in the Barents Sea during the winter months of 2008 and 2009. An evaluation of the conditions is discussed for each observation station on the following pages. A number of documents are use when evaluating the consequences of the conditions with regard to escape, evacuation and rescue. The main documents are listed in the reference section as /1, 3, 6, 7, 9 & 10/. Similar conditions can be found on numerous occasions during these two years. The periods of similar conditions are tabulated and analysed in appendix 9.1.

6.1.1 Bjørnøya

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG	PR	Fog
99710	2009	1	1	1	1014	300	-10,3	-13,2	-1,3	5000	10	9,8	17,5	66,39	2,9
99710	2009	1	1	7	1014	300	-10	-13,5	-1,3	3000	10	10,3	16,5	67,28	3,5
99710	2009	1	1	13	1014	300	-9,4	-12,7	-1,3	10000	10	7,7	14,4	46,57	3,3
99710	2009	1	1	19	1014	300	-10,1	-16,3	-1,3	20000	360	8,7	15,4	57,53	6,2
99710	2009	1	2	1	1014	300	-10,8	-15	-1,3	10000	10	10,3	14,4	73,93	4,2
99710	2009	1	2	7	1014	300	-8,9	-12,7	-1,3	10000	20	10,8	15,4	60,97	3,8
99710	2009	1	2	13	1016	200	-8,9	-12,1	-1,3	15000	30	11,8	17,5	66,61	3,2
99710	2009	1	2	19	1017	300	-10,5	-13,2	-1,3	10000	30	12,9	17,5	89,47	2,7
99710	2009	1	3	1	1019	300	-10,2	-13,2	-1,3	15000	30	11,8	17	78,98	3
99710	2009	1	3	7	1018	300	-11,1	-13,8	-1,3	15000	20	5,1	13,9	37,84	2,7
99710	2009	1	3	13	1015	300	-10	-11,6	-1,3	5000	30	9,8	16	64,02	1,6
99710	2009	1	3	19	1013	200	-11	-13,8	-1,3	3500	40	7,7	13,4	56,51	2,8
99710	2009	1	4	1	1014	300	-12,5	-15,6	-1,3	15000	30	7,2	9,8	61,55	3,1
99710	2009	1	4	7	1013	300	-12,4	-14,4	-1,3	15000	40	2,1	9,3	17,78	2
99710	2009	1	4	13	1006	300	-10,5	-12,1	-1,5	20000	200	6,2	7,7	45,97	1,6
99710	2009	1	4	19	990,9	100	-2,6	-3,3	-1,3	1000	240	12,9	17,5	7,282	0,7
99710	2009	1	5	1	997	300	-16,4	-19,4	-1,3	10000	60	6,2	27,3	72,5	3
99710	2009	1	5	7	990,2	300	-9,1	-13,2	-1,3	10000	350	17	29,8	98,71	4,1
99710	2009	1	5	13	994,1	300	-10,9	-12,7	-1,3	10000	350	15,4	24,2	111,8	1,8
99710	2009	1	5	19	996,5	300	-13,2	-15	-1,3	1500	30	7,7	20,6	70,17	1,8
99710	2009	1	6	1	997	300	-16,4	-19,4	-1,3	20000	60	6,2	11,3	72,5	3
99710	2009	1	6	7	995,4	300	-18,1	-21,4	-1,3	20000	100	5,1	9,3	66,63	3,3
99710	2009	1	6	13	995,9	300	-18,4	-22,4	-1,3	20000	50	7,2	10,8	95,81	4
99710	2009	1	6	19	997	300	-18,9	-22,4	-1,3	20000	40	10,3	14,4	141,2	3,5
99710	2009	1	7	1	997,8	300	-17,5	-20,4	-1,3	20000	20	9,3	12,9	117	2,9
99710	2009	1	7	7	999,6	300	-18,8	-22,4	-1,3	20000	20	9,3	13,4	126,8	3,6
99710	2009	1	7	13	1001	300	-18,1	-21,4	-1,3	20000	30	6,2	12,9	81	3,3
99710	2009	1	7	19	1000	2500	-18,2	-21,4	-1,3	20000	60	5,7	9,3	74,93	3,2

Table 7, Weather data for Bjørnøya 1.-7. January 2009

Air temperature: The average air temperature during the period is -12.6°C. The air temperature is ca. -10°C for the first five days and drops to ca. -18°C for the last two days. The cold air temperature combined with the wind would represent a considerable wind chill and provide the right temperature conditions for considerable icing.

Sea temperature: The sea temperature is stable at -1,3°C providing "ideal" conditions for the growth of ice.

Cloud base: The cloud base is low but would not hinder the use of helicopters in the case of an evacuation or rescue operation.

Visibility and darkness: The visibility in the whole period can be considered mostly as very good. However, January is dark and no daylight should be taken into account as far north as Bjørnøya.

Wind: The average wind speed in the period is 8,95 m/s i.e. mainly below strong breeze, 10.2 m/s, Beaufort force 6 which is considered minimum for icing to start. There are short periods gusting to gale force winds and only 2 observations of gusts up to storm. Icing should be expected in these periods due to the cold air.

Sea conditions: Based on the wind speed and gust observations for the first period, one could expect waves with an Hs=~3m with maximum waves of ~4m. On the 5th of January higher wave conditions could be expected. Almost certainly in excess of Hs=4 to 5m and maximum waves possibly developing to 10m for shorter periods.

Icing factor, ice growth rate: The average icing index for the period is 70,2 with ca 60 for the first 4 days and increasing to over 70 for the last 3 days. This gives a theoretical ice growth of 3 to 4 cm per hour in the beginning and over 5 cm per hour for the end of the period. If the lifeboats have to stay in the sea with the passengers onboard for many hours, considerable ice growth can be experienced and the issues illustrated in the stability calculations could occur. At the same time, any vessel involved in a rescue operation would also suffer from the same icing conditions. A rescue operation under the conditions observed during the 5th to 7th of January could prove to be very difficult.

Discussion

Helicopter evacuation is possible under these conditions. The use of lifeboats would be the second preference. If necessary, escape chutes and life rafts would probably lead to successful evacuation under these conditions, however, the low temperature would be of concern. The main challenge to evacuation by lifeboat in this period is that the icing factor indicates the possibility for severe icing with icing rate starting at 3 to 4 cm/hr and increasing to over 5 cm/hr. If the lifeboats were not recovered from the sea within 4 to 5 hours, the effects of icing, especially towards the end of the period with air temperatures in the region of -18°C, would become noticeable by increased roll period. The sea conditions for most of the period should allow rescue of the passengers and lifeboats due to a low significant wave height of 3 to 4m. One thing that must be taken into account is that any other vessels involved in the rescue operation would also run the risk of ice accretion on the superstructure. Awareness of the issue would be of the utmost importance and maneuvering of all vessels should be done at low speed to limit bow waves and sea spray. Rescue by helicopter or rapid response rescue vessels would be possible under these conditions. Conventional standby vessels with appropriate support equipment should be able to perform a rescue under these conditions.

Conclusion for an evacuation in this period

Evacuation and rescue would be possible. The main challenges would be the low temperature, lack of daylight and the possibility for icing. All possible precautions should be taken to avoid an evacuation in these conditions.

6.1.2 Fruholmen

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG_1	PR	Fog
94500	2009	1	1	1	1007		-6,3	-7,4	5		351	18	23,1	21,06	1,1
94500	2009	1	1	7	1009		-6,1	-8,1	5		360	15	21,5	16,76	2
94500	2009	1	1	13	1009		-4,8	-8,1	5		349	12,8	18,4	9,872	3,3
94500	2009	1	1	19	1009		-5,4	-8,5	5		336	11,9	19,6	11,08	3,1
94500	2009	1	2	1	1008		-5	-8,5	5		330	14,1	20,1	11,63	3,5
94500	2009	1	2	7	1007		-4,9	-7,8	5		329	13,4	17,6	10,69	2,9
94500	2009	1	2	13	1006		-3,5	-4,4	5		24	17,6	23,5	7,489	0,9
94500	2009	1	2	19	1006		-1,8	-4,7	5		17	15,6	20,3	-0,41	2,9
94500	2009	1	3	1	1007		-3	-4,4	5		44	12,7	20,3	3,715	1,4
94500	2009	1	3	7	1008		-2,5	-8,1	5		5	13,7	21	2,186	5,6
94500	2009	1	3	13	1008		-5,3	-6,7	5		342	15,2	20,7	13,74	1,4
94500	2009	1	3	19	1006		-4,5	-7	5		337	15,6	19,7	10,79	2,5
94500	2009	1	4	1	1005		-5,8	-7,8	5		11	13,4	17,1	13,9	2
94500	2009	1	4	7	1006		-5,1	-6,7	5		359	12,8	17,6	10,89	1,6
94500	2009	1	4	13	1007		-5	-8,1	5		17	6,6	14,8	5,441	3,1
94500	2009	1	4	19	1004		-3	-7,4	5		274	10,4	14,9	3,043	4,4
94500	2009	1	5	1	989		1	0	5		251	22	30,3	-17	1
94500	2009	1	5	7	987,7		-1,5	-4,7	5		309	22,8	28,4	-2,43	3,2
94500	2009	1	5	13	987,8		-3,4	-7,8	5		326	24	30,6	9,574	4,4
94500	2009	1	5	19	989,1		-4,1	-5,7	5		314	20,3	25,9	11,88	1,6
94500	2009	1	6	1	991		-6,2	-9,8	5		329	16,9	21	19,33	3,6
94500	2009	1	6	7	990,9		-7,3	-11	5		349	15,1	21,6	21,69	3,9
94500	2009	1	6	13	989,6		-7,7	-14	5		19	14,2	19,9	21,9	6,1
94500	2009	1	6	19	988,9		-7,6	-12	5		4	11,8	17,1	17,89	4,5
94500	2009	1	7	1	987,6		-7,6	-9,8	5		345	12,1	17,3	18,34	2,2
94500	2009	1	7	7	987,5		-7	-8,5	5		308	18,9	23,7	25,64	1,5
94500	2009	1	7	13	987,5		-4,7	-5,7	5		327	22,5	28,1	16,76	1
94500	2009	1	7	19	993,3		-4,4	-5,7	5		330	17,2	21,6	11,44	1,3

Table 8, Weather data for Fruholmen 1.-7. January 2009

Air temperature: The average air temperature during the period is -4,7°C. The air temperature is below the period average at the beginning and the end of the examined period.

Sea temperature: The sea temperature is not recorded for Fruholmen. A typical value of 5°C for the area is used in the calculation of the icing predictor.

Cloud base: The cloud base is not recorded for Fruholmen

Visibility and darkness: Visibility is not recorded for Fruholmen. Taking the difference between the air temperature and the dew point for this period, it is unlikely that visibility would be impaired by fog. The visibility in the whole period should be considered mostly as good. January is dark but short periods of twilight can be expected during the middle of the day. Fruholmen is further to the south than Bjørnøya.

Wind: The average wind speed in the period is 15,6 m/s i.e. mainly in the band of near gale or Beaufort force 7 and is above minimum for icing to start. There are short periods of winds speeds in the band of severe gale or Beaufort force 8. There are periods of wind gusts up to violent storm, Beaufort force 11. Combined with the relatively cold air, the wind chill could be considerable.

Sea conditions: Based on the wind speed and gust observations, one could expect waves with an Hs=~4m with maximum waves of ~5,5m. On the 5th and 7th of January higher wave conditions could be expected. Almost certainly in excess of Hs=7m and maximum waves may develop to 10m for shorter periods.

Icing factor, ice growth rate: The average icing index for the period is 11,0 during the period. Icing during this period is almost negligible. In the period of the 5th to the 7th of January the combination of high wind speeds, potentially rough sea conditions with spray developing, some icing could be expected but probably not more than 0,5cm/hour. This would not threaten the stability of the lifeboat or any vessel involved in a rescue operation.

Discussion

The main challenges for an evacuation in this period would almost definitely be the wind and sea conditions. Helicopter evacuation is possible under these conditions. The use of freefall lifeboats would be the second preference. Davit launch lifeboats, escape chutes and life rafts could potentially be inappropriate for these conditions. With current technology it could be difficult to retrieve the lifeboat from the sea onto a rescue vessel. A rapid response rescue vessel would be recommended in these conditions. An evacuation on the 5th or 7th of January would probably lead to the lifeboat having to ride off the weather and wait until the sea conditions improved before transfer either of the entire lifeboat or the passengers to a rescue vessel. Under these conditions, it would be possible although difficult at times, to perform a helicopter lift of the passengers from the lifeboat. The potential icing conditions would not threaten the stability of the lifeboat or rescue vessel but would make conditions on top of the lifeboat dangerous if the passengers are required to position themselves there for hoisting to a helicopter.

Conclusion for an evacuation in this period

Evacuation and rescue would be possible. The main challenge would be sea conditions and the passengers may have to remain in the lifeboat for some time before being rescued.

6.1.3 Slettnes

St.no	Year	Mnth	Date	Time(	PO	HL	TA	TD	TW	VV	DD	FF	FG_1	PR	Fog
96400	2009	1	1	1	1003,9		-6,6	-7,8	5		347	10,9	18,1	13,63	1,2
96400	2009	1	1	7	1003,6		-5,4	-6	5		337	13,4	19,5	12,47	0,6
96400	2009	1	1	13	1005,2		-5,5	-7	5		356	10,9	19,1	10,44	1,5
96400	2009	1	1	19	1005,1		-5,1	-8,5	5		325	13,2	19	11,23	3,4
96400	2009	1	2	1	1003,9		-5,2	-7,8	5		326	13,2	18,6	11,59	2,6
96400	2009	1	2	7	1001,5		-4,1	-4,7	5		326	15	20,2	8,777	0,6
96400	2009	1	2	13	1001,5		-2,7	-3,5	5		16	11,7	20,5	2,489	0,8
96400	2009	1	2	19	1002,4		-2,5	-5	5		7	13,2	19,8	2,106	2,5
96400	2009	1	3	1	1004,2		-3	-5,7	5		1	11,5	19	3,364	2,7
96400	2009	1	3	7	1004,5		-4,3	-7	5		359	13,7	19,7	8,745	2,7
96400	2009	1	3	13	1002,8		-4,7	-6	5		333	12,8	19,9	9,532	1,3
96400	2009	1	3	19	1001,7		-5,9	-7,4	5		335	11,1	18,8	11,81	1,5
96400	2009	1	4	1	1001,3		-5	-7,4	5		355	10,5	17,6	8,657	2,4
96400	2009	1	4	7	1002,3		-4,8	-8,1	5		358	10,3	15,3	7,944	3,3
96400	2009	1	4	13	1004,1		-3,9	-7,4	5		341	10	14,8	5,319	3,5
96400	2009	1	4	19	1001,7		-3,2	-5,7	5		297	9,3	14,2	3,215	2,5
96400	2009	1	5	1	989,2		-4,5	-5,3	5		217	15,7	21,4	10,86	0,8
96400	2009	1	5	7	981,7		-1,5	-5,3	5		295	20,4	26,8	-2,17	3,8
96400	2009	1	5	13	979,3		-4,8	-6	5		292	22,3	30,5	17,2	1,2
96400	2009	1	5	19	978,6		-1,2	-2,4	5		337	18,7	24,6	-3,48	1,2
96400	2009	1	6	1	982,2		-3	-3,5	5		300	14	20,5	4,096	0,5
96400	2009	1	6	7	985,1		-5,5	-6	5		312	15,8	22,7	15,13	0,5
96400	2009	1	6	13	985,5		-6,1	-6,7	5		311	14,3	20,8	15,97	0,6
96400	2009	1	6	19	984,8		-7,4	-13	5		303	11,1	18,6	16,24	5,3
96400	2009	1	7	1	982,3		-6,3	-7,4	5		280	12	22,2	14,04	1,1
96400	2009	1	7	7	975,9		-6,7	-7,4	5		250	17	29,9	21,7	0,7
96400	2009	1	7	13	980,2		-3,2	-5	5		65	10,6	14,3	3,665	1,8
96400	2009	1	7	19	985,8		-6,3	-9,4	5		219	6	8,6	7,021	3,1

Table 9, Weather data for Slettnes 1.-7. January 2009

Air temperature: The average air temperature during the period is -4,6°C with only small variations during the period.

Sea temperature: The sea temperature is not recorded for Slettnes. A typical value of 5°C for the area is used in the calculation of the icing predictor.

Cloud base: The cloud base is not recorded for Slettnes

Visibility and darkness: Visibility is not recorded for Slettnes. Taking the difference between the air temperature and the dew point for this period, it should be expected that impaired visibility could be experienced during the short intervals where the difference between the air temperature and the dew point are less than one degree. Generally, visibility in the whole period should be considered mostly as good. January is dark but short periods of twilight can be expected during the middle of the day as described for Fruholmen.

Wind: The average wind speed in the period is 13,2m/s i.e. mainly the band of strong breeze or Beaufort force 6 which is the minimum for icing to start. There are short periods of winds speeds in the upper band of gale or Beaufort force 8. There are periods of wind gusts up to storm, Beaufort force 10. Combined with the relatively cold air, the wind chill could be considerable.

Sea conditions: Based on the wind speed and gust observations, one could expect waves with an Hs=~3m with maximum waves of ~4m. Between 5th and 7th of January higher wave conditions could be expected, potentially in the region of Hs=5,5m and maximum waves may develop to 7,5m for shorter periods.

Icing factor, ice growth rate: The average icing index for the period is 8,98. Icing during this period is almost negligible. On the 5th of January when the wind is strongest, the air temperature has increased such that icing is unlikely. However, slippery conditions on the top of the lifeboat should be expected during most of the examined period.

Discussion

The conditions for the area around Slettnes during the examined period are generally similar to the conditions for Fruholmen. However there are slightly improved conditions both with regard to the wind and the sea conditions. There is also a lower probability of icing in this area for the period that has been considered.

Conclusion for an evacuation in this period:

Evacuation and rescue would be possible. The main challenge would be sea conditions and the passengers may have to remain in the lifeboat for a period before being rescued if the evacuation took place on the 5th of January.

6.1.4 Vardø Radio

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG_1	PR	Fog
98550	2009	1	1	1	1000,7	200	-6,2	-8,1	5	10000	335	10,3	17,4	11,78	1,9
98550	2009	1	1	7	999,6	50	-5,9	-7,8	5	6000	353	10,2	19	10,85	1,9
98550	2009	1	1	13	1000,5	100	-4,4	-8,1	5	10000	1	11,6	18,3	7,713	3,7
98550	2009	1	1	19	1001	200	-4,3	-7	5	10000	337	11	17,4	7,021	2,7
98550	2009	1	2	1	1000,1	200	-5,1	-8,5	5	2500	329	11,2	18,7	9,532	3,4
98550	2009	1	2	7	997,7	200	-4,5	-5,7	5	20000	358	10,3	17,4	7,122	1,2
98550	2009	1	2	13	996,2	200	-2,6	-3,5	5	20000	15	11,9	18,5	2,215	0,9
98550	2009	1	2	19	997,6	200	-2	-4,1	5	20000	353	10,3	18	0,274	2,1
98550	2009	1	3	1	998,7	200	-3,5	-4,1	5	500	7	13,1	20,5	5,574	0,6
98550	2009	1	3	7	999,8	200	-4,3	-5,3	5	10000	355	10,7	20,4	6,83	1
98550	2009	1	3	13	998,8	200	-5,3	-6,3	5	10000	346	11,2	18,2	10,13	1
98550	2009	1	3	19	997,5	200	-5,2	-10	5	30000	347	10,3	17,2	9,04	5
98550	2009	1	4	1	997,8	200	-5,6	-6,7	5	6000	343	11,5	17,4	11,32	1,1
98550	2009	1	4	7	998,6	200	-4,1	-9,4	5	20000	350	8,5	15,3	4,973	5,3
98550	2009	1	4	13	1000,9	200	-3,9	-8,5	5	6000	1	8,2	14	4,362	4,6
98550	2009	1	4	19	1001,2	200	-3,6	-7,8	5	30000	320	5,4	10,5	2,441	4,2
98550	2009	1	5	1	993,1	200	-5,2	-7	5	20000	239	12,9	15,6	11,32	1,8
98550	2009	1	5	7	981,7	200	-2,9	-3	5	15000	272	12,9	18,3	3,431	0,1
98550	2009	1	5	13	979,6	200	-5,2	-5,3	5	2500	279	16,2	22,1	14,22	0,1
98550	2009	1	5	19	970	200	-0,6	-2,2	5	10000	331	14	20,2	-4,84	1,6
98550	2009	1	6	1	978,1	200	-0,3	-4,4	5	20000	358	11,1	17,9	-4,72	4,1
98550	2009	1	6	7	979	200	-3,5	-3,8	5	1000	316	15,5	23,4	6,596	0,3
98550	2009	1	6	13	979,6	200	-5	-5,7	5	500	314	16	22,3	13,19	0,7
98550	2009	1	6	19	981,1	.	-6,4	-8,5	5	3000	314	14	20,8	16,76	2,1
98550	2009	1	7	1	981,2	200	-8,3	-8,9	5	3000	279	15,5	19,3	26,38	0,6
98550	2009	1	7	7	980,6	300	-8	-9,4	5	20000	267	13,1	19,1	21,25	1,4
98550	2009	1	7	13	980,6	100	-7,2	-8,5	5	55000	204	9,4	13,7	13,25	1,3
98550	2009	1	7	19	986,4	200	-7,7	-8,9	5	55000	281	4	6,1	6,17	1,2

Table 10, Weather data for Vardø 1.-7. January 2009

Air temperature: The average air temperature during the period is -4,7°C varying between -0,3°C and -8,3°C.

Sea temperature: The sea temperature is not recorded for Vardø. A typical value of 5°C for the area is used in the calculation of the icing predictor.

Cloud base: The cloud base is generally at 200m during the period, ie approaching a limit for normal helicopter operations but not necessarily stopping rescue operations by helicopter.

Visibility and darkness: Visibility is generally good during the period but there are short intervals of reduced visibility. January is dark but short periods of twilight can be expected during the middle of the day as described for Fruholmen and Slettnes. The combination of darkness, low cloud base and reduce visibility at times may have a negative effect on the possibility of helicopter rescue.

Wind: The average wind speed in the period is 11,4m/s i.e. mainly the band of strong breeze or Beaufort force 6 which is the minimum for icing to start. There are short periods of winds speeds in the band of gale or Beaufort force 8. There are periods of wind gusts up to severe gale, Beaufort force 9. Combined with the relatively cold air, the wind chill cannot be ignored.

Sea conditions: Based on the wind speed and gust observations, one could expect waves with an Hs=~3m with maximum waves of ~4m. Between 5th and 7th of January higher wave conditions could be expected, potentially in the region of Hs=4m and maximum waves may develop to 5,5m for shorter periods.

Icing factor, ice growth rate: The average icing index for the period is 8,36. Icing during this period is almost negligible. Slippery conditions on the top of the lifeboat should be expected and taken into account.

Discussion

Visibility and low cloudbase could present a challenge especially when taking the lack of daylight into consideration. The conditions for the area around Vardø during the examined period are generally similar to the conditions for Fruholmen and Slettnes. There are slightly improved conditions both with regard to the wind and the sea conditions. There is also a lower probabilty of icing in this area for the period that has been considered.

Conclusion for an evacuation in this period:

Evacuation and rescue would be possible. The main challenge would be visibility especially for helicopter evacuation or rescue from the lifeboat. Sea conditons are such that it is not likely that the passengers in the lifeboat would have to remain onboard for any prolonged period awating rescue by another vessel.

6.2 *Stability calculation results*

The following parameters have been used in the base case for the stability calculations. The results of the calculations are presented in figure 13 and 14.

Description	Value
Length of lifeboat	13,6 m
Beam of lifeboat	3,6 m
Height of lifeboat	4 m, excluding the height of the cockpit hood
CoG empty lifeboat	30% of height
CoG passengers	40% of height
Mass of empty lifeboat	13500 kg
Mass of single passenger	100 kg, DNV-OS-E406
Number of passengers	65
Density of seawater	1025 kg/m3
Density of deposited ice	600 kg/m3
Type of lifeboat	Approximation of a free fall lifeboat

Table 11, Lifeboat parameters

The diagrams illustrate how the beam and centre of gravity (CoG) of the passengers affect the metacentric height and the roll period. In figure 13 the beam is set at 3.4, 3.5 and 3,6 meter.

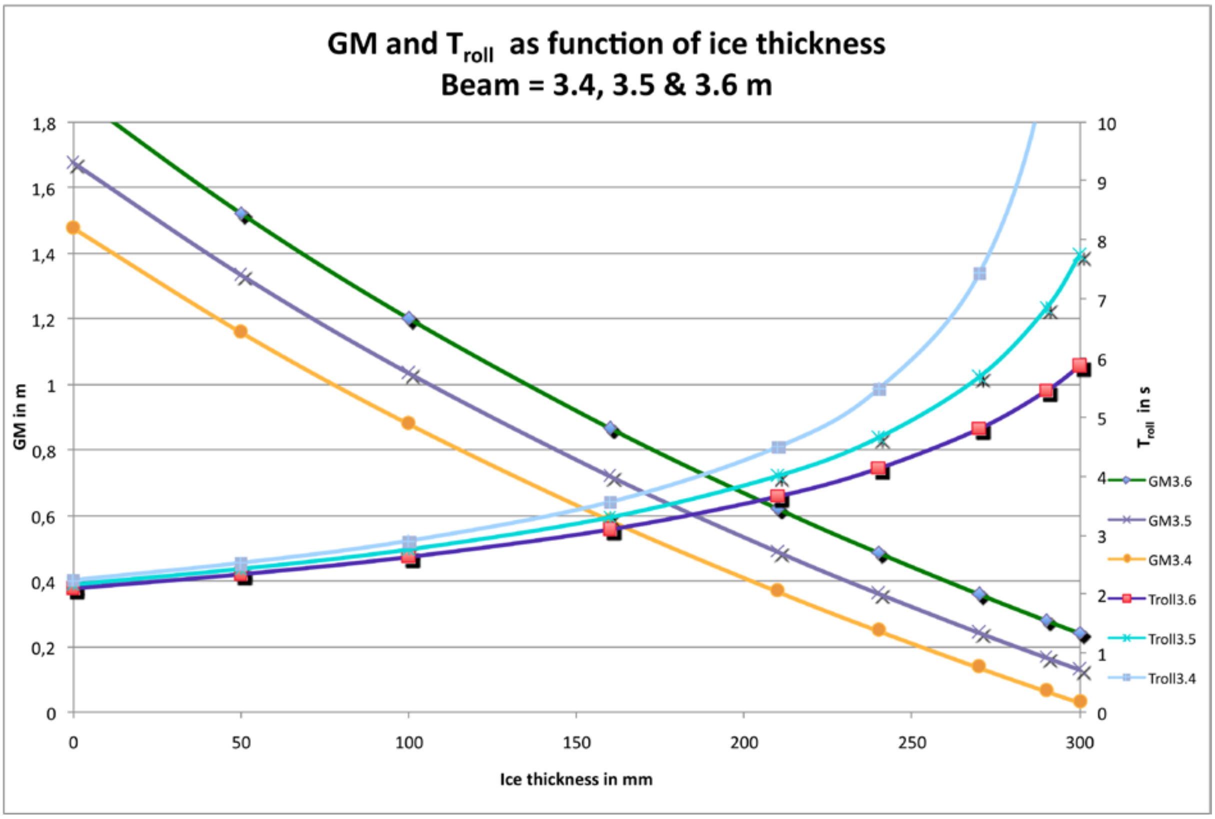

Figure 13, Metacentric height (GM) and roll period (T_{roll}) shown with varying lifeboat beam

The results illustrate how the stability of the model lifeboat increases with increasing beam. A small change in the beam of the lifeboat has a large affect on the metacentric height, GM, as the inertia at the water plane is dependent on the beam raised to the third power. The length of the lifeboat will also effect the inertia but to a much lesser degree than the beam.

In figure 14 the CoG of the passengers is set at 40%, 50% and 60% of the height of the lifeboat.

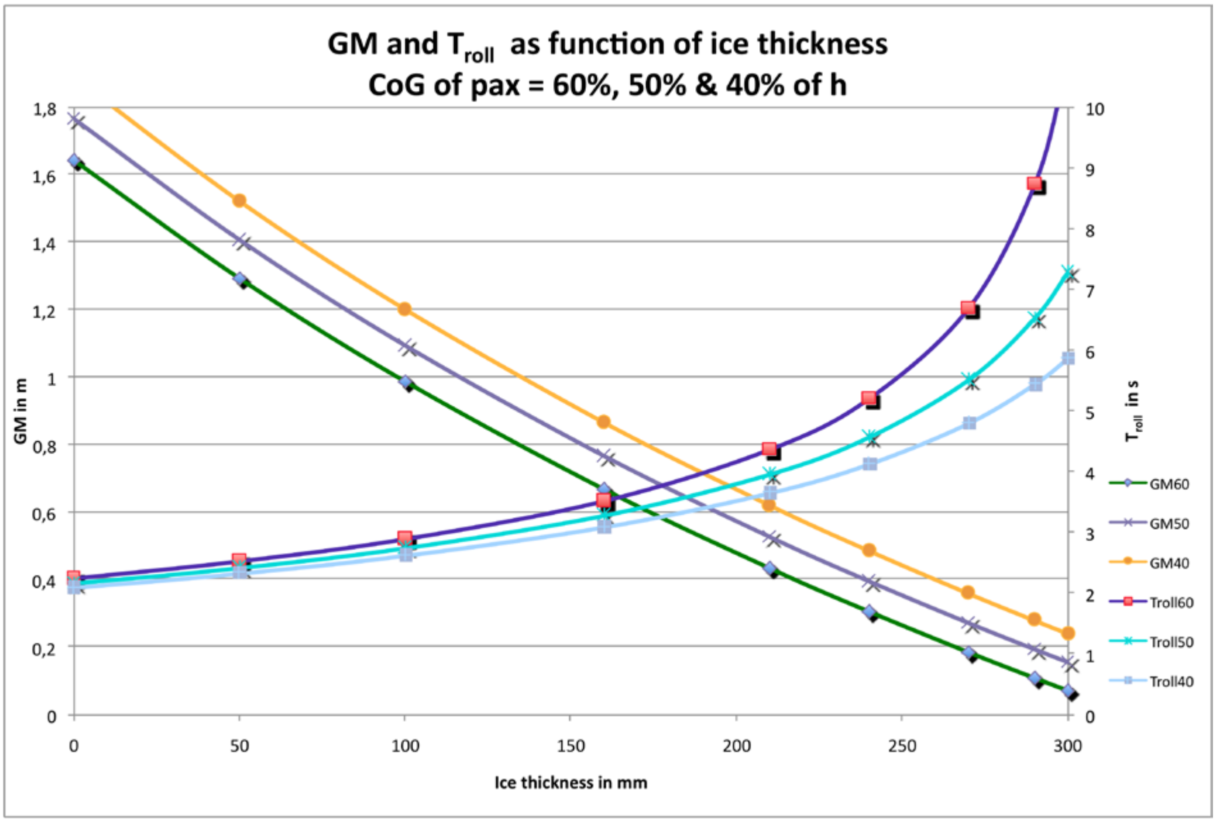

Figure 14, Metacentric height (GM) and roll period (T_{roll}) shown with varying passenger centre of gravity

The results illustrate how the metacentric height is effected by the CoG of the lifeboat, the passengers and the ice. It is always wise to ensure that the CoG in all cases is as low as possible in order to optimise and improve stability.

The effect of ice accretion is clearly illustrated. As the ice load increases and the GM approaches zero, the roll period increases dramatically. This provides an easy method for the occupants of a lifeboat to detect that the lifeboat is icing over. It is extremely important that the lifeboat crew are aware of the issue of icing and manoeuvre the vessel optimally with regard to minimising icing. If icing becomes serious the lifeboat will roll more slowly from side to side. It is unlikely that the lifeboat will capsize due to the ice. The ice has low density compared to seawater and will float. The ice density can be expected to be in the range of 500 to 800 kg/m3 because air will be mixed into the spray before being deposited as ice. The passengers would strapped in and ensure a righting moment as required by the standards. The situation could become worse if the lifeboat is damaged and there is free water inside. Lifeboats are designed to have sufficient buoyancy and stability in a damaged state with free water inside. They are however not evaluated for the combined effects of icing and free water inside due to damage. A slow roll caused by icing may lead to the lifeboat developing a high angle of heel and lack of response to righting. In this damage condition, it can be expected that people may release their seat belts and further increase problems with stability.

7 CONCLUSIONS

7.1 Meteorological conditions

The analysis of the meteorological data for 2008 and 2009 for stations around the Barents Sea coincides with what can be expected from ISO-19906 and Norsok N-003. Ice accretion needs to be considered for lifeboats and rescue vessels. Weather conditions can be such that lifeboats and passengers may need to ride off the weather and wait for a better window for rescue. The main weather concerns during the period of October to May when operating in the Barents Sea will be the threat of polar lows, ice accretion and low air temperature. Impaired visibility due to fog can be experienced mainly from May to August but cannot be ignored for the remainder of the year.

7.2 Lifeboat stability

The meteorological data and the calculations indicate that that stability of lifeboats could be impaired due to ice accretion. Capasizing is not likely but an ustable situation with the lifeboat potentially lying on its side and rolling slowly can be expected. This type of situation may threate stability even further if passenger release their seat belts. Ice accretion is an issue that the designers and producers of lifeboats are aware of, but has not been investigated in any detail. Proper consideration of ice accretion and lifeboat stabilty is required.

7.3 Evacuation and rescue means

Equipment available for evacuation may encounter conditions that render them inappropriate. The limitations of existing evacuation and rescue systems are generally understood/1, 3 & 17/. Life rafts could prove a poor option for evacuation if they do not have sufficient thermal insulation for cold climate conditions. Poor performance of life rafts in rough sea conditions, especially if evacuation should be required in a polar low, must be considered before choosing them as an option.

It is important that the effects of the cold air on human performance during the winter are examined thoroughly and that current evacuation systems are designed accordingly. Thermal insulation of survival suits, lifeboats and life rafts should be examined specifically before being applied as survival equipment in the Barents Sea.

Fog may represent the main threat to medical evacuation of sick or injured personnel form a facility. This is also the case for other areas than the Barents Sea, however there is generally a greater risk of fog in some areas of the Barents Sea.

7.4 Operational considerations

Access to reliable weather forecasts is paramount for operating in the Barents Sea. Responsible personnel onboard facilities operating in the Barents Sea should be competent in the interpretation and understanding of weather forecasts and the implications the conditions may have in an evacuation and rescue situation. Awareness to potential ice conditions is important as activity moves to the north to or beyond Bjørnøya and to the east towards the borderline with Russia. All year operation in the Norwegian sector of the Barents Sea is possible when appropriate risk analysis and risk reduction measures are put in place.

7.5 Recommendations

Third generation rapid response rescue vessels are recommended as standby vessels in the Barents Sea. Response to ice accretion must be investigated for these vessels. Their rescue capacity and ability is by far the best that is currently available. They have a larger operation window for recovering a lifeboat from the sea thereby reducing the exposure of the lifeboat to weather and potential icing situations.

Freefall lifeboats are strongly recommended for the Barents Sea in the areas where ice is not expected. This conclusion is drawn based on their superior performance as indicated by NPD report YA-795, /3/, and the improvements that have been made to these lifeboats during the last five years.

This report indicates that the effect of ice accretion on lifeboat stability should be of concern and must be investigated for each lifeboat model that is intended to be used on facilities operating in the Barents Sea.

The affect of ice accretion on standby and rescue vessels should also be investigated for each vessel that is intended for operation as a support vessel to any petroleum facility.

The adequacy of thermal insulation should be evaluated for all evacuation, rescue and survival equipment that is intended for use in the Barents Sea.

7.6 Regulatory requirements

The currents regulations are functional and risk based. They are considered sufficient to regulate safe evacuation and rescue in the Barents Sea. The guidelines to the regulations should be complemented with references to standards like ISO-19906. Specific requirements for thermal insulation of evacuation, rescue and survival equipment for use in the Barents Sea should be developed and referenced in the regualtions. This is work that will take place in the continuation of the barents 2020 project. Specific requirements to the use of third generation rapid response rescue vessels should also be considered enforced.

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9 APPENDICES

9.1 Analysis of similar weather situations

9.2 Beaufort scale for wind and sea conditions

9.3 Excerpt of DNV-OS-E406

9.4 Twilight chart

9.5 Stability calculations for the model lifeboat

9.1 Analysis of similar weather situations

Bjørnøya

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG	PR	Fog
99710	2008	2	17	1	986,1	600	-3,7	-6	-0,7	20000	290	13,4	22,6	16,3	2,3
99710	2008	2	17	7	985	1000	-3,5	-8,9	-0,7	20000	300	17,5	25,2	18,9	5,4
99710	2008	2	17	13	987	600	-5,9	-7,4	-0,7	2000	290	17,5	24,2	47,3	1,5
99710	2008	2	17	19	986,2	600	-5,2	-6,3	-0,7	20000	290	17,5	23,7	39	1,1
99710	2008	2	18	1	986,1	600	-3,7	-6	-0,7	20000	290	13,4	22,6	16,3	2,3
99710	2008	2	18	7	989,5	300	-13	-15	-0,7	1000	20	12,4	24,2	96,4	1,6
99710	2008	2	18	13	996,5	600	-5,6	-8,5	-0,7	4000	360	3,1	15,4	7,75	2,9
99710	2008	2	18	19	1001	600	-6,1	-10	-0,7	15000	340	14,4	19,6	40,9	4,1

This period has mainly light icing with wind varying from strong breeze to gale, Beaufort 6 to 8. Wind chill is significant. There will be some daylight. Main concerns are cold, slippery surfaces and rough to very rough sea conditions. Davit launch lifeboats and life rafts not preferred.

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG	PR	Fog
99710	2008	2	29	1	1000	300	-3,9	-6,7	-0,9	30000	50	12,4	17,5	17,7	2,8
99710	2008	2	29	7	999,4	300	-5,3	-7,8	-0,9	10000	50	12,4	18,5	30,1	2,5
99710	2008	2	29	13	997,5	300	-6,6	-9,4	-0,9	5000	40	14,4	19	48,3	2,8
99710	2008	2	29	19	995,7	300	-8	-10	-0,9	10000	40	13,9	19,6	60,6	2,2
99710	2008	3	1	1	993,8	300	-9,6	-11	-0,9	6000	40	12,9	17,5	71	1,6
99710	2008	3	1	7	992,7	300	-9,6	-11	-0,9	7000	50	12,4	16	68,2	1,6
99710	2008	3	1	13	992,5	300	-9,8	-12	-0,9	10000	40	12,4	16,5	70	1,8
99710	2008	3	1	19	990,3	.	-7,5	-8,5	-0,9	800	50	10,3	15,4	41,2	1

This period has moderate to heavy icing with a strong breeze, Beaufort 6. The air temperature is low and wind chill is significant. There will be some daylight. Main concerns are low temperature, slippery surfaces, icing and rough sea conditions.

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG	PR	Fog
99710	2008	4	16	19	986,5	.	-1,5	-3,5	*-1,2*	2000	280	21,6	30,4	-6,75	2
99710	2008	4	17	1	992	600	-3,4	-7	-1,6	5000	290	18,5	26,8	24,8	3,6
99710	2008	4	17	7	994,2	300	-5,4	-7,8	-1,6	5000	290	17,5	24,7	54,7	2,4
99710	2008	4	17	13	996,2	300	-4,3	-9,4	-1,6	10000	300	18	26,2	38,6	5,1
99710	2008	4	17	19	997,7	300	-4,5	-9,8	-1,6	20000	310	14,4	24,7	33,4	5,3
99710	2008	4	18	1	996,6	300	-5,7	-8,5	-1,6	10000	320	12,9	20,1	43,8	2,8
99710	2008	4	18	7	995,5	600	-4,1	-8,2	-1,6	20000	330	15,4	19,6	30,3	4,1
99710	2008	4	18	13	998,8	600	-3,7	-7,8	-1,6	20000	340	9,3	19	14,9	4,1

This period has mainly moderate icing with a gale decreasing to near gale, Beaufort 8 to 7. Wind chill is significant. There will be some daylight. Main concerns are cold, slippery surfaces, icing and rough sea conditions. Davit launch lifeboats and life rafts not preferred.

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG	PR	Fog
99710	2008	11	12	7	989,4	300	-5,8	-9,8	0,7	10000	270	11,3	25,2	21,6	4
99710	2008	11	12	13	990,3	200	-4,7	-7	0,7	5000	270	15,4	23,7	21,1	2,3
99710	2008	11	12	19	991,6	200	-4,5	-7,8	0,7	4000	270	15,4	24,2	19,6	3,3
99710	2008	11	13	1	992,7	200	-4,4	-9,4	0,7	10000	260	18	25,2	22,1	5
99710	2008	11	13	7	992,4	200	-3,1	-9,5	0,7	10000	260	18	29,3	10,6	6,4
99710	2008	11	13	13	989,4	300	-2,8	-7,8	0,7	10000	250	20,1	27,8	8,87	5
99710	2008	11	13	19	990,6	300	-2,3	-6,3	0,7	10000	280	18	28,3	3,53	4
99710	2008	11	14	1	991,2	300	-3,9	-8,1	0,7	12000	270	11,8	20,6	11,6	4,2

This period has moderate to light icing with wind increasing to gale, Beaufort 7 to 8. Wind chill is significant. There will be some twilight. Main concerns are darkness, low temperature, slippery surfaces and rough to very rough sea conditions. Davit launch lifeboats and life rafts not preferred.

This period has mainly slight icing with near breeze, Beaufort 6. Low air temperature and some

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG	PR	Fog
99710	2009	2	25	7	991,1	200	-5,6	-6,3	-1,9	600	20	19,6	22,6	72,5	0,7
99710	2009	2	25	13	994,5	200	-8,7	-9,8	-1,9	3000	20	15,4	22,1	105	1,1
99710	2009	2	25	19	996	200	-11	-12	-1,9	1500	20	13,9	19	120	1,1
99710	2009	2	26	1	997,2	200	-11	-12	-1,9	2000	20	13,4	17,5	121	1,2
99710	2009	2	26	7	998,1	200	-11	-12	-1,9	2000	20	13,4	18,5	115	1,1
99710	2009	2	26	13	1000	200	-11	-12	-1,9	2000	20	13,9	18,5	124	0,8
99710	2009	2	26	19	1003	200	-12	-14	-1,9	4500	30	10,8	18,5	111	1,6
99710	2009	2	27	1	1006	300	-13	-16	-1,9	15000	10	8,2	15,4	92,7	2,4

This period has extreme icing with a strong breeze, Beaufort 6. The air temperature is low and wind chill is significant. There will be some daylight. Main concerns are low temperature, slippery surfaces, extreme icing and rough sea conditions.

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG	PR	Fog
99710	2009	3	18	1	998,9	200	-3,8	-7,4	-1,7	4000	310	16	21,1	28,1	3,6
99710	2009	3	18	7	1002	200	-6,8	-12	-1,7	5000	300	19	24,2	86,2	5,4
99710	2009	3	18	13	1004	200	-7,2	-9,4	-1,7	1000	310	20,1	27,8	98,6	2,2
99710	2009	3	18	19	1007	100	-6,5	-10	-1,7	1500	310	21,1	28,3	89,9	3,7
99710	2009	3	19	1	1010	200	-6,2	-9,4	-1,7	6000	320	17,5	27,8	69,7	3,2
99710	2009	3	19	7	1010	300	-6	-9,4	-1,7	8000	320	14,4	24,2	54,7	3,4
99710	2009	3	19	13	1004	300	-6,3	-8,9	-1,7	2000	100	2,6	16	10,6	2,6
99710	2009	3	19	19	993,6	100	-6,1	-7	-1,7	2000	80	7,7	12,9	29,9	0,9

This period has moderate to extreme icing with wind varying from Moderate breeze to strong gale, Beaufort 4 to 9. Wind chill is significant. There will be some daylight. Main concerns are low temperature, slippery surfaces, heavy icing and rough sea conditions. Davit launch lifeboats and life rafts not preferred.

Fruholmen

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG_1	PR	Fog
94500	2008	2	5	7	1013		-2	-7	5		136	10,8	14,9	0,29	5
94500	2008	2	5	13	1013		-2,2	-5,3	5		136	14,2	19,4	1,13	3,1
94500	2008	2	5	19	1012		-4,5	-7,8	5		154	16,5	20,6	11,4	3,3
94500	2008	2	6	1	1011		-2,1	-4,7	5		146	12,2	16,4	0,65	2,6
94500	2008	2	6	7	1010		-1,8	-5	5		143	13	18	-0,35	3,2
94500	2008	2	6	13	1011		-4	-7	5		146	15,3	21,6	8,55	3
94500	2008	2	6	19	1009		-2,6	-6	5		153	12,4	18,8	2,31	3,4

This period has slight icing with wind from strong breeze to near gale, Beaufort 6 to 7. Wind chill is significant. There will be some daylight. Main concerns are low temperature, potentially slippery surfaces, and rough sea conditions.

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG_1	PR	Fog
94500	2008	2	13	13	995,4		-0,6	-5	5		333	20,6	26,2	-7,12	4,4
94500	2008	2	13	19	1003		-1,1	-6	5		326	19,6	24,3	-4,17	4,9
94500	2008	2	14	1	1009		-3,1	-4,7	5		329	17,3	23,4	5,52	1,6
94500	2008	2	14	7	1014		-3,1	-6	5		342	19,3	25,8	6,16	2,9
94500	2008	2	14	13	1021		-4,6	-7,8	5		337	18,2	22,6	13,1	3,2
94500	2008	2	14	19	1024		-4,5	-8,1	5		2	19,1	25,4	13,2	3,6
94500	2008	2	15	1	1029		-5,2	-8,5	5		30	14,4	19,2	12,6	3,3
94500	2008	2	15	7	1032		-4,2	-10	5		317	8,2	11,7	5,02	6

This period has slight icing with wind from gale to near gale, Beaufort 7 to 6. Wind chill is significant. There will be some daylight. Main concerns are low temperature, potentially slippery surfaces, and very rough sea conditions. Davit launch lifeboats and life rafts not preferred.

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG_1	PR	Fog
94500	2009	12	22	7	1003		-0,5	-6	5		121	17,4	25,6	-6,48	5,5
94500	2009	12	22	13	1001		-6,4	-11	5		127	14,3	19,6	17,1	4,3
94500	2009	12	22	19	1002		-7,5	-12	5		128	9,1	15,5	13,6	4,6
94500	2009	12	23	1	1003		-7,5	-12	5		129	9,9	17,4	14,7	4,1
94500	2009	12	23	7	1005		-9	-12	5		122	12,9	19,9	24,4	3,1
94500	2009	12	23	13	1009		-7,5	-11	5		118	12,9	17,2	19,2	3,7
94500	2009	12	23	19	1012		-5,4	-8,9	5		143	12,2	17,2	11,4	3,5
94500	2009	12	24	1	1014		-4,9	-8,9	5		125	12	16,8	9,57	4

wind chill. There will only be some twilight. Main concerns are cold, potentially slippery surfaces, darkness and rough sea conditions.

Slettnes

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG_1	PR	Fog
96400	2008	1	24	1	994,3		-4,9	-8,5	5		360	17,4	22,2	13,9	3,6
96400	2008	1	24	7	987,3		-5,2	-6	5		360	20,8	28,6	18,3	0,8
96400	2008	1	24	13	985,2		-3,2	-6	5		360	15,1	24,4	5,22	2,8
96400	2008	1	24	19	981,5		-3,5	-7	5		360	16,6	20,9	7,06	3,5
96400	2008	1	25	1	979,4		-4,8	-8,1	5		360	12,2	16,8	9,41	3,3
96400	2008	1	25	7	979,3		-3,2	-6	5		360	8,1	10,9	2,8	2,8
96400	2008	1	25	13	980,2		-2,9	-6,3	5		360	9,3	11,6	2,47	3,4

This period has slight icing with wind from gale to fresh breeze, Beaufort 8 to 5. Low air temperature and some wind chill. There will be little daylight. Main concerns are cold, potentially slippery surfaces, and very rough sea conditions. Davit launch lifeboats and life rafts not preferred.

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG_1	PR	Fog
96400	2008	2	13	7	985,2		-2	-3,3	5		x	11,6	17,7	0,31	1,3
96400	2008	2	13	13	988,1		-0,6	-2,2	5		x	18,8	34	-6,5	1,6
96400	2008	2	13	19	995,3		-1,3	-1,4	5		x	19,4	26,7	-3,1	0,1
96400	2008	2	14	1	1003		-1,8	-3,3	5		x	14,7	22,5	-0,39	1,5
96400	2008	2	14	7	1008		-4	-4,1	5		x	17,8	27,7	9,94	0,1
96400	2008	2	14	13	1015		-4,7	-5	5		x	14,8	24,8	11	0,3
96400	2008	2	14	19	1019		-5,5	-6	5		x	16,3	23,9	15,6	0,5
96400	2008	2	15	1	1025		-6,5	-6,7	5		x	13,3	20,1	16,3	0,2

This period has slight icing with wind from near gale to gale, Beaufort 7 to 8. Some wind chill. There will be some daylight. There could be fog. Main concerns are cold, potentially slippery surfaces, visibility and very rough sea conditions. Davit launch lifeboats and life rafts not preferred.

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG_1	PR	Fog
96400	2009	2	9	1	996,8		-8,4	-12	5		124	9,8	13,2	16,9	3,2
96400	2009	2	9	7	991,3		-7,3	-8,9	5		131	15,2	19,8	21,8	1,6
96400	2009	2	9	13	988,4		-8,3	-9,8	5		131	19,3	23,8	32,9	1,5
96400	2009	2	9	19	986,2		-7,7	-8,5	5		123	12,1	16,6	18,7	0,8
96400	2009	2	10	1	986,8		-8	-10	5		187	4,8	9,3	7,79	2,2
96400	2009	2	10	7	986,6		-5,4	-8,1	5		127	11,4	15,3	10,6	2,7
96400	2009	2	10	13	987,7		-11	-13	5		173	10,5	13,3	24,6	2,5
96400	2009	2	10	19	992,5		-13	-16	5		215	3,9	5	11,5	3,3

This period has slight icing to moderate icing with varying wind from gentle breeze to gale, Beaufort 3 to 8. The air temperature is low when the wind is strongest, therefore significant wind chill. There will be some daylight. Main concerns are cold, slippery surfaces with some icing and potentially rough sea conditions.

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG_1	PR	Fog
96400	2009	12	22	1	1011		-3	-8,1	5		128	13,9	19,3	4,07	5,1
96400	2009	12	22	7	1005		-0,2	-3,8	5		102	18,6	23,9	-8,41	3,6
96400	2009	12	22	13	1003		-6	-8,5	5		122	18,4	21,8	20,1	2,5
96400	2009	12	22	19	1004		-6,6	-11	5		147	8,5	14,3	10,6	4,6
96400	2009	12	23	1	1006		-6,7	-11	5		132	9,4	15,2	12	4,5
96400	2009	12	23	7	1008		-6,3	-11	5		126	16,2	21,3	19	4,9
96400	2009	12	23	13	1013		-4,9	-8,9	5		134	11,9	18,9	9,49	4
96400	2009	12	23	19	1016		-4	-8,5	5		134	12,2	17,2	6,81	4,5

This period has slight icing to moderate icing with wind from fresh breeze to gale, Beaufort 5 to 8. Significant wind chill. There will be no daylight. Main concerns are cold, slippery surfaces, darkness and potentially rough to very rough sea conditions. Life rafts not preferred.

Vardø

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG_1	PR	Fog
98550	2008	1	5	1	1035	300	-7,2	-9,4	5	55000	200	13,1	19,2	18,5	2,2
98550	2008	1	5	7	1032	300	-6,1	-7,8	5	55000	202	17,3	23,7	19,3	1,7
98550	2008	1	5	13	1029	300	-6,3	-8,9	5	75000	204	16,5	21,5	19,3	2,6
98550	2008	1	5	19	1024	200	-7,5	-8,5	5	25000	199	16,4	23,1	24,4	1
98550	2008	1	6	1	1021	300	-7,8	-9,8	5	55000	200	12,1	16,8	19	2
98550	2008	1	6	7	1016	300	-6,7	-8,1	5	55000	201	20	26,3	25,5	1,4
98550	2008	1	6	13	1016	200	-7,1	-8,9	5	75000	204	13	23,4	18	1,8
98550	2008	1	6	19	1012	200	-6,1	-7,8	5	75000	201	19,1	25,2	21,3	1,7
98550	2008	1	7	1	1011	200	-7,8	-9,8	5	55000	203	17,4	22,9	27,3	2
98550	2008	1	7	7	1010	200	-9,5	-11	5	30000	216	14	18,1	28,3	1,7

This period has slight icing to moderate icing with wind from strong breeze to gale, Beaufort 6 to 8. The air temperature is low with significant wind chill. There will be no daylight. Cloudbase is low. Main concerns are cold, slippery surfaces, darkness and very rough sea conditions. Davit launch lifeboats and life rafts not preferred.

St.no	Year	Mnth	Date	Time	PO	HL	TA	TD	TW	VV	DD	FF	FG_1	PR	Fog
98550	2009	2	20	7	1018	300	-4,6	-5,7	5	6000	192	17,9	22,8	12,9	1,1
98550	2009	2	20	13	1015	300	-4,1	-6	5	30000	194	18,7	24	10,9	1,9
98550	2009	2	20	19	1012	300	-5,9	-7,8	5	3000	201	20,3	27,2	21,6	1,9
98550	2009	2	21	1	1010	300	-4,8	-6	5	3000	210	22,2	27,2	17,1	1,2
98550	2009	2	21	7	1008	300	-3	-4,4	5	5000	210	19	25	5,56	1,4
98550	2009	2	21	13	1007	300	-1,9	-2,7	5	6000	200	18,1	24,5	0	0,8
98550	2009	2	21	19	1005	200	-2,4	-2,7	5	1000	211	16,6	21,7	2,21	0,3
98550	2009	2	22	1	1003	200	-3,4	-3,8	5	3000	213	17,4	23,2	6,94	0,4

This period has slight icing with wind from near gale to severe gale, Beaufort 7 to 9. The air temperature is low with significant wind chill. There will be some daylight. Main concerns are cold, slippery surfaces, darkness with potentially poor visibility and very rough sea conditions. Davit launch lifeboats and life rafts not preferred.

9.2 Beaufort scale for wind and sea conditions

Beau-fort wind scale	Mean Wind Speed		Limits of wind speed		Wind descript-ive terms	Hs*	Max wave*	Sea state	Sea descriptive terms
	Knots	m/s	Knots	m/s		m	m		
0	0	0	<1	0–0.2	Calm	-	-	**0**	Calm (glassy)
1	2	0.8	1–3	0.3–1.5	Light air	0.1	0.1	**1**	Calm (rippled)
2	5	2.4	4–6	1.6–3.3	Light breeze	0.2	0.3	**2**	Smooth (wavelets)
3	9	4.3	7–10	3.4–5.4	Gentle breeze	0.6	1.0	**3**	Slight
4	13	6.7	11–16	5.5–7.9	Moderate breeze	1.0	1.5	**3–4**	Slight–Moderate
5	19	9.3	17–21	8.0–10.7	Fresh breeze	2.0	2.5	**4**	Moderate
6	24	12.3	22–27	10.8–13.8	Strong breeze	3.0	4.0	**5**	Rough
7	30	15.5	28–33	13.9–17.1	Near gale	4.0	5.5	**5–6**	Rough–Very rough
8	37	18.9	34–40	17.2–20.7	Gale	5.5	7.5	**6–7**	Very rough–High
9	44	22.6	41–47	20.8–24.4	Severe gale	7.0	10.0	**7**	High
10	52	26.4	48–55	24.5–28.4	Storm	9.0	12.5	**8**	Very High
11	60	30.5	56–63	28.5–32.6	Violent storm	11.5	16.0	**8**	Very High
12	-	-	64+	32.7+	Hurricane	14+	-	**9**	Phenomenal

* These values refer to well-developed wind waves of the open sea. The lag effect between the wind getting up and the sea increasing should be borne in mind. Source: http://www.metoffice.gov.uk/weather/marine/guide/beaufortscale.html

9.3 Excerpt from DNV-OS-E406

Det Norske Veritas Offshore Standard DNV-OS-E406, April 2009.

305 This standard is not applicable to design of lifeboats on host facilities located in waters where sea ice or sea floes occur.

A 1000 Ice accretion
1001 For lifeboats to be operated from host facilities where ice accretion may occur, special consideration shall be given to providing robustness to allow removal of ice from the lifeboat without causing degradation of the hull's integrity.

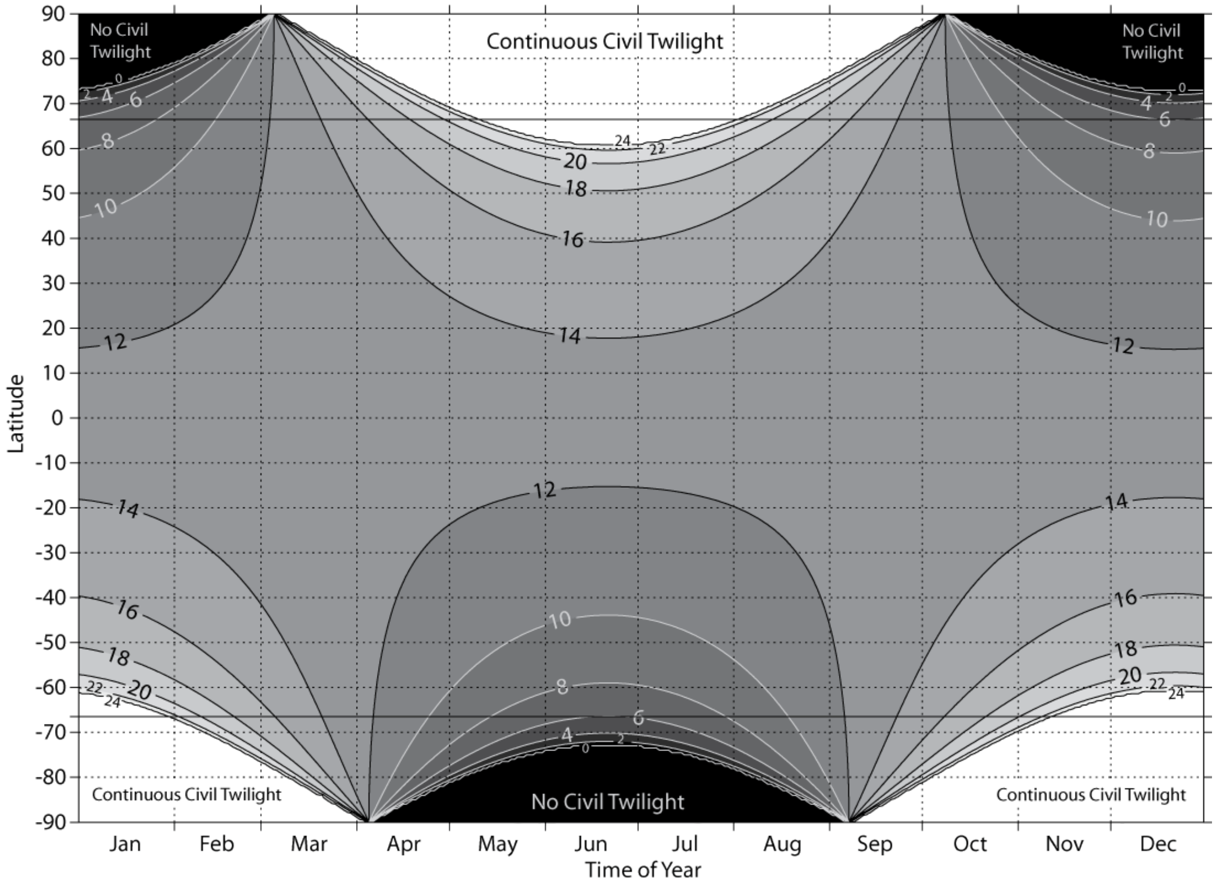
D 300 Stability
301 Lifeboats that become fully submerged after water entry shall be stable and have a positive righting moment for the following two load cases when the lifeboat is in the fully submerged condition:
— fully loaded lifeboat (full complement of occupants)
— empty lifeboat (3 occupants including the pilot).
For either load case, the submerged stability can be documented by calculating the immersed transversal position of centre of buoyancy and making sure that it is located above the transversal position of centre of gravity.

E 200 Buoyancy and stability
201 The lifeboat shall have inherent buoyancy or shall be fitted with inherently buoyant material, which shall not be adversely affected by seawater, oil or oil products, sufficient to keep the lifeboat afloat with all its equipment onboard when the lifeboat is flooded and the hatch is open to the sea. When the lifeboat is in the stable flooded condition, the water level inside the lifeboat, measured along the seat back, shall not be more than 500 mm above the seat pan at any occupant seating position. Additional inherently buoyant material, equal to 280 N of buoyant force per person, shall be provided for the number of persons that the lifeboat is designed to accommodate. Buoyant material provided according to this item shall not be installed external to the hull of the lifeboat.

202 The lifeboat shall be stable and have a positive metacentric height when it is loaded with 50% of the number of occupants that it is designed to accommodate, placed in their normal positions to one side of the centreline of the lifeboat. In this loading condition, the heel of the lifeboat shall not exceed an angle of 20 degrees, and the lifeboat shall have a freeboard, measured from the waterline to the lowest opening through which the lifeboat may become flooded, equal to at least 1.5% of the length of the lifeboat and not less than 100 mm. The freeboard shall be documented by freeboard tests.

203 The lifeboat shall have self-righting ability in the surface condition after resurfacing. The self-righting ability can be documented by tests. Guidance note: The stability and the self-righting ability are dependent on the complement of occupants being strapped in their seats. If the weight distribution in the lifeboat changes, these characteristics may suffer or even disappear.

9.4 Twilight chart



http://upload.wikimedia.org/wikipedia/commons/0/05/TwilightLength.png

9.5 Location of meteorological observation stations

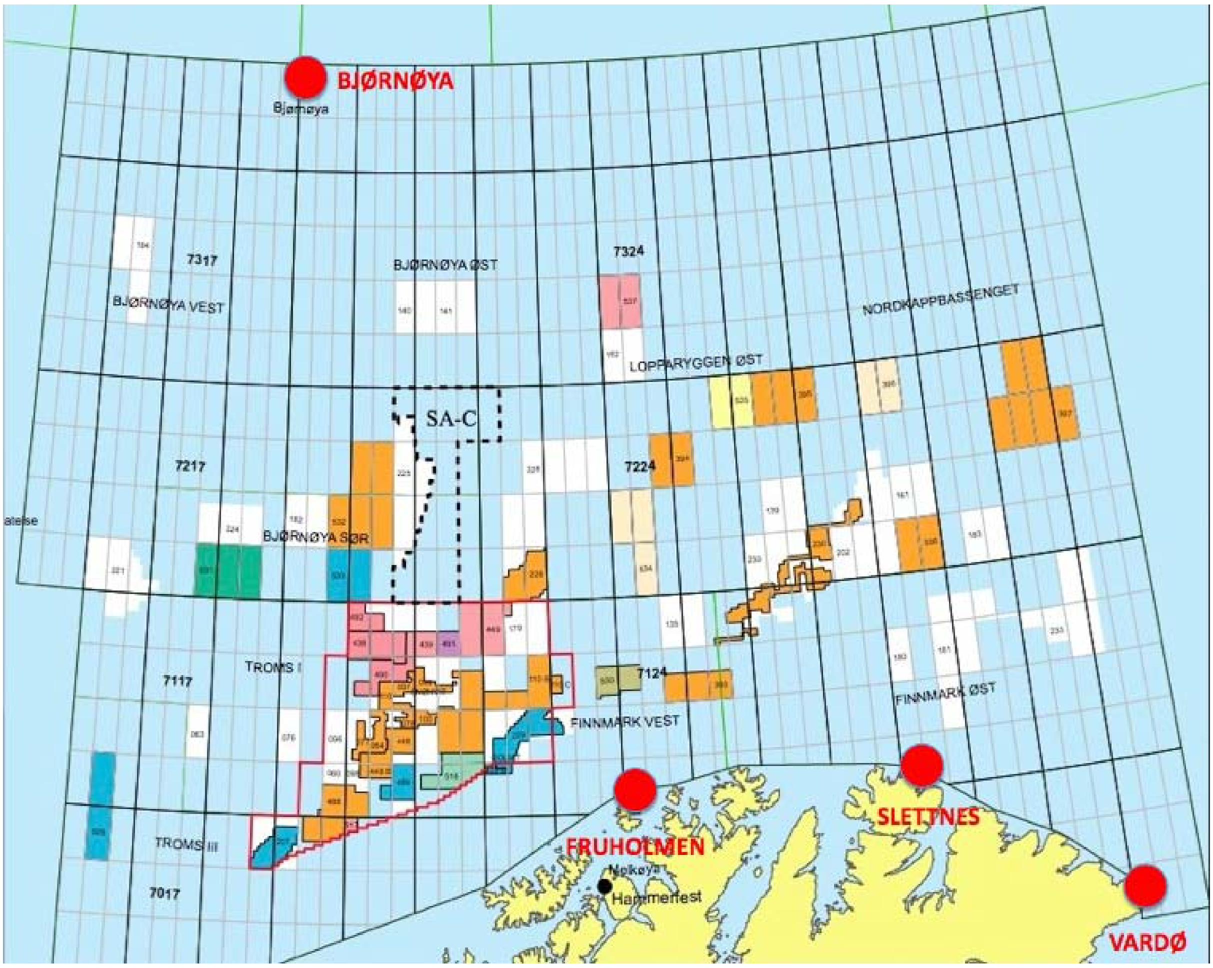


Figure 15, Map showing the approximate location of the meteorological observation stations.

Station no.	Name	Altitude	Latitude	Longitude
94500	FRUHOLMEN FYR	13 m	71,0933	23,995
96400	SLETTNES FYR	8 m	71,084	28,2178
98550	VARDØ RADIO	14 m	70,3707	31,099
99710	BJØRNØYA	16 m	74,5167	19,0167

Table 11, Location of the meteorological observation stations.

9.6 Ice accretion on vessels

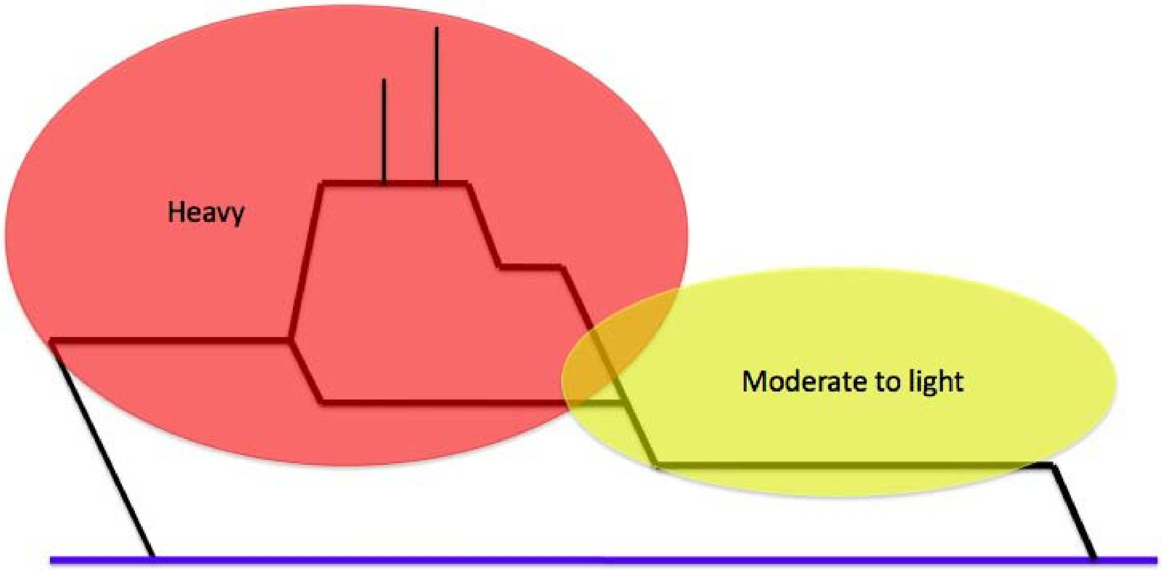


Figure 17, Illustration showing approximate distribution of ice accretion on a vessel

Ice accretion on a vessel due to sea spray is the result of wind blowing water off the sea, breaking waves and the bow wave of the vessel. If the vessel is making headway into the wind and the waves, the situation is made worse as even more sea spray is thrown into the air and over the vessel. Ice will form on the bow, but most of the seawater spray is thrown upwards and travels towards the superstructure of the vessel. Most of the ice will form on the superstructure of the vessel as the seawater consists mainly of fine droplets. Most of the spray will have fallen on the vessel within the first half to two thirds of the vessel length. Less ice will form towards the stern of the vessel. In general, this form of ice accretion will only form at a level of less than 25 meters above sea level due to the loss of energy in the spray and gravity pulling the seawater down. This form of ice accretion can have serious consequences for the stability of the vessel as it mostly occurs on the upper part of the vessel.

9.7 Stability calculations for the model lifeboat

Print out of the two Excel spreadsheets are attached in paper format.

9.5.a) GM and T_{roll} as function of ice thickness, Beam = 3.4, 3.5 & 3.6 meters

9.5.b) GM and T_{roll} as function of ice thickness, CoG of pax = 60%, 50& and 40% of lifeboat height