ARCTIC OFFSHORE TECHNOLOGY ASSESSMENT

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ACRONYMS AND ABBREVIATIONS

ABS	....	American Bureau of Shipping
ACCR	....	Anticyclonic circulation regime
ADEC	....	Alaska Department of Environmental Conservation
AHT	....	Anchor-Handling Tug
AHTS	....	Anchor-handling Tug/Supply
AHV	....	Anchor Handing Vessel
AIS	....	Automatic Identification System
AMAP	....	Arctic Monitoring and Assessment Programme
AMSA	....	Arctic Marine Shipping Assessment
AMSR-E	....	Advanced Microwave Scanning Radiometer
AOGCC	....	Alaska Oil & Gas Conservation Commission
ARRT	....	Arctic Regional Response Team
ASP	....	Application Service Providers
ASTM	....	American Society for Testing and Materials
BHP	....	Brake Horsepower
BMS	....	BOA Marine Services
BP	....	Bollard Pull
CAR	....	Construction All Risks
CCO	....	Cold Climate Operation
CCR	....	Cyclonic circulation regime
CFR	....	Code of Federal Regulations
CORS	....	Continuously Operating Reference Station
CPP	....	Controllable pitch propellers
CSP	....	Communications Service Providers
cSt	....	Centistokes
EPA	....	Environmental Protection Agency
ETA	....	Estimated Time of Arrival
GMDSS	....	Global Maritime Distress Safety System
GRS	....	Geographic Response Strategies
GSK	....	Group survival kits
GWS	....	Global Wave Statistics
HLV	....	Heavy Lift Vessel
IACS	....	International Association of Classification Societies Ltd.
ILO	....	International Labour Organization
ILS	....	Instrument Landing System
IMO	....	International Maritime Organization
IOPP	....	International Oil Pollution Prevention
IPCC	....	Intergovernmental Panel on Climate Change
ISO	....	International Standards Organization
IWC	....	International Whaling Commission
LRIT	....	The Long Range Identification and Tracking
LTE	....	Low Temperature Environments
MDO	....	Marine Diesel Oil
MEPC	....	Marine Environment Protection Committee
MLLW	....	Mean Lower Low Water
MMSI	....	Maritime Mobile Service Identity
MSC	....	Marine Safety Committee
MSD	....	Marine Sanitation Device

MTSA	……………………………	Maritime Transportation Security Act
MWS	……………………………	Marine Warranty Survey
NARL	……………………………	Navy Arctic Research Laboratory
NDBC	……………………………	National Data Buoy Center NDBC
NGS	……………………………	National Geodetic Survey
NOAA	……………………………	National Oceanic Atmospheric Administration
ODPCP	……………………………	Oil Discharge Prevention and Contingency Plan
OHT	……………………………	Offshore Heavy Transport AS
OPA	……………………………	Oil Pollution Act
OSRO	……………………………	Oil Spill Response Organization
PAME	……………………………	Protection of Arctic Marine Environment
PPE	……………………………	Personal protective equipment
PPM	……………………………	Peak Program Meters
PSK	……………………………	Personal survival kits
PSV	……………………………	Platform Supply Vessel
QI	……………………………	Qualified Individual
SAR	……………………………	Search and Rescue
SCBA	……………………………	Self Contain Breathing apparatus
SOLAS	……………………………	International Convention for the Safety of Life at Sea
SOPEP	……………………………	Shipboard Oil Pollution Emergency Plan
SPAR	……………………………	Spill Prevention and Response
STCW	……………………………	Standards of Training, Certification and Watchkeeping for Seafarers
SWL	……………………………	Safe Working Load
SZSC	……………………………	Shanghai Zhenhua Shipping Co.
TMDA	……………………………	Time Division Multiple Access
TRB	……………………………	Transportation Research Board
UHF	……………………………	Ultra High Frequency
UR	……………………………	Unified Requirements
USCG	……………………………	United States Coast Guard
VHF	……………………………	Very high frequency
VRP	……………………………	Vessel Response Plan
VTS	……………………………	Vessel Traffic System
WIS	……………………………	Wave Information Studies

SUMMARY

The Beaufort Sea and Chukchi Sea are believed to hold significant petroleum reserves beneath the seabed. The Chukchi shelf is believed to hold oil and gas reserves as high as 30 billion barrels. The Beaufort Sea contains an estimated 8.22 billion barrels of oil and 27.65 million cubic feet of natural gas.

The exploration of the Arctic for petroleum is more technically and physically challenging than for any other environment. However, with improvements in technology and continuing high oil prices the region is now receiving the interest of the petroleum industry.

The transportation and installation of platforms faces the challenge of operational conditions in the Arctic. In order to maximize the utilization of the weather window during the summer (June through Aug./Sept.) and take advantage of extended periods of daylight and attractive temperatures that facilitates operate, substantial planning and preparations are required.

Consideration of the environment, especially the impact of ice on structures has to be highlighted during transportation, drilling, and exploration operations in the Arctic area. The knowledge and technology needed to extract resources from highly demanding areas exist today. However, the Arctic environment is particularly vulnerable and the extreme weather conditions in the far north demand high standards of safety in all operations. The harsh conditions mean that personnel interaction, equipment, materials and operations must be analyzed and tested before they are installed or carried out.

To plan for successful transportation and installation of platforms, it is necessary to first gather information on the metocean conditions for the Chukchi and Beaufort regions. The topics we addressed in this study cover:

- Wind, seastate and current assessments of Chukchi Sea, Beaufort Sea and any other regions that may be suitable for float-off of drilling exploratory platform from dry transportation vessels
- Air Temperature of Chukchi and Beaufort regions
- Ice cover study to identify ice-free sea conditions
- Trends for air temperature, ice break-up, and ice extent

The predominant summer winds in the U.S. Arctic Ocean are from the east and northeast, with speeds of 4 m/s to 11 m/s (8 to 21 knots). The predominant current direction is ESE-E over the Chukchi shelf and Beaufort slope and the current speed is normally below 1m/s.

The chance of a significant wave height of 2 m is expected to be below 5% from July to September, but increased to 15% in October in Chukchi Sea. In Beaufort Sea, the wave heights in open seasons are also low. The 95% probability of exceedance for significant wave height is between 2.5-3 meters in the open season.

Dutch Harbor lies within Captains Bay and is ice-free year-around. To the North it is open to the wind of the Bering Sea, and on all other sides it is subject to gusty blasts. The 1-min wind speed can reach up to 105 mph in winter. Tides and associated currents in Captains Bay are slight.

Temperatures are mild, and their range is small. In the coldest part of the winter usually January, average daily maximums range 1° to 3°C, while minimums fall into the range of -4° to -1°C. Temperatures begin to moderate after February. July and August are usually the warmest months.

Port of Nome has a subarctic climate with long, cold winters, and short, cool summers. However, conditions in both winter and summer are moderated by the city's coastal location: temperatures are at their lowest in late January/early February, with February being the coolest month -14.6 °C in average. The maximum wind speed and wave height are 15 m/s (29 knots) and 3m, respectively, in June. The maximum wind speed picks up to 20 m/s (39 knots) in July; and the maximum wave height is increased to 4m. The ice conditions are moderate at Norton Basin. It is statistically ice-free by the middle of June, and there is about 8 months of ice coverage (mid October to mid June).

This study finds the Port of Nome during ice-free season and Dutch Harbor year around suitable for facilitating float-off and float-on operations using dry transport vessels.

Arctic sea ice cover attains its maximum seasonal extent in March and shrinks through spring and summer to a minimum extent in September. During the summer, the Beaufort and Chukchi Seas experience a period of open water lasting approximately three months in the Beaufort Sea (August to October) and four months in the Chukchi Sea (July to October). The Chukchi Sea tends to break up before the Beaufort Sea and freeze up afterward.

The most distinguishing feature of the recent changes in average Arctic surface air temperature is its rapid rise (about 1°C) in the mid-1990s. Based on data from 35 stations in the Arctic over the period 1951–2005, this high level of surface air temperature has persisted through the present. The highest temperature rise occurred in autumn and spring, and the lowest in summer and winter.

Arctic sea ice has declined dramatically over the past thirty years with the most extreme decline seen in the summer melt season. There is growing evidence that the shrinking ice extent over recent decades has been attended by substantial thinning. Thick multi-year sea ice is being replaced by thinner, younger ice which melts at lower temperatures. There are strong trends toward a later onset of freezing and warmer winters, and weaker trends toward earlier onsets of melting-season and warmer summers.

In researching the abilities and limitations of equipment used to transport platforms, we identified important factors that could contribute to the decision-making process of selecting the appropriate form of transportation.

Arctic-class barges have been proved successful in previous campaigns in the Canadian Arctic, operating well past the ice-free season. Of those drilling units not specifically designed for the Arctic, independent legged jack-ups and self-propelled drilling units equipped to operate in cold weather are the most suitable.

The mobilization of Jack-up rigs to the Arctic will include two steps. First a dry-tow of a Jack-up MODU aboard a heavy lift unit to a sheltered location along the northern coast of Alaska, followed by a wet tow of several hundred miles to the drilling site.

Under the assumption of ice-free conditions, the marine operations can be conducted with the presently available heavy lift fleet (vessels/barges). Different scenarios of loading arrangements as examples of the possibilities and capacities have been presented in this study. However, every particular case needs its own assessment before execution.

It should be emphasized there are no ice-class transporters available. Equipment winterization will need to be addressed, planned and executed ahead of time. The heavy lift fleet contains 100% foreign flagged vessels. Hence, an application for Jones Act's waiver will need to be submitted and approved in order to transport rigs from ports of the US Gulf of Mexico to Alaska.

The rigs dry transported will be floated off at a sheltered location off the coast of Alaska. Tug companies operating in Alaska and the Pacific coast can provide the proper tugs for float on/off operations. Bollard pulls up to 70 tons, z-drive units and shallow draft tugs are available for relatively easy mobilization.

The rig move between the offloading location and the drilling site will require tugs of sufficient bollard pull capacity. For rig moving operations, there is local capacity available, although only a limited number of ice-class tugs have been identified. Tugs with ice-class capacity should be considered for purposes of adequate and safe ice management.

Self propelled drilling vessels have been identified as the other possible option for the Arctic venture. Drilling vessel equipment needs to be winterized and some structural studies for ice re-enforcement will be required if they extend their operations after the ice-free season. With regards to anchor handling tugs for deploying the mooring lines of drilling vessels, the local capacity is almost none and these units will need to be mobilized from the US Gulf of Mexico. When running anchors in the depths of the Chukchi Sea and Beaufort Sea, a bollard pull requirement of 100 or more tons can be expected.

Ice management is identified as a limitation because there is a need to obtain ice-class anchor handling vessels and icebreakers to re-direct ice floes. Diesel spill recovery operations in ice require effective ice management. Spill response training for vessel crews in low temperature environments is identified also as a potential limitation, if the demand for performing spill recovery operations increases.

The abilities and limitations identified in this study reflect the current stage of preparations for the Arctic exploration. The transportation plan can be safely established with the current resources available if all considerations established are addressed in proper operational procedures.

The support requirements during platform transportation to the Chukchi and Beaufort Seas were further identified. Logistics and planning are vital because these remote areas can not rely on last minute decisions, especially in case of an accident where emergency response units will take a long time to reach the location.

The main consideration is that the vessels and platforms involved in this project should assess every possible risk and implement a contingency plan with the idea of being self-sufficient and being capable of addressing the risk with no or minimum external support. After identifying areas of weakness, the mitigation plan should be developed.

Support operation assessment covers the following areas:

- Selection of suitable tugs and/or anchor handling vessels with adequate equipment, strength and capacity as well as competent and trained crews.
- Identification by all stakeholders of the rules and guidelines to abide by
- Vessel's equipment and level of redundancy.
- Communications, control and tracking of the transportation venture
- Routing arctic navigation and vessel traffic control.
- Pollution response
- Collision, Fire and Grounding
- Evacuation.
- Fuel Supplies
- Food Supplies
- Drilling equipment Storage

Working in the Arctic region requires personnel to be aware of safety issues related to the specific cold environment. Cold weather awareness and training for offshore personnel is regarded as imperative in order to reduce risk and to provide conscious responsibility.

Protective clothing for the Arctic environment should be provided. Proper balance in work activities and leisure will maintain productivity to acceptable levels. The offshore worker will need a physical and fitness assessment. Emergency response organization should be clearly defined in the response procedures.

Helicopter operations play a key role in the offshore industry. Helicopters are a fundamental component to conduct crew changes, deliver spare parts, and in medical evacuations. Specific requirements for helicopter operations in ice and Arctic conditions briefly reviewed in this study include:

- Improved in-flight de-icing system
- Ice accumulation in landing areas
- Consideration to Automatic Landing System to be fitted due to zero visibility for extended period of time.

Most shipping in the Arctic today is moving goods into the Arctic or moving natural resources out of the Arctic to world markets. Arctic shipping and platform transportation pose a threat to the region's unique ecosystems. Release of oil into the Arctic marine environment is the most significant threat from shipping activity.

Diesel fuel is highly toxic to plants. Diesel is the type of fuel most commonly spilled in the State of Alaska. Along the west coast of the Alaska, the total number of diesel spills is the highest among all spill types in all regions, although they are not always dominant in the percentage of total volume spilled with the exception of Bristol Bay and Western Alaska, in the period July 1, 1995 to June 30, 2005.

In addition to classification societies' standards or rules, there are also governmental or statutory requirements to protect the interests of society and the general public with regard to safety and environmental concerns as they relate to the marine industry. Numerous vessels operating in

Alaska are subject to Alaska's spill response planning and financial responsibility statutes. Alaska has a Subarea Contingency Plan that directs the state and federal actions in a response to the release of hazardous substances and oil spills.

Clean up methods differ for diesel spills in the open season, spills in transition seasons, and spills in frozen seasons. An effective response plan must have a clear understanding of the different spill scenarios, and find the most effective responses to a spill.

The Arctic environment is challenging with a range of weather and with little human infrastructure. Consequently, strong prevention measures must be of primary concern. It is very important to implement aggressive efforts both to prevent a spill and contain one. Procedures for fueling operations and contingency measures need to be established and strictly adhered to. Vessels need to be routinely inspected and any incompliance needs be addressed properly prior to being engaged in marine operations.

1. TASK1: ASSESSMENT OF ENVIRONMENTAL CONDITIONS

1.1 General

The Arctic environment requires planning considerations besides those associated with similar installations or construction in more temperate areas. These considerations relate to natural processes associated with the extremely low temperatures and the performance of the system, equipment, and personnel. In addition to low temperatures, snow, sea ice, structural icing, icebergs, ice gouges and permafrost are also major environmental factors that require the investigation of Arctic conditions (API RP 2N).

The transportation and installation of platforms faces the challenge of operational conditions in the Arctic. In order to maximize the utilization of the weather window during the summer (June through Aug./Sept.) and take advantage of extended periods of daylight and attractive temperatures, substantial planning and preparations are required.

Because the Arctic environment is frequently subject to large fluctuations in seasonal and year-to-year conditions, long-term observations are needed to understand the potential perturbations. Coordination of assessment activities with early planning can reduce costs. Cost saving can also be achieved through efficient use of different sources of information and traditional knowledge.

Our subtasks for Task 1 are to gather information on the metocean conditions for the Chukchi and Beaufort regions. The subtasks include:

- Wind, Seastate and Current Assessment of Chukchi Sea, Beaufort Sea and any other regions that may be suitable for float-off of drilling exploratory platform from dry transportation vessels
- Air Temperature of Chukchi and Beaufort regions
- Ice cover study to identify ice-free sea conditions
- Trends for air temperature, ice break-up, and ice extent

1.2 Objective

The objective of the Task 1 of the Arctic Offshore Technology Assessment is to evaluate meteorological and oceanic trends to identify safe time windows to transport and set platforms.

1.3 Wind, Seastate and Current Assessment

The predominant summer winds in the U.S. Arctic Ocean are from the east and northeast, with speeds of 4 m/s to 11 m/s (8 to 21 knots). The major storm winds blow from the southwest, a direction that gives them maximum fetch for the southwest-facing coastline of the Chukchi Sea. The Beaufort Sea is more protected. The seasonal increase in wind speeds starts in the Bering Strait in June, and progresses northward into the U.S. Arctic Ocean from July to October. In November and December, the maximum winds in the area start to decrease with a southward migration into the Chukchi Sea. The winds will eventually break through the Bering Strait into the Bering Sea, and the direction of the wind is coincident with the sea ice retreat and advance.

1.3.1 Beaufort Sea

The wind and sea conditions in the Beaufort Sea are considerably less severe than most open-ocean environments. The 95% probability of exceedance for significant wave height is between 2.5-3 meters in the open season. The regional presence of ice dampens wave action and often limits the fetch over which winds might otherwise create larger fully developed waves.

The wind is generally from the E-NE (40-60% of the time) or W-SW (20-40% of the time). Northerly or southerly winds occur less than 7% of the time. The average wind speed increases gradually from July to October. It can be seen from Figure 1 that a wind speed exceeding 15 knots (8 m/s) is expected to be in the range of 20%, 24%, 30% and 37% from July to October. The probability of having a wind speed exceeding 25 knots (13 m/s) is below 10% for the worst month, i.e., October, of the open season.

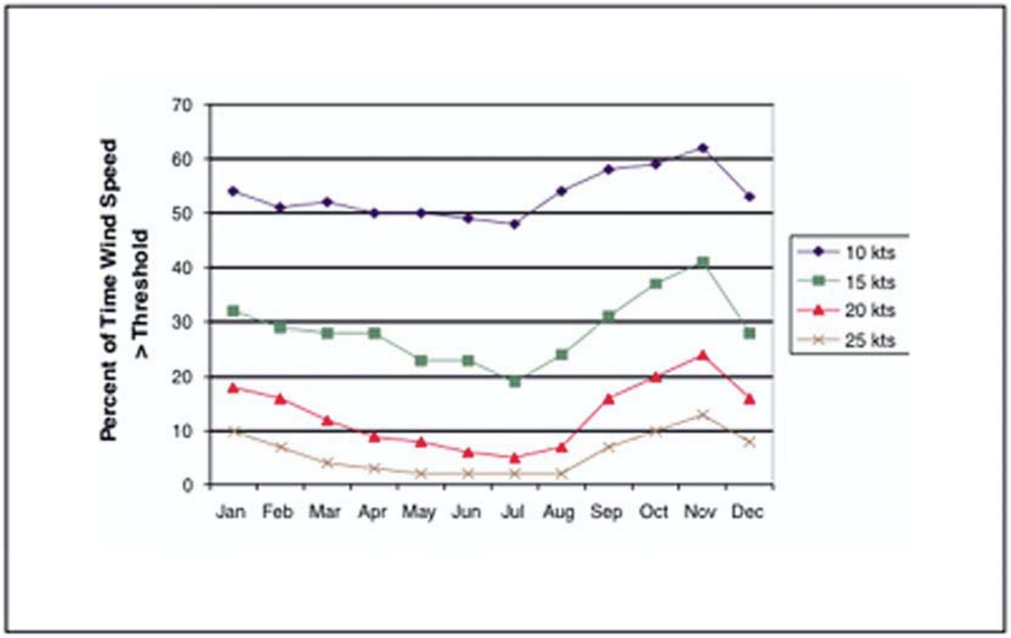


Figure 1: Monthly wind speed exceedance. Source: Vaudrey (2000) based on long-term data for the Prudhoe Bay area, Beaufort Sea

For Beaufort Sea, the potential maximum sea states during the period of maximum open water (mid-August to mid-October) can be estimated from the standard Beaufort scale relationship. A moderate breeze of 11-16 knots (Force 4) will typically result in a wave height of 3.5 to 5 feet.

The boundary current along the Beaufort slope shows frequent changes in direction. The mean flow is cyclonic, even though the flow of ice and near-surface water is westward. According to the data gathered by direct current meter measurements at the shelf edge of the Alaskan Beaufort Sea, the mean vectors reveal that the flow is generally to the east along the bathymetric contours (Figure 2).

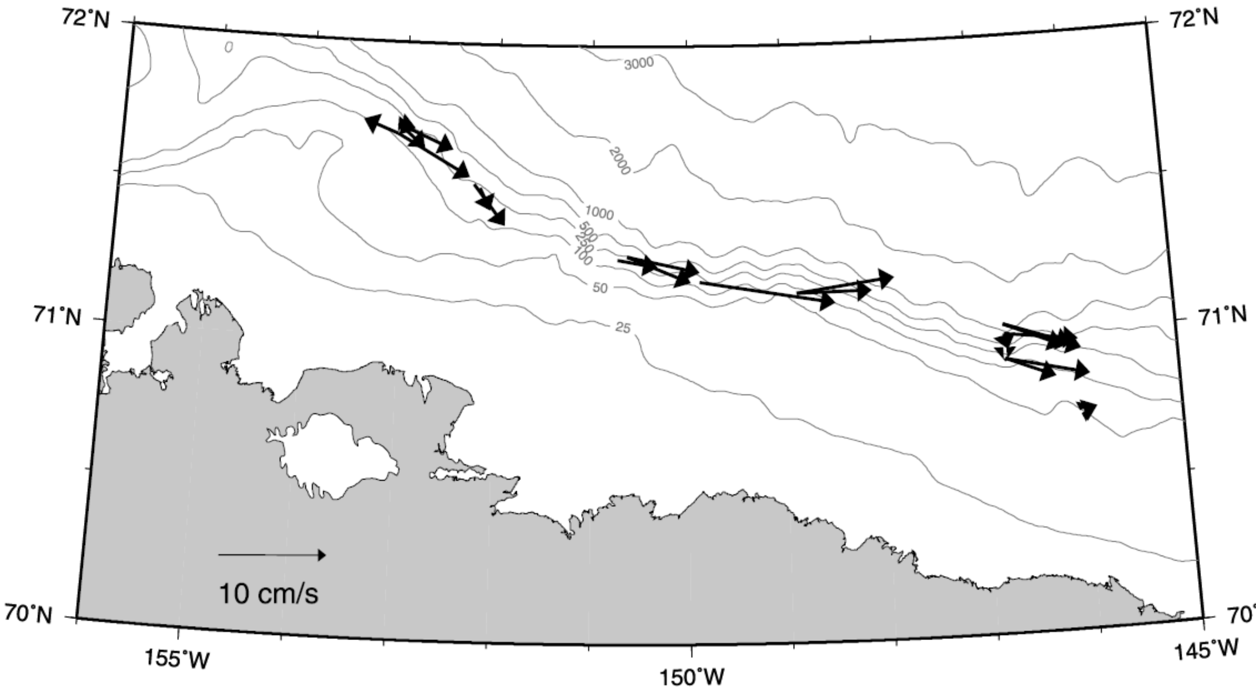


Figure 2: Current circulation at the shelf edge of the Alaskan Beaufort Sea (Pickart, 2004)

As shown in Figure 3, currents are generally strong and directed eastward or westward in the summer on Alaska's Beaufort Sea Inner Shelf; large fluctuations are often tied to wind events. In the winter, currents beneath the ice and near to shore are small (< 0.10 m/s or 0.2 knots) even in the presence of strong winds (Weingartner et. al., 2009).

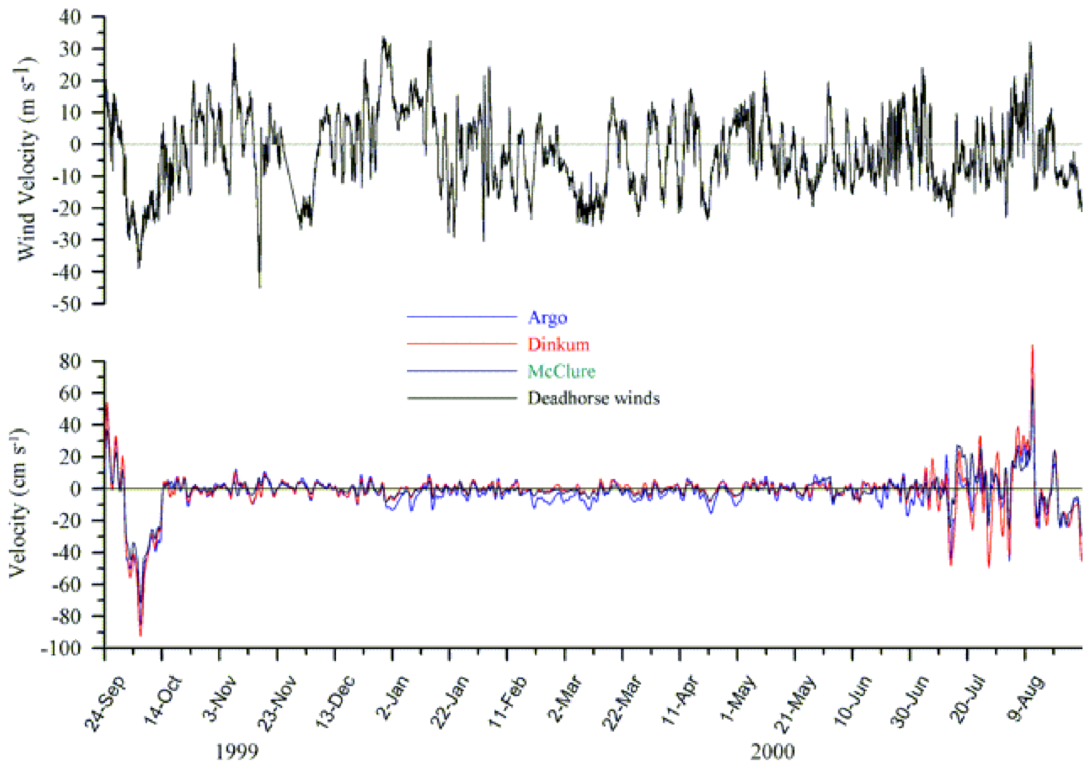


Figure 3: Wind and Current Observations data at Alaska's Beaufort Sea (Weingartner et. al., 2009).

According to Danielson and Weingartner (2007), the nearshore zonal current is driven by the zonal winds at Beaufort Sea in summer. The current data is taken here from the Dinkum site, while the wind data is from the Deadhorse airport. Positive winds and current values represent the flow to the east, negative to the west. It is shown clearly in Figure 4 that the current direction follows the wind direction, and the wind-driven component of associated current is approximately equal to 3% of the wind speed.

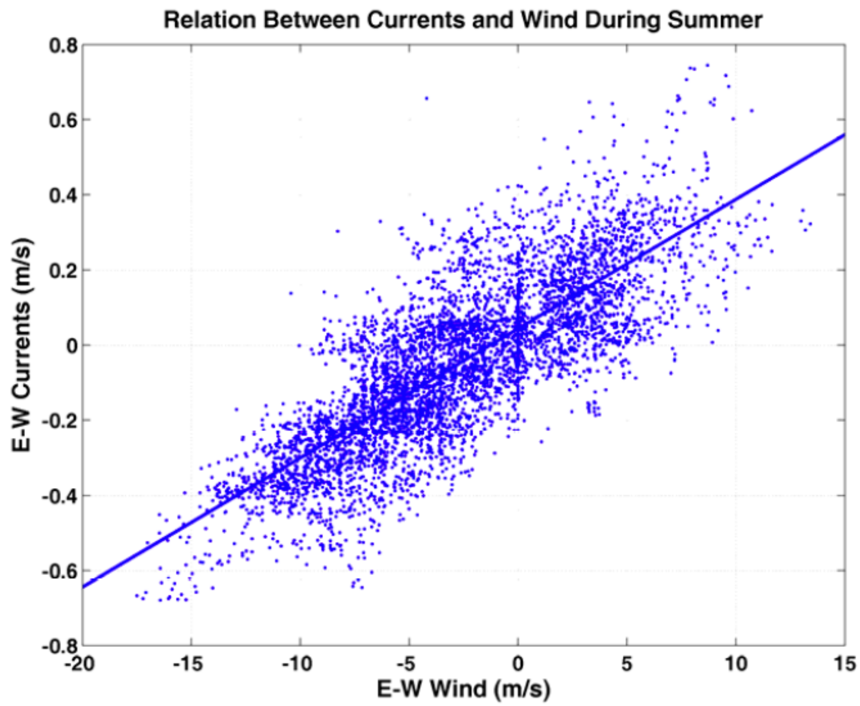


Figure 4: Regression Analysis; Relation between currents and wind during summer at Beaufort Sea

1.3.2 Chukchi Sea

Over the years there have been many studies on the wind and wave conditions in the Chukchi Sea. The Wave Information Studies (WIS) was authorized in 1976 by the Office of the Chief of Engineers, and the U.S. Army Corps of Engineers, to produce wave climate information for U.S. coastal waters. WIS information is generated by numerical simulation of past wind and wave conditions by a process called hindcasting. The WIS project produces a high-quality online database for nearshore wave conditions covering U.S. coasts (Ref. [88]). The hindcast data provides a valuable source of decades-long wave data needed in coastal engineering design. To assess WIS data quality, extensive comparisons between hindcast and measured wave parameters can be viewed at this site. Every effort has been made to maximize use of measurements from the National Weather Service's National Data Buoy Center (NDBC) to assess hindcast quality.

Multi-year time series of bulk wave parameters, significant wave height, period, and direction, as well as wind speed and direction are available for downloading and viewing (Ref. [88]). This data is provided at 1-hour intervals. Time series are available for a densely-spaced series of nearshore points along the U.S. coastline (in water depths of 15-20 m) and a less-dense series of points in deep water (water depths of 100 m or more).

Alaska Station 82033 is chosen to represent the general characteristics of the Chukchi Sea. This station is located at -163.00°W and 70.25° N at 29m of water depth.

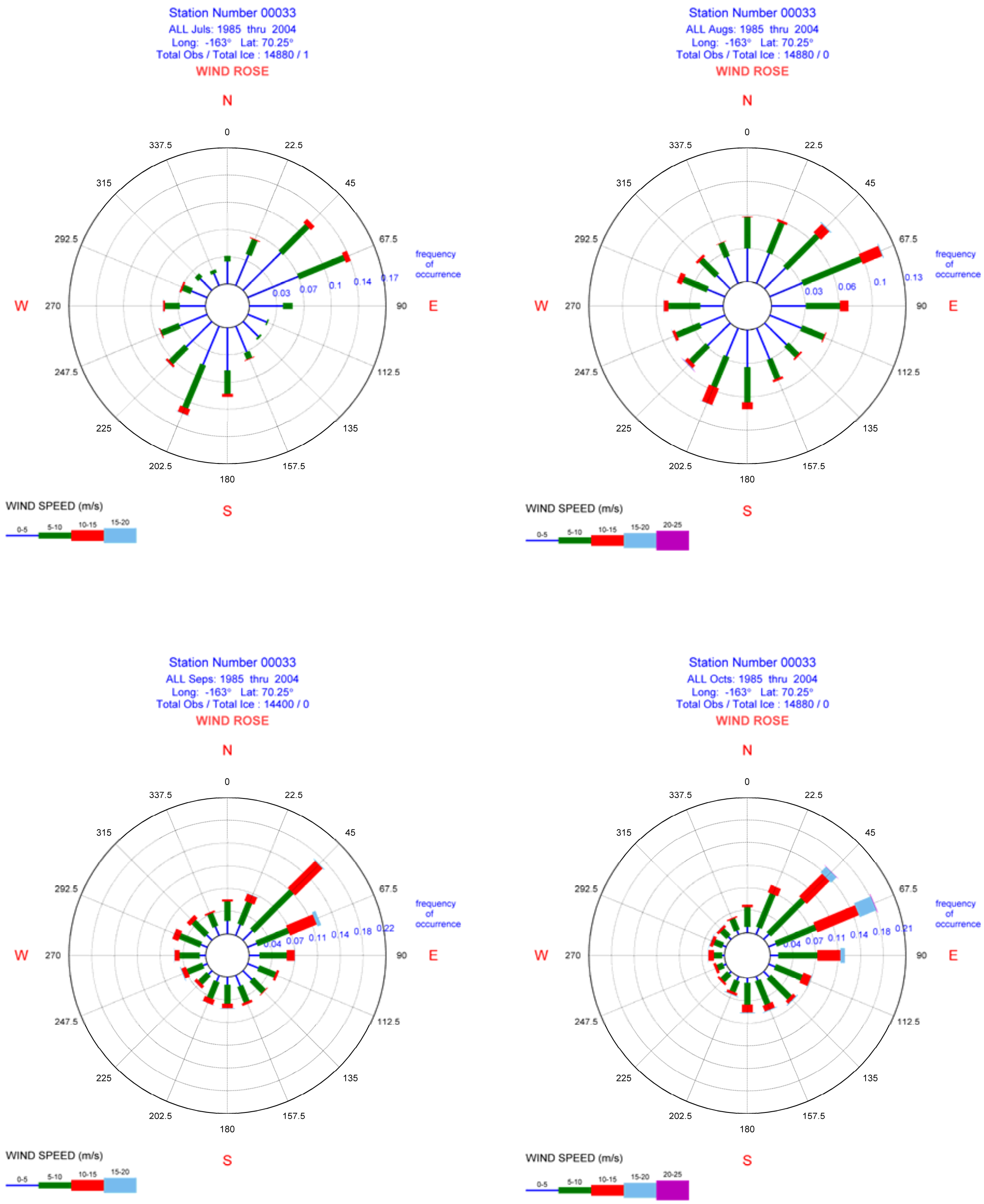


Figure 5: Wind Rose at Station Location: (-163.00° W, 70.25° N), Chukchi Sea for July, August, September, and October.

The wind is generally from NE-ENE or SSW during the month of July and is mostly from NE-E (30-40% of the time) from August to October. Northerly or southerly winds occur less than 6% of the time (See wind rose diagram shown in Figure 5).

The wind speed gradually increases from July to October. It can be seen from the Figure below that the chance of a wind speed over 15 knots (8 m/s) is expected to be in the range of 4%, 10%, 22% and 31% for open season months from July to October, respectively. The probability of having a wind speed of over 25 knots (13 m/s) is below 6% for October of the open season.

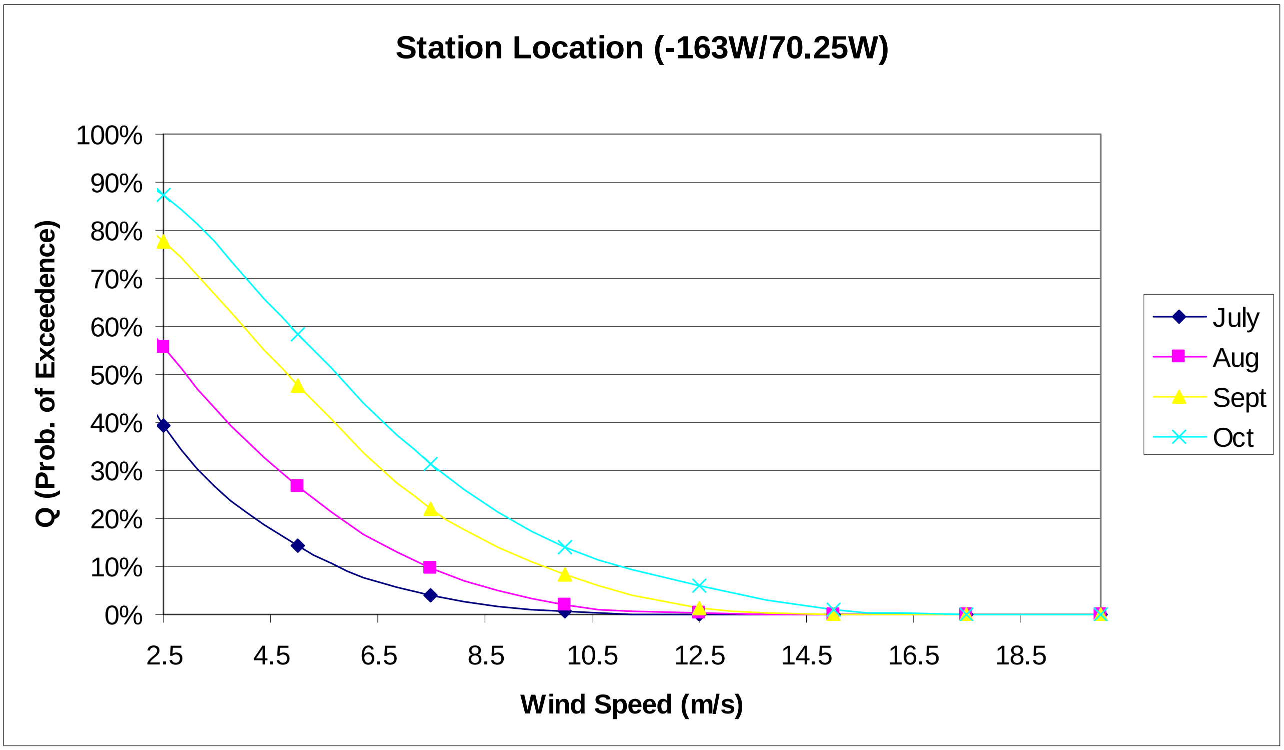


Figure 6: Probability of Exceedance of Wind Speed at Alaska Station 82033 (-163.00 W/70.25 N), Chukchi Sea for July, August, September, and October.

Zhang et al. studied the climatology of the detailed surface wind field distribution over the Chukchi/Beaufort Seas between 1979−2006. The monthly mean wind speeds show that the wind speeds over the Beaufort Sea are relatively small (<4 m/s or 8 knots) for most of the year (November–July), with an increase occurring from August through October (~5 m/s, or 10 knots). Wind speeds over the Chukchi Sea evolve by advancing northward and retreating southward over the course of the year. The maximum monthly mean wind speed is 9 m/s (18 knots) in October. Figure 7 plots the average wind speed for the months of July-October.

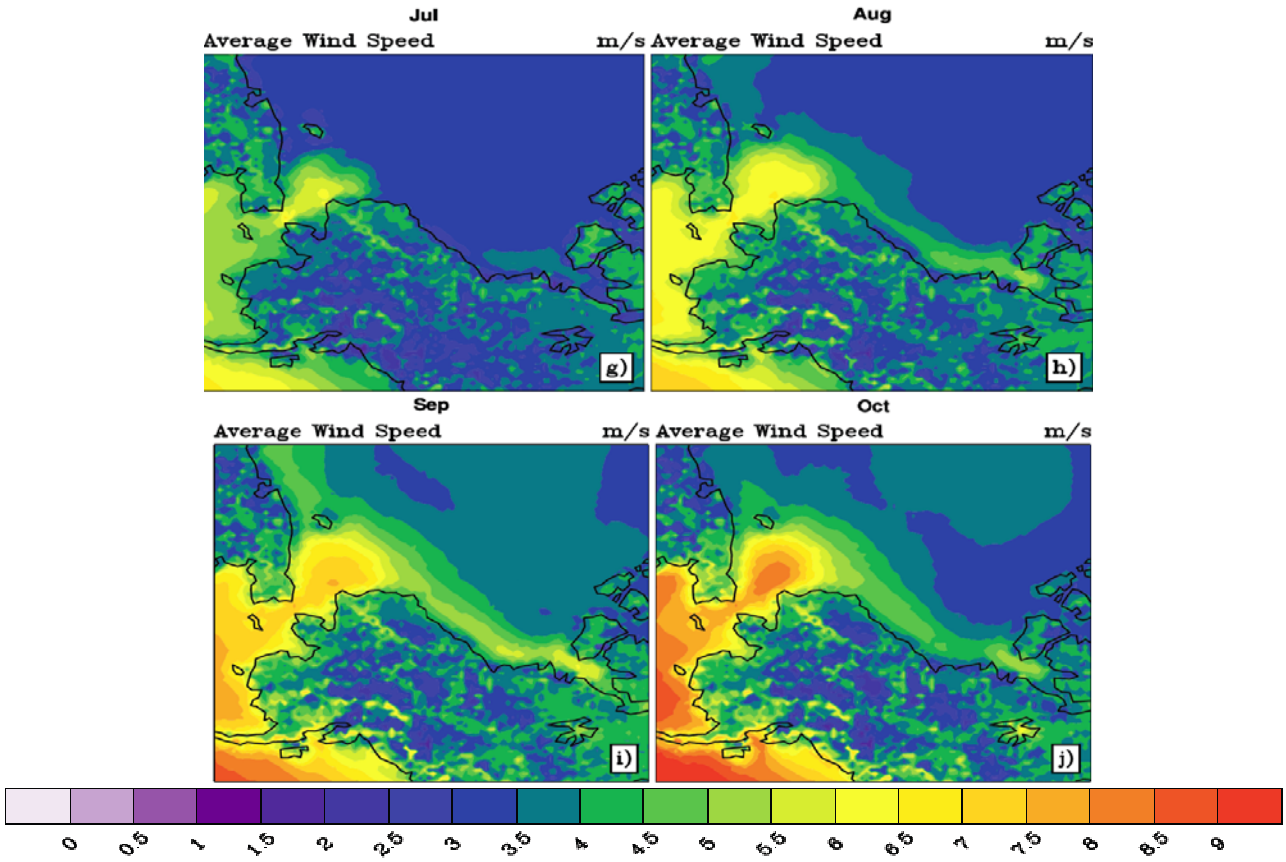


Figure 7: Monthly mean wind speed (m/s) averaged over 1979-2006

The maximum daily average wind speed for Barrow is highest in October (20 m/s or 40 knots), November (18 m/s or 35 knots) and December (11 m/s or 21 knots). Wind data collected over the past 10 years from communities along the Chukchi and Beaufort Sea coast show a substantial increase in the maximum wind speeds in September and October (Western Regional Climate Center 2009a and 2009b).

Wave roses at Station Location: (-163.00 W, 70.25 N) show that the direction of waves are primarily from NW and SE in July, and the waves stay more in the NE between August and October (Figure 8). The waves are predominantly generated by the wind forces during the open water season.

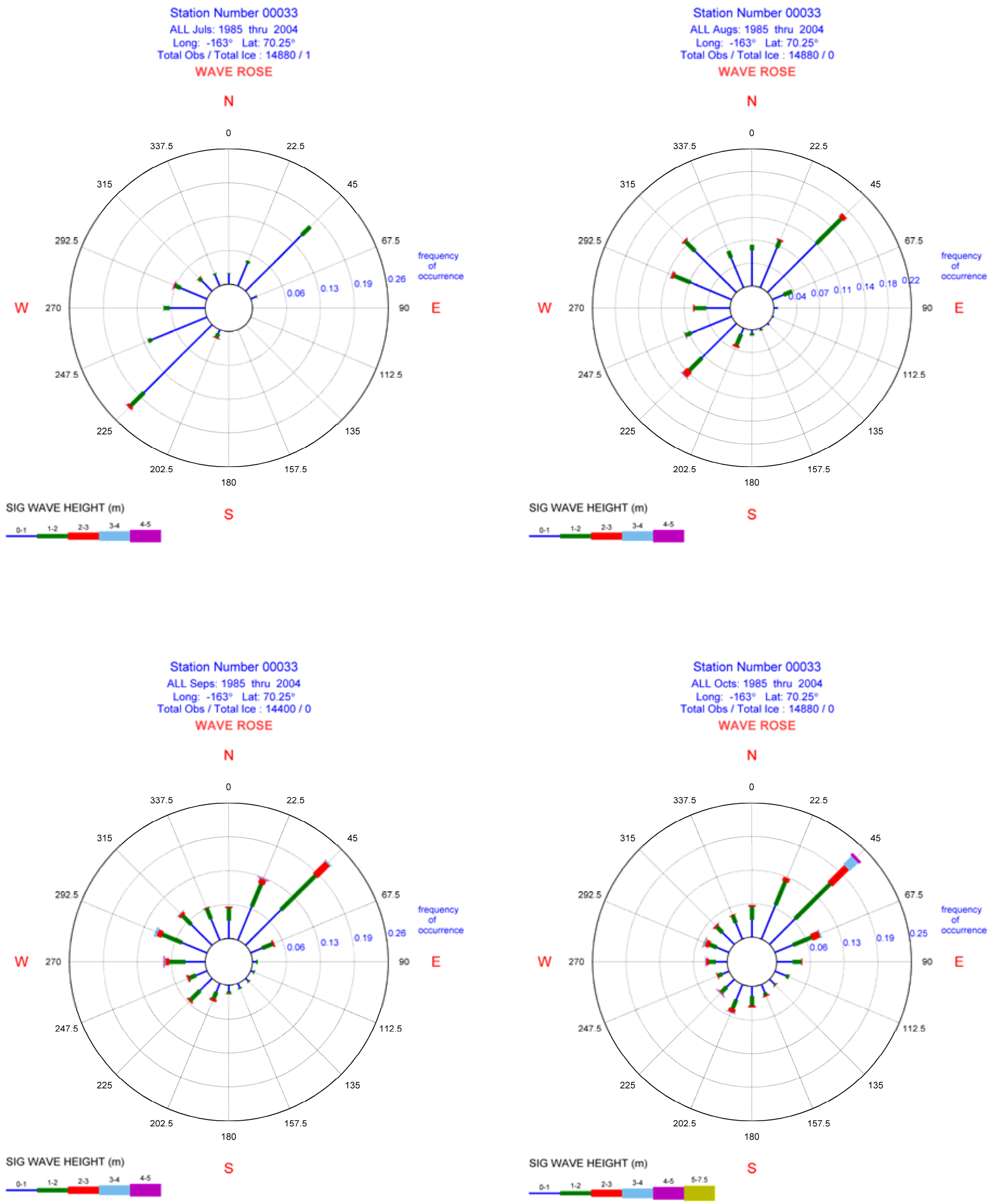


Figure 8: Wave Rose at Station Location: (-163.00° W, 70.25° N), Chukchi Sea for July, August, September, and October.

It can be seen from Figure 9 that the chance of a wave height of 2 m is expected to be in the range of 1%, 4%, 5% and 15% for open season months from July to October, respectively. The probability of having a significant height of 3m is below 4.2% for October.

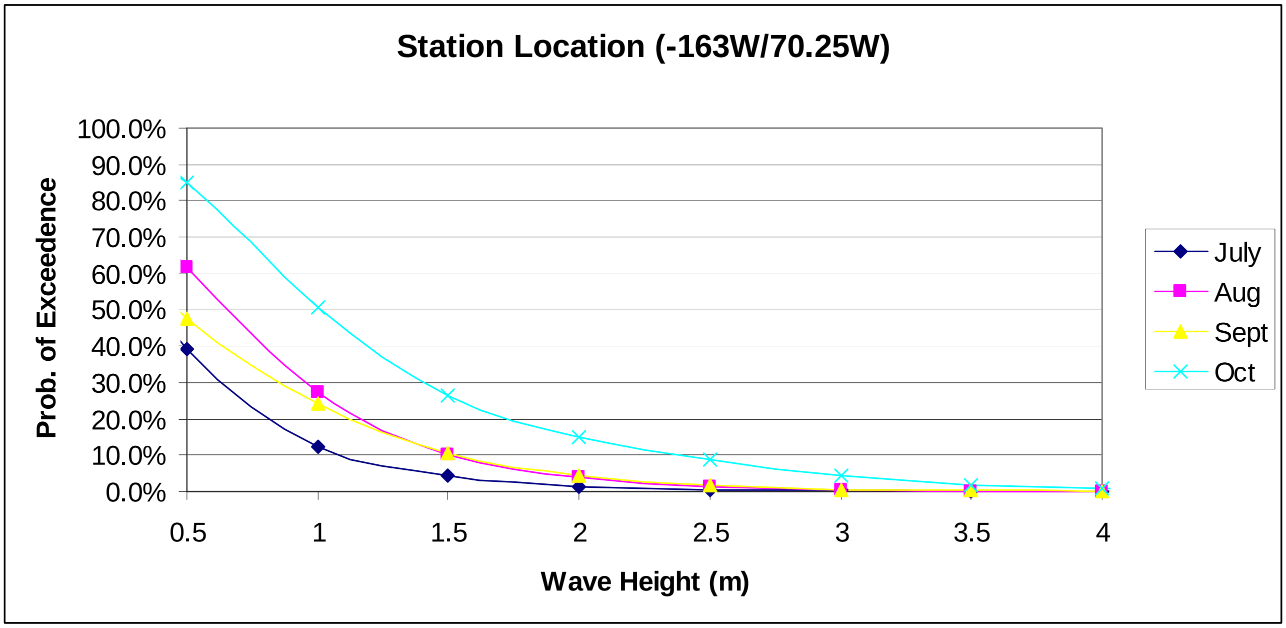
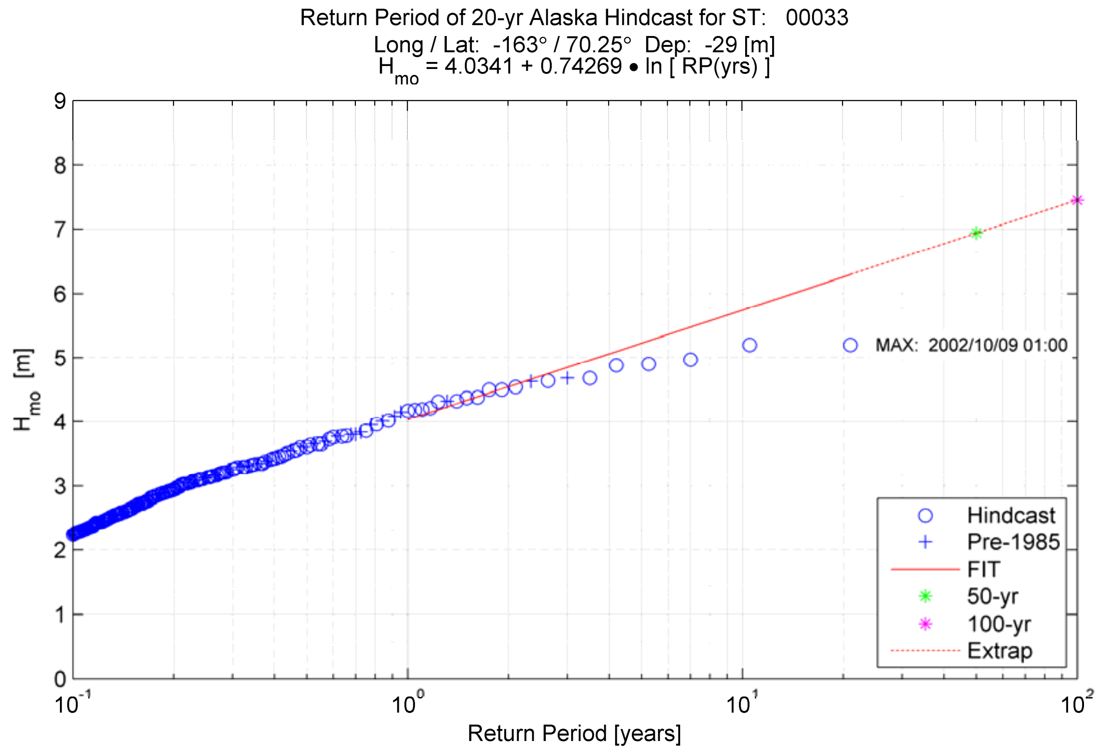


Figure 9: Probability of Exceedance of Wave Height at Alaska Station 82033 (-163.00° W, 70.25° N), Chukchi Sea for July, August, September, and October.

The omni-directional wave data is plotted log(return year period) against Hs, and a best fit line is drawn through the resulting points to derive the extreme values shown below in Figure 10. The significant wave heights for 1-yr, 10-yr and 100-yr return are 4, 5.7m, 7.5m meters respectively.



(01): 2002/10/09 01:00 H_{mo}: 5.20 / T_p: 10.15 / θ_m: 300.00	(06): 2004/09/28 15:00 H_{mo}: 4.68 / T_p: 11.17 / θ_m: 21.00
(02): 1995/11/30 04:00 H_{mo}: 5.20 / T_p: 11.17 / θ_m: 297.00	(07): 1957/09/13 01:00 H_{mo}: 4.68 / T_p: 9.23 / θ_m: 49.00
(03): 1998/10/24 19:00 H_{mo}: 4.97 / T_p: 10.15 / θ_m: 45.00	(08): 2002/08/15 07:00 H_{mo}: 4.64 / T_p: 8.39 / θ_m: 230.00
(04): 1996/10/29 09:00 H_{mo}: 4.90 / T_p: 11.17 / θ_m: 218.00	(09): 1978/10/09 07:00 H_{mo}: 4.63 / T_p: 9.23 / θ_m: 51.00
(05): 2002/11/07 01:00 H_{mo}: 4.88 / T_p: 9.23 / θ_m: 44.00	(10): 1990/11/11 03:00 H_{mo} 4.54 / T_p: 10.15 / θ_m: 226.00

Direction Convention FROM WHICH (Meteorological)

Figure 10: Extreme Omni-directional Significant Wave Height for station (-163.00° W, 70.25° N), Chukchi Sea.

The current at Shell's drilling sites in the Chukchi Sea is normally below 1 m/s (2 knots) as shown in Figure 11. The predominant current direction is ESE-E over the Chukchi shelf and Beaufort slope.

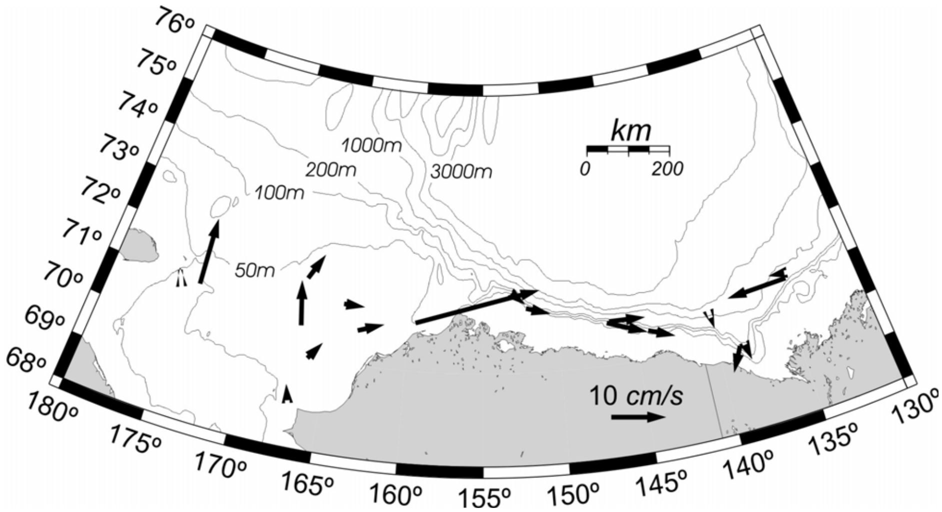


Figure 11: Mean currents over the Chukchi shelf and Beaufort slope (Weingartner, 2006).

In an effort to derive meaningful relationships for associated wind speed and wind-driven current, a regression equation was derived from extreme wind and current values in the Chukchi Sea. The wind-driven component of the associated current is approximately equal to 3% of the wind speed as shown in the Figure below.

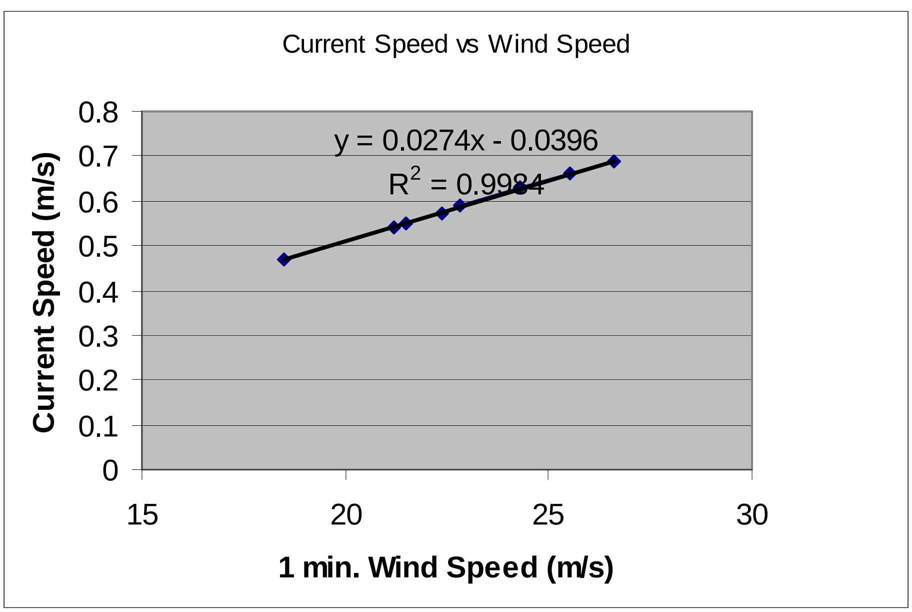


Figure 12: Regression for 1 min wind speed and current speed in Chukchi Sea

1.3.3 Dutch Harbor and Captains Bay

Dutch Harbor is on Unalaska Island in the Aleutians-a World War II Navy base and already a base for oil company exploration operations. Dutch Harbor lies within Captains Bay and is ice-free year-around. To the North it is open to the wind of the Bering Sea, and on all other sides it is subject to the gusty blasts. The 1-min wind speed can reach up to 105 mph in winter. The prevailing wind direction for coastal area off Dutch Harbor is north easterly in January, northerly in February and westerly from March to December.

Captains Bay is well protected from the sea and swell from most directions with the exception of infrequent north-easterlies. Captains Bay is well guarded from the prevailing northerly and westerly surge and, by a lesser degree, winds by Amaknak Island. This holds especially true towards the head of the bay; strong southerly winds do also present in Captain's Bay albeit with far less frequency. Tides and associated currents in Captains Bay are slight.

Temperatures are mild, and their range is small. In the coldest part of the winter usually January, average daily maximums range 1° to 3°C, while minimums fall into the range of -4° to -1°C. Temperatures begin to moderate after February. July and August are usually the warmest months. Daytime highs from 13° to 16°C are common, while at night temperatures usually fall to about 7° to 10°C. The poorest visibilities in the Alaska area occur along the Aleutians. They are best in winter, though even then they can be hampered by fog, snow, and rain. In summer as warm air from the Pacific moves over relatively cooler waters near the Aleutians, extensive fog formation takes place. The foggiest months are July and August when an average of 26 of the 31 days has fog.

1.3.4 Norton Basin

The Norton Basin in the Bering Sea could be used as an alternative basin for offloading rigs from dry transport vessels. The transit time from the port of Nome to the Chukchi Sea and Beaufort Sea is approximately 8-12 days with 3.5 knots of towing speed of the platform by tug boat(s). The areas south of the Bering Strait have a less severe climate. In the Norton Basin, the extreme low temperature is -37° C. Some support for Norton Basin exists at Nome. In anticipation of increased offshore oil activity, Nome plans to build a deepwater harbor. Nome has a subarctic climate with long, cold winters, and short, cool summers. However, conditions in both winter and summer are moderated by the city's coastal location: temperatures are at their lowest in late January/early February, with February being the coolest month -14.6 °C in average. Highs do not break freezing until late April. Temperatures peak in mid/late July, with a July average 11.4 °C. Daytime temperatures average below freezing starting in mid October.

The ice conditions are moderate at Norton Basin. There is about 8 months of ice coverage. Smooth ice is about 3.5-4 ft thick, rafted ice is about 15 ft thick, and ridges are 75 ft thick.

The predominant wind direction is NNW in June at Nome (Figure 14). The maximum wind speed and wave height is 15 m/s (29 knots) and 3m respectively. The predominant wind direction changes to SW direction during the month of July. The maximum wind speed picks up to 20 m/s (39 knots); the maximum wave height is increased to 4m (see Figure 13).

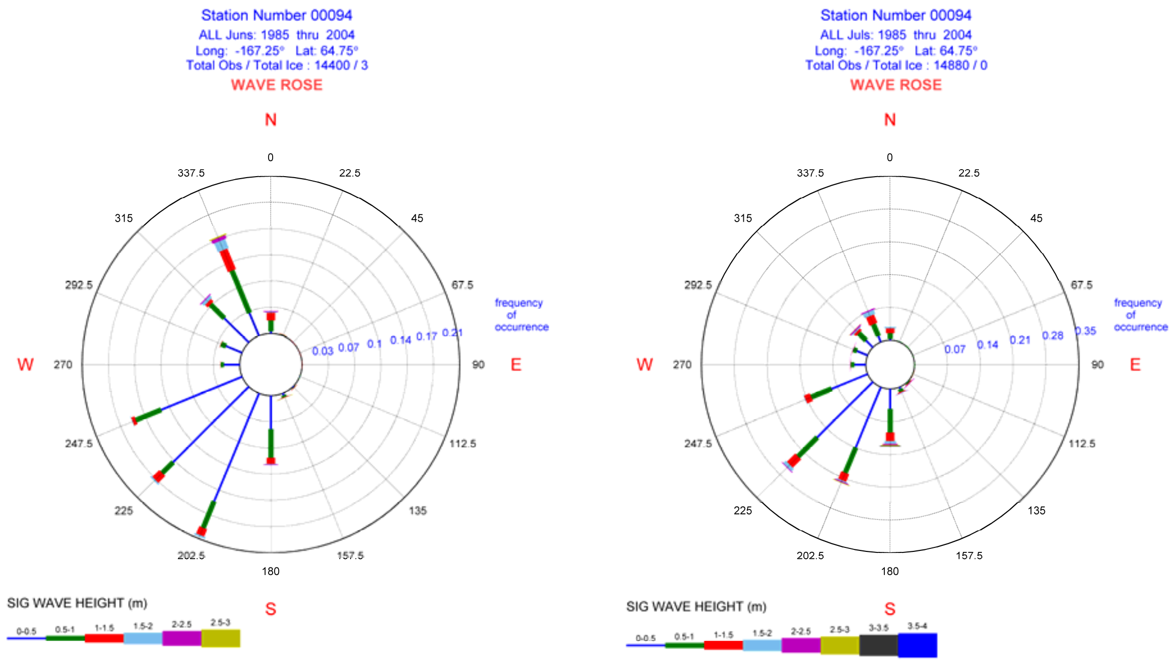


Figure 13: Wave Rose at station (-167.25° W / 64.75° N) near Nome for June and July.

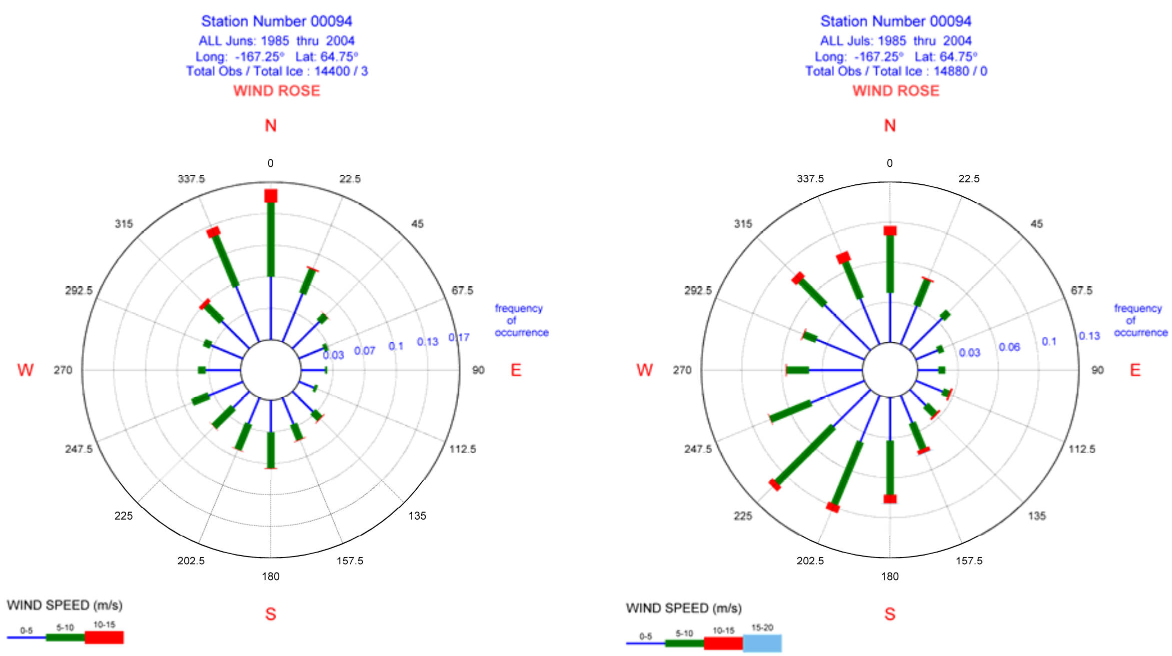


Figure 14: Wind Rose at station (-167.25° W, 64.75° N) near Nome for June and July.

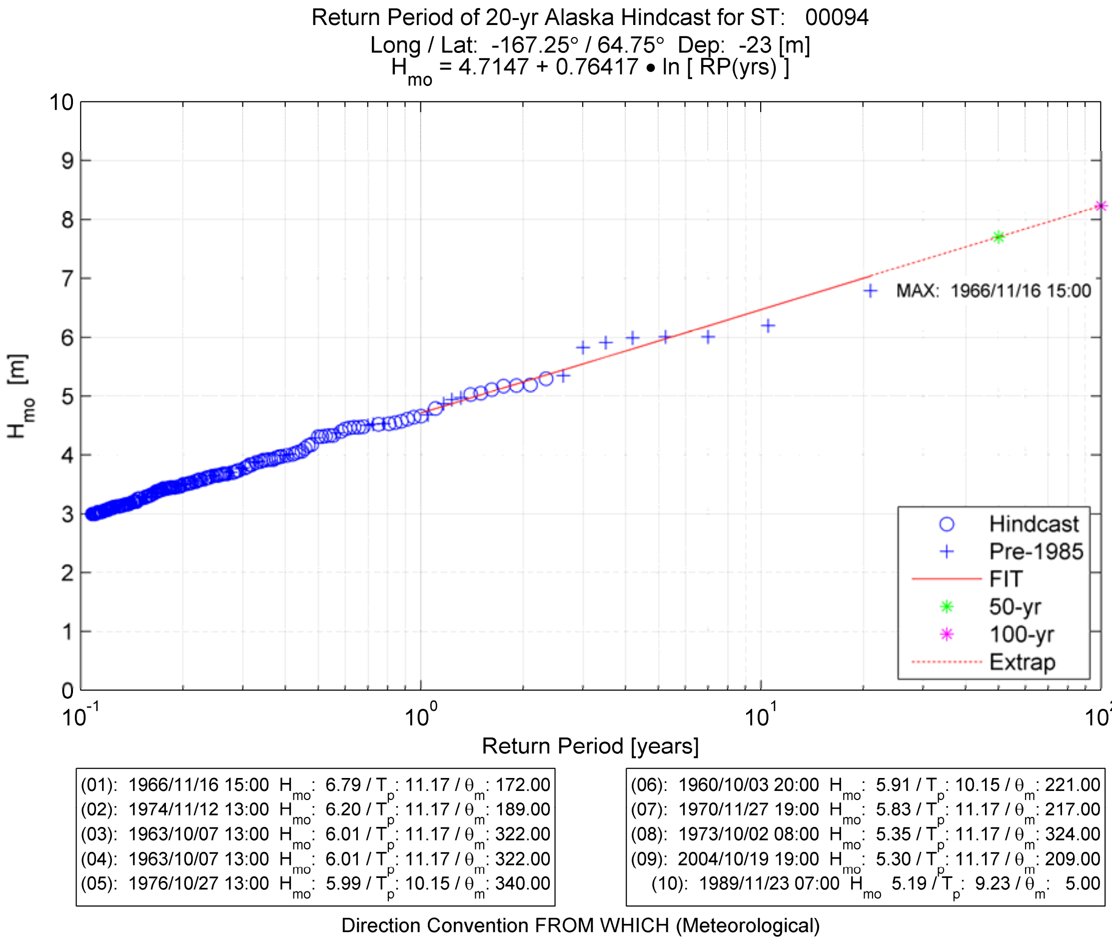


Figure 15: Extreme Omni-directional Significant Wave Height for station (-167.25° W, 64.75° N) near Nome.

Figure 15 above shows the extreme values of the significant wave height occur in the month of November. The 10 year and 100 yr significant wave heights are 6.5 and 8.2m respectively. According to 'Oil and gas technologies for the Arctic and deepwater', the maximum 100-year wind speed is 55 to 85 knots (28 m/s to 44 m/s).

1.4 Air Temperature

The annual variability of the Arctic Ocean is characterized by a large seasonal cycle. The seasonal variations are imposed upon a background of significant interannual and decadal timescale variations. One of the most significant of these interannual variations is the wind-driven motion in the upper Arctic Ocean which alternates between anticyclonic regime and cyclonic regime.

Arctic atmospheric pressure is higher, wind speed is lower, and winter temperatures are colder during an anticyclonic regime compared with the cyclonic regime. During the cyclonic regime, precipitation increases over the ocean and decreases over land. Summer wind divergence produces more openings in the sea ice, allowing the upper ocean to accumulate heat. This positive heat anomaly extends to the ice melt season, increases freshwater content, and leads to generally thinner ice (Proshutinsky, et. al, 2003).

Regional characteristics of the monthly mean air temperature regime over the Beaufort and Chukchi Seas are presented in Figure 16, Figure 17 and Figure 18 . Summer air temperature is close to 0 °C for both circulation regimes. During cyclonic regime years (1989-1996), air temperature is higher than during anticyclonic regime (1998-2000), in agreement with the general characteristics of two regimes. Summer air temperature is close to 0°C for both circulation regimes.

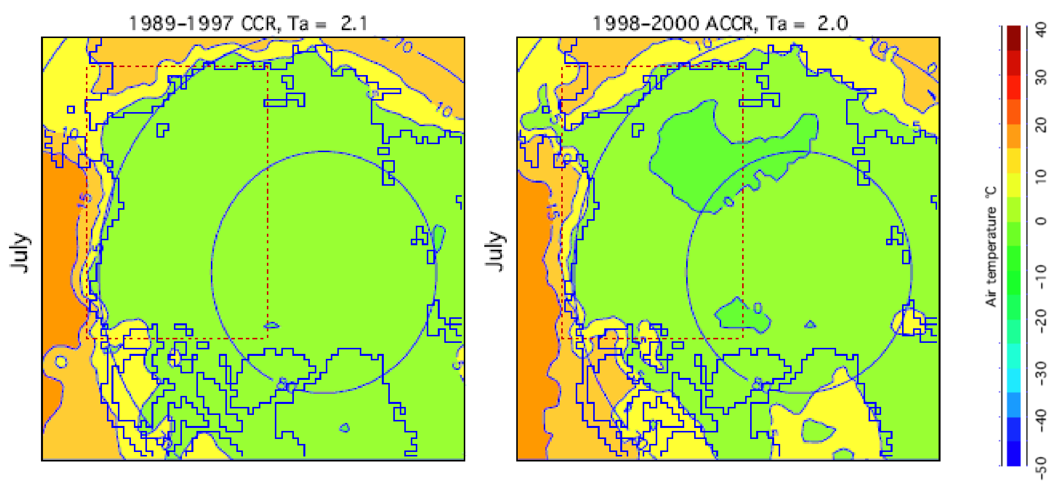


Figure 16: Surface air temperature in July for years with Cyclonic Regime (CCR) and Anticyclonic Regime (ACCR) circulation regimes (Proshutinsky, et. al, 2003). Chukchi Sea is shown at the top-left corner.

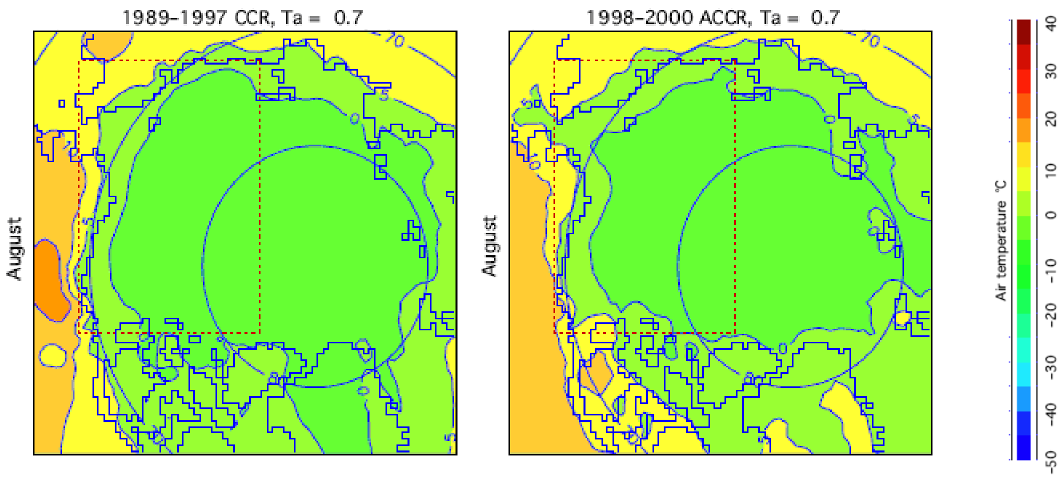


Figure 17: Surface air temperature in August for years with CCR and ACCR circulation regimes (Proshutinsky, et. al, 2003).

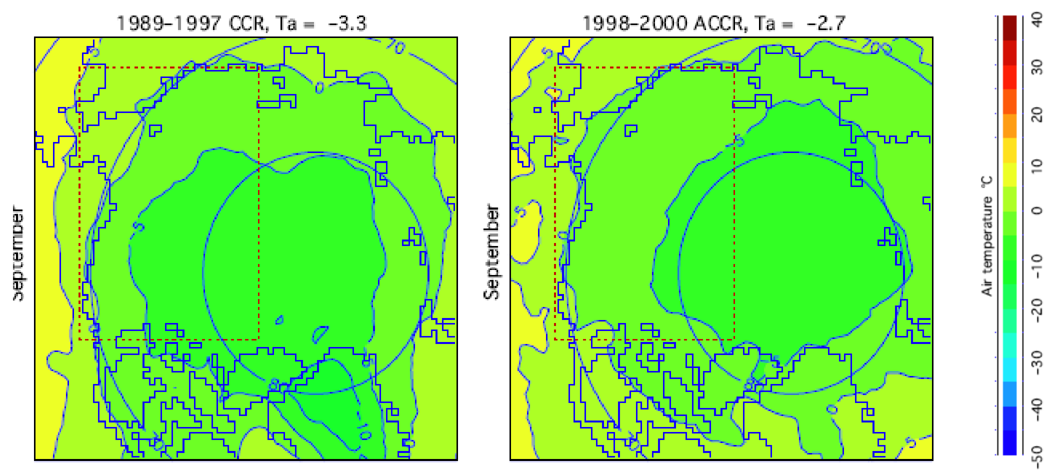


Figure 18: Surface air temperature in September for years with CCR and ACCR circulation regimes (Proshutinsky, et. al, 2003).

Following the emission scenarios developed by the Intergovernmental Panel on Climate Change (IPCC), the projected Arctic Surface air temperature shows a 2°C degree rise by 2040 (Ref. [38]). As shown in Figure 19, all coupled ocean-atmosphere simulations of the 20th, 21st and 22nd century climate are projecting a warmer trend.

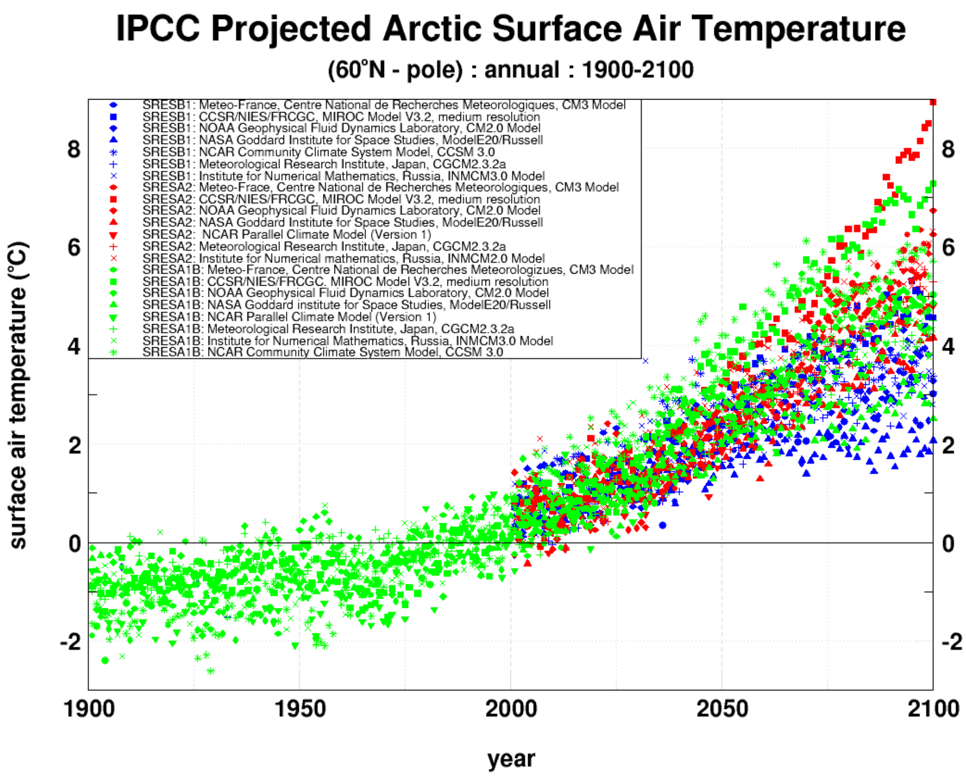


Figure 19: IPCC Projected Arctic Surface Air Temperature

The Beaufort Gyre is a large ocean circulation feature that plays a very important role in moderating the Arctic Climate. The usual rotational direction for the Beaufort Gyre is anticyclonic, in line with the prevailing atmospheric circulation pattern. Study indicates that the Arctic Ocean surface layer currents are consistent with the Arctic atmosphere surface layer motion, alternating between cyclonic and anticyclonic circulation regimes (Proshutinsky et al. 1997). Each regime persists from 4 to 8 years, resulting in a period of 8–16 years. The anticyclonic pattern prevailed from 1997 to 2008. In 2009 the annual wind-driven Arctic Ocean circulation regime was cyclonic for the first time since 1997 (Proshutinsky et al. 2010). This regime significantly influenced the characteristics of the sea ice cover and ocean. The maximum upper ocean temperatures in the summer of 2009 continued to decline relative to the historical extreme warm conditions observed in summer 2007.

The two regimes may help explain the significant, basin-scale changes in the Arctic's temperature observed recently and the variability of ice conditions in the Arctic Ocean.

1.5 Ice Cover

Arctic sea ice reflects sunlight keeping the polar regions cool and moderating global climate. According to scientific measurements, Arctic sea ice has declined dramatically over the past thirty years with the most extreme decline seen in the summer melt season. There is growing evidence that the shrinking ice extent over recent decades has been attended by substantial thinning (Polyak et al., 2010). Thick multi-year sea ice is being replaced by thinner, younger ice which melts at lower temperatures. This process reinforces the downward spiral and makes it difficult for the multi-year sea ice to recover. Shrinking of the Arctic sea ice concentration, especially in summers, is significant. Since 1993, the summer sea ice concentrations have been declining throughout the Arctic. It should be noted that since the open-water operations regime lasts longer, there is a potential for ice incursions.

Arctic sea ice cover attains its maximum seasonal extent in March and shrinks through spring and summer to a minimum extent in September. Figure 20 shows the minimum sea ice extent and ice concentration in 2010. For comparison also the record minimum sea ice extent of September 2007 and the mean September sea ice extents of the five years 1979 to 1983 are shown as red and green contours, respectively. The 2010 minimum sea ice extent is the third lowest in the more than 35 year long satellite data time series. The 2010 sea ice extent is at the same level with 2008 but about 0.5 million km^2 higher than 2007 (Ref. [5]).

Marine transportation in the Arctic is expected to increase as ice extent decreases and platform installations could reach further northern remote areas.

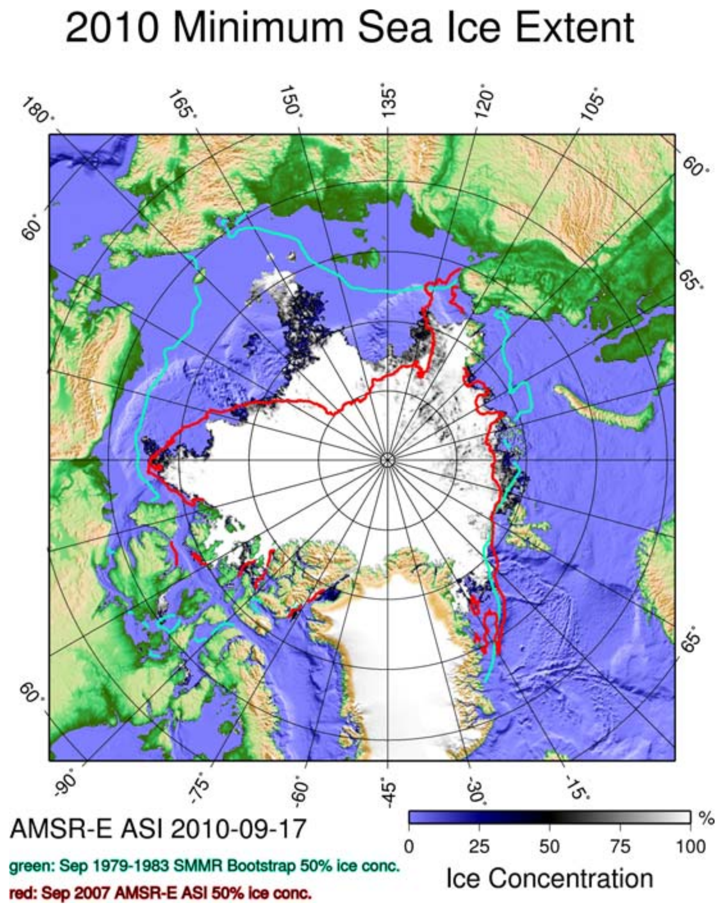


Figure 20: Overview map of the Arctic and adjacent regions showing the Ice Concentration and the minimum Sea Ice Extent in 2010.

Ice conditions in the summer months are largely dictated by the wind patterns; persistent easterly winds tend to move the ice along the Beaufort Sea coast and away from the Chukchi coast, promoting extensive clearing along the coast, while westerly winds tend to keep the ice close to shore and limit the extent of summer clearing (Dickins and Allen, 2007).

Polyakov et al (2003) pointed out that the prevailing easterly winds over the Chukchi Sea cannot contribute much to the northward advection of ice into the Arctic Ocean. However, northward surface currents fed by Pacific waters entering the Chukchi Sea through the Bering Strait provide an effective mechanism of ice transport to the Beaufort Sea.

During the summer, the Beaufort and Chukchi Seas experience a period of open water (predominantly ice-free, though scattered sea ice may be present) lasting approximately three months in the Beaufort Sea and four months in the Chukchi Sea. The brief ice-free summer ranges from late June to late October, depending upon location, distance from shore, and the conditions of each year. The Chukchi Sea tends to break up before the Beaufort Sea and freeze up afterward. Drilling was restricted to ice-free periods, which in the Beaufort Sea is typically August to October and in the Chukchi Sea is July to October.

Figure 21-Figure 23 present the sea ice concentration archive for the months of June to November 2010, using AMSR-E (Advanced Microwave Scanning Radiometer) data (see Ref. [17]). It can be seen that the Norton Basin is clear of ice from the middle of June, 2010 to end of October/beginning of November. So the drilling exploratory platform could be dry transported to the Norton Basin in the middle of June and towed to drilling site in July or August.

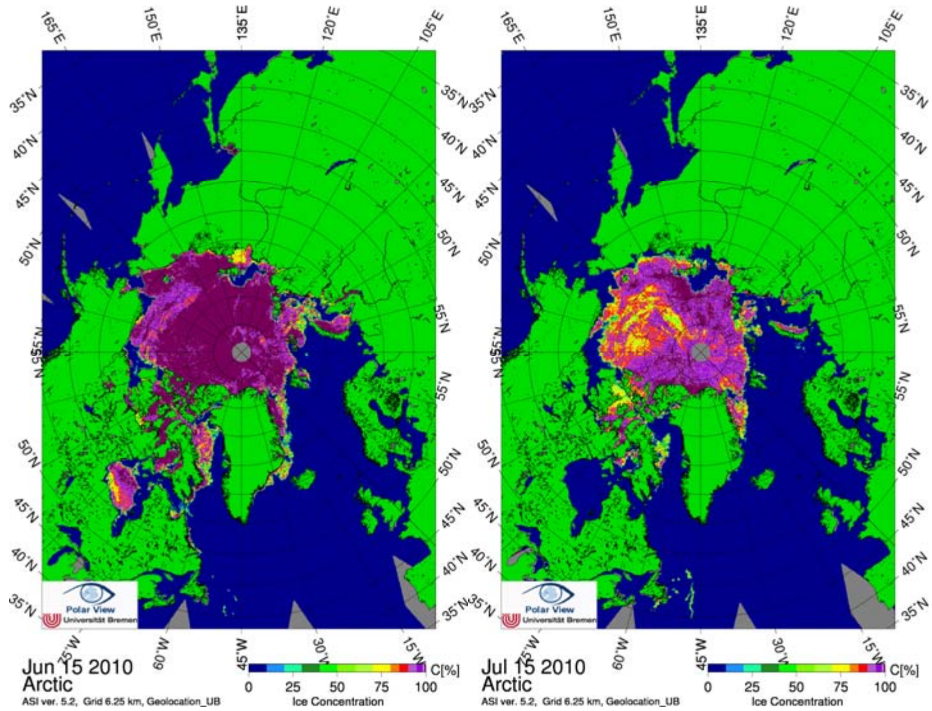


Figure 21: Overview map of the Arctic and adjacent regions showing the ice concentration from Jun to July, 2010.

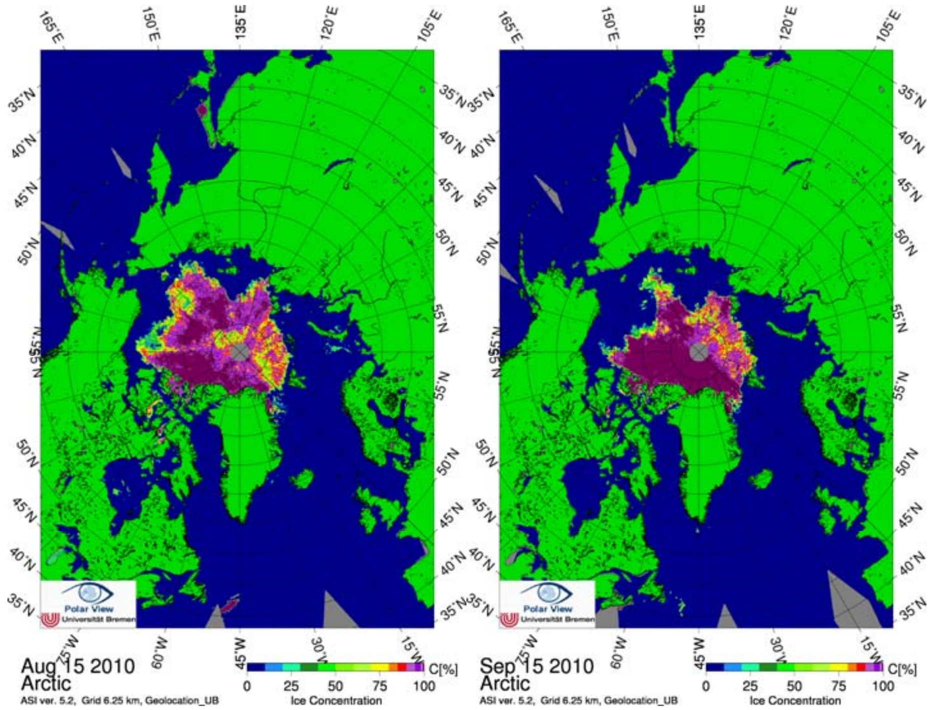


Figure 22: Overview map of the Arctic and adjacent regions showing the ice concentration for August & September, 2010.

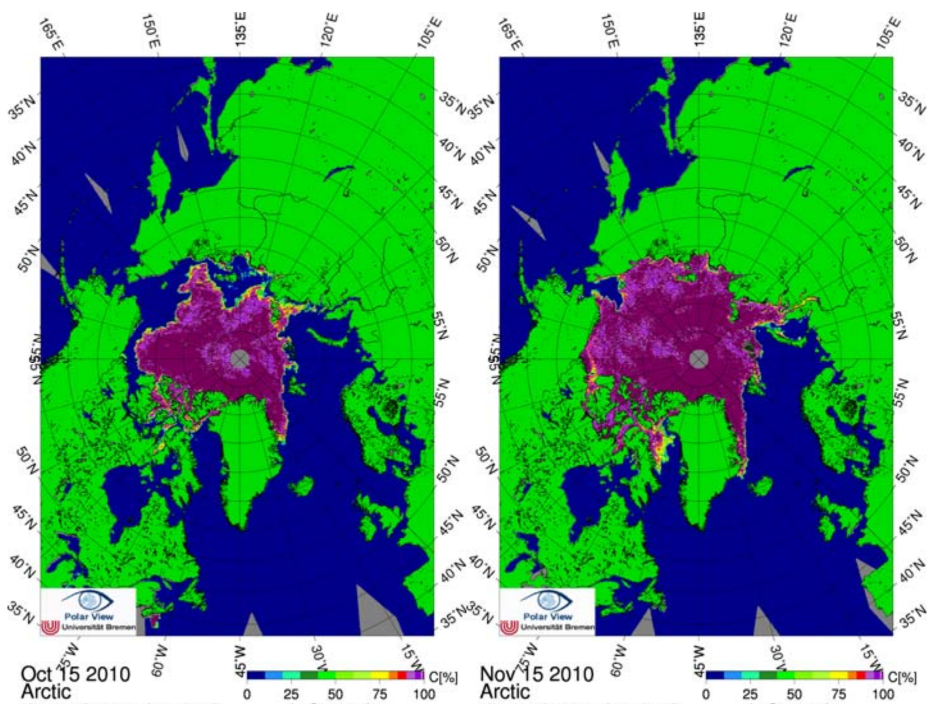


Figure 23: Overview map of the Arctic and adjacent regions showing the ice concentration for October & November, 2010.

1.6 Trends

1.6.1 Air Temperature

The most distinguishing feature of the recent changes in averaged Arctic surface air temperature is its rapid rise (about 1°C) in the mid-1990s. Based on data from 35 stations in Arctic over the period 1951–2005, this high level of surface air temperature has persisted through the present (see Figure 24).

The highest temperature rise occurred in autumn and spring, and the lowest in summer and winter. In the period 1995–2005, the warming was greatest in the Pacific (by 1.46°C) and Canadian (by 1.26°C) regions (Przybylak, 2007). In the period 2001-2005, the Pacific is 1.93°C above the average of 1951-2005 and the Canadian region is 1.11 °C above the average.

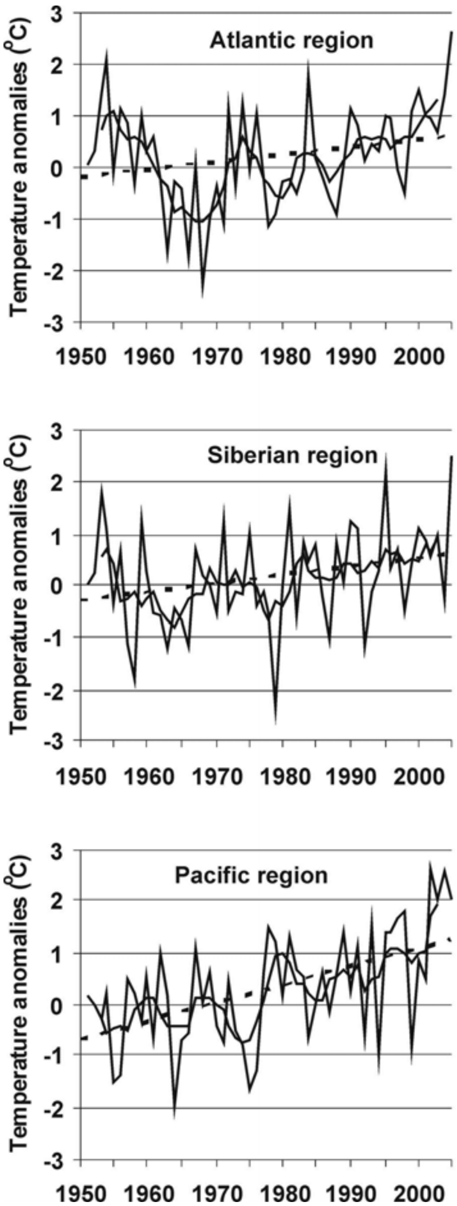


Figure 24: Mean annual anomalies of Surface Air Temperature and their trends in the climatic regions of the Arctic and for the Arctic as a whole over the period 1951–2005. Solid lines are year-to-year values, heavy solid lines are running 5 year mean and dashed lines are linear regression lines (Przybylak, 2007).

The temperatures in spring, summer and autumn from 1995 onwards are notably greater than in the 1930s, which was the warmest period in the 20th century in the Arctic. On the other hand, the surface air temperature in winter had slightly smaller values. Overpeck and others, 1997, and Przybylak and Vizi, 2005, concluded based on an analysis of historical data that the period 1995–2005 was the warmest since at least the 17th century. The year 2005 was also exceptionally warm, and was even warmer than 1938, the warmest year in the 20th century.

According to Proshutinsky et al. (2010), the maximum sea temperatures in 2007, 2008 and 2009 are above the mean value of 1982-2006. However, since the historical extreme in maximum upper ocean temperature in summer 2007, the maximum upper ocean temperatures continued to decline (Figure 25). The summer sea ice retreat and its effect on local atmospheric warming are closely associated with these changes. High summer sea surface temperature contributes to more heat flux back to the atmosphere in the fall, which will affect the sea ice conditions in the future.

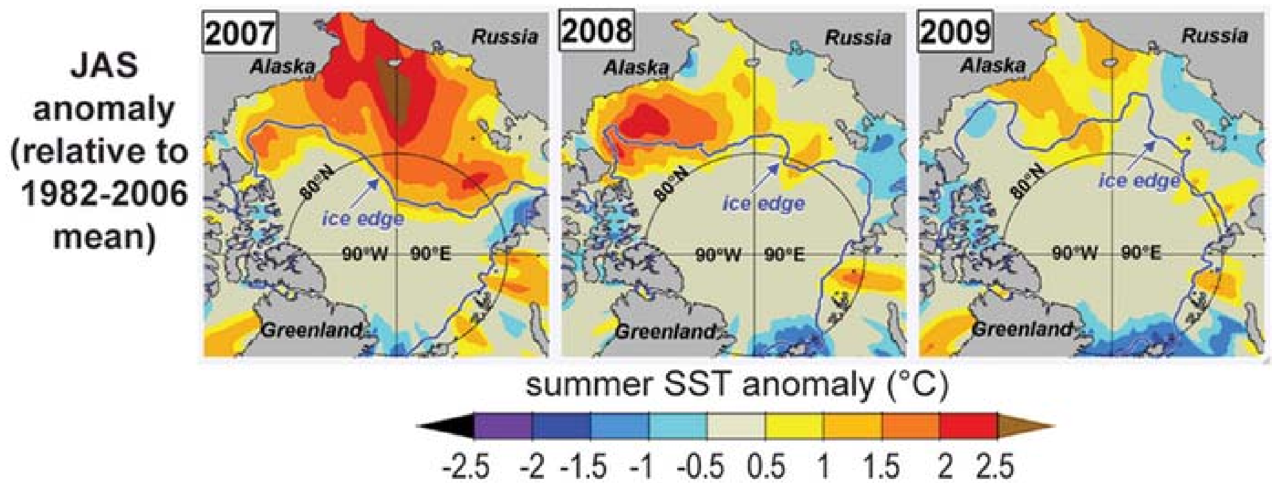


Figure 25: Satellite-derived summer (July, August and September) sea surface temperature anomalies for 2007, 2008 and 2009 (Proshutinsky et al. 2010).

Wind anomalies are the dominant factor responsible for creating inter-annual variability in the Beaufort-Chukchi Sea ice cover. Temperature anomalies appear to play a major role for longer time scale fluctuations, whereas the effects of runoff anomalies are small (Tremblay and Mysak, 1998)

The warm trends continue in the Arctic. According to the National Snow and Ice Data Center, while air temperatures were below freezing over much of the Arctic in October 2010, they were 4 to 6°C (7 to 10° F) higher than normal. The regions of open water contributed to the loss of heat to the atmosphere, in addition, and warm air was brought from lower latitudes to the Arctic by the cyclonic atmospheric circulation pattern.

Open water in summer absorbs heat from the sun that would normally be reflected back to space by the bright sea ice cover. In order for the ocean to refreeze in autumn, it must first release the heat accumulated during summer in these open water areas to the atmosphere. While the unusually warm temperatures tend to be focused over areas of open water, winds can move this heat around, warming other regions of the Arctic.

Additional evidence of the dramatic increase in winter air temperature can be seen in Figure 26. The differences between the average temperature at Barrow in 2009-2010 and the long-term average computed for the period 1971-2000 show the temperatures in 2009-2010 higher than the 1971-2000 average with the exception of the month of January. The highest increment occurs in

October, 2009, when the average monthly temperature is 10°F (5.6°C) above the averaged temperature for 1971-2000.

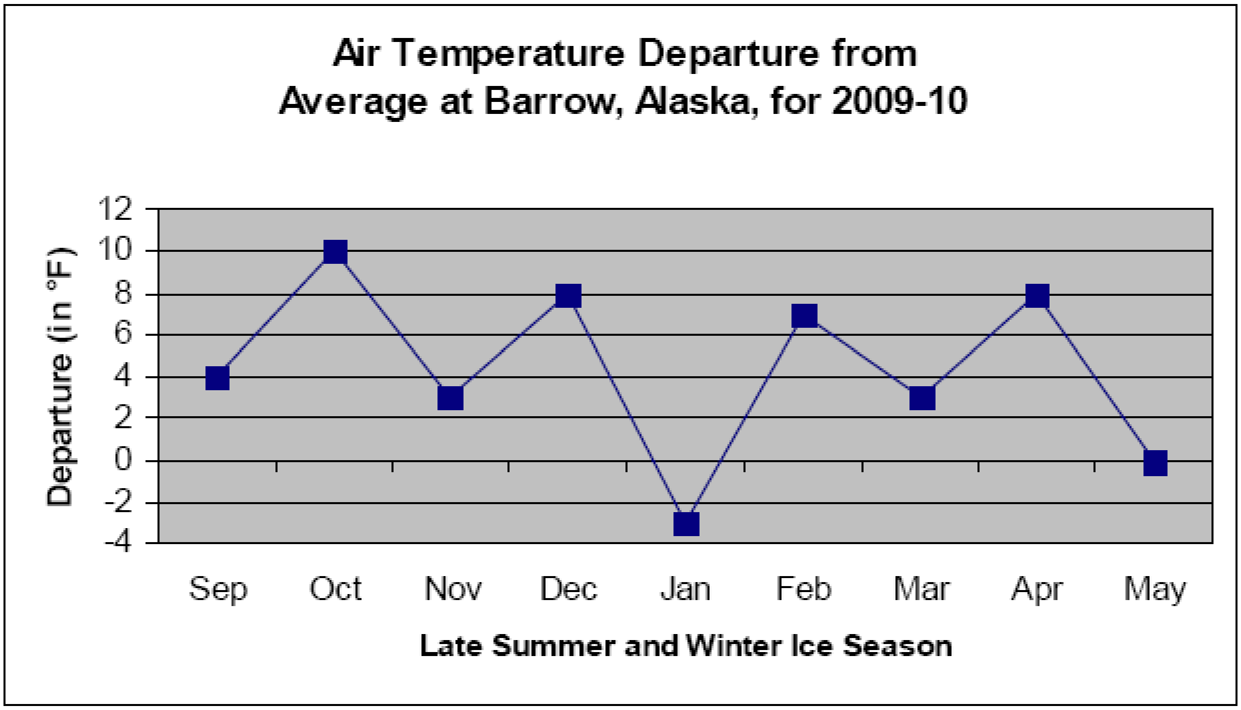


Figure 26: Monthly Air Temperature Deviation from Average at Barrow for Period from September 2009 to May 2010 (Coastal Frontier Cooperation and Vaudrey & Associates, 2010)

The increment of temperature causes the thinning of the first-year ice. Based on the air temperature study (Coastal Frontier Cooperation and Vaudrey & Associates, 2010) the first year ice thickness during an average winter from 1990 has decreased by 8% to 10% relative to that attained in the early to mid-1980's.

1.6.2 Ice Break-up & Freeze-up

Ice break-up in the near-shore waters of the Beaufort Sea normally begins in the mid June to early July period, with near total ice clearance typically seen in water depths to about 20m by late July. Diminishing ice concentrations and floe sizes are typical as break-up proceeds. The patterns of ice break-up and clearing change from year-to-year. The break up period is characterized by a high degree of annual variability with a period of three to six weeks where dynamically changing ice concentrations mark the transition from winter to summer.

The break-up process starts with a general declining of the ice cover, together with melting of its surface. This is caused by rising air temperatures and long daylight hours. Melting is first seen close to shoreline. The channels of the Mackenzie River thaw earlier, in late May–early June. This thawing increases the average water discharge from about 150,000 to 250,000 m^3/s. Such melting is further enhanced by run-off from the Mackenzie River in many areas. At the same time, the pack ice (ice formed by freezing of seawater that is not landfast) in the transition zone to the north of the landfast ice (sea ice that has frozen along coasts along the shoals, or to the sea floor over shallow parts of the continental shelf, and extends out from land into sea) begins to move offshore. Large sections of the landfast ice cover tend to fracture and then drift northwards during this period. The shallow southern portions of Beaufort Sea are normally clear of ice by late July, and the more northerly intermediate water depth areas is clear of ice over the early August period. Based on the ice database for Sivulliq 1997-2006, the ice concentrations have an average value of 3/10 by August 7th (Dickins and Allen, 2007). Generally, in order for non-ice class tugs to operate, the ice concentration should be below 4/10.

At Shell's central Beaufort Sea drilling locations, the ocean is normally open, with ice concentration less than 1/10, from August 20 to October 10. The open water area reaches its maximum at the 2nd part of September (Dickins and Allen, 2007). The durations of the open season do vary though. In the summer of 2006, the drilling locations were invaded by pack ice until September 18, so the open water season lasted only about 3 weeks. During the open-water period, the area was subject to frequent pack ice incursions. Ice incursions happened in three of the past 10 years and lasted from one to three weeks. Easterly winds tend to move the pack away from shore, resulting in extensive clearing along the coast, while westerly winds tend to drive the pack ice to shore.

Mahoney et al. (2007) calculated a mean climatology of the annual ice cycle in northern Alaska and northwestern Canada using Radarsat Synthetic Aperture Radar imagery for the period 1996–2004. Thawing degree days and the onset of thawing were defined similarly for days with temperatures above 0°C. Thawing degree days are a useful index of ice decay.

The timings of breakup and ice-free coasts in spring are found closely correlated with temperature and atmospheric circulation. It can be seen in Figure 27 that despite large interannual variability, there are strong trends toward a later onset of freezing and warmer winters. There are also weaker trends toward earlier onsets of thawing and warmer summers. The onset of thawing temperatures occurred normally 3 weeks prior to break up and 1 month prior to ice-free coasts.

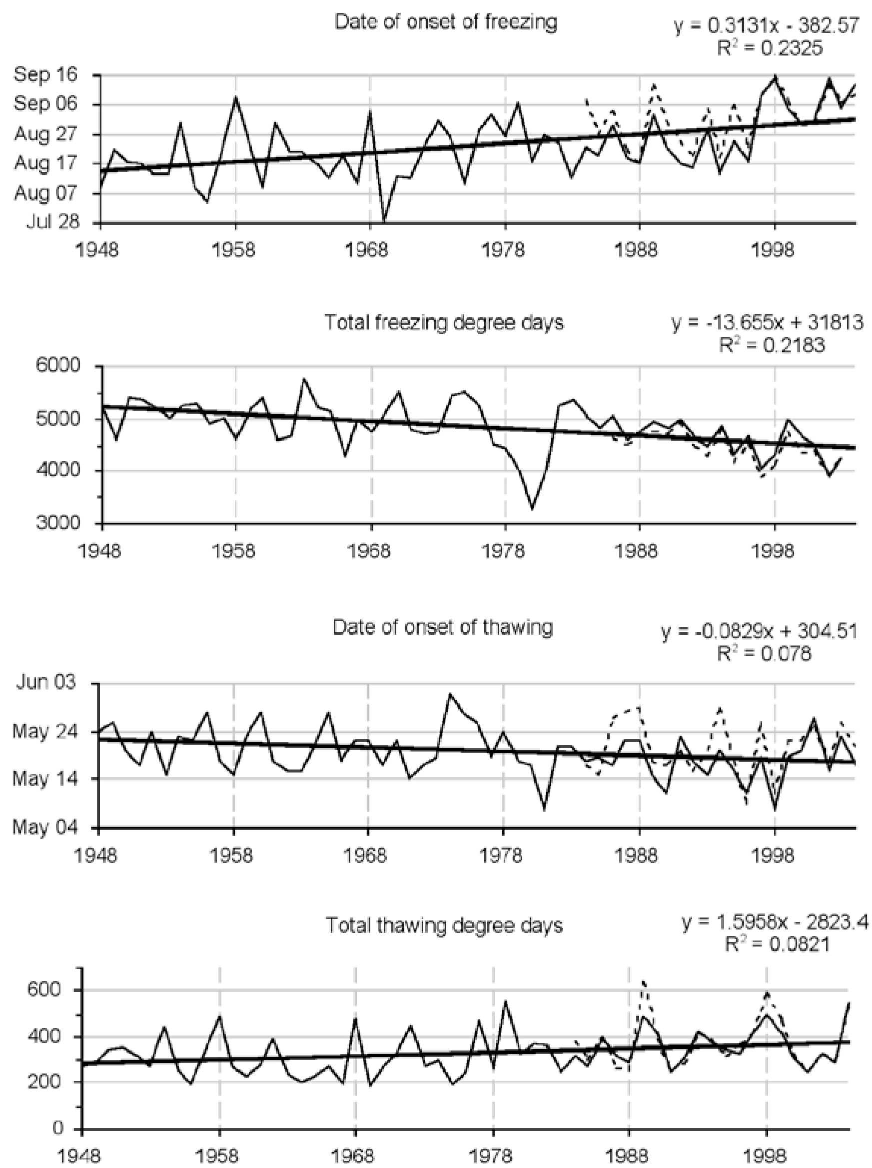


Figure 27: Dates of onset of freezing and thawing and total freezing and thawing days. The solid curve is based on National Centers for Environmental Prediction data, while the dashed line is from Barrow Wiley Post Airport weather station data for the period 1984–2004. The linear trends are also shown.

The first detected movement of landfast ice shoreward of grounded ridges within the 20 m-isobath off NARL, approximately 5 miles north of Barrow, is recorded as break-up by the Sea Ice Group at University of Alaska. The ice movement is detected from coastal RADAR and from Satellite imagery. In typical years, the timing of break-up is associated with the amount of incoming solar energy. The Sea Ice Group has been tracking and forecasting breakup of this ice for the past decade. According to their records, the earliest breakup occurred in 2004 on June 16. Ice breakup occurred at NARL on July 11, 2009, while ice broke out a week earlier in 2010 than 2009 (Ref. [31]).

The average drift rate measured for Beaufort Sea pack ice during the 2009-10 freeze-up season (ice concentration 8/10 or more) is comparable to the values obtained in the 1980's, suggesting that the drift rate has remained unchanged (Coastal Frontier Cooperation and Vaudrey & Associates, 2010). This finding is not in line with of Walsh and Eicken (2007), who suggested that thinner sea ice in the winter may lead to increased ice movement.

Stroeve and colleagues (2006) used passive microwave imagery to assess the changes in Arctic sea ice melt season duration, start date, and end date. They compared data from the period from 1979–1988 with data from 1989–2001. Results of this work show a clear shift in the melt season duration, resulting from both earlier onset of melt and later freeze-up dates toward the end of the study period as shown in Table 1.

Region	Melt onset trend	Freeze-up trend	Duration of melt-season trend
Beaufort Sea	-4.7	4.9	9.2
Chukchi/East Siberian	-4.6	6.9	11.8

Table 1: Regional trends in the dates of melt onset and freeze-up and in the length of the melt season. The units for the trends are days per decade.

Since the 1980's, the onset of freeze-up has slipped by two to three weeks in the Alaska Beaufort Sea and one month in the Chukchi Sea. Freeze-up in the nearshore region currently tends to occur during the third week in October in the Beaufort Sea, and during the first week in November in the northern Chukchi Sea (Coastal Frontier Cooperation and Vaudrey & Associates, 2010).

1.6.3 Sea Ice Extent

Satellite data reveal unusually low Arctic sea ice coverage during the summer of 2007, caused in part by anomalously high temperatures and southerly winds. The extent and area of the ice cover reached minima on 14 September 2007. Acceleration in the decline is evident as the extent and area trends of the entire ice cover (seasonal and perennial ice) have shifted from about -2.2 and -3.0% per decade in 1979-1996 to about -10.1 and -10.7% per decade in the last 10 years (Comiso et al., 2008).

Sea ice extent averaged over October 2010 was the third lowest over the satellite data record at 7.69 million square kilometers (2.97 million square miles). This was 1.60 million square kilometers (618,000 square miles) below the 1979 to 2000 average for October, but 920,000 square kilometers (355,000 square miles) above the record low for the month, which occurred in October 2007 (Ref. [49]).

The drilling exploratory platforms need to be towed out of the Arctic during periods of low ice concentration, navigating towards openings in the ice and away from multiyear ice that has accumulated over several years. Figure 28 shows the sea ice concentration trends in October, 2010.

There was about a 10% decrease of ice concentration in Beaufort region in October. Hence the evidence of the shrinking of the Arctic ice is emerging in both sea ice concentration and sea ice extent.

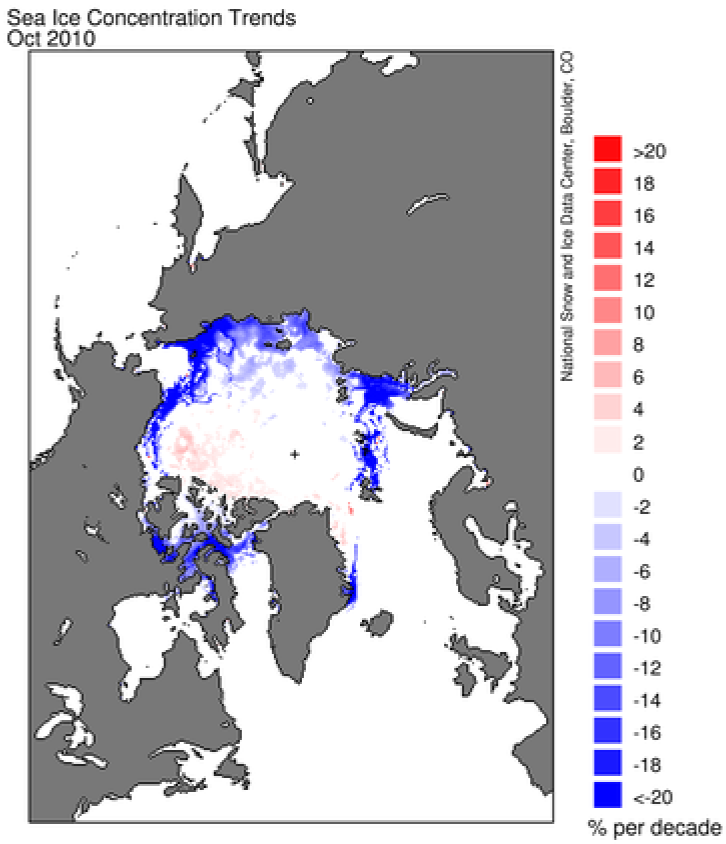


Figure 28: Extent images show the total area of ocean covered with at least 15 percent ice. Concentration images show varying degrees of ice coverage, from 15 to 100 percent. Concentration trend and anomaly images highlight decadal variances. (National Snow and Ice Data Center, Boulder, Colorado).

In 2008, the sea ice extent was slightly bigger than 2007, but still dramatically low. The 2009 data shows that the sea ice extent is bigger than the two previous years. The 2010 sea ice extent is at the same level as 2008. However, this does not mean that the Arctic sea ice is recovering, rather the opposite. As plotted in Figure 29, monthly October ice extent shows a decline of 6.2% per decade, while monthly November ice extent shows a decline of 4.7% per decade.

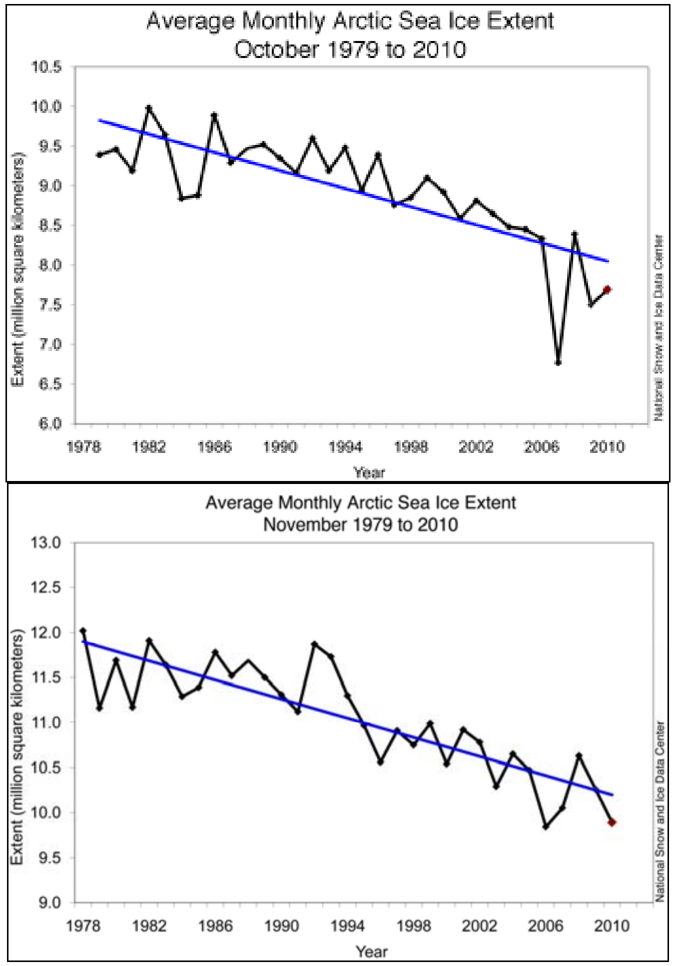


Figure 29: Monthly October ice extent for 1979 to 2010 (top). Monthly November ice extent for 1979 to 2010 (bottom). (Source: National Snow and Ice Data Center, Boulder, Colorado).

In Chukchi Sea, the August ice extent in the Arctic marginal seas declined from 1900 to 2000 at a rate of 2.7% per decade (Polyakov et. al. 2003), as shown in Figure 30.

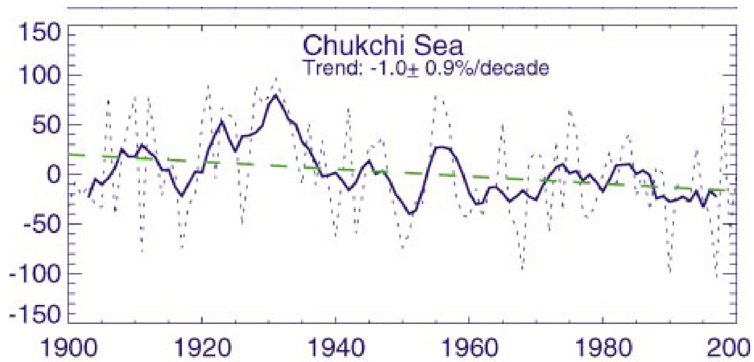


Figure 30: Time series of the Aug ice-extent anomalies (unit: 1000 km^2) in the Chukchi Sea. Dotted lines show yearly Aug values, solid lines show 6-yr running means, green dashed lines show linear trends (quoted limits represent 95% confidence levels, (Polyakov et. al. 2003).

Although the ice area remains stable in Beaufort Sea, the ice structure has changed recently. The new ice is thinner and much weaker structurally. There is also a loss of thick multiyear ice in Beaufort Sea during summer.

2. TASK2: STUDY OF ABILITIES AND LIMITATIONS OF EQUIPMENT USED TO TRANSPORT PLATFORMS

2.1 General

In order to determine the abilities and limitations of transporting platforms into the Arctic area (Chukchi and Beaufort Seas), it is necessary to define the class of drilling units that will suit the characteristics of the Arctic conditions in the intended operating windows and the capabilities of the existing transportation equipment available.

The window of operation is dictated by the Arctic ice-free condition season, and in order to maximize the utilization of these units, the following factors will affect the decision making process to achieve an efficient and cost effective approach.

- Types of Drilling Units suitable for Operations in the Chukchi and Beaufort Sea
- Unit Geographical Location
- Suitable Dry Transportation Equipment
- Mobilization and Preparation Time
- Base of Operations
- Float-on/ Float-off Procedures
- Wet Transportation
- Transportation Operations
- Ice Management

2.2 Objective

The objective of Task 2 of the Arctic Offshore Technology Assessment is to study the abilities and limitations of the equipment used to transport platforms. The platforms will be initially operating in the Chukchi and Beaufort Sea exploration leasing areas. For this objective it is crucial to establish the kinds of units intended to operate in this area.

2.3 Class vs. Marine Warranty-Definition and Concept

In the marine industry, there are three primary groups into which the criteria, which define the acceptability of a vessel or other complex system, can be placed. These are classification society rules, regulatory requirements, and shipowner requirements [74].

Marine Warranty provides independent 3rd party review of the planning, design and execution of high value/high risk marine construction and transportation on behalf of underwriters and their assured.

2.3.1 Classification and Regulatory Requirements

Classification Societies: Classification societies are organizations which develop and apply technical standards to the design, construction, and assessment of ships (and other marine facilities) and carry out survey work on ships. Flag states can authorize classification societies for the inspection and statutory certification of their ships.

Statutory Rules: Statutory Rules are a compendium of international conventions dealing with safety at sea and environment protection. Over the years, International Maritime Organization (IMO) has promoted the adoption of some 30 conventions-such as SOLAS, Load Line and MARPOL-and protocols and additionally well over 500 codes and recommendations.

The conventions and codes usually implement inspection requirements and the issuance of certificates as a mean of enforcement.

SOLAS convention's main objective is to specify minimum standards for the construction, equipment and operation of ships.

MARPOL convention is the main international convention covering prevention of pollution to the marine environment by ships from operational or accidental causes.

International Convention of Load Lines regulates the freeboard, which should ensure adequate stability and avoid excessive stress on the ship's hull as a result of overloading.

Technical rules: Adequate construction and maintenance of a ship, including its essential machinery and electrical installation are safeguarded throughout the world by the classification society through their involvement during construction, and subsequently during ship's service life. All flag states therefore accept the class certificates issued by a classification society recognized by them to be a sufficient basis for the issuance of the statutory certificate called Cargo Ship Safety Construction Certificate required internationally by the SOLAS Conventions.

Finally, there is a large body of requirements, which do not necessarily fall into classification and regulation categories but is of paramount interest to the shipowner. These include characteristics, which affect the mission performance or economic viability of the asset such as speed, cargo throughput, crew habitability as well as many others. These can be grouped as shipowner requirements and are usually conveyed as specific requirements in the contract. Usually shipowners rely upon classification society rules and governmental statutory requirements to form the core of the criteria, which will define their vessel and add to those the shipowner requirements, which will shape the vessel to its specific mission.

2.3.2 Marine Warranty Overview

A Marine Warranty company is a multidisciplinary team of engineers and marine expertise that provides services including:

- Pre- Risk analysis
- Naval Architecture and Structural Analysis
- Engineering Verification review
- Marine Operations technical support
- Participates in HAZID s and mitigations studies
- Vessel inspections and audits

- Marine operations oversight and approval
- Damage Claim assessment

During the construction phases of offshore projects, a Construction All Risks (CAR) insurance policy will be taken out by the Owner, Operator or their Contractor to cover against losses during construction, installation and commissioning activities. In most cases the terms of this insurance policy will include a “Marine Warranty Clause” within which the underwriter who is placing the insurance will require that an Independent Marine Warranty Surveyor (MWS) be appointed for the project top act as marine experts on their behalf. It is the responsibility of the “Assured” (the insured party) to engage the MWS provider either through existing agreement or via commercial Tender. However, the Warranty Surveyor chosen must be acceptable to the insurer and in many cases only a few specialized Warranty Companies will be listed in the policy as acceptable for the performance of the work.

The role of the Marine Warranty Surveyor is to act on behalf of the Insurer and the Assured to ensure that specific project operations are performed to recognized codes & standards and within acceptable risk levels. These risk levels being tolerable to the insurance interests, to the industry as well as to national and international regulatory bodies where appropriate.

The scope of the approval activities to be performed by the MWS will be agreed between the Assured and the Underwriter based on the proposed project activities and the associated risk levels for these activities. If MWS approval is not provided prior to the commencement of a scope defined operation, then the Assured can be called in breach of their Warranty and this will allow the Insurer to avoid the policy in the event of an incident.

2.4 Chukchi and Beaufort Sea

The Chukchi Sea is a part of the Arctic Ocean, bounded by Wrangel Island (west), northeastern Siberia and northwestern Alaska (south), the Beaufort Sea (east) and the Arctic Continental Slope (north). It has an area of 225,000 square miles (582,000 sq km) and an average depth of 253 feet (77 m). The Chukchi Sea is navigable between July and October both eastward and westward from the shallow Bering Strait (south).

The Chukchi Sea is fed from the south by the Pacific water through-flow through the Bering Strait from the Bering Sea. Patterns of ice melts suggest the mean flow (which is northwards in the annual mean) is split into four main outflows. One through Barrow Canyon in the east, one through Central Gap in the Central Chukchi Sea, one through Herald Canyon just east of Wrangel Island, and one through the long strait between Wrangel Island and the mainland of Russia.

The Beaufort Sea is an outlying sea of the Arctic Ocean, situated north of Canada and Alaska. It extends northeastward from Point Barrow, Alaska, towards Lands End on Prince Patrick Island, and westward from Bank Island to the Chukchi Sea. Its surface area is about 184,000 square miles (476,000 sq km). The average water depth is 3,239 feet (1,004 m), and the deepest spot is 15,360 feet deep. It was named for the British Rear Admiral Sir Francis Beaufort.

The continental shelf is narrow, especially close to and east of Point Barrow; it widens somewhat north of the Mackenzie River mouth, but nowhere will it exceed 90 miles (145 km). The usual depth is less than 210 feet, although the slope descends steeply from 5,000 to 6,500 feet in the seas upper part. Small gravel islands or shallows are often found. The largest islands are west of Mackenzie River mouth – Herschel (7 sq miles) and Barter (5 sq miles). Very small islands and banks are found in the Mackenzie River Delta.

The Beaufort Sea is under ice almost year round. Only in the period from August to October does the ice break up, and then only near the coasts. The largest settlement on the Beaufort Sea is Prudhoe Bay, Alaska, which is the center of petroleum production on the coastal low land of the North Slope.

2.5 Types of Drilling Units

2.5.1 Jack-ups

The jack-up rig is a type of mobile offshore drilling platform that is able to stand still on the sea floor, resting on a number of supporting legs. The most proved design is the three independent legs. There are other designs of jack-ups with four or more legs, and a “mat-type” design in which the legs are connected to a submerged hull. The three independent legs will be the preferable type to be utilized in the Arctic Ocean waters.

A jack-up is a floating barge with long supporting legs that can be raised and lowered. The jack-up is generally towed onto location with its legs up and the barge section floating in the water. Upon arrival to the location the legs are jacked down onto the sea floor. Then the “preloading” operation takes place where the weight of the barge and additional ballast water are used to drive the legs securely into the sea bottom so they will not penetrate further while operations are carried out. After preloading is completed, the jacking system is used to raise the entire barge and drilling structure above the water to a predetermined height or “air gap”, so that wave, tidal and current loadings act only on the leg structures and not on the barge hull. Jack-ups can only be placed in relatively shallow water, generally less than 400 feet, which makes them a possible option for the North Slope exploration. These units are suitable for oil or natural gas drilling and there are more jack-up rigs in the worldwide offshore fleet than any other type of mobile offshore drilling rigs (References [12] and [41]).

In order to mobilize these units from distant locations, a suitable Heavy Lift Vessel (HLV) needs to transport them to the nearest port or offload location. The mobilization to the final drilling location needs to be completed with towing vessels.

The disadvantage of these types of units is their mobilization time, because it can take an extended time to move a unit from its current location to the Alaska region. In addition, their legs are a sensitive area that could be exposed to the occasional loose ice packs.

Figure 31: Jack-up Rigs

Jack-up drilling rigs are designed for shallow water operations. The minimum depth in which they can operate is determined by each individual jack-up's model design. In general, they are able to operate from 30 feet of water depth and up. In order to approve an operation in shallow water, the rig characteristics will need to be analyzed and minimum operational water depth established individually.

2.5.2 Drillships

A drillship is a maritime vessel that has been fitted with drilling equipment. It is often used for exploratory offshore drilling of new oil or gas wells, ranging from medium to deep water. The drillship is often built to the design specifications of an oil production company or investors, but can also be a modified tanker hull outfitted with a dynamic positioning system.

The greatest advantage of these modern drillships is their ability to drill in water depths of more than 2,500 meters, and the time needed to sail between oilfields worldwide. The proven safe operating mode for these units is to moor them to the seabed of the shallow Arctic waters. Dynamic Position reference systems have not been fully tested in high latitudes, and this may result in serious position instability. In addition, the footprint for shallow water operations requires very tight drilling positioning to maintain riser angle within the allowable limits.

Figure 32: Conventionally moored Drillships

Figure 33: Ice Strengthened Special Purpose Drillship

2.5.3 Drilling Semi-submersibles

A Semi-submersible is a specialized marine vessel with good stability and good sea-keeping characteristics. The Semi-submersible vessel design is commonly used in a number of specific offshore roles such as offshore drilling rigs, safety vessels, production platforms, and heavy lift cranes. Offshore drilling rigs are generally designed to operate in water depths greater than 120m. This makes them highly unlikely to be used in the exploration of the Chukchi Sea and the shallow area of the Beaufort Sea. Semi-submersibles can be moved from place to place under tow, although currently there are a number of self propelled units fitted with Dynamic Positioning Systems. A majority of semis are moored to the seabed using a combination of chain, wire rope or even polyester ropes.

Figure 34: Drilling Semi-submersible

2.5.4 Ice Strengthened Drilling Barges

There are some drilling barges purpose-built for ice conditions. Arctic drilling unit Kulluk incorporates a 24-faceted conical hull which is ice strengthened to meet the American Bureau of Shipping lAA Requirements and the Canadian Arctic Shipping Pollution Prevention Act (Arctic Class IV classification). The double hull barge Kulluk has an outer diameter of 81 meters at the main deck and is in the form of an inverted cone which causes the ice to break downwards and away from the vessel protecting the drilling riser and the mooring system. The unit needs to be towed onto location and moored by 12 radially deployed anchor lines. It is designed to operate in shallow waters of from 24m to 55m. This particular unit is fitted to operate year around in the Arctic environment.

Figure 35: Ice-breaking drilling Barge-Kulluk

2.5.5 Rigs Operational Perspective

The drilling units reviewed above could all be suitable for exploration within their capabilities and capacities. However, since it is highly unlikely for a semi-submersible unit to operate in the Arctic area due to water depth limitations, we will be focusing only on evaluating the requirements of transporting the jack-up units and drillship units to the Arctic region in this study.

2.6 Drilling Units Geographical Locations

The current rig utilization for the most prominent areas of the world for offshore drilling is shown in the Figure 36 below. It also provides the rig utilization by rig type. The statistics were provided by Rigzone, dated April 29, 2011.

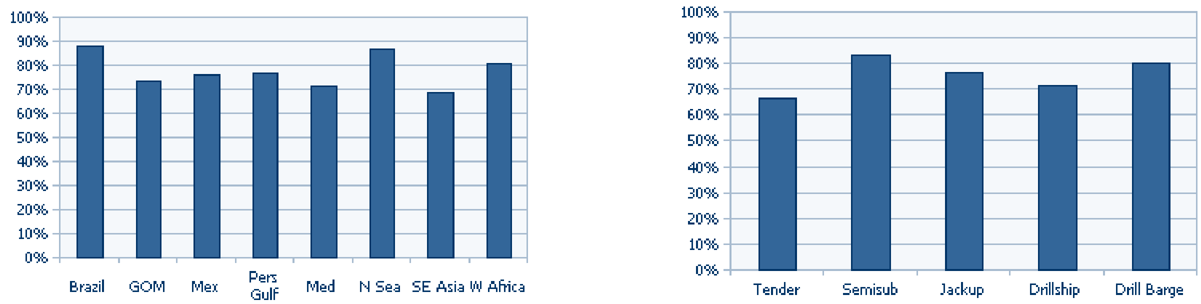


Figure 36: Offshore Drilling Rig Utilization by Region (left) and Rig Type (right)

Mobilization of units for drilling exploration on the North Slope could then be planned with different departing scenarios. Gulf of Mexico, Brazil, SE Asia, and North Sea seem to be the preferred areas from which these drilling units could be mobilized. The US GoM has one important consideration related to the transportation, which is that the mobilized unit will need to comply with the Jones Act since the departure and arrival locations are within the US territories. Waivers for this requirement will be needed for non-US flagged transporters.

Due to the characteristics of the transportation, the selected tow route should be carefully planned. It is noted that due to the size of the units to be transported or mobilized, the Panama Canal is not a transit option and alternative routes through Cape Horn/Magellan Strait or Cape of Good Hope coming from the US GoM to Alaska are to be considered for the transit.

Table 2 shows the approximate days to reach Alaska from the rig concentration area, and the estimated time for float-on operation and fuel stop. They are estimated based on the information included in [48].

	Dutch Harbor	Float-on Operation	Fuel Stop	Total
GoM	53 days	7 days	2 days	62 days
North Sea	53 days	7 days	2 days	62 days
Brazil	25 days	7 days	None	32 days
SE Asia	22 days	7 days	None	29 days

Table 2: Approximate days to reach Alaska (Conservative Speed of 12 Knots)

2.7 Dry Transportation

2.7.1 General

Towing floating objects over the oceans has always been a risky business. Many accidents, ranging from minor damages to total losses, have been recorded in history. Often the cause is identified as being a failure of the towing connection. Realizing the risks, the heavy lift market introduced the semi-submersible barge with auxiliary propulsion.

Conventional barges need to be grounded during submerging, so the ground site is an item for special consideration. Over the years heavy lift and semisubmersible, ocean going Heavy Deck Cargo Barges were improved the installation of buoyancy casings at the four corners. These casings on the deck made the free float submerging method possible. As a result, the water depth for submerging is not limited to provide bottom resistance during submerging.

In 1979, the first self propelled semi-submersible heavy lift vessel, the HLV "Super Servant", was introduced by Weijsmuller. The first jack-up rig dry-transported weighed 5,500 tons and had a leg length of 85 m. Since then, jack-up rigs of 21,500 tons and 167 m legs have been transported. A variety of cargoes ranging from TLP (Tension Leg Platforms), Semi-submersible drilling rigs, Spar hulls, and fully Erected Container Cranes, etc. have been transported around the world.

The demand for heavy lift dry transport has been increasing recently. Since there are a relatively small amount of vessels available, booking ahead of time is imperative. Some companies have ordered new vessels with lift capacity above 70,000 tons. Nevertheless, many of them don't have ice-class classification, and are normally only operated below the Arctic Circle. Standard hull insurance coverage is maintained and a special risk policy needs to be acquired if there is an intention to operate in this area during the ice-free season.

It is interesting to mention that 100% of the semi-submersible heavy lift fleet are flagged and owned by non-American companies. This means that none of the vessels currently operating are allowed to trade between USA ports (Jones Act). In case there is a need to transport a rig from the US Gulf of Mexico to Alaska on the heavy lift vessel, a special waiver must be obtained.

2.7.2 Rig Principal Dimensions

As a reference, the main dimensions of the jack-up rig listed in the table below are based on a Keppel FELS Mod BV design capable of operating in waters of up to 350 feet and equipped with offline handling features and accommodations for up to 150 people. This kind of rig is designed for harsh environments of the North Sea & Arctic Ocean.

Characteristics are as follows:

Dimension	Feet	Meter
Hull Length (between perpendiculars)	225.0	68.6
Length including heliport	312.0	95.1
Hull Width	208.0	63.4
Hull Depth (@side)	25.0	7.62
Longitudinal Leg Spacing	129.0	39.30
Transverse Leg Spacing	142.0	43.28
Overall Leg Length	517.0	157.6
Spudcan Height	19.0	5.8

Table 3: Main Rig Parameters

Hull, legs and variable load are given in the table below:

Item	**Kips**	**Tonnes**
Hull Lightship	16,470	7,476
Leg Dry Weight (including spud-can weight)	7,380	3,350
Afloat Variable Load	7,500	3,404
Total	31,350	14,230

Table 4: Rig Weights

2.7.3 Heavy Lift Market

The Heavy Lift Market is relatively small for capabilities beyond 10,000 tons. Some of the HLV units are non self-propelled and would require tug assistance during the voyage. The non self-propelled and propelled units have been successfully used in the past in transportation of platforms between US GoM and the Arabian Gulf.

There are Dry Transporters with deck space in their fore and aft direction that exceeds the jack-up hull length of 95.1 m (including the Heliport). The hull width is 63.4 m, which exceeds the transverse deck space for all vessels, so some overhanging of the hull will occur, but it is not unusual for this kind of transportation.

As a requirement for transporting the Mod BV jack-up, the HLV is expected to have a lifting capacity of at least 15,000 tons, thus exceeding the rig weight of 14,230 tons. It is worth mentioning that this study is done using jack-up with 517 feet of leg as a reference. This unit will be suitable to operate in the water depths of the Chukchi Sea and in the shallow area of the Beaufort Sea. If an operator intends to use a different jack-up Class, he should review the heavy lift transporter's capacity table and consult the transportation company for further information.

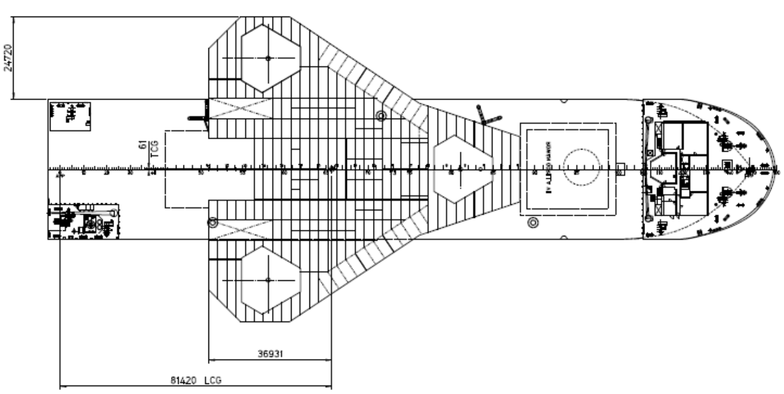


Figure 37: Standard Arrangement of the Rig on the Transport Vessel

There is capability on some of the vessels to transport two such rigs simultaneously. It has been done in the past; furthermore, some of the jack-up operators transported three of their 116C class rigs on board of one of the transporters on a trip from the US GoM to the Arabian Gulf.

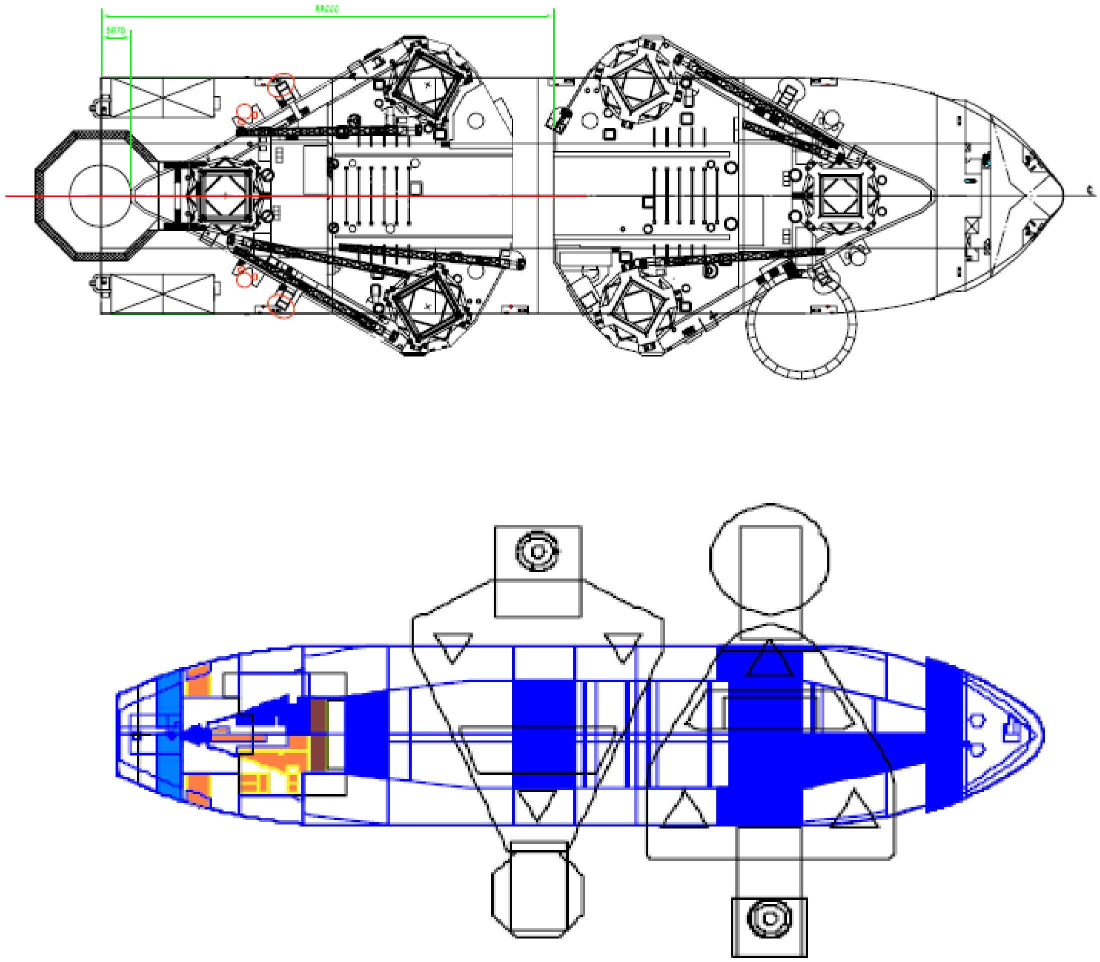


Figure 38: Arrangements for Two Rigs on the Transport Vessel

For dry transports, the spud cans should be empty and vented. Safety notices should be posted at each spudcan and at the control panel.

2.7.4 Heavy Lift Operators

The heavy lift operators covered in this study are Dockwise, Offshore Heavy Transport, Cosco-NMA, Viatech, Fairmount Marine, SZSC (Shanghai Zhenhua Shipping Co.), ALP (Marine Services BV) and BOA Group.

The above-mentioned companies operate dry transport vessels with sufficient deck space and vessel lifting capacity to accommodate rigs within and above the rig parameters used for the study. None of them have ice strengthened vessels; therefore, these vessels are restricted to operate in ice-free conditions. A total of 28 self propelled units and 7 barges have been identified and their characteristics are described in Table 5-Table 11.

Dockwise Ltd is the largest heavy lift provider with 20 semi-submersible heavy transport vessels of different designs. It was created in 1993 as a joint venture between Wijsmuller Transport and Dock Express Shipping. It has carried an ISM code certification by the Netherlands Shipping Inspectorate since 1997. Their transportation capabilities range from small yachts up to fully integrated production and drilling units weighting up to 73,000 tons. Their head office is in the Netherlands with worldwide offices and representatives.

Figure 39: M/V Black Marlin (3 Jack-up Loads, left). M/V Transhelf (Single Jack-up Load, right).

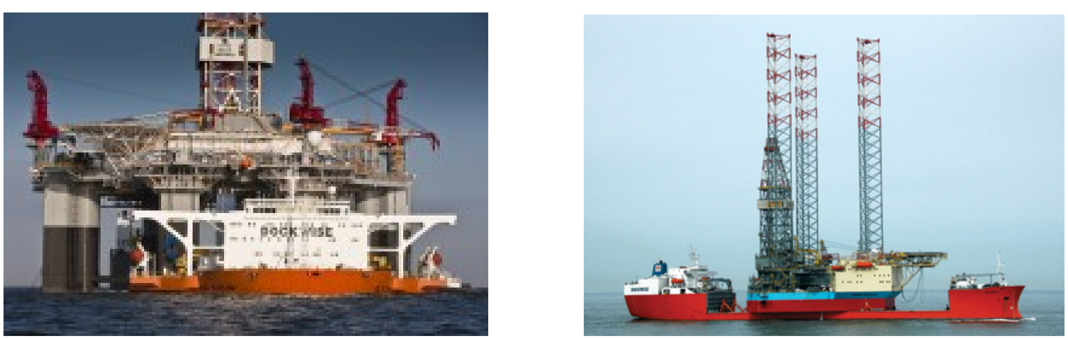


Figure 40: MV Blue Marlin (Semi-Sub Drilling Rig) to the left. M/V Triumph (Single Jack-up Load) to the right.

Offshore Heavy Transport AS (OHT) is a Norwegian Oil Service company owning vessels suitable for dry transportation of offshore drilling rigs and offshore modules. OHT is the second largest heavy lift owner and presently owns and operates 4 semi-submersible heavy lift vessels.

Figure 41: M/V Hawk (Single Jack-up Load) to the left. M/V Osprey (Drilling Semi-sub) to the right.

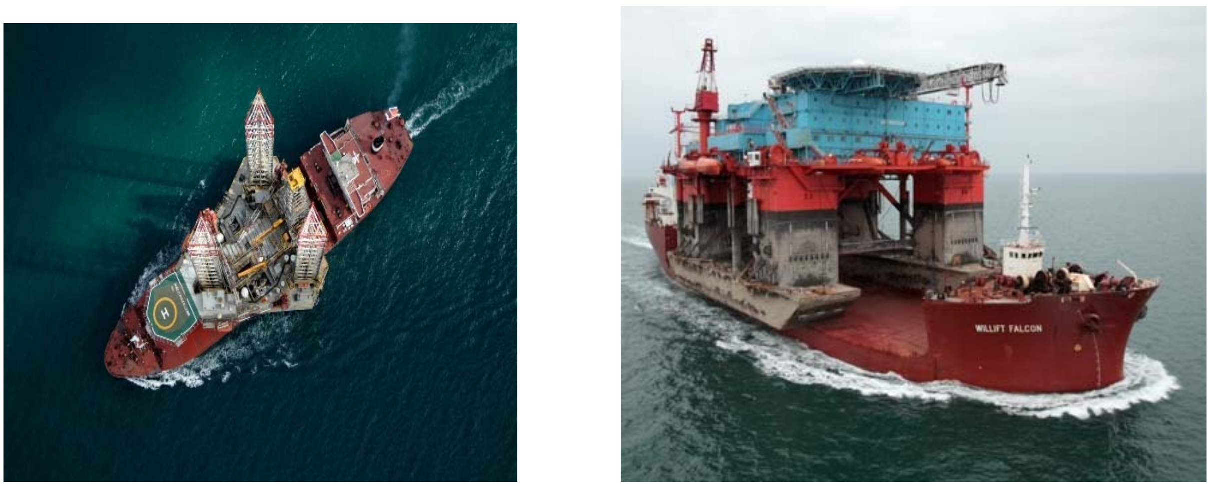


Figure 42: M/V Eagle (Single Jack-up Load) to the left. M/V Falcon (Accommodation Semi-submersible) to the right.

COSCO-NMA- China Ocean Shipping Company and it subsidiary COSCOL China Ocean Shipping Company Limited owns two heavy lift vessels and two new built vessels expected to be delivered during 2011. NMA Maritime and Offshore Contractors provide the exclusive commercial management for the semi-submersibles vessels.

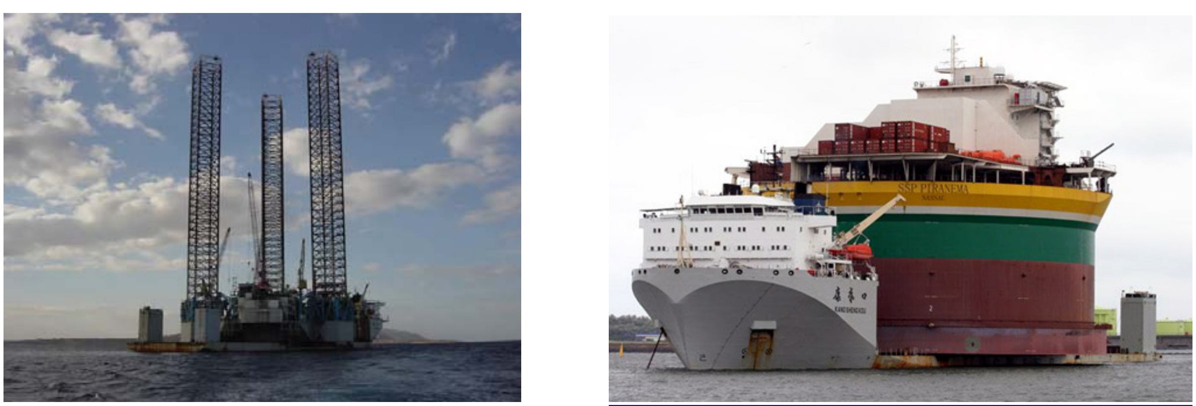


Figure 43: M/V Tai An Kou (Single Jack-up) to the left. M/V Kang Sheng Kuo (Cilindrical FPSO) to the right.

Viatech Engineering Ltd. of Hong Kong and one of its subsidiaries, Viatech of Canada Ltd. were established in 1987. They are specialists in shipbuilding and modification works, and own and operate a Heavy Lift Semi-Submersible vessel. This vessel is able to carry platforms and rigs and has a maximum lift capacity of 45,000 tons.

Figure 44: M/V Asian Atlas with a Jack-up Load (left) and a floating crane load (right)

SZSC-ALP Marine Services: Shanghai Zhenhua Shipping Co. Ltd. is a Shanghai based company that owns and operates a heavy lift semi-submersible fleet dedicated mainly to the transport of port machinery and cranes around the world. They recently opened their services to potential clients in the oil and gas market with commercial management of APL Marine Services B.V.

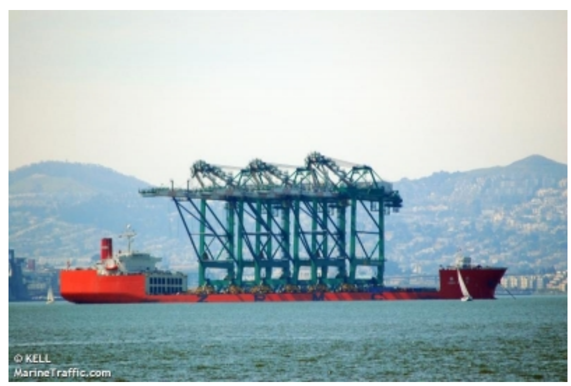


Figure 45: M/V Zhen Hua 28 (left). M/V Zen Hua 22 (right)

Fairmount Marine was established in 1980 and has developed into a world class contractor for ocean towage and heavy lift transportation by semi-submersible barge. In May of 2007, the company became a subsidiary of Louis Dreyfus Armateurs SAS of Paris, which operates the largest semi-submersible barge, the Gavea Lifter (50,000 dwt), and 2 other units.


Figure 46: Barge Gavea Lifter (Two Jack-up Load to the left). Barge Gavea Lifter (Semi-Sub Drill Rig to the right)

BOA Group- BOA Marine Services (BMS) is a contracting unit of the Norwegian group Boa Offshore based in Houston since 2009. BOA offshore has been providing services since 1970 first as a tug company, then developing as an offshore diversified service provider. Among those services is Heavy Lift transportation on barges through float-on, float-off methods.

Figure 47: Barge Boa Barge 35 (left). Barge Boa Barge 29 (right)

2.7.5 Particulars of the Heavy Lift Vessels

Name of the Vessel	Class	Free deck Space (m)	Subm. Draft (m)	DWT Tons	GRT	Lifting Capacity (tons)	Service Speed kts
BLUE MARLIN	DNV	178.2x 63.0	28.4	76,410	51,821	>60,000	12
BLACK MARLIN	DNV	157.2 x42.0	23.3	57,021	37,938	>45,000	13
MIGHTY SERVANT 1	LR	150.0x 50.0	24	40,480	29,193	>35,000	14
MIGHTY SERVANT 3	LR	165.0x 40.0	22	27,720	22,391	>35,000	14
TRANSHELF	USSR/LR	132.0x 40.0	22	34,030	26,547	>30,000	14
SWAN	DNV	126.8 x 31.6	20	32,650	22,788	>25,000	14
SWIFT	DNV	126.8x 31.6	20	32,187	22,835	>25,000	14
TERN	DNV	126.8 x 31.6	20	32,650	22,788	>25,000	14
TEAL	DNV	126.8 x 31.6	20	32,187	22,835	>25,000	14
TRANSPORTE R	DNV	129.0 x 44.5	23	54,000	42,500	>35,000	14
TARGET	DNV	128.0 x 44.5	23	53,868	42,500	>35,000	13
TREASURE	DNV	128.0 x 44.5	23	53,868	42,500	>35,000	13
TALISMAN	DNV	128.0 x 44.5	23	53,868	42,500	>35,000	13
TRUSTEE	DNV	128.0 x 44.5	23	53,868	42,500	>35,000	13
TRIUMPH	DNV	128.0 x 44.5	23	53,868	42,500	>35,000	13

Table 5: Heavy Lift Vessels owned by Dockwise Ltd.

Name of the Vessel	Class	Free deck Space (m)	Subm. Draft (m)	DWT Tons	GRT	Lifting Capacity (tons)	Service Speed kts
EAGLE	DNV	114.0 x 42	19.5	31,809	31,000	>30,000	14
FALCON	DNV	114.0 x 42	19.5	31,809	31,000	>30,000	14
HAWK	DNV	157.0 x 44	23	54,000	39,000	>45,000	14
0SPREY	DNV	157.0 x 44	23	54,000	39,000	>45,000	14

Table 6: Heavy Lift Vessels owned by Offshore Heavy Transport AS.

Name of the Vessel	Class	Free deck Space (m)	Subm. Draft (m)	DWT Tons	GRT	Lifting Capacity (tons)	Service Speed kts
TAI AN KOU	CCS/DNV	126.0 x 36	19	20,247	N.A.	>15,000	14
KANG SHENG KUO	CCS/DNV	126.0 x 36	19	20,131	N.A.	>15,000	14
XIAN YUN KUO (in trials)	CCS/DNV	165.0 x 43	26	50,000	N.A.	>45,000	14
XIAN AN KUO (to deliver 1st Q 2011)	CCS/DNV	165.0 x 43	26	50,000	N.A.	>45,000	14

Table 7: Heavy Lift Vessels owned by COSCO Ltd.

Name of the Vessel	Class	Free deck Space (m)	Subm. Draft (m)	DWT Tons	GRT	Lifting Capacity (tons)	Service Speed kts
ASIAN ATLAS	NA	119.8 x 41.2	20.1	52,092	40,000	>45,000	14

Table 8: Heavy Lift Vessel owned by Viatech Engineering

Name of the Vessel	Class	Free deck Space (m)	Subm. Draft (m)	DWT Tons	GRT	Lifting Capacity (tons)	Service Speed kts
ZHEN HUA 29	NA	150 x 42.0	20.5	91,538		>15,000	8.5
ZHEN HUA 28		150 x 42.0	20.5	91,680		>15,000	6.2
ZHEN HUA 22		151 x 32.2	16.5	65,034		>15,000	12.8
ZHEN HUA 15		154 x 42	20.5	95,987		>15,000	9.8

Table 9: Heavy Lift Vessels owned by Shanghai Zhenhua Shipping CO.

2.7.6 Particulars of the Heavy Lift Barges

Name of the Barge	Class	Free deck Space (m)	Subm. Draft (m)	DWT Tons	GRT	Lifting Capacity (tons)	Service Speed kts
GAVEA LIFTER	BV	160.0 x 46	22	50,000	32,521	>35,000	
OCEAN SEAL	NK	141.0 x 36	16.7	24,000	12,709	>15,000	
OCEAN ORC	NK	141.0x 36	16.7	24,000	12,709	>15,000	

Table 10: Heavy Lift Barges owned by Fairmount Marine.

Name of the Barge	Class	Free deck Space (m)	Subm. Draft (m)	DWT Tons	GRT	Lifting Capacity (tons)	Service Speed kts
BOABARGE 29	DNV	124.0 x 31.5	16	17,500	8,762	>15,000	
BOABARGE 30	DNV	124.0 x 31.5	16	17,500	8,762	>15,000	
BOABARGE 35	DNV	124.0 x 31.5	16	17,500	8,762	>15,000	
BOABARGE 36	DNV	124.0 x 31.5	16	17,500	8,762	>15,000	

Table 11: Heavy Lift Barges owned by BOA Group-BOA Marine Services

2.7.7 Design Criteria and Meteorological Data

Stability and strength are the main aspects of a transportation operation that need to be verified. These engineering studies are normally performed:

- Environmental condition of the route. A stability study to show that the stability of the vessel during submerging/emerging shall be positive at all times, and the intact & damage stability of the vessel during the dry transport meet requirements of the IMO or classification society
- Motions and acceleration study. The motion response analysis can be performed in the frequency-domain using hydrodynamic software with a 3-D diffraction/strip theory method for calculation of the hydrodynamic characteristics of the vessel. If motion analysis is not performed, there are some recommended motion criteria that can be followed
- Structural integrity study to show that the cargo can withstand the motions and accelerations for the route
- Seafastening design
- Strength of the Dry Transporter including local and global strength assessment

There are some outlines of design wind and wave calculations in Dockwise Engineering Guidelines and Criteria. The wind and wave are calculated based on the exposure to waves within the worst area in the route, with wave data from Global Wave Statistics (GWS). The route from point of departure to point of destination is entered as waypoints through the Global Wave Statistic areas (shown in Figure 48). Global Wave Statistics provides worldwide coverage of wave climate in 104 sea areas, and an additional database provides a higher spatial resolution for the North European Continental Shelf. Based on 130 years of observations to provide a stable climatic average, the data has been quality enhanced by the well established NMIMET process. It should be noted that GWS does not cover the Nome area, so voyage specific environmental data needs to be purchased from weather services.

If neither a motions study nor model tests are performed, then for standard configurations and subject to satisfactory marine procedures, the following motion criteria may be acceptable as per Noble Denton (Table 12).

Vessel or towed object, type, size and nature of transport	**Full cycle period**	**Single amplitude**		**Heave**
		Roll	**Pitch**	
Large vessels L $\geq$ 140 m LOA **and** B $\geq$ 30 m	10 secs	20°	10°	0.2 g
Medium vessels L $\geq$ 76 m **and** B $\geq$ 23 m (other than large vessels)	10 secs	20°	12.5°	0.2 g

Table 12: Noble Denton Motion Criteria

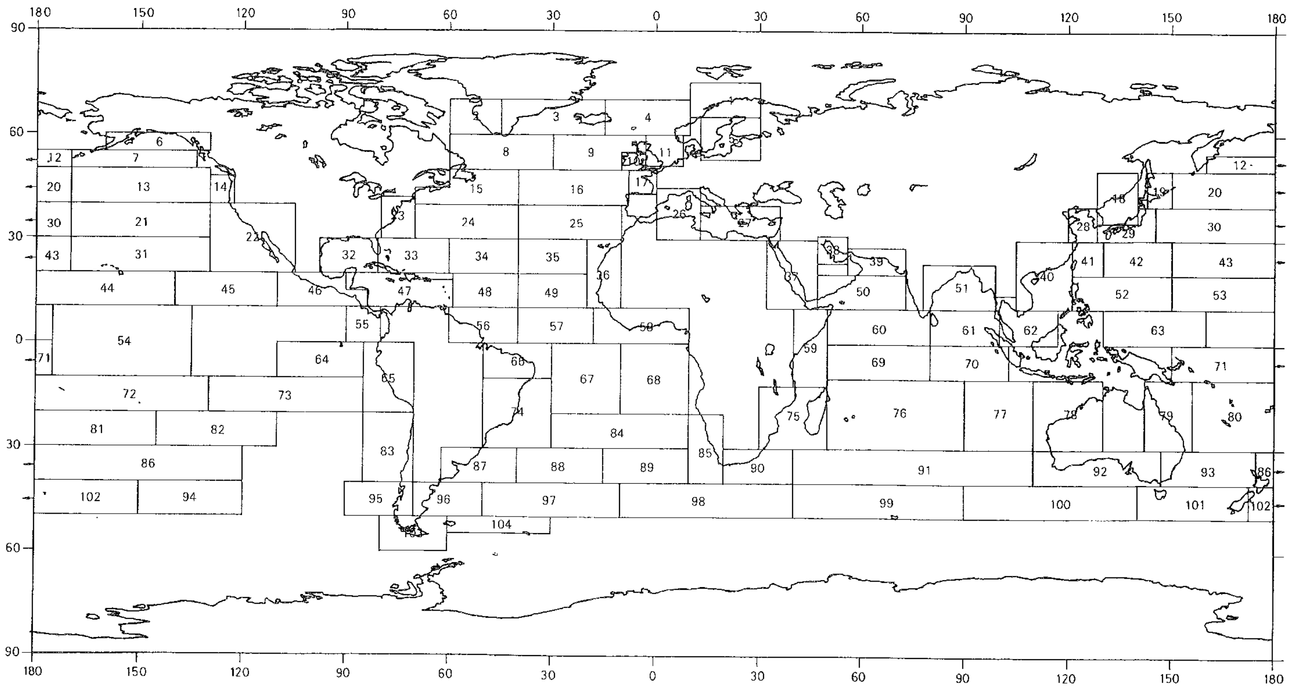


Figure 48: Global Wave Statistics Area

2.8 Base of Operations

2.8.1 Port of Nome

One of the oldest towns in Alaska, Nome was established on the gold-rich sands by the Bering Sea. Gold mining is still one of the industries in Nome along with government services, road constructions/repairs, and carpentry building.

The Port of Nome is located in Latitude 64°30’ N and Longitude 165°24’ W on the southern side of Seward Peninsula in Norton Sound. Since 2004 Nome Port has undergone extensive improvement that includes breakwater extension and building city docks. Construction was completed in 2006 and the city dock can accommodate vessels up to 200 feet in length and draft of 22.5 feet (MLLW). Nome is the regional center of transportation for surrounding villages and there are two state owned airports with daily service to Anchorage.

Figure 49: Port of Nome view (left). Nome location (right)

The general anchorage for deep draft vessels is in the 7/8 fathoms mark about one mile from the beach abreast of Nome. Vessels with higher draft should anchor farther offshore. Under strong southern winds, it is also recommended to anchor further away from the shore line.

The water levels are influenced more by the wind than tide. An offshore wind can sometimes cause a level of 2 to 3 feet below mean lower low water for days. About 2 miles offshore in Nome roadstead the tidal current averages about 1 knot at times of strength. It is chiefly diurnal. The flood sets E, and the ebb NW.

The moderating influence of the open water of Norton Sound is effective from early June to about the middle of November. Temperatures generally remain well below freezing from the middle of November to February and start to rise near the end of February and continue to rise until they reach maximum in July.

Precipitation reaches its maximum towards the end of summer and minimum during April and May, although the annual average precipitation is light at only 15.8 inches. Snow has fallen as early as August but does not accumulate on the ground until early November. It normally reaches its maximum in February/March and decreases rapidly in April and May and normally disappears by the middle of June.

Average wind speeds range around 9 to 19 knots. Severe windstorms occur with winds reaching up to 61 knots recorded several times. The strong winds occur during the winter season.

Navigation is difficult because of ice formation from early December to June and is usually suspended from late December to mid-May.

The Port of Nome outer anchorage could be used for the purpose of float-off and float-on operations in ice-free season. The general conditions of Norton Sound are favorable to carry out these operations. Heavy Lift vessels can be anchored about 4.5 to 5 miles SSW of Port of Nome where water depths are suitable for float on/off operations (between 80 to 90 feet). Tug services have to be arranged ahead of time, and units with large bollard pull capacity are not regularly operating from Port of Nome.

2.8.2 Unalaska, Dutch Harbor

Unalaska, the 11th largest city in Alaska, is a bustling community of about 4,000 residents located along the Aleutian Chain, approximately 800 miles southwest of Anchorage. Dutch Harbor, the official name of the city's port, is often applied to the portion of the City of Unalaska located on Amaknak Island, which is connected by bridge to the rest of the community on Unalaska Island.

This booming community boasts the most productive seafood processing port in the U.S., with five large processing facilities and ships from countries throughout the world. The port has ranked #1 in the nation for seafood delivered in terms of the number of pounds processed and total dollar value.

The Port of Dutch Harbor is located in Latitude 53° 53' 49" N, Longitude 166° 31' 30" W. The Department of Ports and Harbors is responsible for managing, operating, and maintaining the Port of Dutch Harbor’s five city-owned port facilities. The Department also conducts marine search and rescue services. The Department employs six full-time harbor officers and two office staff in addition to the director and the harbormaster.

The city-owned and operated marine facilities in the Port of Dutch Harbor include the United States Coast Guard Dock, the Unalaska Marine Center, the Spit Dock, the Light Cargo Dock, and the Robert Storrs International Small Boat Harbor. The Spit Dock in the Port of Dutch Harbor contains about 731 meters of dock and offers several berths for short- and long-term moorage. The berths can accommodate vessels to 61 meters long, and they offer shore power, fresh water, and refuse removal services.

Port of Dutch Harbor has its entrance between Spithead and Rocky Point. The water is deep close to the shores and in all parts of the harbor except off Rocky Point. The entrance is about 0.5 mile wide and 12 to 18 fathoms deep.

Figure 50: Port of Dutch Harbor views

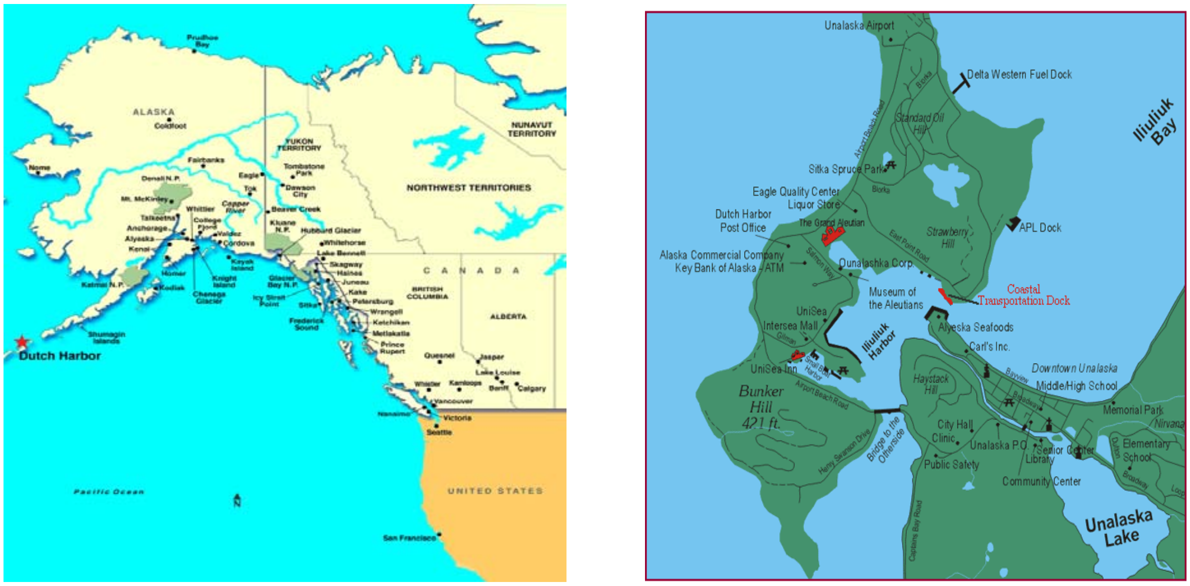


Figure 51: Geographical perspective of Dutch Harbor

Anchorage may be had within the harbor in 13 to 18 fathoms. Violent williwaws (sudden blasts of wind) are experienced during gales, especially from the SW, and the best shelter will be found under the high part of the island well north of the entrance. SW gales practically have a clear sweep across the entrance because of the lowland W. Vessels forced to moor at Delta western, Dutch Harbor Terminal Wharf during the early spring and fall will find it necessary to use chains and wire cables in addition to mooring lines during the severe gales.

The diurnal range of tide is 3.7 feet. The tidal current in Dutch Harbor is inappreciable and in Iliuliuk Harbor the velocity does not exceed 1 knot.

Unalaska bay is open to navigation at all seasons. It is reported that on two occasions the drift ice of the Bering Sea entered Unalaska Bay, but such occurrence is so rare that it need not to be considered. Ice often forms in the sheltered coves and harbors in cold, calm weather, but it never attains any thickness or interferes with navigation.

Captains Bay is the arm at the head of Unalaska Bay, Its main entrance from Unalaska Bay is W of Amaknak Island. The bay is also entered by passing E of Amaknak Island through Iliuliuk Harbor, and through the channel leading S from the Harbor. Large vessels entering the Bay should pass 100 to 200 yards off Arch Rock due to an existing reef.

Several wharves, piers, and docks are on the E side of Captain's Bay. Anchorage may be had in 17 to 20 fathoms, with an even bottom of mud and sand, about 0.4 mile E of the northernmost island of the group at the head of Captain's Bay.

Harbor tugs of less than 50 tons BP (Bollard Pull) are available year around at Port of Dutch Harbor, larger units can be ordered with sufficient time to mobilize from Seattle or Tacoma.

2.8.3 Suitability for Operations

From the operational point of view, this study finds the Port of Nome and Dutch Harbor the most suitable ports to receive the HLV Dry Transporters for float-off and float-on operations.

Norton Sound is statistically ice-free by the middle of June and general weather conditions (wind and seas) are favorable for the float-on/off operations. During ice-free season, extended periods of daylight duration are expected. HLV transporters will be anchored at a float off/on location with 80 to 90 feet of water depth (approximately 4.5-5 miles off the shore line). Port of Nome will be used as a support base to provide logistics and supplies to the rigs and transporters. Nome is located approximately 200 nautical miles from the southern boundary of the Chukchi Sea. It also has an airport facility with daily flights to Anchorage and other cities in Alaska. The one area of concern is the tugs available for the operation. There are no permanent tugs based in Nome. Tug boats have to come from other ports, and this will require integrating logistics planning into tug selection.

Unalaska area, specifically Dutch Harbor, is ice-free year around and is better suited for year around mobilization. Weather conditions in this area are statistically more harsh than Nome. Both Dutch Harbor and Captain's bay provide sheltered anchorage with deep waters to perform the float on/off operations. There are three harbor tugs operating year around with limited bollard pull capacity for this particular operation. It will be necessary to make arrangements for appropriate tug assistance ahead of time. An additional consideration is the distance to the Chukchi Sea boundary, which is approximately 840 nautical miles, and will have to be covered under a wet tow operation. This wet tow will increase the time required to reach the location and will need a combined bollard pull of around 200 tons.

2.9 Float-on /Float-off Operations

2.9.1 Description

A heavy lift ship is defined as an ocean-going vessel capable of submerging its large open deck to well below the water's surface, thus allowing a rig to be floated over it and landed on a cribbing mounted on the heavy lift ship's deck. The heavy lift ship then rises out of the water by pumping out its ballast tanks in a process very similar to the operation of a floating dry-dock. The transported rig then rides on the deck of the heavy lift ship for the voyage to its destination.

The float on/float off operation requires a careful selection of the area where the operation is going to be conducted. The location should meet loading/offloading criteria such as the following:

- **Water Depth:** 24 to 27 meters water depth. Deeper water depth could pose safety constrains. A clearance of 1m to the seafloor during loading and offloading is recommended.
- **Anchorage:** Good holding ground and sufficient space for the transport vessel to weathervane.
- **Wave height:** Normally no more than 0.5 m (varies with Dry Transporter and cargo)
- **Swell period:** 5 – 7 seconds

- **Max Wind Speed:** 15 knots
- **Current:** Limited to a maximum of 0.5 m/s (1 kt)

2.9.2 Float-on Procedure

The Heavy Lift Dry Transporter will proceed to the selected anchorage location and an anchor will be deployed to allow the vessel to weathervane.

Cribbing will be arranged in accordance to the cribbing plan. Blocks will be installed within a pre-calculated tolerance and secured to the Dry Transporter's deck. The material for the cribbing will be soft wood with plywood on top in order to create a shape and shim out the variations in bottom plate thickness.

In order to position the rig correctly on deck, guideposts will be installed in pre-engineered locations. To minimize the effect of wind and seas during float on operations, catchers are required to accurately position the rig above the cribbing. Once all the above is completed ballast down operations will take place to sink the deck up to a predetermined condition that allows the float-on operation. The rig will then be towed with assistance of tugs (3 or 4) of a predetermined capacity and be placed on the Dry Transporter. The Dry Transporter will use tugger lines to maintain the rig in position and disconnect the assisting tugs. A schematic of the float-on operation is illustrated in Figure 52 below.

The Dry Transporter will de-ballast and come up until cribbing makes contact with the rig hull. At this moment verification of contact points should be done by divers. Once the rig is considered in position, de-ballasting can be resumed until the deck is clear of the water and transporter achieves an appropriate draft and trim for transportation.

Seafastening installation will be then performed in accordance with an engineered plan. The float-on procedure takes an average of 5 to 7 days to be completed.

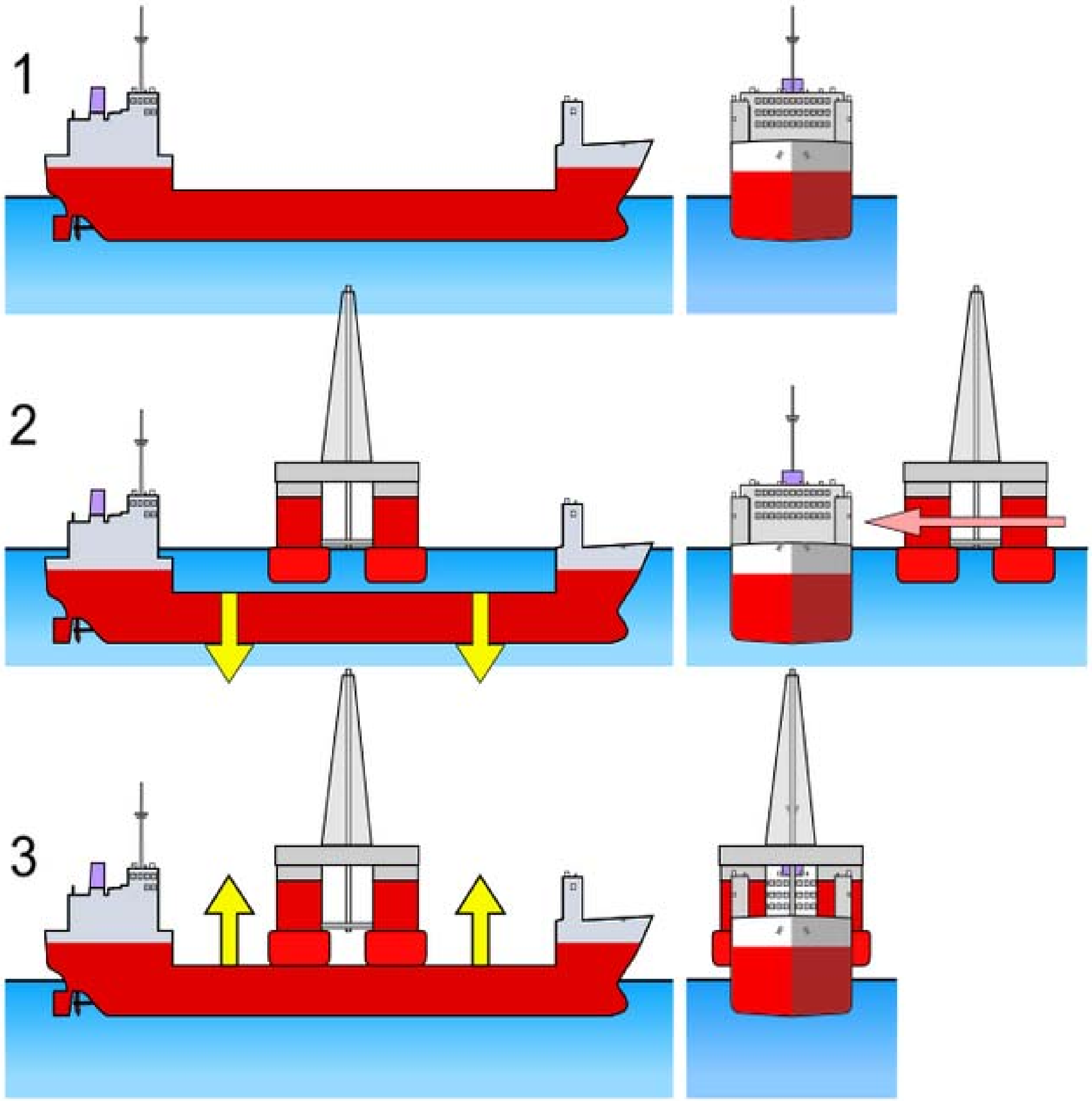


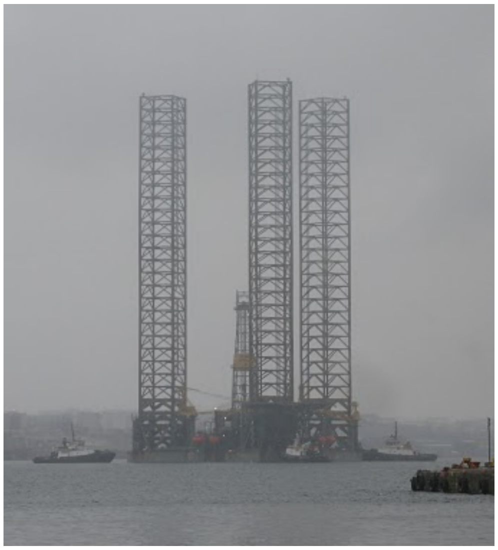
Figure 52: Float-on Procedure. (1) Prepare the HLV Vessel. (2) Ballast down and float on. (3) De-ballast and take the cargo on

2.9.3 Float-off Procedure

The float-off is the reverse maneuvering of the loading operation. The following describes the float-off steps:

- Proceed to a selected anchorage and deploy the anchor
- Remove all seafastening once the weather conditions have been reviewed and are within float-off criteria for a 48 hrs period
- Start ballast down and confirm watertight integrity of the rig at a preselected draft.
- Connect the tugs for float off operation

- Continue de-ballasting until rig is floating and slowly tow the rig off the Dry Transporter.



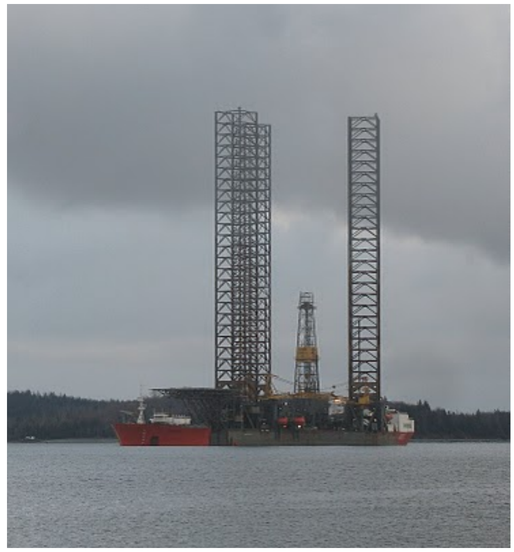


Figure 53: Tugs positioning the rig for float-on (left). HLV De-ballasting (right)

2.10 Wet Transportation

2.10.1 Towing Operations

Towing of drilling units from the port, where the rigs are floated off, to their final destinations in Chukchi Sea, or Beaufort Sea will require a “wet tow”. It is a common practice to require the tug(s) to have sufficient power to maintain the tow at zero forward speed under the following minimum environmental criteria:

- Wind speed of 20 m/s
- Wave height of 5 m
- Current speed of 0.5 m/s

In addition, the tugs should be prepared to operate in low temperature environments. The implementation of an ice management vessel should be considered while operating in the Chukchi Sea and mandatory in the Beaufort Sea.

2.10.2 Tug Boat Services

The tug companies operating in Alaska render services mainly in harbors and terminals for docking operations and towing barges along the coast and Islands of Alaska. There is tug and barge traffic between Seattle/Tacoma area to Alaska as well.

The maximum bollard pull range for harbor tugs goes up to 70 tons and z-drives are available in Dutch Harbor. The Port of Nome does not have tug service. If it is required, it will be provided most probably from companies with bases in Anchorage, or the Seattle/Tacoma area and will need to be arranged with sufficient time.

Crowley Marine Services is one of the companies providing tug services in Alaska with offices in Anchorage. Crowley has been operating in the area since 1953 and has a large fleet that can be mobilized to the Ports of Nome or Dutch Harbor from several areas in Alaska and from the pacific west coast ports during ice-free season. They can provide Ocean Class tugs of up to 150 tons of bollard pull, and down to low draft Avec and River class tugs, suitable for working over the submerged Dry Transporters if required during a float on/off operation. Crowley has been supporting energy companies operating in the North Slope with a variety of services ranging from towing barges and rigs to providing all terrain Arctic transportation. Crowley has been working in other harsh regions around the world including operations in Sakhalin peninsula.

Foss Maritime is another Anchorage based tug service provider. Foss was established many years ago out of Tacoma, since when the company has continued growing and established services in Anchorage. The company provides harbor assistance, escort and ocean towing services along Alaska and west pacific coast. They also supported energy development projects working in extreme North Slope environments delivering cargoes and structures. Foss also successfully provided services in Sakhalin peninsula. They fleet is suitable for harbor services, regional and ocean towing. Foss fleet includes tractor tugs and conventional tugs.

Dunlap Towing Company is based in Seattle and has services in Alaska as well. This company provides harbor tug services in Dutch Harbor and barge transportation in general from the Pacific west coast to Alaska, including Arctic Alaska and other offshore destinations like China, Korea and Russia. Their fleet has Z-drive units up to 50 tons BP and conventional units ranging from 2,000 HP to 5,000 HP.

2.10.3 Tug Feasibility

The study shows that there are sufficient local companies capable of providing services for float-on and float-off operations during the ice-free season. The vessels involved in the float on/off maneuvers normally consist of two or three 50 BP tugs, plus a smaller tug that can cross the vessel’s submerged deck.

It is also noted that there is a possibility within the companies to commit larger capacity tugs for the tow to location activity. As shown in Figure 54 and Figure 55, a combined BP of approximately 200 tons meets the bollard pull criteria for towing a jack-up & drill barge unit to the Chukchi-Sea/Beaufort Sea from the float on/off location. However, it should be noted that towing curves should be created for the each unit prior to the tow in order to maximize tug utilization.

The towing resistance at a given forward towing speed is estimated from the combined steady state wind, mean wave drift, still-water hull drag, and current forces. This represents the total force required to tow the vessel at that speed. To determine the actual towing force available, the bollard pull rating must be reduced to take into account the tug efficiency.

The generally accepted minimum environmental criteria for holding position in a storm is a significant wave height of 5m and a wind velocity of 20 m/s, which corresponds approximately to a Beaufort 8 sea state, with a head current velocity of 0.5 m/s. Less stringent criteria can be used if the tow will be accomplished within a weather window that can be confidently forecasted.

Below are examples of towing curves along with reference curves corresponding to effective tug pulling force at regular intervals.

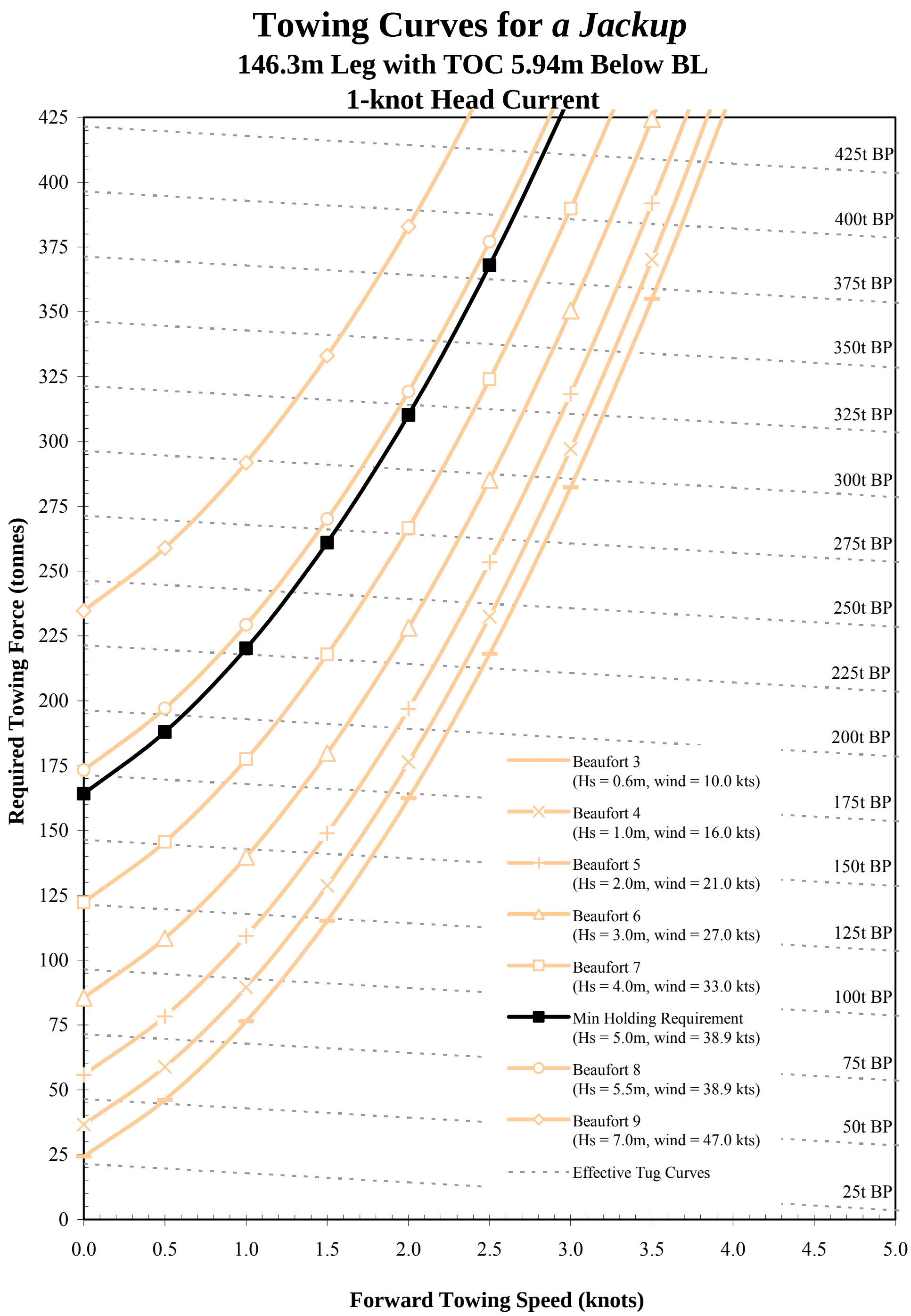


Figure 54: Towing Curve for a Jack-up rig

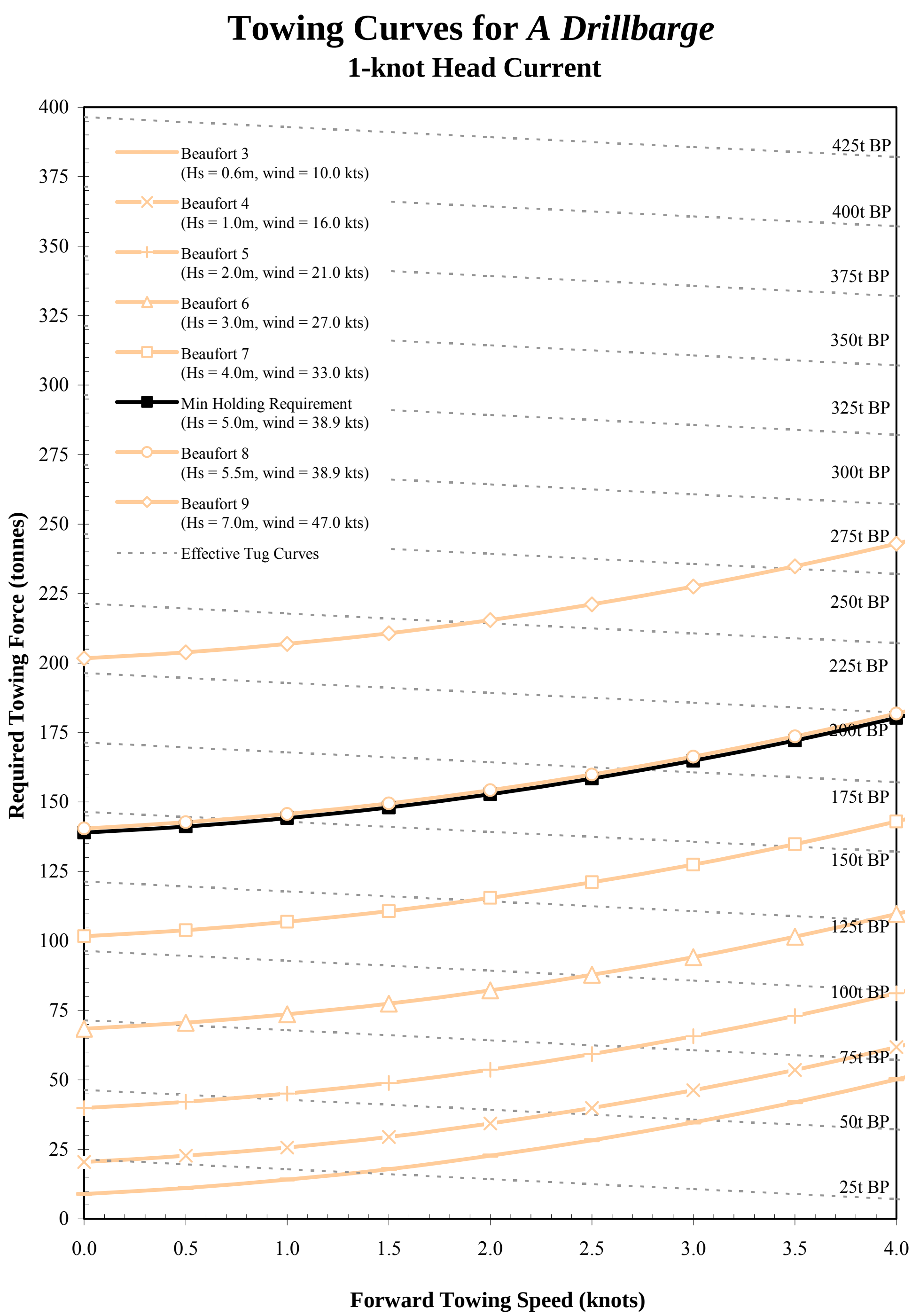


Figure 55: Towing Curve for a Drill barge

2.11 Drillship Mobilization

2.11.1 General

We mentioned in this chapter that the self-propelled drillships are also feasible for operations in the Alaska Arctic. Mobilization time for drillships to reach Chukchi Sea or Beaufort Sea should be at least a week shorter than for the dry-transported units. The advantages will be no need for float-on/float off operations. The drillships can proceed to close proximity of the operation area ahead of time and wait for the ice-free confirmation. It will be necessary to implement an ice management plan, including an assisting fleet accompanying the drill ship in the venture.

In general, the advantages for utilizing this self-propelled drillship compared to a semi-submersible are:

- lower building costs

- higher payload

- higher transfer speed

The main reasons for selection of a drillship for the challenges in Arctic operations are station keeping, ice strength capacity, and its ability to operate in remote locations for extended periods of time without the need for re-supply.

The Arctic waters are relatively shallow and it is important to limit the vessel offsets to maintain the integrity of the connection to the wellhead. Compared to deep water operations, the margin for allowing the drilling riser to deviate horizontally is much smaller. In addition, the possibility of floating ice impacting on the vessel could have the effect of moving it from its position. Turret moored drilling vessels are better suited to operate in the Arctic areas. The turret system enables the vessel to be moored to the sea floor, and allows the hull to weather or ice vane as necessary. Ice will be avoided where possible, while operating in open season. Nevertheless, mitigation measures should be incorporated into the marine activities. Procedures for utilizing ice management vessels for redirecting ice floes close to the vessel while drilling should be established. It is required to have ice strengthened and/or ice-class vessels performing the ice management.

Ice strengthened drillships have drilled in the arctic for a number of years, and they always go to sheltered locations when ice conditions prevail. When the ice is managed with icebreakers, drilling can continue into freeze-up. However, drilling much beyond late November is not generally possible. Drill barge Kulluk is a circular, conical shaped drilling unit which could remain on location in ice up to 1.3 m thick. So far Kulluk has a performance record beyond expectations, and the drilling season has been extended. Two Class 4 icebreakers and two ice-class supply ships were providing the ice management when Kulluk was drilling two discovery wells.

Another benefit for employing drilling ships is their larger capacity to store equipment and supplies, thus reducing the need of supply trips that will be a costly affair. The ideal is to achieve four to six months' operation without re-supply, by being able to carry large stocks of drill string, drilling mud, fuel and other consumables on the vessel.

2.11.2 Anchor Handling Vessels

Both conventional moored and turret moored drillships will need the assistance of suitable anchor handling vessels to deploy their mooring system. An Anchor-Handling Tug (AHT) moves anchors and tows drilling vessels. An Anchor Handling Tug is a tug equipped with a winch to lift a working barge's anchors. It is also often used as the working barge's tow tug. An Anchor-handling Tug/Supply (AHTS) vessel is a combined supply and anchor-handling ship. It is an offshore supply vessel specially designed to provide anchor handling services and to tow offshore platforms and barges. The AHTS is often equipped for fire fighting, rescue operations and oil recovery.

Highly maneuverable and robust craft, anchor handlers have to be able to work in marginal weather. In addition,, the tug's wide open deck aft of the superstructure is able to accommodate stores for the rigs, enabling it to potentially play a role in rig supply. Furthermore, tanks below decks are available for storing fuel, drilling mud and cement. The working deck will be heavily reinforced with timber to protect the steel structure beneath from being damaged by anchors, which could weigh 25 tonnes or more, along with the heavy mooring wires and chains.

The availability of these units in Alaska is not in the same level as the regular tugs for rig towing. It will be necessary to organize the services with sufficient time. There are several companies along the US Gulf of Mexico that can supply these units. These tugs can be mobilized through Panama Canal and reach location in around 20 to 30 days.

Specific requirements for tugs should be determined by the drilling vessel's anchor characteristics and the water depth of operation. When running anchors in the depths of the Chukchi Sea and Beaufort Sea, a bollard pull requirement of 100 tons or more can be expected. Even though operations during ice-free season may imply less stringent criteria for AHT, there are always potential needs for redirecting ice flows as a result of drilling delays or early ice formation. Ice strengthened hulls and ice-class AHT would be the desired vessels.

Below is a list of some of the companies who can provide the anchor handling vessels:

Edison Chouest of Galeano LA has a large fleet of AHT & AHTS. They are building their first arctic ice-class anchor AHTS for Shell oil company. The tug is scheduled to be in service in 2012.

Seacor Marine is another company in the Gulf of Mexico with a fleet of anchor handlers from 8,000 to 15,000 BHP (Brake Horsepower). No ice strengthened or ice-class units are available.

Tidewater and Trico Marine are also among the US Gulf of Mexico companies, which are able to provide AHT or AHTS vessels above 10,000 BHP.

2.12 Transportation Operations

2.12.1 Ice-Free Season and Weather Conditions

The extended ice-free season will result in rising marine activities in the Arctic. It is expected that platform installations could reach further northern remote areas. To efficiently use the resources available, it is crucial to organize and prepare the necessary logistics and support for marine operations in the Alaska region as early as possible.

The ports of Nome and Dutch Harbor are better suited for rig float off/on operations. The final transportation leg from the named ports to the final location in Chukchi Sea or Beaufort Sea will need some careful monitoring of ice and weather conditions, and the utilization of suitable equipment.

Beaufort Sea has approximately three months (August-October) of ice-free conditions, while the Chukchi Sea has about four months (July-October). The ice in Chukchi Sea breaks up before Beaufort Sea, and the ice freezes up afterward in Chukchi Sea. This pattern can be taken into consideration in order to maximize the utilization of the tugs and other assisting vessels available. The rigs deployed to Chukchi Sea could be positioned ahead of those in Beaufort Sea, and removed after the activities in Beaufort Sea are completed prior to the winter.

The wind and sea conditions in the Beaufort Sea are considerably less severe than most open-ocean environments. The monthly probability of winds exceeding 15 knots (8 m/s) are expected to be in the range of 20%, 24%, 30% and 37% from July to October. The wind is generally from the E-NE or W-SW. The maximum sea states during the open season can be estimated from the standard Beaufort scale relationship.

The probability of winds over 15 knots (NE-ENE and SSW) are expected to be in the range of 4% for July, 10% for August, 22% for September and 31% for October in the Chukchi Sea. The possibility of having wind speed over 25 knots is below 6% for October. Wind speeds over Chukchi Sea are found to be the highest with a monthly mean of 18 knots (NE-E) in October. The maximum wind speed at Barrow can go up to 40 knots. The probability of encountering higher seastates is expected to increase towards the end of the season. The monthly chance of a wave height of 2 m is expected to be in the range of 1%, 4%, 5% and 15% for open season from July to October. Currents are mainly wind driven and are below 2 knots.

The predominant current direction is ESE-E over the Chukchi shelf and Beaufort slope. This is a general description of what can be expected during the transit of drilling platform to and from location, for more details of the climatology trends, please refer to Section 1 'Assessment of Environmental Conditions'.

Ice break up starts in the middle of June and reaches its maximum in September. Norton Basin is expected to be clear of ice in the middle of June, allowing vessel operations performed by non ice-class or non ice-strengthened vessels. Ice concentrations of 4/10 are agreeable for non ice-class vessels to operate safely.

Extended day light periods are experienced during the summer season in the Alaska region. This adds a safety factor to the marine operations to be performed. The chart below describes the monthly day light, air temperature, ice concentration for operations and ice conditions offshore. It provides a good picture for the operational conditions in which the transportation window is envisaged.

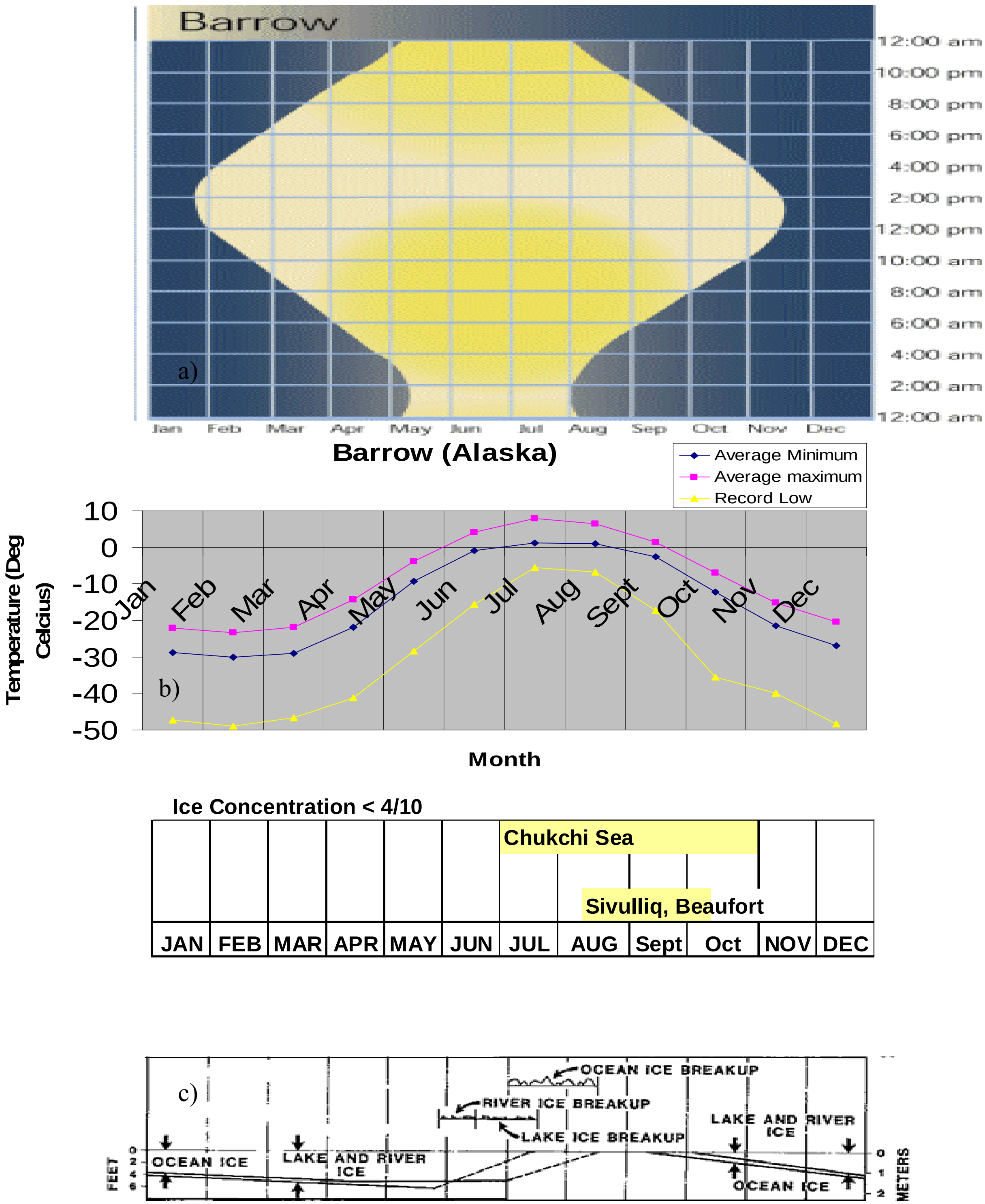


Figure 56: Monthly variations of the a) Day Light b) Temperature based on Climate Chart c) Ice conditions for Offshore Transportation (Gulick, 1983).

2.12.2 Low Temperature Environments

Marine operations in low temperature environments present many challenges for the owners and operators of the vessels. Challenges include both hardware issues related directly to the construction, outfitting and operation of vessels, as well as those issues pertaining to the ability of the crew to function in a difficult environment. To assist the industry, ABS issued the 'Guide for Vessels Operating in Low Temperature Environments' originally in 2006, and then revised in 2010. This Guide is intended for design service temperatures of -10°C (14°F) or less, excluding ice-class requirements, if specified. It is recommended that all units operating in the intended area to have a copy on board.

Vessels designed and constructed without addressing the effects of low temperatures may experience increased structural and equipment failures and non-functioning systems. Personnel performance will typically be reduced by the effects of low temperatures.

According to ABS guidelines, the general certification requirements for operating in low temperature environment are: vessels expected to operate in ice must have applicable ice-class notation, vessels not expected to operate in ice may obtain a CCO (Cold Climate Operation) notation (not necessarily limited to ABS), and must have hull structural materials suitable for design service temperature.

2.12.3 Ice Management

Transporting, mooring, or installing platforms in the Arctic will need to address the risk of encountering floating ice packs or ice related risks associated with this activity. Pack ice should be viewed as manageable, providing that ice capable equipment and appropriate ice operating procedures are used. Ice management techniques oriented towards ice clearance rather than ice breaking will be of the highest importance, since most of the ice expected during the ice-free season will be pre-broken. Potential contact with "sizeable" small ice masses drifting with the pack will represent the "highest risks" situations during the transportation and installation stage. The potential effect of non-collinear forces from ice, winds, waves and currents on "vaning" vessels should be considered. Well trained and experienced personnel will be the key for success.

Information on the ice monitoring and forecasting system, ice alert system, and icebreaker support system will define the ice management techniques to be employed. Basic ice management is viewed as mandatory for moored drilling vessels and jack-ups and should be considered for the transportation stage as well.

Earlier ice build-up during the ice-free season can be possible. Within the ice management plan, an emergency de-mobilization plan should be included. Ice-monitoring and ice-alert system will need to consider the minimum time required to:

- shut down drilling operations
- de-rig and offload drilling equipment that cannot remain on board during the tow
- pull up the legs of the jack-up rigs/ retrieve mooring lines on drillships.

It is envisaged that two vessels with adequate levels of ice strengthening will be sufficient for effective ice management support in the current locations of interest. A typical tow to location could be composed of one ice strengthened Anchor Handling Vessel (AHV), one ice-class support vessel with towing capacity, and one ice strengthened oil response vessel.

The oil response vessel is viewed as mandatory due to the restricted access to these remote areas. Training crews in spill response and adequate oil recovery equipment will be paramount if prevention and the onboard first stage containment barrier fail.

Icebreaker Fleet (2008) is shown in Table 13.

Ship Name	Country of Ownership	Year Entered Service	Propulsion Plant	Operations
ARKTIKA	Russia	1975	N:75,000	NSR
ROSSIYA	Russia	1985	N:75,000	NSR
SOVETSKIY SOYUZ	Russia	1990	N:75,000	NSR; Arctic tourism
YAMAL	Russia	1993	N:75,000	NSR; Arctic tourism
50 LET POBEDY	Russia	2008	N:75,000	Not yet operational
TAYMYR	Russia	1989	N:47,600	NSR
VAYGACH	Russia	1990	N:47,600	NSR
KRASIN	Russia	1976	DE:36,000	NSR; Antarctic
VLADIMIR IGNATYUK	Russia	1977	D:23,200	Arctic escort
KAPITIN SOROKIN	Russia	1977	DE:22,000	NSR; Baltic escort
KAPITIN NIKOLAYEV	Russia	1978	DE:22,000	NSR
KAPITIN DRANITSYN	Russia	1980	DE:22,000	NSR; Arctic and Antarctic tourism
KAPITIN KHLEBNIKOV	Russia	1981	DE:22,000	NSR; Arctic and Antarctic Tourism
AKADEMIK FEDOROV	Russia	1987	DE:18,000	Arctic and Antarctic research and logistics
FESCO SAKHALIN	Russia	2005	DE:17,500	Standby or supply vessel, Sakhalin Island
SMIT SAKHALIN	Netherlands–Russia charter	1983	D:14,500	Beaufort Sea; Sea of Okhotsk; Sakhalin Island
SMIT SEBU	Netherlands–Russia charter	1983	D:14,500	Beaufort Sea; Sea of Okhotsk; Sakhalin Island
MUDYUG	Russia	1982	D:10,000	NSR coastal
MAGADAN	Russia	1982	D:10,000	NSR Pacific coastal

DIKSON	Russia	1983	D:10,000	NSR coastal
URHO	Finland	1975	DE:21,400	Baltic escort
SISU	Finland	1976	DE:21,400	Baltic escort
OTSO	Finland	1986	DE: 20,400	Baltic escort
KONTIO	Finland	1987	DE: 20,400	Baltic escort
FENNICA	Finland	1993	DE:20,000	Arctic offshore/ Baltic escort
NORDICA	Finland	1994	DE:20,000	Arctic offshore/ Baltic escort
BOTNIKA	Finland	1998	DE:13,000	Arctic offshore/ Baltic escort
LOUIS ST. LAURENT	Canada	1969, 1993[a]	DE:30,000	Arctic research and escort
TERRY FOX	Canada	1983	D:23,200	Arctic escort and logistics
HENRY LARSEN	Canada	1988	DE:16,000	Arctic escort and logistics
AMUNDSEN	Canada	1982, 2002[b]	DE:15,000	Research
PIERRE RADISSON	Canada	1978	DE:13,400	Arctic escort and logistics
DES GROSSELIERS	Canada	1983	DE:13,400	Arctic research and escort
ODEN	Sweden	1989	D:23,200	Arctic research/Baltic escort
ATLE	Sweden	1974	DE:22,000	Baltic escort
YMER	Sweden	1977	DE:22,000	Baltic escort
FREJ	Sweden	1975	DE:22,000	Baltic escort
TOR VIKING	Sweden	2000-2001	DE:18,000	Baltic escort
BALDERR VIKING	Sweden	2000-2001	DE:18,000	Baltic escort
VIDAR VIKING	Sweden	2000-2001	DE:18,000	Baltic escort/Arctic research
POLAR STAR[1]	US	1976	GT:60,000 DE:18,000	Arctic and Antarctic research and logistics
POLAR SEA[1]	US	1977	GT:60,000 DE:18,000	Arctic and Antarctic research and logistics
HEALY	US	2000	DE:30,000	Arctic research and response
NATHANIEL B. PALMER	US	1992	D:12,700	Antarctic research and logistics

[1] Reference [50]

SHIRASE	Japan	1982	DE:30,000	Antarctic research and logistics
POLARSTERN	Germany	1982	D:17,200	Arctic and Antarctic research and logistics
KIGORIAK	Netherlands	1979	DE:16,600	Offshore support
ALMIRANTE IRIZAR	Argentina	1978	DE:16,000	Antarctic research and logistics
SVALBARD	Norway	2002	DE:13,500	Patrol
AURORA AUSTRALIS	Australia	1990	D:12,000	Antarctic research and logistics

NOTE: D = Geared Diesel; DE = Diesel-Electric; GT= Gas Turbine; N= Nuclear; NSR = North Sea Route. Ships of at least 10,000 propulsion horsepower are listed.

a. LOUIS ST. LAURENT in service in 1969 was rebuilt and re-commissioned in 1993.

b. AMUNDSEN in service in 1982 as SIR JOHN FRANKLIN was converted and returned to service in 2002.

Table 13: Icebreaker Fleet (2008)

2.12.4 Transportation Abilities and Limitations

In the task of researching the abilities and limitations of equipment used to transport platforms, we identified important factors that could contribute to the decision-making process of selecting the appropriate form of transportation.

Arctic-class barges have been proved successful in previous campaigns in the Canadian Arctic, operating well past the ice-free season. Of those drilling units not specially designed for the Arctic, independent legged jack-ups and self-propelled drilling units equipped to operate in cold weather are the most suitable.

The mobilization of jack-up rigs to the Arctic will include two steps. First a dry-tow of a jack-up MODU aboard a heavy lift unit to a sheltered location along the northern coast of Alaska, followed by a second step, the wet tow of several hundred miles to the drilling site.

The geographical location of the drilling unit is a key factor for transportation. The rig utilization rate in different areas and the time required to transport the rigs from their main concentration areas should be evaluated for timely and cost-effective rig deployment. Lengthy mobilization requires engineering studies and planning with sufficient time.

The factors in selecting a jack-up rig for drilling exploration include the feasibility assessment of using commonly available heavy lift vessels for dry-transportation, tug availability for float-off/float on operation in a sheltered place, tug availability for towing the rig to site and trends of weather, currents, ice and statistical climate data that will affect the area of operation in Alaska.

A list of 28 self propelled units and 7 barges is given in Sections 2.7.5 and 2.7.6. Considering available deck space and lifting capacity, these heavy lift units could transport a rig with the main dimensions and weight detailed in Table 3 and Table 4.

Under the assumption of ice-free conditions, the marine operations can be conducted with the presently available heavy lift fleet (vessels/barges). However, the current utilization of the heavy lift fleet is about 65%, so these ships need to be chartered well in advance. The time required for early mobilization of the HLV is determined by the transit time to the designated location, where the rig will be discharged and wait for favorable weather condition for the wet tow step and ice-free conditions at the drilling site. Approximate days to reach Alaska from the rig concentration area have been estimated and presented in Table 2. Different scenarios of loading arrangements as examples of the possibilities and capacities have been presented in this study. However, every particular case needs its own assessment before execution.

It should be emphasized there are no ice-class transporters available. Equipment winterization will need to be addressed, planned and executed ahead of time. The heavy lift fleet contains 100% foreign flagged vessels. Hence, an application for Jones Act's waiver will need to be submitted and approved in order to transport rigs from ports of the US Gulf of Mexico to Alaska.

The rigs dry transported will be floated off at a sheltered location off the coast of Alaska. Dutch Harbor is ice-free year around and is better suited for year around mobilization. Norton Basin is statistically ice-free by the middle of June. This study finds the Norton Basin with the support of Port of Nome and Dutch Harbor both suitable for facilitating float-off and float-on operations using dry transport vessels. Tug companies operating in Alaska and the Pacific coast can provide the proper tugs for float on/off operations. Bollard pulls up to 70 tons, z-drive units and shallow draft tugs are available for relatively easy mobilization.

The rig move between the offloading location and the drilling site will require tugs of sufficient bollard pull capacity. For rig moving operations, there is local capacity available, although only a limited number of ice-class tugs have been identified. Tugs with ice-class capacity should be considered for purposes of adequate and safe ice management.

Self propelled drilling vessels have been identified as the other possible option for the Arctic venture. Drilling vessel equipment needs to be winterized and some structural study for ice re-enforcement will be required if they extend their operations after the ice-free season. There is one unit which has been winterized and adapted to operate in Arctic waters. One major oil company has been supporting and supervising two ice class drilling ships being built by a drilling operator for future Arctic projects.

With regards to anchor handling tugs for deploying mooring lines of the drilling vessels, the local capacity is almost none and these units will need to be mobilized from the US GoM. When running anchors in the depths of the Chukchi Sea and Beaufort Sea, a bollard pull requirement of 100 tons or more can be expected.

Ice management is identified as a limitation because there is a need to obtain ice-class AHV and icebreakers to re-direct ice floes. Ice-class AHV can only be provided by foreign countries since the US icebreaker fleet is limited and already committed to Great Lakes ice-route maintenance and research services.

Spill recovery operations in ice require effective ice management. Currently there is only one spill response vessel in the Arctic with this capacity. Spill response training for vessel crews in low temperature environments is identified also as a potential limitation, if the demand for performing spill recovery operations increases.

The abilities and limitations identified in this section reflect the current stage of preparations for the Arctic exploration. Some oil companies have already done important research and their level of preparation, readiness, and their investment in technology is commendable. They definitely have set the pace, and new companies that expect to join ventures in the Arctic experience should look at what has been achieved and look for cooperation to ensure good operational procedures, safety standards, training, and environmental care. The transportation plan can be safely established with the current resources available if all considerations established are addressed in proper operational procedures.

3. TASK 3: SUPPORT OPERATION ASSESSMENT

3.1 General

Transportation of platforms to the Chukchi Sea and Beaufort Sea will require the assessment of the supporting operations, equipment and human interaction to achieve a successful operation, to minimize the risk of personnel injuries, and to prevent damages to assets and environment as far as reasonably practicable. Safe and reliable operations are essential in cold climates, as these areas are often classified as ecologically sensitive. Knowledge of the challenges and hazards involved when operating in Arctic areas is of vital importance for sustainable operations.

Vessels operating in such remote areas are very vulnerable and set higher requirements for equipment redundancy and reliability. To some degrees, ice strengthening and/or winterization will be necessary and may vary from just control of icing in open waters to ice-breaking capabilities in temperatures -40°C and below.

The support assessments of the Anchor Handling Vessels/Platform Supply Vessels (PSV) and transportation vessels, which will be involved during the transportation of the drilling units to their destinations, are provided in this study.

3.2 Objective

The objective of this task is to identify the support requirements during platform transportation to Chukchi and Beaufort Seas. Logistics and planning are vital because these remote areas cannot rely on last minute decisions, especially in case of an accident where emergency response units will take a long time to reach a North Slope location. The first line of response in these areas is local communities with limited resources. The United States Coast Guard (USCG) bases in Juneau, Kodiak and Anchorage will take several hours to reach the location by plane and maybe days by sea (Ref. [82]). As identified in Section 2, both Nome and Dutch Harbor could be the initial base appropriate for float off and float on operations. Dutch Harbor provides year around operational support. Nome provides operational support during the ice free season. To organize the necessary support we need to evaluate possible scenarios in which assistance would be required.

The main consideration is that the vessels and platforms involved in this project should assess every possible risk and implement a contingency plan with the idea of being self-sufficient and being capable of addressing the risk with no or minimum external support. After identifying areas of weakness, plans should be developed to mitigate the risk.

Support operation is assessed in the following areas:

- ***Selecting the suitable Tugs and/or AHV*** with adequate equipment, strength and capacity, as well as competent and trained crews will be the first step on the list to build the barriers against incidents. Experienced surveyors need to get involved in inspecting, evaluating and approving the condition of these units for the intended service. An important step in this stage is the agreement of all stakeholders regarding the rules and guidelines to abide by in this process.

- ***Vessel's Equipment and Level of Redundancy***. Propulsion and steering redundancy can reduce grounding, collision and pollution risks in case of mechanical failure
- ***Weather and Ice Forecast***. Weather and ice monitoring services can be provided by shore support at regular intervals.
- ***Routing Arctic Navigation, Charts and Vessel Traffic System***. Ice-free season has attracted shipping companies to use the Northern Sea Route as a feasible option to shorten distances between Europe and Asia. Traffic will increase, but a Vessel Traffic System (VTS) or monitoring control has not been established. This increases the risk of collision in critical areas through the Bering Strait and the risk of grounding if inappropriate charts and navigation systems are used. The implementation of an Automatic Identification System (AIS) and Long Range Identification and Tracking (LRIT) systems could improve safe navigation in the region. However, no infrastructure has been developed in the Arctic region to fully establish these systems yet.
- ***Communications***. Control and tracking of the transportation venture will need to be defined in order to establish a first line of shore support and assistance, if needed.
- ***Vessel Operating Procedures*** will address emergencies, personnel training, safety, navigation, stability, towing, and other working procedures.
- ***Spill response***. USCG has limited resources to provide assistance in the North Slope area. Local communities are the first to respond and can provide some assistance. Vessels should plan to have sufficient equipment and personnel on board or to have an additional vessel whose main function will be pollution response.
- ***Crew Training***. Crew training and qualifications help to maintain safety and provide an important tool to reduce risks. The more knowledge a person has, the more precautions he or she will take when performing their duties.
- ***Collision, Fire and Grounding***. The strategy here will be prevention, preparedness and response from the vessels side. USCG does not have a base in North Slope to provide immediate assist. Mobilizations will have to come from the Kodiak base.
- ***Evacuation and Medical Emergencies***. If a person is in a critical state in an isolated area, medical transportation by both air and sea will take a long time to arrive. Also, hospital facilities are only located in large cities.
- ***Fuel Supplies.*** Nome will be the best place to go for fuel supplies. Barge transfer of fuel in a safe area offshore (location to be determined) is another option.
- ***Food Supplies***. Thirty days of food will be necessary. Fresh vegetables and produce will last only 2 weeks, so canned vegetables and long life produce products will be needed. Food supplies can be obtained from Nome.
- ***Drilling equipment Storage.*** Drilling equipment should be planned ahead of time to be in Nome and ready for transport with supply vessels. Hazardous items need proper storage on shore and the adequacy of storage places needs to be confirmed.

3.3 Support Operations

All vessels involved in the rig transportation will have to be prepared to mitigate risks prior to starting operations in the Arctic. Owners, vessels crew, oil companies, authorities, and local indigenous communities will have to get together and agree on what will be the acceptable level of risk and the level of preparedness that can be achieved in order to guarantee a successful venture.

Arctic response problems were brought into the light when the M/V Selandang Ayu lost power and eventually broke up off Unalaska Island in the Aleutians in 2004. During the rescue, a US Coast Guard helicopter crashed and 6 crewmen of the vessel died. Miles of pristine shoreline were oiled in remote locations that could only be accessed by helicopter. In some cases, living quarters were established in these areas for workers in case the weather turned bad and the helicopter could not return. Much of the cleanup had to wait until spring and summer.

The only presence in this area has been the USCG, but they are limited in resources and any response time can take a long time to reach remote areas. The USCG 17th district is headquartered in Juneau and there are no personnel permanently stationed north of the Arctic Circle. The closest air station is Kodiak (600 miles South) and the closest office is Anchorage (400 miles south). The North Slope of Alaska has about 2500 miles of shoreline and local communities provide the first response in Search and Rescue (SAR) in many occasions. The oil companies and State of Alaska provide security and local Oil Spill Response Organizations (OSROs) provide emergency response. The oil companies made plans to provide their own spill response vessels during the summers of 2008 and 2009 for exploration and drilling. The Department of Defense provides the SAR through the Alaskan National Guard with cooperation with Canadian forces.

What may be the most important issue is the effect the changing arctic will have on indigenous people. The main impact is coastal erosion and its effect on subsistence hunting. Coastal impacts are already being felt; the lack of ice has exposed the land to severe erosion. There are already a large number of natural oil and gas seeps, and exploration and development may cause more. Spill response in these remote areas is a serious challenge. Some wildlife species may change locations or be forced to adapt to a new environment. These changes may be caused by climate changes or human intervention. Indigenous peoples must be engaged to find solutions in order to protect their culture and livelihood.

Wildlife and protected species have an important role for indigenous people. The hunting of Bowhead whales is allowed; the International Whaling Commission (IWC) has permitted up to 280 to be taken by between 2008 and 2012. But there are four types of seals, 7 types of whales, a porpoise and two eiders that are on the protected species list now and more may soon be added. These are protected under the Endangered Species and Marine Mammal Acts. Under the Arctic Council, the Protection of Arctic Marine Environment (PAME) Working Group developed 4 general scenarios of how the combinations of multiple interests may evolve (Figure 57). These range from an Arctic race that is a “no hold barred” rush for resources to a polar preserve that has stringent no shipping zones. Only time will tell how this will play out (Ref. [7]).

Figure 57: Scenarios on the Future of Arctic Marine Navigation in 2050 (PAME)

3.4 Selecting the Suitable Tugs, Anchor Handling and Support Vessels

In selecting the appropriate vessels for assisting and supporting transportation of drilling rigs to the Arctic region, it is necessary to identify and establish the requirements with which they will have to comply. The vessels will have to be fitted with suitable equipment to perform the tasks of moving rigs and fulfill all safety guidelines to operate in the area. As the operating areas are remote from any assistance, vessels will have to rely mainly on themselves in the event of emergencies or breakdowns. Equipment redundancy, a program of regular maintenance and maintaining key spare on board will therefore be needed.

3.4.1 Federal and International Regulations

The vessels proposed to work in the Arctic environment must comply with the following regulatory frame. This frame gives the general view of the different bodies and organizations that have established guidelines for construction and operation of this type of vessels, and additional requirements to work in the Arctic environment. A verification process by a competent surveyor is recommended to be performed before the vessel is hired to ensure vessel compliance status.

Class Certification: The first step in this process will be marked by the Classification Societies which will certify the compliance of the vessel with construction codes and equipment requirements. Special attention to winterization and Ice Class compliance will determine the operational restrictions.

IMO regulations: The IMO is an organization of 160 member countries with observers from governmental, industry, environmental, public interest, and labor organizations that is concerned with the safety of shipping and cleaner oceans. To achieve its objectives, the IMO has promoted the adoption of some 30 conventions and protocols, and has adopted well over 700 codes and recommendations concerning maritime safety, the prevention of pollution, and related matters.

Code of Federal Regulations (CFR) is the codification of the general and permanent rules and regulations (sometimes called administrative law) published in the Federal Register by the executive departments and agencies of the Federal Government of the United States. The titles covering marine activities are described in Title 33 Navigation and Navigable Waters, and Title 46 Shipping [52]. The Oil and Gas and Sulphur Operations in the Outer Continental Shelf-Safety and Environmental Management System is included in 30 CFR Part 250 [56].

SOLAS Convention (International Convention for the Safety of Life at Sea) is an international maritime safety treaty. The SOLAS Convention in its successive forms is generally regarded as the most important of all international treaties concerning the safety at sea.

MARPOL 73/78 is the International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978 and it's amendments ("MARPOL" is short for marine pollution and 73/78 short for the years 1973 and 1978),

COLREGS The International Regulations for Preventing Collisions at Sea 1972 (COLREGS) are published by the IMO, and set out the "rules of the road" to be followed by ships and other vessels at sea. COLREGS can also refer to the specific political line that divides inland waterways (subject to one set of navigation rules) and coastal waterways (subject to international navigation rules).

STCW95 The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (or STCW), 1978, as amended, sets qualification standards for masters, officers and watch personnel on seagoing merchant ships. STCW was adopted in 1978 by conference at the IMO in London, and entered into force in 1984. The Convention was significantly amended in 1995. The Convention prescribes minimum standards relating to training, certification and watchkeeping for seafarers which countries are obliged to meet or exceed.

Environmental Protection Agency (EPA) Alaska Clean Water Act and Clean Air Act The Clean Water Act provides for performance standards governing the disposal of wastewater and prohibits it from being dumped into lakes, streams, and other waters. The Clean Air Act is a federal law that requires EPA to set national health-based air quality standards to protect against common pollutants including ozone, carbon monoxide, lead, sulfur dioxide, and particulate soot.

IMO Arctic Shipping Guidelines (Guidelines for Ships Operating in Arctic Ice covered waters) MSC (Circ. 1056), Ref. [32]. The guidelines for ships operating in Arctic ice-covered waters are intended to address those additional provisions beyond existing requirements of the SOLAS Convention deemed necessary in order to take into account the climatic conditions of Arctic ice-covered waters and to meet appropriate standards of maritime safety and pollution prevention. The guidelines aim to promote the safety of navigation and to prevent pollution from ship operations in Arctic ice-covered waters, and are currently recommendatory.

IMO Guidelines for Ships Operating in Polar Waters. The IMO has developed voluntary Guidelines for ships operating in Polar Waters, adopted at the 26th session of the Assembly (Ref. [33]). The IMO Resolution A.1024 (26) updates MSC/Circ.1056 and MEPC/Circ. 399 - guidelines for ships operating in Arctic ice-covered waters.

The guidelines are intended to be applicable to new ships with a keel laying date on or after January 1, 2011, operating in Polar Regions (the Arctic and the Antarctic). They contain provisions that recognize the additional challenges in Polar waters other than ice-coverage and emphasize the need to consider the nature of the operations that are anticipated and provisions for environmental protection. Ships with a keel laying date before January 1, 2011, are encouraged to observe the guidelines as far as is reasonable and practicable.

The guidelines are recommendatory in nature and are intended to address the additional provisions deemed necessary for consideration beyond the existing requirements of the SOLAS Convention, in order to take account of Polar climatic conditions and meet appropriate standards of maritime safety and pollution prevention. The IMO has set up a correspondence group with a view to developing mandatory requirements.

3.4.2 Alaska State Regulations

Alaska statutes and regulations also establish and enforce clear guidelines than can be considerer a barrier to reduce risk in Marine Operations.

Alaska Oil & Hazardous Substances Pollution Control Regulations

Title 46 of Alaska Statutes refers to Water, Air Energy and Environmental conservation; Chapter 46.04 refers to Oil and Hazardous Pollution Control.

Alaska Oil & Gas Conservation Commission (AOGCC)

AOGCC is to protect the public interest in exploration and development of Alaska's valuable oil and gas resources through the application of conservation practices designed to ensure greater ultimate recovery and the protection of health, safety, fresh ground waters and the rights of all owners to recover their share of the resource.

Spill Prevention and Response (SPAR)

Under the Alaska Department of Environmental Protection, the Division of Spill Prevention and Response prevents spills of oil and hazardous substances, prepares for when a spill occurs and responds rapidly to protect human health and the environment, Ref. [19].

Solid Waste Disposal Act

This provides for performance standards governing the disposal of solid waste. Solid waste means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material.

3.5 Vessel's Equipment and Redundancy

The vessel's equipment needs to be stipulated by contract and be verified before the unit arrives in Alaska territory. We have established that the tugs with 50 tons or more bollard pull required for float off/on operations could be arranged with local companies. These tugs should be in compliance with the Alaska environmental requirements; inspections will be required in any case.

Float on/off Tug Equipment

Four 50 tons or more BP tugs with the following requirements should be needed:

- Classed Tugs
- Two Azipods able to produce a minimum of 50 tons BP tension
- Bow tow drum with towing line of sufficient Safe Working Load (SWL)
- Stern Tow Drum with towing line of sufficient SWL
- Proper Licensed personnel
- All Navigation equipment in order
- Winterization for summer Navigation in Arctic waters

Large Tugs/AHV Vessels to assist Jack-ups

The towing vessels that would be required to tow a jack-up unit to location will be of bigger capacity. They normally are not available in the Alaska Ports, and need possibly to be mobilized from the Gulf of Mexico or from Asia.

Two units will be required for the tow and one unit as a contingency/ice management vessel. Two units of 140 tons BP with the following requirements should be needed.

- Classed Tugs
- Two Azipods able to produce a minimum of 140 BP tons
- Double tow winch with sufficient wire on both drums and proper SWL
- Bow Thruster unit no less than 800 HP
- Minimum of 4 pennants of sufficient strength
- Fire Fighting capability
- Proper licensed personnel
- Cold water survival training
- All Navigation equipment in order
- Enclosed lifeboat
- De-icing system for life saving appliances
- De-icing system for navigation systems
- Ice navigation training

- Ice accretion study and stability effect
- Area 4 compliant GMDSS (Global Maritime Distress Safety System) equipment
- AIS equipment
- Winterization for summer navigation in Arctic waters

Ice Management Tug/AHV

The Ice Management Tug should comply with the same AHV general requirements, but the BP capacity required will be 200 tons and the tug should be a Polar Class 5 unit or equivalent.

Heavy Lift Transporters

Heavy Lift Transporters will be mobilized in the Alaska region only for float on or float off operations. In addition to their class and Alaska state requirements, they should have:

- Ballast system winterization
- Hydraulic systems winterization
- Ice accretion study and stability effect
- De-icing system for navigation equipment
- De-icing system for life saving appliances
- Double propulsion system*
- Double steering system *
- AIS equipment
- GMDSS area 4
- Licensed personnel
- Cold water survival training

* If transporters with double propulsion and double steering system are unavailable, an escort tug should be arranged when vessel arrives at a close radius (to be determined) from Alaska shore line.

Vessels Infrastructure

In order to reduce the risk and limit the need for shore support, the equipment capabilities on the vessel should be enhanced. Redundancy on vessel's equipment operating in remote Arctic areas should be considered and implemented. In addition, the vessels should carry sufficient spares and have trained technical personnel on board. These measures will improve the chances of success in the Arctic region.

Vessels Winterization

Figure 58: Ice on Vessels

From the first perspective, consideration is traditionally given to winterization issues such as: de-icing, ice effects mitigation (such as sea chest designs), interaction between ice breakers and their escorted ships, piping arrangements, fire fighting arrangements and main/auxiliary machinery [43].

The second considers the implications of winterization on ship design and operation to meet the requirements and needs of the crew. These include concerns related to: environmental controls, cold weather clothing, crew support and habitability, human performance in cold weather, safety and medical issues, personnel characteristics, and machinery operation and maintenance.

Effects of ice accretion need to be considered in terms of protection of personnel and safety of the vessel. Following issues need to be evaluated and addressed:

- Stability and operability of support vessels due to icing
- Operability and adequacy of evacuation equipment
- Weather forecasts

The American Bureau of Shipping recently published the Guide for Vessels Operating in Low Temperature Environments (LTE Guide) to address various design, operational and crew requirements related to extreme cold weather conditions.

The LTE Guide has requirements addressing:

- Materials and coatings (materials for cold climate, steel, plastic etc)
- Hull construction/arrangement and equipment
- Vessel systems and machinery (Operation of ballast water and fire water)
- Safety systems for personnel (Instrumentation deicing)
- Specific vessel requirements for different vessel types
- Crew considerations
- Crew training

The degree of winterization will have to be evaluated and assessed by the level of exposure of the vessel to low temperatures since transportation is expected to be carried out in the ice-free season.

Winterization will at least cover vessels' systems and machinery, safety for personnel, crew considerations and crew training. The winterization requires some equipment to be located inside deck houses, for instance the anchor winch and life boats. Heating is required for some systems like the fire extinguishing system, hydraulic systems in cold spaces, and heating is required in engine rooms and other spaces containing important equipment unless the equipment and piping installations can operate at the lowest temperature generated by the outdoor temperature, with realistic space ventilation. For design temperatures below -10°C heating in ballast tanks above sea water line and of fuel oil systems will also be required. Non-toxic and biodegradable oil is recommended for stern tube and Controllable Pitch Propellers (CPP) systems, since these systems may leak oil on a daily basis.

Redundancy

Redundant propulsion is recommended for more reliable propulsion power when operating in remote and vulnerable waters. Two engine rooms will be preferred. In this way, with one engine room out of action due to fire or flooding, the ship may be able to return to civilization under its own power, or at least to stay safe and warm where it is, until rescued. A redundant steering system is also recommended.

Redundant propulsion and steering systems are based on the "single-fault" concept; i.e. in the event of a single failure of a propulsion or steering plant, or part thereof, all safety objectives - such as the maneuverability of the ship under difficult weather conditions and maintaining of a minimum speed - must always be met.

Redundant propulsion and steering systems must be available at all times, and it must be possible to activate them on demand. Rapid reinstatement of propulsion and steering of the ship could be essential in Arctic waters. Furthermore, the time-consuming starting of "cold" systems or prolonged switch-over procedures do not fulfill the aim of redundancy. IMO gives highest priority for various plant configurations and system components, whereby auxiliary systems such as fuel, lubricating-oil, cooling-water and control-air installations must be provided separately for each propulsion plant as a matter of principle.

As an example, the Azipod (electric azimuthing thrusters) propulsion and steering system concept is widely used in ice application vessels like ice breaking and ice management ships. It consists of a podded electric main propulsion and steering device driving a fixed pitch propeller at variable speed settings (See Figure 59 and Figure 60), Ref. [11]. In order to drive the Azipod propulsion system, the ship needs an electric power plant and a switchboard for distribution to consumers. The distribution switchboard can be arranged to provide power to each unit individually giving the power redundancy needed.

Figure 59: Vessels with Azipod Units

Figure 60: Typical Azipods

3.6 Weather and Ice Forecast

Ice and weather forecasts in the Arctic region can be obtained from the National Weather Forecast office division of National Oceanic Atmospheric Administration (NOAA) as shown in example in Figure 61 (Ref. [51]). The Anchorage forecast office produces graphic analyses of sea surface temperatures and sea ice as well as five day sea ice forecasts year round. Scheduled sea ice analyses and 5-day sea ice forecasts are produced Monday, Wednesday and Friday. A sea surface temperature chart of Alaskan waters is produced Tuesday and Thursday. Annotated satellite analyses of sea surface temperatures and sea ice are produced when clear skies allow these features to be observed. Amended ice forecasts are made anytime the Ice Forecaster becomes aware that the forecast is in error. Phone and fax numbers for contact are (907) 266-5138 and (907) 266-5188.

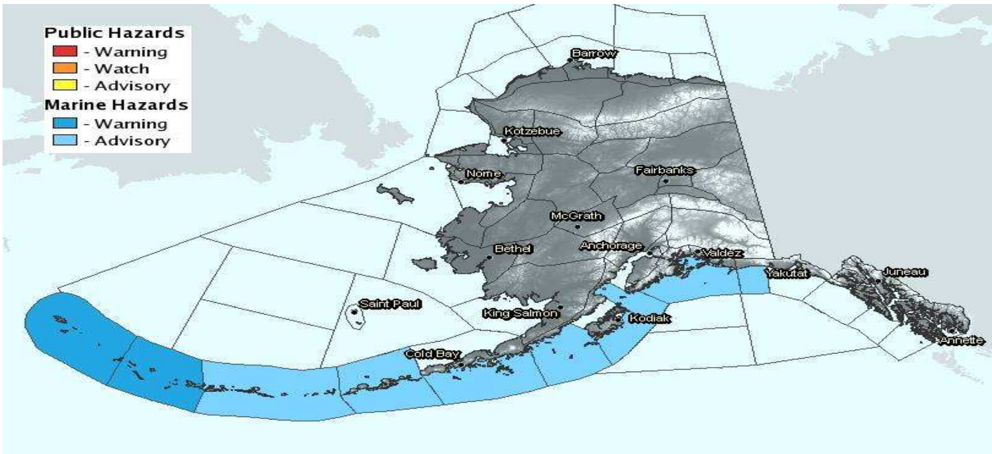


Figure 61: NOAA weather areas

3.7 Routing, Arctic Navigation, Charts and Vessel Traffic System

To promote the safety of navigation and to prevent pollution from ship operations in Arctic ice-covered waters, the Marine Safety Committee (MSC) and Marine Environment Protection Committee (MEPC) of IMO approved the Guidelines for Ships Operating in Arctic Ice-Covered Waters, as an addition to the mandatory and recommendatory provisions contained in existing IMO instruments.

IMO Guidelines define special measures for safety of life and protection of the environment in the Arctic region. The guidelines harmonize different national requirements relating to hull structure, equipment, navigation and operation for different types and sizes of ships that may travel in the Arctic ice-covered waters. The standards expressed in these Guidelines have been developed to deal with additional risks imposed on ships due to harsh environmental and climatic conditions existing in Arctic ice covered waters. These standards are an addition to the basic requirements from relevant conventions.

IMO Guidelines cover a wide range of issues related to safety of vessels operating in the Arctic region. They are recommendatory rather than mandatory for vessels traveling in the Arctic ice-covered waters and are divided into three principal parts: the design and construction of hull structure and machinery; specific equipment requirements for a low temperature environment, including fire safety equipment, life saving appliances and navigational equipment; and operational guidelines, such as operational control, operating manual, training manual, crewing and emergency equipment.

IMO Guidelines refer to the International Association of Classification Societies Ltd (IACS) Unified Requirements (URs) for Polar Class for structural design and construction. These have been adopted by ABS and are available as the ABS Guide for Building and Classing Vessels Intended for Navigation in Polar Waters.

The IACS Polar Class UR was developed to harmonize the ice class requirements of various classification societies and Maritime Administrations.

To secure safety of navigation through the Alaska Arctic Region and to prevent pollution of the marine environment from ships, it will be recommended to establish a Vessel Traffic System similar to that described in the Guide to Navigating Through the Northern Sea Route to regulate and control the traffic in the Barents, Chukchi and Beaufort Seas and to ensure safe, secure, and reliable marine shipping in the Arctic. This would include the provision of aids to navigation, updated charts, vessel escorts, spill response capability, and maritime search and rescue in the Arctic. There is no regulation approved yet to implement these guidelines.

The Council of the European Union in their council meeting of December 8, 2009 adopted the following conclusion:

"The Council underlines the need to further explore the options and consequences of exchanging AIS information with non-EU/Europeans Economic Area Arctic states and to assess to what extent operational assistance in the field of pollution prevention and response can be extended to the Arctic area. To this end, the Council invites the Commission to examine, with the full support of the SafeSeaNet High Level Steering Group, the possible development of a policy of access rights to define the relations of SafeSeaNet with other information systems used by third countries."

Automatic Identification System Development

The maritime VHF Automatic Identification System was created in the 1990's primarily to provide an aid in safety of navigation. AIS is intended to operate independently of the vessel crew and additionally provide monitoring and tracking information to shore based stations. These messages are sent using several variations of Time Division Multiple Access (TMDA) to interleave traffic from multiple vessels and base stations using two channels 161.975 MHz (Channel A) and 162.025 MHz (Channel B). By using these VHF frequencies, transmissions are primarily limited to line of sight communication with typical receive distances of roughly 30 nautical miles.

Complete deployment of AIS to SOLAS class vessels was required by December 2004. Vessels equipped with AIS units automatically broadcast two primary message types. The most important message is a position report that includes the ship's "User ID" (MMSI-Maritime Mobile Service Identity) for identification, the position from the ship's GPS, speed over ground, course over ground, rate of turn, and several additional parameters. The position updates range from every two seconds to every three minutes depending on vessel speed. The second key message is a ship and cargo data report. This message contains the name, call sign, type of ship and cargo, estimated time of arrival (ETA), size of ship, draft, and destination. Much of the information in the ship data message is entered by hand and as such care must be taken when relying on information that may be incorrectly entered or not updated.

In the last several years, a number of AIS receiver networks have been created to collect AIS message traffic for large regions of the world. In 2002 the Maritime Transportation Security Act (MTSA) was passed by the U.S. Congress instructing the U.S. Coast Guard "to collect, integrate and analyze information concerning vessels operating on or bound for waters subject to the jurisdiction of the United States," for which AIS was considered a key component. The goals of the MTSA program are specifically to improve maritime security, marine and navigational safety, SAR operational capabilities, and environmental protection. The MTSA also called for two-way maritime data communications using AIS, which has the capability of allowing vessels at sea with AIS that are operating in proximity to create a virtual network, forwarding information from each other along to shore stations, and carrying information from the shore to ships at sea beyond normal AIS range.

AIS systems have a potential capability to reduce the occurrence of catastrophic shipping accidents simply by providing updated positional information that can perhaps minimize the effects of human error. Likewise, AIS systems can shorten the response time by agencies charged with responding to accidents by providing them near-real time situational information. When a ship goes aground, real-time availability of its positional information to response agencies can almost immediately alert them that response actions should be initiated. This is important, as studies have shown that response time to spills can be critical. Burning of oil spilled into the sea is considered to have the least effect on the marine environment, but if the oil is diluted more than about 50% with seawater, this option is no longer available. Dilution of oil spilled into the sea to levels at which burning is no longer possible can be typically considered to occur within a period of roughly eight hours or less, so any ability of AIS to hasten response time to catastrophic maritime oil spills in particular is critically important.

The Long Range Identification and Tracking of ships was established as an international system on 19 May 2006 by the IMO as resolution MSC.202(81). This resolution amends Chapter V of SOLAS, regulation 19-1, and binds all governments which have contracted to the IMO.

The LRIT regulation will apply to the following ship types engaged on international voyages:

- All passenger ships including high-speed craft
- Cargo ships, including high speed craft of 300 gross tonnage and above
- Mobile offshore drilling units

These ships must report their positions to their Flag Administration at least four times a day. Most vessels set their existing satellite communications systems to automatically make these reports. Other contracting governments may request information about vessels in which they have a legitimate interest under the regulation.

The LRIT system consists of the already installed (generally) shipborne satellite communications equipment, Communications Service Providers (CSPs), Application Service Providers (ASPs), LRIT Data Centers, the LRIT Data Distribution Plan and the International LRIT Data Exchange. Certain aspects of the performance of the LRIT system are reviewed or audited by the LRIT Coordinator acting on behalf of the IMO and its Contracting Governments.

This LRIT device is another device that can work in conjunction with the AIS system to provide better marine safety in the Alaska Arctic region.

3.8 Arctic Nautical Charts

To ensure sustainable marine transportation throughout the Arctic, updated nautical charts of appropriate scales are required. The updated NOAA nautical charts can greatly improve safety, environmental protection, and traffic efficiency. In addition, the charts will provide a more detailed shoreline, depths, hazards, aids to navigation and recommended routes throughout the region. Current charts data in much of the Arctic is out of date or does not exist. The US Coast Pilot indicates that the Bering Sea area is partially surveyed, so charts must not be relied upon too closely, especially near shore. The planning and review of new NOAA (Chart Division) charts and publications could include the vessel traffic schemes, anchorages, limitations for float on/off operations, report areas, and tide & current information.

NOAA's National Geodetic Survey (NGS) provides information for mapping and charting as well as other positioning information with the geodetic and geographic positioning services. NGS is also working with partners to add Continuously Operating Reference Stations (CORS) to fill some critical gaps in coverage for the Arctic region (Ref. [9]).

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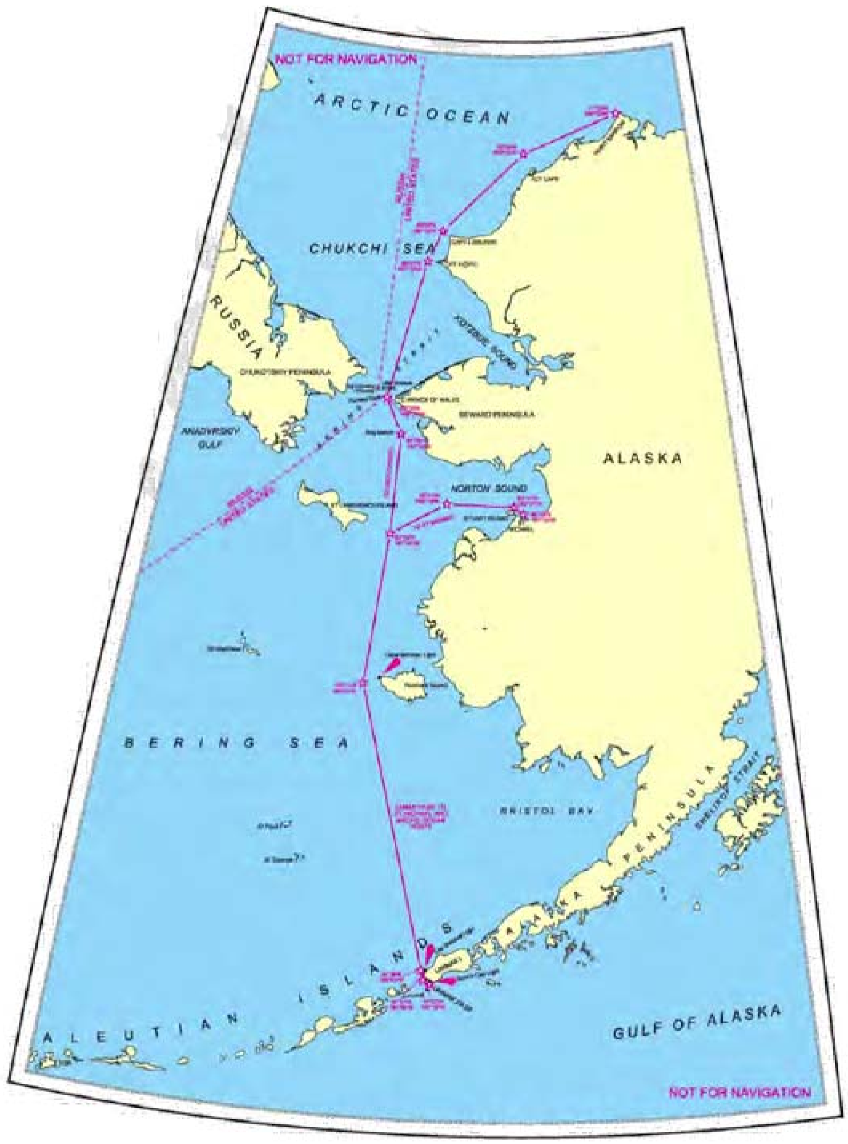

Figure 62: US Coast Pilot suggested route to the North Slope

3.9 Communications Control and Vessel Tracking

Marine traffic control in addition to a vessel tracking system could improve navigation safety and emergency response in the Alaska Arctic area. Vessel tracking through a combination of real-time vessel position updates via UHF communication links and Inmarsat links for vessels transiting and operating in the Arctic will address safety concerns and security concerns as well. A central location will receive all the information and will be able to interact with the vessels in case of necessity.

3.10 Vessel Operating Procedures

The vessel operating procedures contain procedures for that particular vessel, ranging from how to the deploy anchor to sailing in reduced visibility. The procedures should be considered as examples of good marine practice and guidelines on how to perform certain jobs. They are also good references for understanding the equipment on board and their correct usage. Familiarization with and understanding of these procedures are a must for all personnel on board. This will reduce the risk of damage or personal injury while performing regular tasks on board. Operating procedures will include but not limited to:

- Communications
- Ice navigation and navigation equipment
- Life saving appliances
- Fire fighting equipment
- Spill response
- Medical response
- Emergency maneuvering procedures
- Permits to work
- Ice management techniques
- Helicopter operations
- Fuel transfer
- Collision, grounding and explosion
- Emergency drills program
- Ice accretion and stability
- Weather forecast and ice forecast
- Required underkeel clearance
- Anchoring procedures
- Reduced visibility

3.11 Spill Response

Tugs and AHV involved in towing rigs to the North Slope will be fully compliant with MARPOL regulations. The vessel owners need to have their Shipboard Oil Pollution Emergency Plan ("SOPEP") plan organized and drills performed as per requirements. In addition, the IOPP (International Oil Pollution Prevention) certificate will have to be checked before commencing operations in Alaska.

The spill kits on-board include equipment to contain and recover on-board ship spills and also include containment equipment for over-the-side spills. The total capacity of diesel oil on the large AHVs could reach up to a few hundred thousand gallons. In case of collision or grounding, the amount of diesel spilled will be significant and will require support from shore to assist in the recovery and cleaning process.

The USCG, agents, and owners will be contacted as stipulated in the SOPEP, in case of a spill. A response coordination team will be directed by the USCG. The USCG does not have enough resources to be stationed along the North Slope Coast, so some local communities will be the first to respond if situation requires. Benefits of the AIS and tracking system would include keeping the response team informed of the progress of the platform tow, and allowing them to decide which community should be the first one to respond based on proximity.

3.12 Crew Training

The development of qualified and capable workforce for the specific technical challenges of the Arctic exploration requires training of personnel in harsh environment know-how, and creating workplace conditions adapted to a uniquely inhospitable environment. Personal who are conscious of safety, environmental and social responsibility considerations will respond better to emergency situations. Training should address:

- Evacuation of personnel
- Emergency rescue equipment
- Offshore protective equipment
- Helicopter and marine support
- Spill response equipment and techniques
- Waste management
- Monitoring and Control of emission and discharges
- Traditional lifestyle of indigenous population

3.13 Collision, Fire and Grounding

Procedures for collision, fire and grounding incidents are normally addressed in the vessel's operating procedures. It is important to keep the personnel trained through drills and safety talks. Training in wearing SCBA (Self Contained Breathing Apparatus), usage of fire fighting equipment, and care of fire fighting equipment in low temperatures are some of the topics to be covered.

It is necessary to point out again that the USCG has limited resources to assist in case of emergencies. In addition, the time needed to reach the vessels' position makes on-board personnel the first barrier to contain a fire, and/or to take action in a collision or grounding event.

3.14 Evacuation and Medical Emergencies

A typical crew will size be no more than 10 persons and medical support is minimal, to the extent that some medical equipment and medicines are kept on-board. In the event of a need for medical care, the Captain will need to initiate a radio/phone contact with a Physician who can provide a preliminary diagnosis of the injured or sick person.

A medical evacuation could take several hours to be accomplished. Kodiak is the USCG Air Base and helicopter operations could take a long time if weather conditions are unfavorable for take-off and refueling, etc. An emergency evacuation of personnel onboard a vessel will also require shore-support to arrange accommodations in hotels and/or medical centers. Medical assistance for treating acute disease is available only in the main cities of Alaska. Hospital facilities that are able to provide emergency medical care and are located along the Chukchi and Beaufort Seas are listed below:

Unalaska/ Dutch Harbor	Iliuliuk Family & Health Services and Oonalaska Wellness Center
Nome	Norton Sound Regional Hospital
Kotzuebue	Manilap Health Center
Barrow	Samuel Simmonds Memorial Hospital

The presence of a Medic on one of the vessels would be a good backup plan. The Medic can carry a larger medicine kit that is in compliance with international recommendations.

3.15 Fuel Supplies

Another important logistical issue is the refueling of tugs during the transportation of platforms, or positioning of platforms. Large tugs have a good capacity of marine diesel oil storage and in general their endurance ranges from 40 to 60 days under tow, depending on their power usage.

Considering a long-distance scenario of towing a drilling rig from Dutch Harbor to the Beaufort Sea, the tow can take up to 20 days with speeds of 3 – 3.5 knots. There should not be a need for refueling during a trip in ice-free season. But if tugs are to remain on location, they will need to be refueled. This will require planning in getting a supply vessel or barge to a nearby area where the tugs can proceed and safely refuel, or have a rotation system with a standby tug of similar characteristics that can rotate in location while the other tugs will proceed to refuel one at the time.

Nome has possibilities to receive and deliver fuel during ice-free season, although it is still a good distance away from site. Dutch Harbor has fuel capacity year around and the round trip to refuel will be around 10 days. The North Slope is a shallow water area and it will not be possible for these tugs to access Prudhoe Bay or Barrow in order to refuel. If weather conditions allow, a fuel barge can be moved to an area deep enough to perform fuel transfer operations. During ice-free season, there are companies in Alaska that regularly transport fuel and these become the potential providers for this service.

In the practical world, tugs performing continuous operations for more than 30 days will start to get lighter in draft. Many of them don’t have sufficient ballast capacity to keep the tug in deeper draft. This can make the tug less effective with high seas and deteriorating weather conditions. If possible, tugs will be preferably topped off on fuel every 30 days.

The endurance of the Anchor Handlers will vary depending on the amount of activities they are performing. In general, their fuel capacities will be around 60 days and the provisions stated above will also apply.

3.16 Stores and Food Supplies

Food supplies and stores are another component that requires good logistics and planning. In desolate and confined environments, comfort, food quality and quantity play important roles in keeping up personnel morale for the Arctic venture.

One of the issues that can be faced in Tugs and AHV is the restricted capacity of food storage, thus, planning ahead of time and having the knowledge of regional crew's food habits are very important. A 15 days' supply of perishables will be ideal, but canned food can replace this and a schedule of food orders and delivery will be necessary.

During ice free season, barges that carry fuel may have possibilities to carry food containers as well. The maximum time that food can be handled is approximately 30 days. Long life milk and canned fruits will need to be available on board since these items can last longer. If there are several rigs moving on location simultaneously, the food order could be significant and logistics to properly address those orders will be critical.

3.17 Drilling Equipment Storage

Drilling equipment for exploration and production will be used during the drilling season. Drilling pipes, mud, cement and chemicals will have to be stored as close as possible to the working site. This provides a challenge for local communities and ports that could eventually serve as bases for storage and supply.

The Port of Nome could be used for this particular task. It is quite challenging for the port authorities to be prepared to receive such a large amount of drilling equipment. Training will be needed to handle chemicals and marine equipment.

Another option will be the use of barges to carry the drilling equipment to close proximity of the drilling areas. This scheme will require an agreement among all involved parties and authorizations from the stakeholders. It needs to be established that this method will not add additional hazard. A careful individual risk analysis will need to be carried out addressing the weather conditions and risks that may emerge during the operation. Crane operations will be required, thus properly certified and trained personnel will need to be involved in this operation. A procedure for transferring and handling equipment will have to be produced and presented to all parties involved.

Special attention should be paid to the chemicals and their potential pollution. This will require a risk analysis study for loading, transportation, storage and handling.

3.18 Support Operations Assessment

Support operations assessment for transportation of platforms to the Chukchi Sea and Beaufort Sea should be performed in two main areas: logistics and emergency requirements.

Logistics will provide initial coordination and organization of the activities previous to the platforms' arrival in Alaska territory. The fleet will need to designate a "Logistics Coordinator" whose function will be to link and coordinate activities with port authorities, tug companies, and USCG. The Logistics Coordinator will also provide all documentation requirements to the Alaska state authorities. He or she will also verify that all the documentation related to the vessels' and rigs' inspection processes are completed and all involved authorities have reviewed and approved the mobilization initiation.

The Logistics Coordinator should keep a daily track report of the platforms' progress during the transportation phase and keep all parties informed of the expected day of arrival in Alaskan waters. Tugs and personnel required for the float-off stage will receive direct instructions to proceed through the Logistic Coordinator. The same procedure will be applied for the de-mobilization process.

Another function of the Logistic Coordinator will be to coordinate crew changes and find accommodations for the personnel arriving/departing job site. He or she will produce a contact list for emergency situations including hospitals, USCG, Med-Evac helicopters, and hotel facilities along the route of platform transportation. In addition, a very important task will be the coordination of transportation of food and supplies to the vessels in the field.

Emergency Requirement Support in this remote area is a very important issue due to the limited available resources. The main USCG air station is in Kodiak, and the USCG marine response will take a long time to reach the North Slope of Alaska. Along with platform transportation activities, increased shipping activities are expected in Arctic routes. The need for state and federal support and control in this area is identified during this study. The best way to reduce emergency risk at this stage is to strictly enforce compliance with rules, regulations, and guidelines (IMO, SOLAS, CFR, STCW95, and Class) through inspections before the Arctic transportation starts. It is of upmost importance to have:

- licensed, qualified, and trained personnel on Arctic navigation
- emergency procedures
- life safety training in cold waters
- pollution prevention and control procedures

Traffic control & navigation are also identified as weak points in the study. A couple of mitigating methods for reducing collision, possible fire, and pollution risks are discussed: (1) establishment of the vessel traffic systems in which vessel transiting the area are organized in traffic lanes; (2) implementation of AIS shore reception stations to provide real time situation and possible prevention of an incident. If an incident occurs, AIS assistance can provide valuable information of the vessels' actions in the investigation process.

For some marine operations where exposure to risk increases due to the nature of the job itself, prevention barriers can be implemented by requiring: redundancy in propulsion and steering and activity procedures where limiting parameters are established.

Evacuation procedures are also identified as an area of focus. An evacuation can happen at any time, so life saving appliances need to be quickly deployed and followed by a recovery of personnel by another vessel or rescue team. Evacuation training is important and the performance of personnel during the training is to be carefully evaluated and ranked.

The initial response for a spill is crucial to minimize the consequences of pollution. The MARPOL convention sets minimum requirements for on board containment & recovery and for containment when an overboard spill occurs. Consideration should be given to increasing containment and recovery equipment at least on some of the vessels participating in the venture, or to including a dedicated oil pollution response vessel.

At this stage, the emergency support can be limited and the main measures of reducing the risk of incidents/accidents of any kind will be from the crew members involved in the transportation of oil rigs. Training and clear understanding of everyone's role and responsibility on board will provide the initial step to prevent incidents and to limit the potential need for external support.

4. TASK 4: PERSONNEL AND SAFETY EQUIPMENT CONSIDERATIONS

4.1 General

When working in Arctic and Sub-arctic regions, the combination of cold, darkness and remoteness requires special consideration in terms of work organization, preparation and safety equipment. In particular, training in survival and first aid must be provided. Appropriate safety equipment should be provided and be made easily available at work.

The prevention of the physiopathological effect of exposure to cold must be considered from two points of view: the first concerns the physiopathological effects observed during general exposure to cold (that is, the entire body) and the second concerns those observed during local exposure to cold mainly affecting extremities (hands and feet). Preventive measures are the corrective aimed to reduce the incidence of the two main types of cold stress – accidental hypothermia and frostbite of extremities.

A twofold approach is required: Physiological method (adequate feeding and hydration development of adaptational mechanisms) and Technological measures (shelter, clothing). Ultimately all these methods aim to increase tolerance at both the general and local levels. Moreover it is essential that workers exposed to cold have the information and the understanding of such injuries needed to ensure effective prevention [23].

4.2 Objective

The objective of this task is to identify safety issues related to cold and offshore environments. While operating in harsh and isolated conditions during extended periods of time, certain considerations need to be addressed for the personnel involved including:

- Cold Weather Protective Clothing
- Isolation in a desolate Environment
- Cold Weather Training
- Medical Requirements
- Training, Facilities and Equipment onboard
- Rest and Relaxation Considerations

4.3 Physiological & Technical Methods for Preventing Cold Injury

Exposure to cold in the human being is accompanied by peripheral vasoconstriction which limits cutaneous heat loss and by metabolic heat production (essentially by means of the activity of shivering), which implies the necessity of food intake. The expenditure of energy required by all physical activity in the cold is increased on account of the difficulty of walking in snow or ice and frequent needs to deal with heavy equipment. Moreover, water loss may be considerable on account of the sweating associated with this physical activity. If this water loss is not compensated for, de-hydration may occur, increasing susceptibility to frostbite. The need for water in the cold is difficult to estimate. It depends on the individual's workload and the insulation of the clothing. Observation of the color of the urine, which must remain clear, gives a good indication of the course of fluid intake.

As regards caloric intake, it may be assumed that an increase of 25 to 50% in a cold climate, as compared to a temperate or hot climate, is necessary. As far as possible, meals must be taken hot and divided in breakfast and lunch in normal amounts. A supplement may be provided by hot soups, dry biscuits and cereal bars nibbled throughout the day, and by increasing the caloric intake at dinner. Excessive consumption of drinks containing caffeine could be harmful because this substance has a peripheral vasoconstrictor effect (increased risk of frostbite) and a diuretic effect [23].

Technical methods such as shelter & clothing for preventing cold injury are a basic element in the prevention of cold injury, and without their use, human beings would be incapable of living in cold climatic zones. The availability of shelters, the use of a source of heat, and the use of clothing permit people to live and work in very cold regions by creating a favorable ambient microclimate.

4.4 Cold Weather Protective Clothing

When working in Arctic weather, proper protective clothing must be worn for the safety of personnel and in particular to protect the head, face, neck, hands and feet from the cold. Since the feet get wet easily, both on the outside and from perspiration, they are more vulnerable to cold than other parts of the body. Footwear, therefore, is one of the most essential items of cold weather clothing.

Cold weather clothing must provide insulation and at the same time permit ventilation to prevent overheating. The most practical method of insulating the body is to use clothing in the layer method. Cotton garments don't provide much insulation from the cold. They are even less effective to keep the body warm when wet. Materials that hold quantities of motionless or dead air are the best insulators, e.g., wool and fur.

The influence of cold on the human body can result in general or local hypothermia (cooling and freezing). Hypothermia occurs when the body's temperature drops below 95 °F or 35°C. Local hypothermia causes damages to local tissues and needs proper medical care. General hypothermia is an injury by cold to the entire body, either by immersion or exposure. Prolonged exposure will result in death. Appropriate cold weather clothing helps to prevent hypothermia. Because water is a great conductor of heat, immersion suits can assist in prevention of hypothermia, if properly put on.

Air temperature alone can not give a complete indication of the potential body heat loss. The chilling effects produced by a combination of relatively mild temperatures and high winds are equivalent to sub-zero temperatures combined with light winds (Table 14), [76]. The importance of Personal Protective Equipment (PPE), heated shelters, appropriate work procedures and other actions should be considered when workers are outside.

WIND CHILL FACTOR											
	LOCAL TEMPERATURE										
	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
Wind Speed (km/h)	EQUIVALENT TEMPERATURE										
Calm	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
8	6	-7	-12	-17	-23	-28	-33	-38	-44	-49	-54
16	-8	-14	-20	-26	-32	-38	-44	-51	-56	-63	-68
24	-11	-18	-25	-32	-38	-48	-52	-58	-65	-72	-69
32	-14	-21	-28	-36	-42	-49	-57	-64	-71	-74	-78
40	-16	-23	-31	-38	-46	-53	-61	-68	-76	-83	-85
48	-17	-25	-32	-41	-48	-56	-63	-72	-73	-86	-90
56	-18	-26	-34	-42	-49	-57	-65	-73	-81	-88	-94
64	-19	-27	-35	-43	-51	-59	-66	-74	-82	-91	-97
72	-19	-28	-36	-43	-52	-59	-67	-74	-83	-91	-99
80	-20	-28	-38	-44	-53	-60	-68	-76	-84	-92	-100
	Little Danger for Properly clothed Persons		Considerable Danger			Very Great Danger					

Table 14: Danger from Freezing Exposed Flesh

Adequate supplies of protective clothing and thermal insulating materials should be provided in all ships operating in Arctic ice-covered waters for all persons on board at any time.

Personal Survival Kits (PSK) should be carried whenever a voyage is expected to encounter mean daily temperature below 0°C. Group Survival Kits (GSK) should be carried whenever a voyage is expected to encounter ice conditions which may prevent lowering and operating of survival craft. The design of the escape passage needs to take into consideration that the personnel might wear bulky polar clothing.

The contents of the personal survival kit and group survival kit are specified in IMO guidelines (Ref. [32]). Viking Life-Safe Equipment is among many companies which offer a full range of safety products (Ref. [85]) specially designed for frozen water and harsh Arctic environment, complying with IMO standards.

PSK and GSK as advertised in the Viking Offshore Safety Catalogue are shown in Figure 63 and Figure 64.

MSC recommended
Personal Survival Kit (PSK)

- According to IMO guideline MSC/Circ. 1056
- Consist of: Head protection, Neck and face protection, hand protection (mits and gloves), foot protection (socks and boots), insulation suit, immersion suit, thermal underwear, handwarmers, sunglasses, survival candle, matches, whistle, drinking mug, pen knife, handbook (arctic survival) carrying bag

ITEM NO.: 1035354

Figure 63: PSK as shown in Viking offshore Safety Catalogue.

MSC recommended
Group Survival Kit (GSK)

- According to IMO guideline MSC/Circ. 1056
- Consist of: Tent, air mattresses, sleeping bags, stove, stove fuel, fuel paste, matches, pan, fortified health drink, flashlights, candle and holder, snow shovel, tarpaulin, foot protection - booties, container (dry bag)
- Further spare personal equipment is included according to ontents of GSK

ITEM NO.: 1035516

Figure 64: GSK as shown in Viking offshore Safety Catalogue

In summary, the principles of keeping warm in Arctic environment can be abbreviated by the catch-word "COLDER" [76].

- C-Keep clothing **clean**. This principle is always important for sanitation and comfort. In winter, it is also important from the standpoint of warmth. Clothes matted with dirt and grease lose much of their insulation value. Heat can escape more easily from the body through the clothing’s crushed or filled up air pockets.
- O-Avoid **overheating**. When you get too hot, you sweat and your clothing absorbs the moisture. This affects your warmth in two ways: dampness decreases the insulation quality of clothing, and as sweat evaporates, your body cools. Adjust your clothing so that you do not sweat. Do this by partially opening your parka or jacket, by removing an inner layer of clothing, by removing heavy outer mittens, or by throwing back your parka hood or changing to lighter headgear. The head and hands act as efficient heat dissipaters when overheated.

- L-Wear your clothing loose and in **layers**. Wearing tight clothing and footgear restricts blood circulation and invites cold injury. It also decreases the volume of air trapped between the layers, reducing its insulating value. Several layers of lightweight clothing are better than one equally thick layer of clothing, because the layers have dead airspace between them. The dead airspace provides extra insulation. Also, layers of clothing allow you to take off or add clothing layers to prevent excessive sweating or to increase warmth.
- D-Keep clothing **dry**. In cold temperatures, your inner layers of clothing can become wet from sweat and your outer layer, if not water repellent, can become wet from snow and frost melted by body heat. Wear water repellent outer clothing, if available. It will shed most of the water collected from melting snow and frost. Before entering a heated shelter, brush off the snow and frost. Despite the precautions you take, there will be times when you cannot keep from getting wet. At such times, drying your clothing may become a major problem. On the march, hang your damp mittens and socks on your rucksack. Sometimes in freezing temperatures, the wind and sun will dry this clothing. You can also place damp socks or mittens, unfolded, near your body so that your body heat can dry them. In a campsite, hang damp clothing inside the shelter near the top, using drying lines or improvised racks. You may even be able to dry each item by holding it before an open fire. Dry leather items slowly. If no other means are available for drying your boots, put them between your sleeping bag shell and liner. Your body heat will help to dry the leather.
- E-**E**xamine your clothes for worn areas, tears, and cleanliness.
- R-**R**epair your clothes early before tears and holes become too large to patch.

4.5 Isolation in a Desolate Environment

One occupational hazard associated with offshore personnel working in desolated areas could be physiological problems that may result from physical isolation and the extended work periods required in this industry. Some workers cannot handle the stress of working offshore at a demanding pace for extended periods of time in relative confinement and subject to harsh weather conditions. The signs of stress in workers include unusual irritability, other signs of mental distress, and excessive smoking. Problems of insomnia, which may be aggravated by high levels of vibration and noise, have been reported by workers in the offshore industry. Disturbance of nocturnal sleep leads to daytime fatigue, and sleepiness impairs motivation and vigilance, perhaps affecting safety performance at work. Individuals required to work a night shift or an early morning shift suffer from sleep disturbance in that the quantity and quality of the sleep differs as a consequence of shift working. Daytime sleep is more fragile and more unstable than nocturnal sleep. Seasickness due to exposure to severe weather conditions is another contributing factor to the stress and irritability. Other consequences of offshore work stress could lead to:

- physical and/or psychological ill-health
- premature death
- forced early retirement
- absenteeism
- high labor-turnover
- poor job performance

- poor productivity
- unsatisfactory employee relations
- job dissatisfaction
- increased rate of accidents
- alcohol problems
- drug abuse
- increased insurance premiums
- cumulative stress trauma litigation

Productivity can be seriously affected and morale brought down if we fail to recognize the effect of the isolation in desolated working conditions. The offshore environment must provide satisfying physical conditions for both working and living because the workforce is confined to one location for an extended period of time without respite. A clean and orderly place of work and living is important for both safety and hygiene reasons, and has implications for the morale of the workforce, especially in an environment where the work situation is acknowledged as hazardous.

According to Ref. [80], the living environment for the offshore personnel should provide suitable conditions in which the employee can relax and recuperate from the demands of the job, and which includes:

- the ability to get adequate sleep; that is, undisturbed sleep of a quality and quantity necessary to restore physical and mental equilibrium;
- a balanced and adequate diet;
- leisure and recreational activities in reasonable amounts to satisfy the varying needs for exercise, entertainment, maintenance of links with outside society (communication links, news, etc.), and the opportunity to maintain some interests and hobbies. The importance of exercise and physical fitness as a method of stress control cannot be overstated. It has a positive impact on both physical and psychological well-being and reported organizational benefits, which include reduced sickness absence and job turnover and stronger commitment to the organization. For these reasons, the provision of exercise facilities offshore is highly recommended. The introduction of a health and fitness club would also help to create a more supportive environment and would encourage offshore personnel to use the facilities provided. Education about the links between stress and ill-health and the role of fitness and exercise in reducing the risk of cardiovascular diseases should be included in this health care program.
- The opportunity to live in pleasant and comfortable surroundings that are conducive to rest and relaxation.
- A living environment which is perceived as comfortable, hygienic and satisfying.

4.6 Cold Weather Training

One of the most difficult survival situations is a cold weather scenario. Cold weather is an adversary that can be very dangerous. Every time you venture into the cold, you are pitting yourself against the elements. With a little knowledge of the environment, proper plans, and appropriate equipment, you can overcome the elements. As you remove one or more of these factors, survival becomes increasingly difficult. Cold weather is highly variable. Prepare yourself to adapt to blizzard conditions even during sunny and clear weather.

Cold is a far greater threat to survival than it appears. It decreases your ability to think and weakens your will to do anything except to get warm. Cold is an insidious enemy; as it numbs the mind and body and subdues the will to survive.

For the reasons mentioned above, safe operation in Arctic conditions requires specific attention to human factors, including training and operational procedures.

Training is to address means to prevent and treat potential cold weather-related maladies of crew, including hypothermia and frostbite. Certifications are to be recorded, where applicable, and the records updated.

According to the ABS Guide for Vessels operating in low temperature environments, the training is to cover at least the following subject matter areas:

- Ice recognition
- Safe navigation in ice
- Conduct during escorted operations
- Instructions for drills and emergency response
- Cold weather-related maladies

Cold weather training may include several or all of the topics listed below:

- Preparing for Cold Weather Living
- Cold Weather Psychology & Physiology
- Energy Use, Loss & Conservation
- Environmental Hazards & Injuries
- Working in Sub-Zero Temperatures
- Clothing & Equipment
- Survival Kits & Equipment
- Sheltercraft, Firecraft & Signaling
- Search & Rescue
- Travel Considerations & Techniques

4.7 Medical Requirements

The offshore work site in the Arctic exists in a remote and potentially hostile environment. Adverse weather may cause delays in medical evacuation, and convert a minor medical problem into a major emergency.

The offshore worker will need a physical and fitness assessment by a competent physician. The medical assessment of a prospective offshore worker relates to the particular work factors and environment of the work site. It should be noted that emergency illness puts others, for example rescuers and co-workers, at risk in the event of medical evacuation, particularly in adverse conditions.

The examining physician should have a thorough knowledge of the factors affecting offshore workers, which include, but are not limited to [1]:

- Physical exertion (climbing walkways, stairs, work tasks, etc.) and exposure to heights
- Shift work with long hours, for example twelve-hour shifts, and changes in routine
- Absence from home for prolonged periods, up to three weeks
- Adverse weather
- Helicopter and boat travel, possible basket transfer (crane-suspended transport from installation to vessel along side)
- Smoke, heat and cold exposure
- In-water exercises including exit from and entry into water
- Confined, close community
- Limited privacy
- Peer group pressure
- Abstention from alcohol.

The offshore work site is remote and has unique characteristics that set it apart from more familiar shore-based work environments.

A set of similar rules for the physicians to consider when assessing offshore workers are included in Reference [13]:

- The site may be remote from shore-based medical services.
- Adverse weather conditions may prohibit or delay medical access to or evacuation from the offshore location.
- The physical structure of an offshore installation, with numerous stairways and ladders, requires a reasonable degree of physical stamina and agility.
- Emergency situations, including abandonment, may involve the individual being exposed to extremes of physical exertion, to thermal/smoke exposure, as well as cold water immersion and severe sea states.
- All offshore personnel must undergo training in fire fighting, sea survival, and helicopter escape training, which simulate these situations.
- The physical and mental health of an individual must not cause an additional hazard, whether to the individual or to his or her colleagues in an emergency situation (for example, fear of flying, fear of confined, closed communities, severe seasickness).

Episodes of ill-health or disability may prevent the individual from working offshore, either temporarily or permanently, if the condition places the affected individual, or his or her colleagues, at risk. As a result, designated offshore personnel are in a special medical category and a medical assessment for fitness to work offshore should be performed.

4.8 Training, Facilities and Equipment on board

Personnel working on tugs should have Basic First Aid and Advanced First Aid training as part of their requirement for a license (STCW95). The total crew number on a tug will normally not be more than 10, and it is not required to have a medic or doctor on board. A sick bay on these units should be able to accommodate one or two sick persons at the most and the medical equipment and drugs are suitable to provide a limited primary care for minor ailments.

Exploration platforms' medical situation is different. They have a trained medic or paramedic and their medical facilities are larger with more equipment and medicines available.

In any case both situations are limited and for a major accident the crew member will need to be evacuated. Evacuation of an ill person in remote areas will take time and create an increased risk for accidents involving personnel transfers and/or helicopter operations. Procedures, personnel training, and frequent drills will lessen the risk of an accident and build confidence in the crew.

A medical emergency response plan will need to be developed for this particular region. This plan should define the procedure to follow in case of a medical emergency. If a medical emergency occurs in a tug while under tow, this procedure should address the possibility of transferring the sick person to a rig where a medic in consultation with an offshore physician may be able to offer assistance. Also, a medevac situation will work more efficiently on a rig with a heliport where the unit can land, thereby avoiding the basket lifting procedure.

A list of hospital contacts along the route and types of emergencies they can handle should be prepared and made available onboard.

4.9 Rest and Relaxation Consideration

A study on offshore workers in the Norwegian sector of the North Sea found that sleep problems were indicative of the strains of the offshore environment. Personnel reported that they wake up tired and/or wake up and have trouble going back to sleep (Ref. [80]).

Disturbance of nocturnal sleep leads to daytime fatigue, and sleepiness impairs motivation and vigilance, perhaps affecting safety performance at work. Individuals required to work a night shift or an early morning shift suffer from sleep disturbance in that the quantity and quality of the sleep differs as a consequence of shiftworking. Daytime sleep is more fragile and more unstable than nocturnal sleep. Although the night shiftworker may be able to take catnaps to catch up on sleep loss, a sleep debt accumulates over a seven-day period, to the extent that the worker has effectively lost the equivalent of at least one night's sleep.

Offshore workers tended to report less somatic anxiety than onshore workers (somatic anxiety is associated with tiredness, fatigue and sleep disturbance). However, getting insufficient sleep while offshore was reported as a high stress situation. Work-shift patterns and length of tour as a source of stress offshore requires more detailed examination before guidelines for the industry can be set down. It has not been proved that the work pattern for offshore workers is an independent source of pressure, or the degree to which it exacerbates other stressors in the environment; for example, irritability with the constant company offshore, tolerance of noise and physical conditions.

The ability to get adequate sleep, i.e., undisturbed sleep of sufficient quality and quantity is necessary to restore physical and mental equilibrium.

As mentioned in Section 4.5, leisure and recreational activities help offshore workers to relax and recuperate from the demanding job. The importance of exercise and physical fitness as a method of stress control cannot be overstated. It has a positive impact on both physical and psychological well-being and reported organizational benefits. For these reasons, the provision of exercise facilities offshore is highly recommended.

IMO in conjunction with ILO (International Labor Organization) developed the guidelines under ILO Convention No. 180 (Seafarers Hours of Work and the Manning of Ships Convention, [35]) and IMO STCW 95 convention. They provide a standardized table showing shipboard working arrangements, a standard format for records of seafarer's daily hours of work and rest, and guidelines for monitoring compliance.

4.10 Personnel and Safety Equipment Considerations

Working in the Arctic region requires personnel to be aware of safety issues related to the specific cold environment. Cold weather awareness and training for offshore personnel is regarded as imperative in order to reduce risk and to provide conscious responsibility.

Protective clothing for the Arctic environment should be provided. It is the responsibility of the personnel to take proper care and to maintain good conditions of the protective clothing.

Proper balance in work activities and leisure will maintain productivity to acceptable levels. Adequate arrangements for onboard recreation areas and communication facilities will have a positive effect on diminishing stress levels.

The offshore worker will need a physical and fitness assessment. Emergency response organization should be clearly defined in the response procedures. Tugs and AHV should have a bridging document to address the offshore transfer of sick or ill personnel to the platform.

Rest and relaxation hours will be in accordance with IMO/ILO guidelines in order to assure proper resting of all offshore personnel.

5. TASK 5: HELICOPTER OPERATIONS REVIEW

5.1 General

Helicopter operations play a key role in the offshore industry; they have been part of the oil and gas industry for decades and as rigs have moved further offshore crew changes have increasingly been conducted by air rather than boat. Helicopters are also a fundamental component to deliver spare parts, and in medical evacuations. They also provide rapid response to time sensitive events, like safety related tasks, pollution countermeasures and search and rescue. Helicopters can be used to conduct spring ice surveys to determine how fast ice is clearing.

The USCG helicopters mission is to ensure the safety of marine traffic, protect maritime trade and commerce, protect the marine environment and save lives. They are a key element in the USCG readiness profile and response capability. USCG D17 has air stations in Kodiak and Sitka with a complement of HH-65B Dolphin Helicopters that can be deployed from the 378' High Endurance Cutters, and the HH-60J Jayhawk Helicopters for monitoring US and international fishing fleets. The Alaska marine zones covered by USCG is shown in Figure 65.

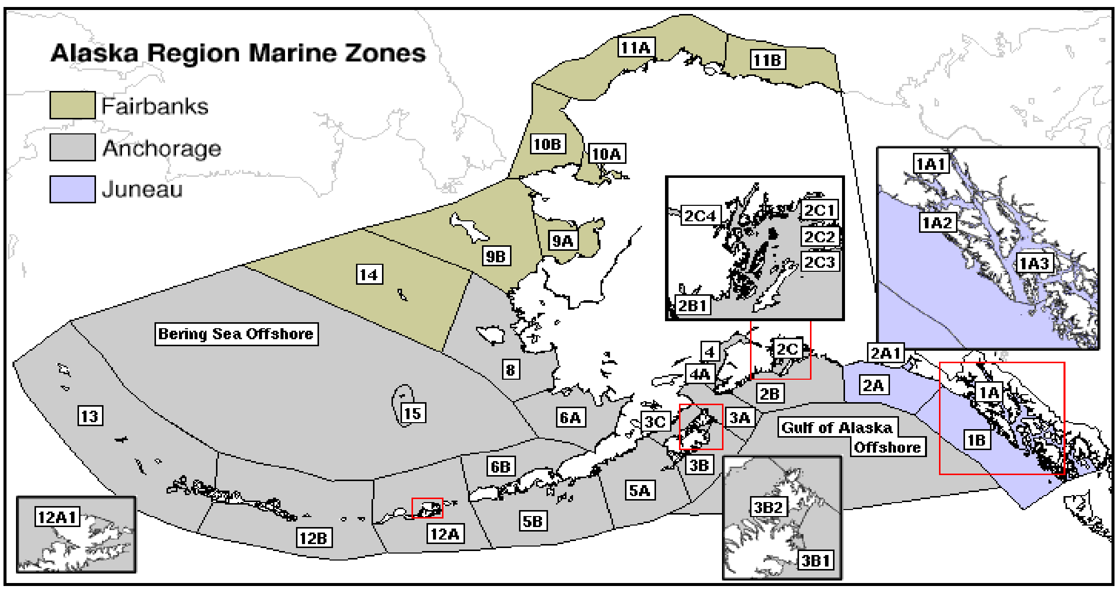

Figure 65: Alaska Marine Zones Covered by USCG

The HC-130H and HH-60J aircraft serve as the primary SAR response assets in the entire Alaska marine zones.

5.2 Objective

The objective of this task is to perform a brief review of the specific existing requirements for helicopter operations in ice and Arctic conditions. Detailed plans for helicopter operations are to be prepared and analyzed further by the parties involved in the transportation. The requirements for the following topics are reviewed in this Section:

- Improved in-flight de-icing system
- Ice accumulation in landing areas
- Consideration to Automatic Landing System to be fitted due to zero visibility for extended period of time.

5.3 Helicopters Equipment (De-icing Systems)

When working in cold weather, preflight de-icing of helicopters is critical for readiness. Helicopters unsheltered by hangars are subject to frost, snow, freezing drizzle, and freezing rain that can cause icing of rotor blades and fuselages, rendering them un-flyable until cleaned. Conventional glycol-based de-icing fluids used for commercial fixed-wing aircraft are harmful to the environment, expensive, and potentially damaging to helicopter rotor head components. Composite blades and fuselage components are susceptible to damage from de-icing operations because physical impact, scraping, high temperatures, and rapid thermal cycling may cause de-lamination. Manual de-icing methods requiring up to four hours to prepare a single aircraft for flight, and the inefficiency of these methods, justify the need for improved helicopter preflight de-icing methods [37].

Infrared systems optimize the ability to melt ice and snow from aircraft, and to prevent overheating of composite materials.

Work has been done to characterize in-flight icing conditions and develop techniques to remotely sense icing. Because icing cloud characteristics affect engine performance, ice shape, and iced airfoil aerodynamics, methods have been developed to characterize the spatial fluctuation of icing cloud liquid water. Technology is used for remotely detecting icing conditions ahead of aircraft using radar and microwave radiometry. Icing remote sensing systems reduce the frequency of icing mishaps and accidents, potentially saving millions of dollars and tens of lives annually.

5.4 Landing Areas

IMO Resolution A.855(20) recommendations in Helicopter Landing Areas [36] specify that landing areas should be as large as possible and set out to provide safe access for helicopters from the ship's side. Due account must be taken of possible helicopter slippage and wind and ship movement. Where the boundary of the clear zone is close to or in line with the ship's side, and where the height of fixed obstructions so permits, helicopter safety will be improved by extending the clear and maneuvering zones to the ship's side symmetrically, thereby widening the approach to the landing area. This extended landing area at the ship's side is therefore the preferred operating area.

Dimensions of Landing Area

In establishing a landing area, it is essential to ensure a safe correlation between -

1. the dimensions of the aiming circle, clear zone and maneuvering zone and the maximum permitted height of obstructions in these zones; and
2. the sizes of helicopters expected to use the facility.

In particular, the clear zone of the landing area should be as large as practicable. Its diameter D should be not less than the overall length of a helicopter (with its rotors turning) which may use it.

Other dimensions of the landing area should be in proportion to the diameter of the clear zone, as illustrated in Figure 66.

Aiming Circle (Touch down zone)

The aiming circle is an area concentric to the centre of the clear zone and has a diameter half that of the clear zone itself. A circle of some 10m diameter is required for the aiming circle of a landing area suitable for the large helicopters in normal marine use. The circle should accommodate with safety the landing gear of the helicopters for which it is intended and should therefore, if possible, be completely obstruction-free. If there are unavoidable obstructions, they should have rounded edges capable of being traversed without damaging the landing gear of a helicopter, and should be no higher than 0.1m.

The aiming circle should be completely covered with a matt anti-slip surface painted in a dark non-reflecting color which contrasts with the other deck surfaces. Its circumference should be marked with a yellow line 0.2m wide, with the diameter in meters of the aiming circle clearly indicated in white figures at four points in the circumference line as shown in Figure 66.

The letter 'H' should be painted at the centre of the aiming circle in 0.4m wide white lines forming a letter of dimensions 3.6 x 1.8m.

Clear Zone

The diameter of the clear zone will depend upon the available landing area. The clear zone should however be as large as practicable recognizing that its diameter D must be greater than the overall length, with rotors turning, of a helicopter able to use the landing area (d). Where the landing area is at the ship's side, safe helicopter access will be enhanced by widening, where possible, the boundaries of the obstacle-free clear zone at the ship's side to a dimension of at least 1.5D (see Figure 66). The circumference of the clear zone should be marked by a yellow line of 0.2m width, with the diameter D in meters indicated in white figures at points in the circumference line as shown in Figure 66.

There should be no fixed obstructions in the clear zone higher than 0.25m.

Maneuvering Zone

The maneuvering zone of the landing area extends the area in which a helicopter may maneuver with safety by enlarging, to a diameter of at least 1.3D, the area over which the rotors of the helicopter may overhang without danger from high obstructions. When the landing area is at the ship's side, safe helicopter access will be enhanced by widening, where possible, the boundaries of the obstruction-free maneuvering zone at the ship's side to a dimension of at least 2D (see Figure 66).

If it is impossible to remove all obstructions from the maneuvering zone, a graduated increase in the permitted height of obstructions, from 0.25m at the circumference of the clear zone to a maximum of 1.25m at the circumference of the maneuvering zone, is acceptable. However, such height above 0.25m should not exceed a ratio of one to two in relation to the horizontal distance of the obstruction from the edge of the clear zone (see Figure 67). So, for example, an obstruction of 1m in height (0.75m more than the maximum obstruction height in the clear zone) should be at least 1.5m outside the circumference of the clear zone. All obstructions in the maneuvering zone should be clearly marked in contrasting colors.

To assist the helicopter pilot in his positioning, the circumference of the maneuvering zone should be indicated by a broken yellow line of 0.2m width (see Figure 66)

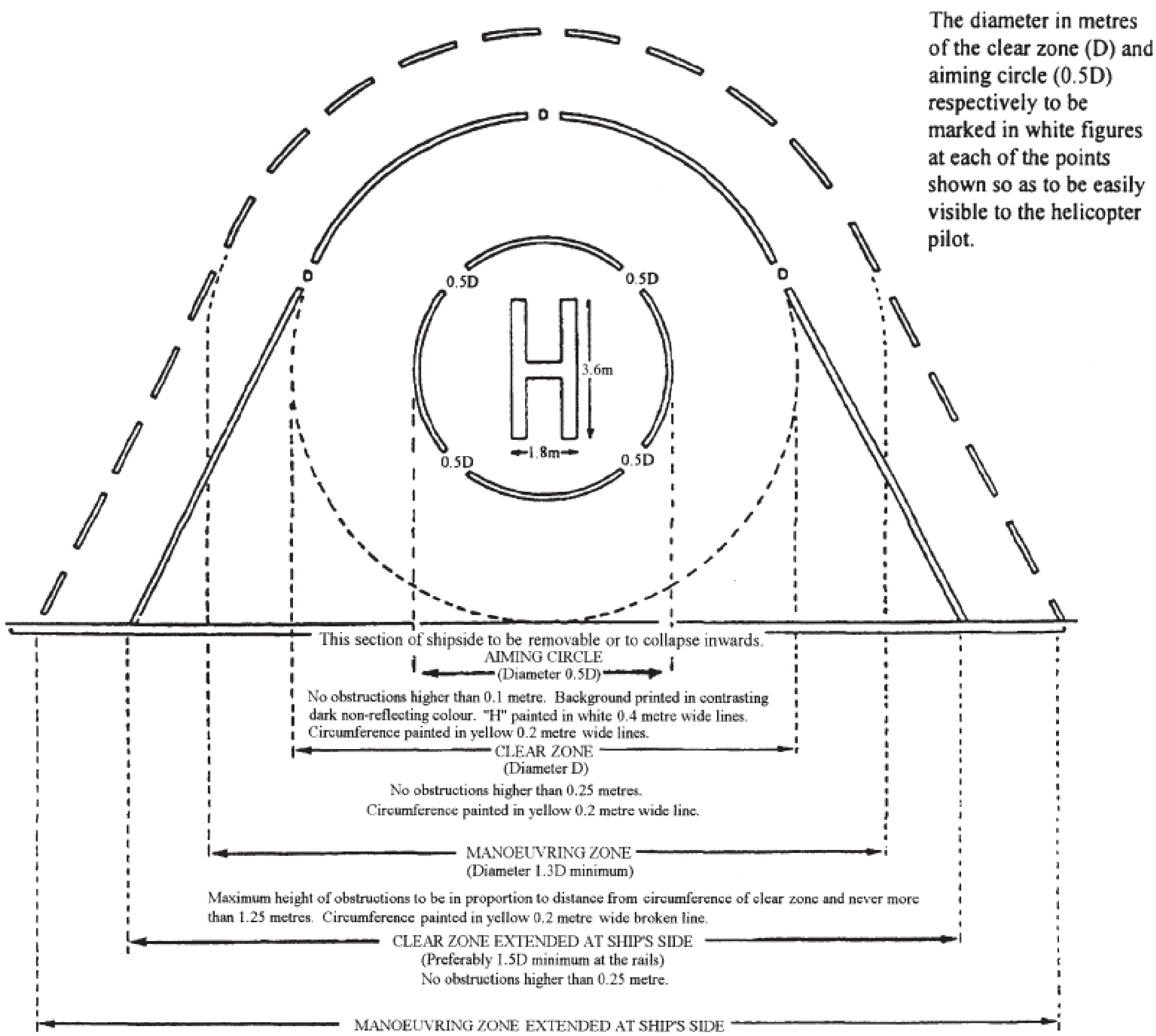

Figure 66: Landing Area at Ship's Side

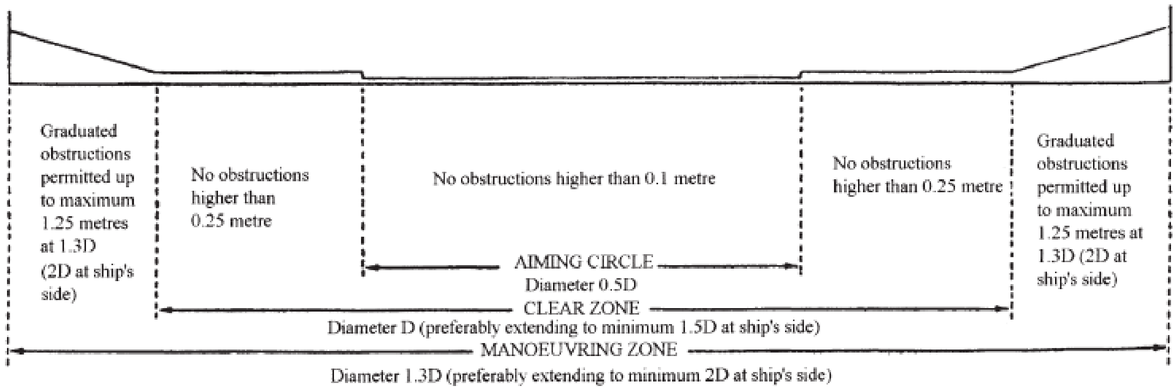

Figure 67: Landing Area-permitted Height of Obstructions (Elevation)

Fire Fighting Appliances and Rescue Equipment

Where helicopters land or conduct winching operations on an occasional or emergency basis on ships with helicopter landing areas, equipment fitted in accordance with Chapter II-2 of SOLAS 74, as amended, may be used. This equipment should be made readily available in close proximity to the landing or winching areas during helicopter operations, and should include the following -

1. at least two dry powder extinguishers having a total capacity of not less than 45 kg;
2. carbon dioxide extinguishers of a total capacity of not less than 18 kg or equivalent;
3. a suitable foam application system consisting of monitors or foam making branch pipes capable of delivering foam to all parts of the helicopter landing area;
4. at least two nozzles of an approved dual-purpose type (jet/spray) and hoses of sufficient length to reach any part of the helicopter landing area;
5. two sets of fireman’s outfits; and
6. in addition, at least the following equipment –
    - adjustable wrench
    - blanket, (fire resistant);
    - cutters, bolt 60 cm;
    - hook, grab or salving;
    - hacksaw, heavy duty complete with 6 spare blades;
    - ladder;
    - life line 5 mm diameter x 15m in length;
    - pliers, side cutting;
    - set of assorted screwdrivers; and
    - harness knife complete with sheath

Landing surfaces must be firm enough to prevent helicopters from bogging down, creating excessive dust, or blowing snow. Rotor wash on dirt, sand, or snow-covered surfaces may obscure the ground and should be avoided, especially at night. Remove from landing points debris that could damage the rotor blades or turbine engine. Means of removing Ice accumulation from the

Helipad/Helideck must be operational and a visual inspection should be carried out before giving a green light for landing.

5.5 Automatic Landing System

The most demanding task for a helicopter pilot is the landing of the aircraft in foggy conditions and in a moving environment. In an isolated environment where life can depend on an emergency rescue, the Automatic Landing System can be a determining factor on whether to safely perform the maneuvering or to abort until conditions improve. This system can not guarantee a perfect landing. It is to ensure that the pilot and aircraft have the best and safest approach and descent.

Automatic Landing System is system that permits aircraft to be landed automatically without any input from the pilot, and is the means for guiding and controlling aircraft from an initial approach altitude to a point where safe contact is made with the landing surface. Such systems differ from low-approach systems in three major respects [45]:

1. They furnish not only guidance but control of the aircraft as well.
2. They furnish information on the aircraft's position with respect to the terrain below it, and the rate at which the landing surface is being approached.
3. They do not require the pilot to assume manual control near the ground.

Two automatic landing systems have been developed. One, a radar-beam type, detects the position and rate of change in position of the landing aircraft by means of a radar beam emitted from a ground derived-control complex. The other, a fixed-beam type, derives position and rate of change in position by instrumentation within the landing aircraft, but it makes use of Instrument Landing System (ILS) type equipment on the ground. In the aircraft are accelerometers (which may be part of an inertial navigation system) and a radio altimeter. Essential to both systems is an autopilot in the aircraft, commanded by a computer on the ground in the radar-beam system and by a computer in the aircraft for the fixed-beam system.

6. TASK 6: DIESEL SPILL RISK ASSESSMENT

6.1 General

Environmental damage in the Arctic from oil spills is usually more severe and lasts longer than in more temperate climates (AMAP, 1998). Most oil spills contain either of two types of oil: diesel fuel and crude oil. Both diesel and crude oil are mixtures of different hydrogen and carbon based chemicals normally called hydrocarbons. Because they are mixtures, different oils can be harmful in different ways.

The International Standards Organization (ISO) and the American Society for Testing and Materials (ASTM) have published standard specifications for marine fuels. Table 15 is a summary of Marine Diesel Oil (MDO) physical properties. Fuel oil viscosities are specified at elevated temperatures. For MDOs, the low viscosities are not likely to increase significantly at the lower temperatures.

Property	Range	Median
Density at 15 °C (g/mL)	0.839 to 0.903	0.863
Viscosity at 40 °C (cSt)	2.9 to 11	5.2
Flash point (°C)	71 to 116	104
Pour point (°C)	-23 to 5	-1

Table 15: Physical Properties of Marine Diesel Oils

Lighter oils such as diesel fuel have less impact on birds, mammals and shorelines than heavier fuels, which are more persistent and viscous oils. Spills of diesel and crude oil, however, can have higher impacts on marine life such as fish, shellfish and plankton than equal volume spills of heavy fuels or gasoline. This is due to the fact that heavy fuels are not easily carried in the water column, and gasoline is much more volatile and so results in lower water column toxicity than the light fuels and crude oils (Ref. [58]).

Diesel fuel is highly toxic to plants. Even after decades have passed, tundra vegetation has been unable to recover from diesel spills. An earlier study of diesel spills in Alaska's arctic showed that over 20 years later there were still substantial toxic hydrocarbons in the soil and little vegetation recovery (Ref. [86]).

Global climate change may lead to year-round marine transport via the Northwest Passage and also the expansion of offshore oil and gas exploration in the Arctic region. The anticipated growth of marine activities in the Arctic indicates that there will be potential impacts on the marine environment due to increased marine oil spills. There have been steady developments in technologies to prevent the spill of oil and strengthened screening on ships entering Arctic waters to enhance the safe and efficient movement of maritime transportation. Despite all efforts, accidental spills will occur in the future. Recovering spilled marine oil in Arctic waters is difficult due to the presence of ice and the long hours of darkness in winters. Therefore, it is prudent to assess the risks proactively, review the risk mitigation plan and evaluate the oil response tools and corrective actions ahead of any projected marine operations.

Our subtasks for Task 6 are to gather information on diesel spill risk assessment during the transportation operations of rigs and equipment to the Arctic region. The subtasks include:

- Oil and Hazardous Substance Spills by Alaska Subarea
- Ship Based Environmental Impact
- Risk Assessment
- Geographic Response Strategies for Alaska
- Spill response tools
- Mitigation and Response Measures

6.2 Objective

The objective of Task 6 of the Arctic Offshore Technology Assessment is to provide an insight into the diesel spill risk assessment during the transportation stage in the Arctic regions and evaluate the risk management plan and the corrective actions that will necessarily have to be taken.

6.3 Summary of Oil and Hazardous Substance Spills by Alaska Subarea

In order to assess the risk of a diesel spill and the response measures, it is necessary to first review the past spills in Alaska subareas and summarize the lessons learned.

According to the Alaska Department of Environmental Conservation records (ADEC, Ref. [79]), the top subarea for oil spills is the North Slope region. Diesel is the type of fuel most commonly spilled in the State of Alaska. Oil Exploration and Production were responsible for more than 1.89 million gallons of hazardous substance spilled (40% of the total volume), while spills from vessels total 549,176 gallons and contributed to 13% of the total volume of fuel spilled in the State (Table 16).

Diesel spill incidents are typically caused by infrastructure failure, human errors during fuel transfer or natural hazards. Between 1995 and 2005, there were 7698 diesel spills, which accounted for over 1 million gallons of diesel oil.

Top 5 Subareas

Subarea	Spills	Gallons
North Slope	4,481	1,916,958
Northwest Arctic	1,483	1,105,220
Interior Alaska	4,179	782,403
Cook Inlet	5,819	622,231
Aleutian	683	469,439

Top 5 Products

Product	Spills	Gallons
Diesel	7,698	1,128,729
Seawater	143	1,067,912
Other	1,394	657,633
Crude	853	457,738
Produced Water	336	420,125

Top 5 Causes

Cause	Spills	Gallons
Leak	3,360	1,219,158
Human Error	1,667	606,681
Other	1,290	482,077
Line Failure	3,036	462,331
Equipment Failure	1,453	378,286

Top 5 Facility Types

Facility Type	Spills	Gallons
Oil Production	3,918	1,885,170
Mining Operation	1,854	1,070,151
Vessel	1,799	549,176
Pipeline	732	506,337
Noncrude Terminal	857	261,642

Table 16: Top Five Oil Spills in Facility Types, Product, Causes and Subareas in the State of Alaska (1995-2005).

For this study, the spills released from vessels in the Aleutian Islands, Bristol Bay, Western Alaska, Northwest Arctic, and North Slope regions are of special interests.

6.3.1 North Slope Region

The North Slope of Alaska is bordered to the north by the Chukchi and Beaufort Seas and to the south by the Brooks Mountain Range. The outer continental shelf of the Beaufort and Chukchi Seas is one of the most promising undeveloped oil and gas provinces in the United States. According to US Department of Energy, the North Slope could yield up to 36 billion barrels of oil and 137 trillion cubic feet of natural gas though 2050 using optimistic assumptions.

The North Slope region encompasses a vast area that has relatively limited risks in some respects, but elevated risks when considering certain factors. Approximately 93% of the reported spills in the North Slope subarea were from Transportation facilities as shown Figure 68. This category includes pipelines that carry crude oil and other substances to the production facilities and on to the Trans Alaska Pipeline System (Ref. [79]).

Structural/Mechanical (66%) was the leading cause of most spills in the North Slope subarea, and also accounted for 82% of the total volume spilled. 49% of the total number of spills involved noncrude oil, followed by hazardous substances (31%) and crude oil (12%). In terms of total volume, process water represented 75% of the total volume spilled, followed by hazardous substances (13%), noncrude oil (7%), and crude oil (5%).

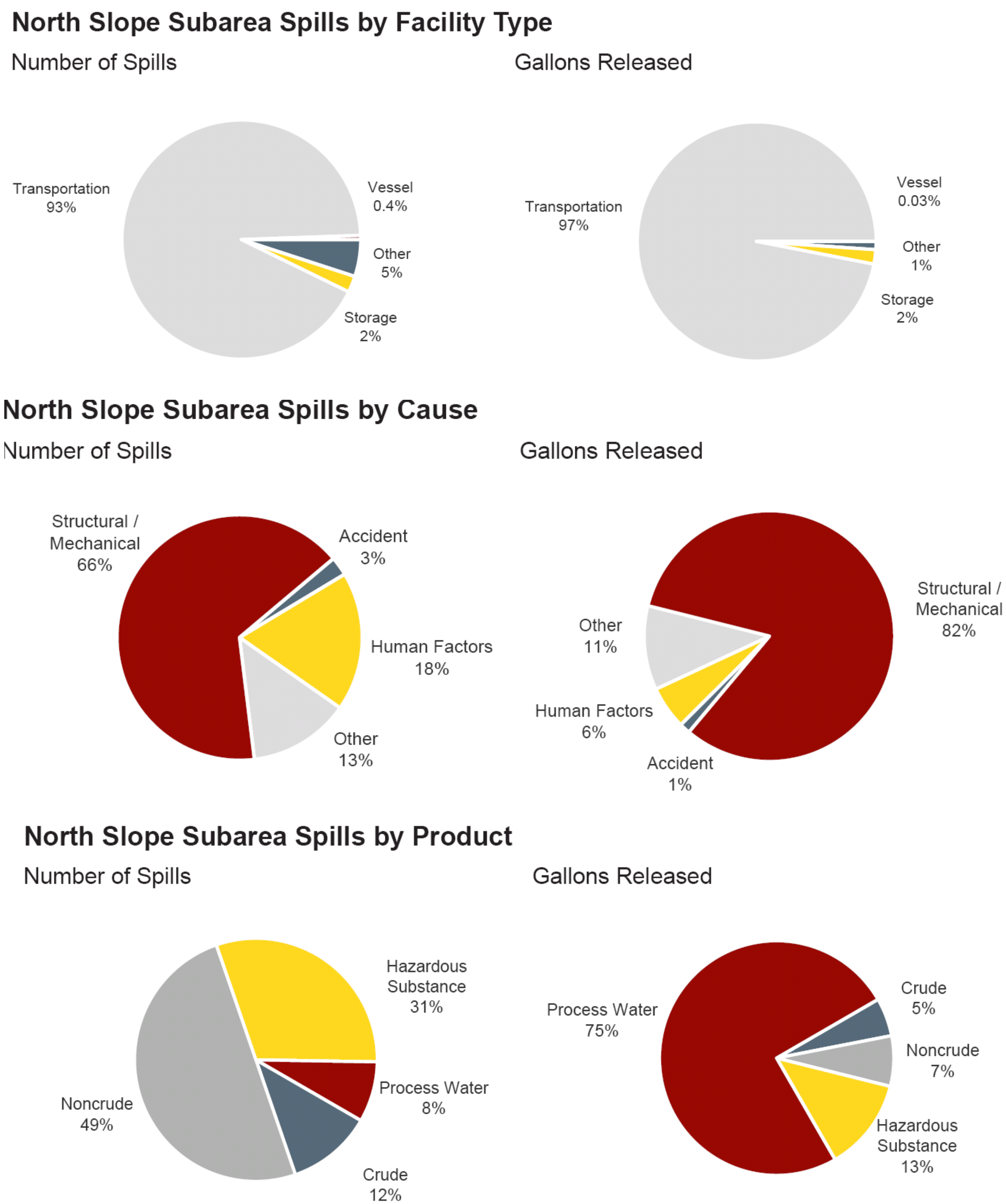

Figure 68: North Slope Subarea Spills by Facility Type, by Cause and by Product

On the North Slope a seasonal increase in the number of spills occurs during the January through April timeframe, which is related to the increased oil exploration activity in the winter.

Alaska Regional Response Team (ARRT) published their findings on North Slope risk assessment and contingency planning in Ref. [54]. The maximum most probable and average most probable scenarios envisioned are diesel spills. The maximum most probable case is determined by the largest recorded spill to date. The average most probable case is determined by the greatest percentage of average spills in the area.

Maximum Most Probable Scenario: The fuel barge planning to refuel the Barter Island Long Range Radar Site strikes a partially submerged object en route to the anchoring location. The object is suspected to be ice. The vessel continues to the anchoring location without leak from the damaged tanks. But after the vessel anchors up, awaiting fuel transfer, free product is detected on the water. Approximately 500 barrels (21,000 gallons) of arctic diesel will be released over a one hour period.

Average Most Probable Scenario: A lightering vessel is transferring fuel to the Wainwright bulk fuel storage facility when the 4 inch transfer hose ruptures near the marine header. Approximately 50 gallons of No. 1 diesel fuel is discharged into the Chukchi Sea.

Based on the situation, location and spill information, the response plans in the following areas are detailed in Ref. [54]:

- Cargo Salvage
- Sensitive Areas at Risk
- Initial Actions-Notification, Response Activation, Initial Response Actions on-Scene, Initial Agency Evaluation and Recommendations
- Spill Response Organization
- Containment, Countermeasures and Cleanup Strategies
- Response Requirements including equipment and personnel
- Resource Availability and Resource Procurement
- Shortfalls
- Spill Cleanup Timetable
- Disposal Options
- Cleanup Termination

6.3.2 Other Regions

In this Section, diesel spill data in the Aleutians, Bristol Bay, Western Alaska, Northwest Arctic regions are compared with data from the North Slope region.

Based on ADEC data cited in Ref. [79], the total number of diesel spills is the highest among all spill types in all regions, although they are not always dominant in the percentage of total volume spilled with the exception of Bristol Bay and Western Alaska.

The North Slope has the highest number (990 spills) and volume of diesel spills (about 98,000 gallons) among the five western Alaska sub-regions. There are approximately 87,000 gallons of diesel spilled in the Aleutians and Northwest Alaska in the period July 1, 1995 to June 30, 2005 (Figure 69).

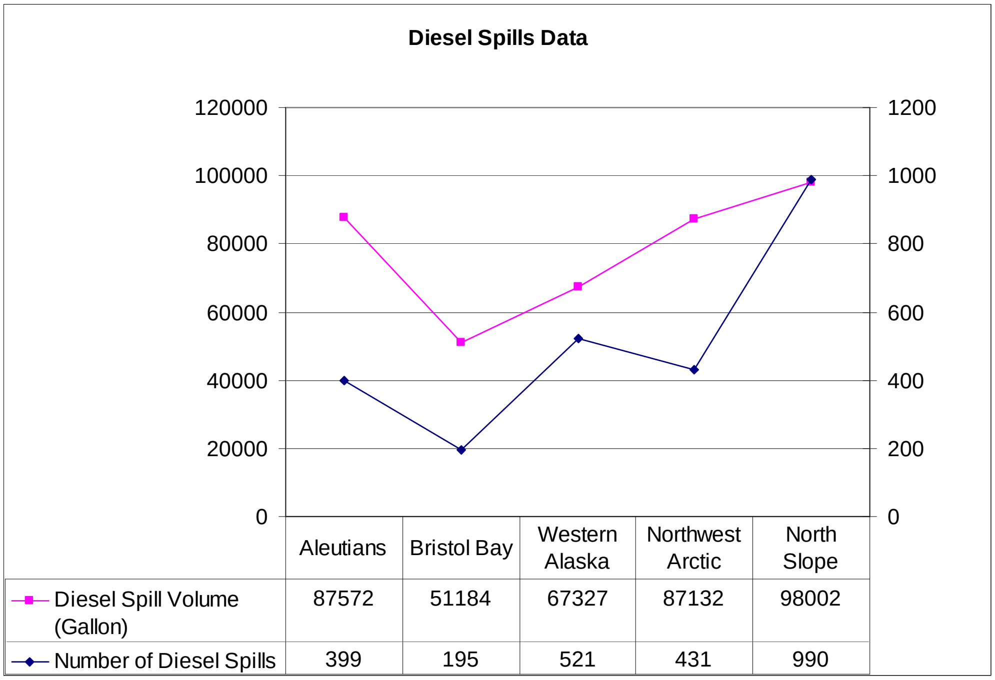

Figure 69: Diesel Spill Data in the period July 1, 1995 to June 30, 2005

Diesel spills were most common and accounted for 88% of the total number of spills in Aleutians region, 77% of the total number in Bristol Bay Area. Diesel spills accounted for 87% of the total volume of spills in Bristol region, 78% of the total volume in Western Alaska (Figure 70).

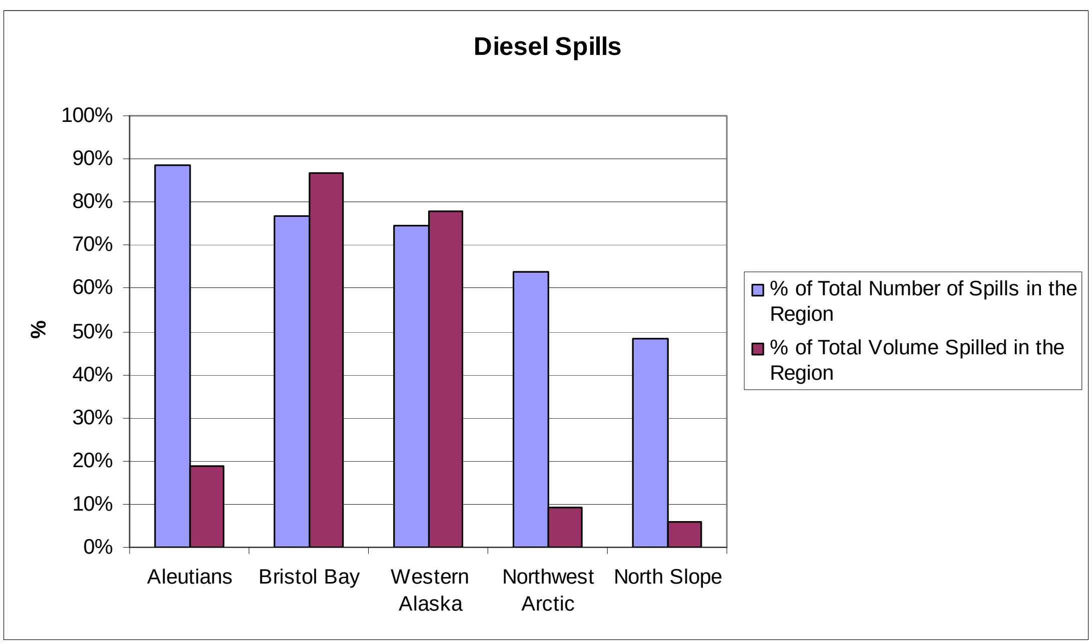

Figure 70: Percentage of Diesel Spills in the period July 1, 1995 to June 30, 2005

Spill from vessels is the primary cause of pollution in the Aleutians, i.e., 47% of the total number of spills and 88% in the total gallon released. Spills from unregulated vessels (< 400 gross tons) are responsible for more than 90% of the spills and nearly 100% of the total volume for the Aleutians. Seasonal trends for marine spills are related to the fishery season openings that occur along the Aleutian chain. The spills due to vessel dropped dramatically in the North. The percentage of spills in numbers and gallons released are below 1% in the Northwest Arctic and North Slope regions (Figure 71).

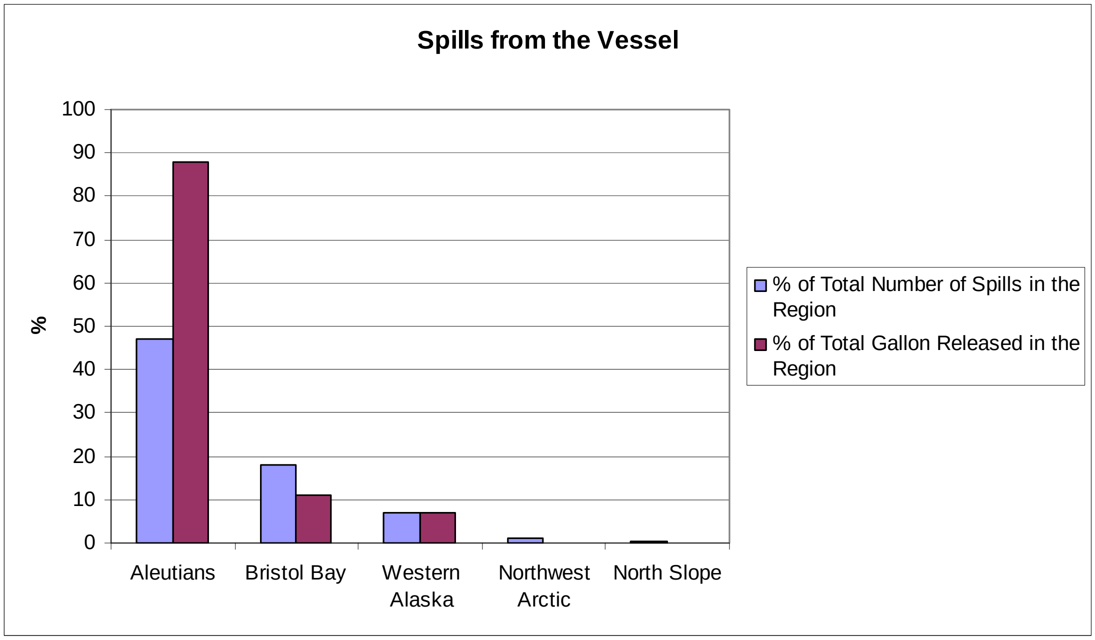

Figure 71: Percentage of spills from Vessels in the period July 1, 1995 to June 30, 2005

The high spill rate from vessels in the Aleutians is to a large extent due to the frequent and sudden storms, high winds, and severe sea conditions to which the region is subjected. The Transportation Research Board (TRB) conducted a study on the Risk of Vessel Accidents and Spills in the Aleutian Islands. Study results in Figure 72 show that grounding is the most probable cause of a spill incident, collision and equipment failure are second most probable reason to cause spills (Ref. [63]).

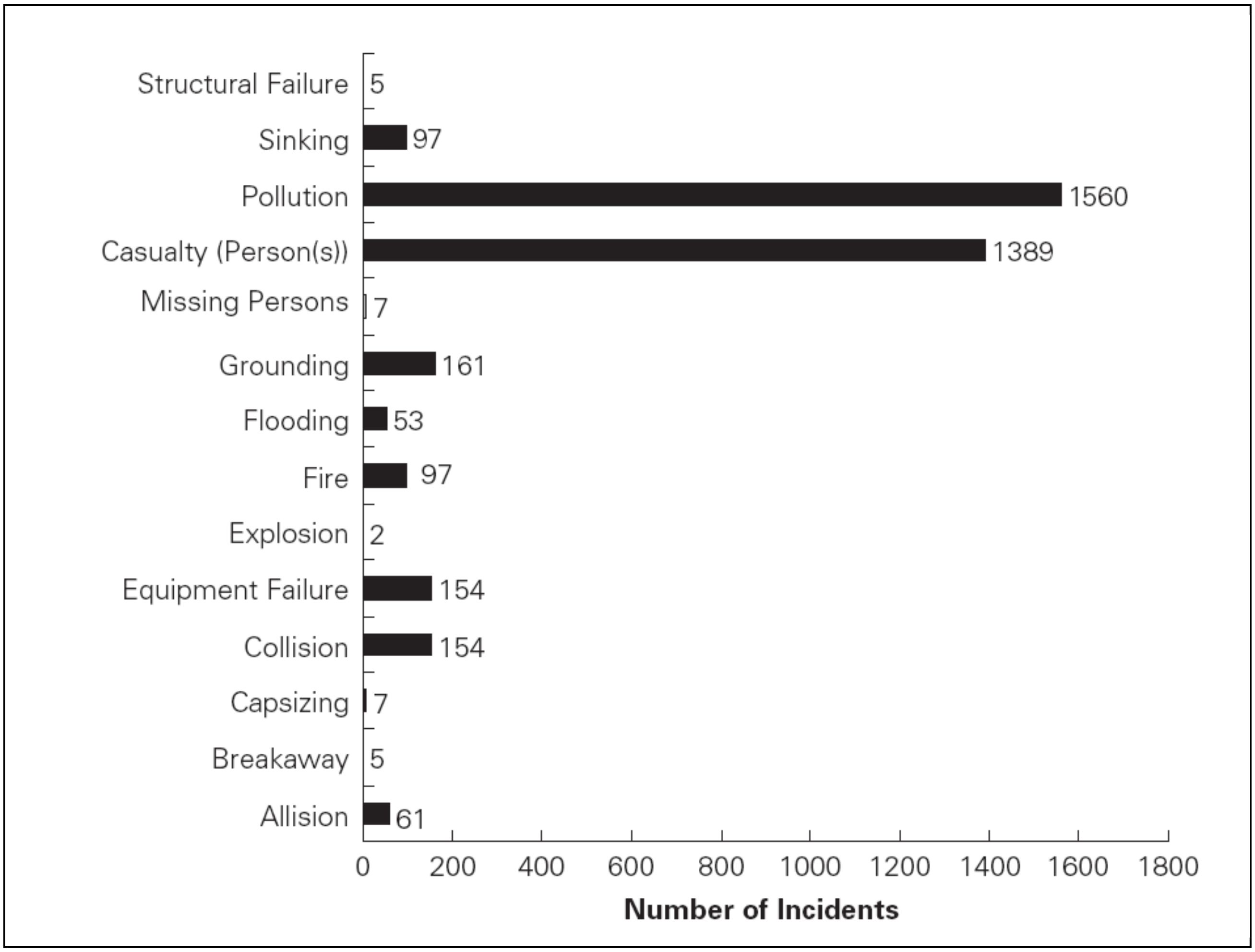

Figure 72: Primary nature of incident: all vessel types. (Source: Marine Safety Management System 1991-2000)

6.4 Ship Based Environmental Impact

Most shipping in the Arctic today is moving goods into the Arctic or moving natural resources out of the Arctic to world markets. Arctic shipping and platform transportation pose a threat to the region's unique ecosystems. Release of oil into the Arctic marine environment is the most significant threat from shipping activity. Ships will also have certain impacts linked to the release of grey water, sewage, ballast and bilge water; air emissions and accidental discharge of fuel/oil.

ISO 19906 is guidance for the design, construction, transportation, installation, and decommissioning of offshore structures, related to the activities of the petroleum and natural gas industries, in arctic and cold region environments. The objective of ISO 19906 is to ensure that arctic and sub-arctic offshore structures provide an appropriate level of reliability with respect to personal safety and environmental protection.

The IMO 'Guidelines for Ships Operating in Arctic Ice-Covered Waters' were designed with regards to Arctic conditions. They set out construction, equipment, operational and environmental provisions with special consideration for the risks of navigating in ice-covered waters. Risk reducing measures can be found in existing IMO instruments and in their present and future amendments.

6.4.1 Regular Discharges to Water

The International Convention for the Prevention of Pollution From Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78), was promoted by IMO [34] to prohibit all ships from discharging wastes at sea which could result in pollution of the marine environment. MARPOL 73/78 applies to oil tankers, cruise ships, general cargo, container vessels, tugs, ferries, yachts, and small pleasure crafts. The MARPOL 73/78 Convention is a frame convention with six annexes containing detailed regulations regarding permissible discharges, equipment on board ships, etc.

Referred to as regular discharges these include oil, ballast water, bilge water, tank washings (oily water), oily sludge, sewage (black water), garbage and grey water. Special measures to provide adequate protection from the potential impact of vessels operating in Arctic water have been built-in in MARPOL Annex I, II and V. A brief introduction of these three annexes is included below:

- Annex I to the MARPOL 73/78 Convention is extensive and contains regulations as to how tankers and other ships shall be constructed to minimize the risk of pollution. The Annex also contains criteria and limits for permissible discharges of oil and oily residues under different circumstances. The Annex may, for practical reasons, be split up into the two groups: oily waste from machinery spaces including oil contaminated bilge water (operational waste) and ballast and tank-cleaning water from cargo tanks and pump rooms of oil tankers (cargo related waste).
- Annex II: Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk. Annex II details the discharge criteria and measures for the control of pollution by noxious liquid substances carried in bulk.
- Annex V to the MARPOL 73/78 Convention comprises regulations to prevent pollution by discharges of household waste and other solid waste. The Annex defines

the different types of waste that are to be regarded as garbage, the distance from land where they are allowed to be discharged and in what way.

- According to the MARPOL 73/78 Convention the following types are waste are regarded as garbage: Ordinary household waste including food waste; Waste from cargo holds, like dunnage, broken pallets, lashings, ropes and covers; Harmless cargo residues; Waste from machinery spaces that is not covered by any other annex of the Convention; Medical wastes; Fishing gear that is out of order, fish boxes, etc.

SOPEP is to be seen as information from the owners to the Master of a particular ship. It is compulsory for all ships of more than 400 Gross Tons (Oil tankers of more than 150 GT) to carry a SOPEP onboard. For vessels over 400 gross tons SOPEP meet the requirements of MARPOL 73/78 and provide guidelines to follow in emergency situations. Plans are written to meet the needs of specific vessels and fleet operations.

As provided in 33 CFR 151.28, an annual review of this SOPEP will be conducted within one month of the anniversary date of Coast Guard approval. Plan amendments will be submitted to the Coast Guard immediately for changes of a significant nature. Changes of an informational nature will be submitted at the time of the annual review. The Coast Guard will approve changes before they will be incorporated. Records of the annual review of this SOPEP will be kept on the Record of Annual Reviews below. Any changes to this plan will be treated as a change to the entire Vessel Response Plan (VRP), and will be recorded on the Amendment Log.

The purpose of the SOPEP is to provide guidance to the Master and officers on board the vessel with respect to the steps to be taken when a pollution incident has occurred or is likely to occur. At a minimum, MARPOL 73/78 requires that the plans contain:

- Reporting procedures
- Contact notification lists
- Spill containment and mitigation measures to be taken aboard
- Procedures for coordinating response activities with shore-side authorities

After the spill of the Exxon Valdez, the US Congress passed the Oil Pollution Act of 1990 (OPA 90). OPA 90 sets forth an extensive liability scheme that is designed to ensure that, in the event of a spill or release of oil or other hazardous substance, the responsible parties are liable for the removal costs and damages that result from the incident. A responsible party includes an owner, operator, or demise charterer of a vessel. A responsible party may be liable for removal costs and damages to natural resources, real or personal property, subsistence use, revenues, profits and earning capacity, and public services.

For U.S.-flag vessels, these guidelines were enacted as federal regulations (33 CFR§151.05, §151.09, and §151.26 et. seq.). §151.27(d) provided that a single plan could meet the requirements both for a VRP under OPA '90 and a SOPEP under MARPOL 73/78. Such a plan must be prepared in accordance with §155.1030(j), which requires that the vessel response plan also includes:

- Guidance on discharges of all oils carried aboard, including bunker fuel
- Coastal State and port contacts for the vessel's areas of operations

6.4.2 Accidental Release from Vessels

The Arctic Marine Shipping Assessment (AMSA), as the study is named, was put together by Arctic Council nations, including the United States, and serves as a formal policy document. The assessment provides a range of potential environmental impacts linked to ship types operating within the Arctic oil gas exploration activities as shown in Table 17.

Ship Category	Ship Sub-category/ Use	Ship Type–Specific Pollution Sources
Tug / Barge	Re-supply vessels	Increased accident hazard (non-propelled), hazardous goods in transit, spills during oil transfer, heavy emitters of air contaminants (black carbon).
Oil and Gas Exploration/Exploitation Vessels	Seismic exploratory vessels, oceanic and hydro-graphic survey vessels, drilling vessels, oil and gas storage vessels, offshore re-supply, portable oil platform vessels, other oil and gas support vessels	Hazardous cargo, explosives, acoustic impacts from seismic activities, hydrocarbon contamination, contamination from extraction chemicals, accidental loading/offloading spillage, fire hazards.

Table 17: A range of potential environmental impacts linked to ship types operating in the Arctic Oil Gas Exploration Activities (Source Arctic Marine Shipping Assessment)

Accidental release from vessels can be caused by leaks, ruptured lines, valves that were faulty or left open, seal failures, tanker overfills, faulty connections, vent discharges, and corrosion. Spills are also due to vessels breaking through the ice, crashing, rolling over, and collisions; grounding, hull failure, explosion, fire, high winds, and other factors.

The Arctic environment is challenging with a range of weather and with little human infrastructure. Consequently, strong prevention measures must be of primary concern. Section 6.8 provides an example of vessel self inspection procedures for preventing pollution.

6.4.3 Arctic Ship Emissions

Ships are powered at sea by diesel engines (i.e., main and auxiliary engines) to provide propulsion and electrical power. According to Corbett and Fischbeck (1997), ships are among the world's highest polluting combustion sources per quantity of fuel consumed. Therefore, the air pollution threat caused by diesel engines cannot be neglected (Lin and Huang 2003). Diesel engines are considered a major source of air pollution in port and urban areas because of their release of black smoke, hydrocarbons (HC), nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2), and other toxic chemical compound contaminants into the air (Lin and Huang 2003).

New northern passages (the north-east coast of Siberia, northern Alaska and around the Canadian archipelago) could drastically increase levels of low-lying ozone as ship exhausts pump pollutants into the pristine environment. Climate models indicate that the northern passages may be open to shipping during the summer months from around 2050. Emission of NOx and CO from ships could triple ozone levels, making them comparable to those in industrialized regions today (Granier et. al. 2006).

Oil operations on Alaska's North Slope emit more than 70,000 tons of NOx, which lead to smog and acid rain. Pollutants from Prudhoe Bay have been detected approximately 200 miles away in Barrow, Alaska.

MARPOL Annex VI sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts as well as particulate matter and prohibits deliberate emissions of ozone depleting substances. Emission control areas set more stringent standards.

6.5 Risk Assessment

Risk assessment is widely used in the marine industry to help manage the risks associated with shipping operations. Risk-based methodologies must consider the probability of an incident and the severity of its consequences. The combination of likelihood and consequence for ship operations is normally illustrated as shown in Figure 73 (Ref. [1]):

		Consequence		
		Slightly Harmful	Harmful	Extremely Harmful
Likelihood	Highly Unlikely	Trivial Risk	Tolerable Risk	Moderate Risk
	Unlikely	Tolerable Risk	Moderate Risk	Substantial Risk
	Likely	Moderate Risk	Substantial Risk	Intolerable Risk

Figure 73: Risk Matrix in Ship Operation

Table 18 below indicates the recommended response in each case.

Trivial	No action is required
Tolerable	No additional controls are required. Monitoring is required to ensure control is maintained.
Moderate	Efforts are required to reduce risk. Controls are to be implemented within a specified time.
Substantial	New work not to start until risk reduced. If work in progress, urgent action to be taken. Considerable resources may be required.
Intolerable	Work shall not be started or continued until the risk has been reduced. If reduction is not possible, the activity shall be prohibited.

Table 18: Recommended Response for Risk.

The Alaska Department of Conservation is evaluating a set of spreadsheet tools that may be used to characterize risk and benefit from special remediation approaches depending on site-specific data. One of the tools is a so-called hydrocarbon risk calculator, which characterizes the human risk, soil ingestion, ground water ingestion, migration to outdoor air, migration to indoor air, and migration to groundwater routes (Geosphere & CH2MHILL 2006).

Risk-based approaches provide structured methods for analyses that acknowledge uncertainties. It is crucial to identify the highest priority risk reduction measures that can be implemented to reduce spills from vessels. It is important to develop a regional risk assessment. The planning and execution of risk assessment can be divided into two categories:

- Assess risk for each vessel and plan accordingly
- Assess risk geospatially and plan accordingly (zone)

The threat to Arctic ecosystems due to vessel spills can be effectively mitigated through careful planning and effective regulation in areas of high risk. The purpose of a risk assessment process is the identification and implementation of appropriate measures to reduce the risk of accidents to acceptable levels.

Diesel spill management has the following key steps:

- Risk Assessment
- Risk Management & Mitigation Plan
- Plan Execution
- Assessment/Corrective Action

Performance of the program is measured on a regular basis to ensure that all components of the program are executed in a satisfactory manner.

An overview of the spill risk assessment process is shown below:

- Identify vessel equipment, systems and limits

- Identify areas for assessment
- Identify applicable threats and failure modes
- Assess probability of failure
- Assess impact of failure
- Determine criticality
- Define recommended mitigations
- Assessment review

6.6 Geographic Response Strategies for Alaska

Typical arctic conditions such as extreme temperature, unstable ice, and poor visibility could limit the ability to clean up spills. Numerous vessels operating in Alaska are subject to Alaska's spill response planning and financial responsibility statutes. Geographic Response Strategies for Alaska can be found online at http://www.dec.state.ak.us/SPAR/PERP/grs/home.htm. This website describes the process used to develop Geographic Response Strategies (GRS) to protect sensitive coastal environments. GRS' are oil spill response plans tailored to protect a specific sensitive area from oil impacts following a spill. These response plans are map-based strategies that can save time during the critical first few hours of an oil spill response. They show responders where sensitive areas are located and where to place spill protection resources.

Alaska is divided into 10 regions as shown and each region has a Subarea Contingency Plan that directs the state and federal actions in a response to the release of hazardous substances and oil spills (Figure 74).

Figure 74: Ten Subareas for Geographic Response Strategies, Alaska

Figure 75 provides the Alaska local response agreements and response equipment locations, as of January 2010. The local response agreements are intended to facilitate coordinated and effective oil and hazardous substance release within the state. It should be noted that the base of operations sites proposed in Section 2.7, i.e., Dutch Harbor and Nome are among the state response equipment sites. Dutch Harbor has in addition a community spill response agreement and emergency towing packages.

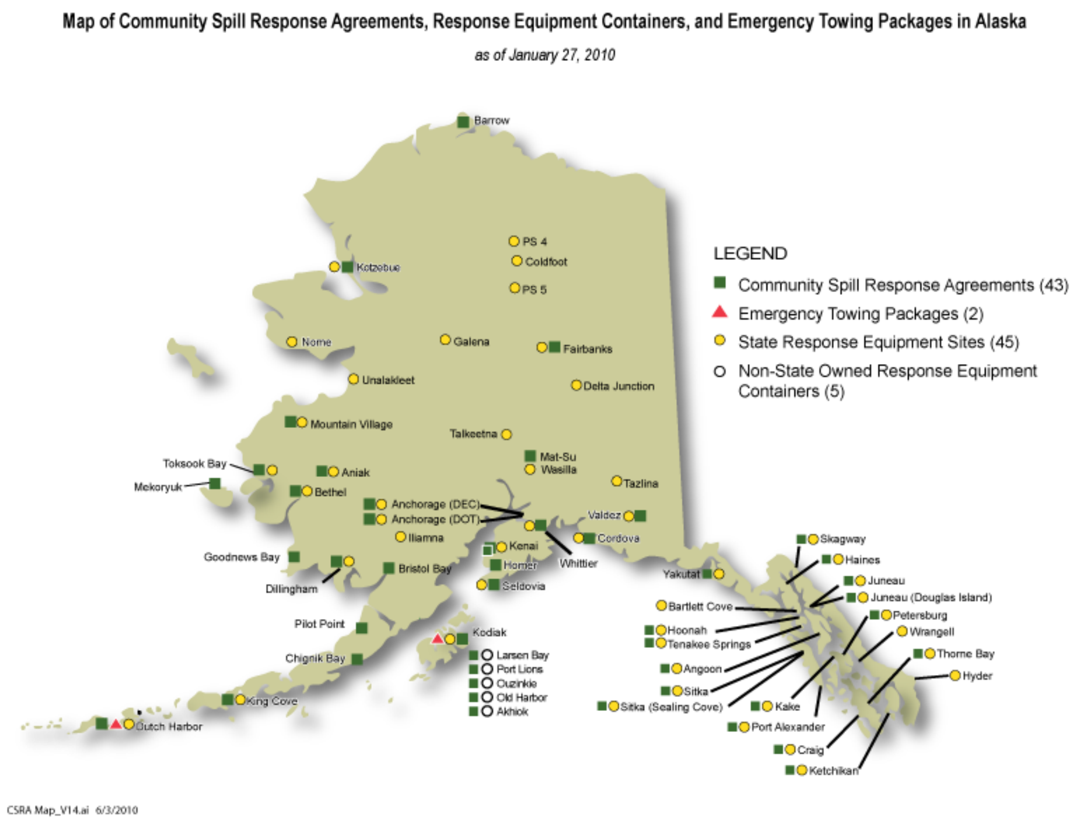

Figure 75: Local Response Agreements and Response Equipment Locations, as of January 2010

6.7 Marine Diesel Oil-Spill Response

There are several comprehensive references that discuss spill response in Arctic environments (e.g., Owens, 1996; Owens et al., 1998; Dickens et al., 2000; Alaska Clean Seas, 2001). A summary of the Spill Planning and Response in Arctic and Cold Water Environment is provided in Ref. [83] and is included below. An effective response plan must address the following factors:

a) A thorough understanding of spill under different spill scenarios;
b) An Operations Plan with strict procedures in place to accurately monitor weather and hazardous ice conditions that safeguard operations against hazards caused by changes;
c) The availability of equipment, designed to operate in cold and icy environments, that can be activated immediately and continue to operate for extended periods in open water and broken ice conditions;
d) The training and experience of response personnel to work safely and effectively under harsh conditions;
e) A comprehensive assessment of all applicable response tools that are proven to be reliable in ice and extreme cold climates;
f) The identification and preparation of specific response strategies and tactics that could be implemented safely and effectively under a broad range of conditions including: drifting floes at break-up, open water, summer ice incursions, and new ice at freeze-up, consolidated fast ice and very close pack ice in winter.

This Section is to provide a quick review on fate and effect of diesel spills, offer an assessment of the applicable response tools that are proven to be reliable on spills in open-water season, transition seasons and ice and extreme cold climates.

6.7.1 Oil Fate

Diesel vaporizes over a short period of time. Table 19 summarizes the natural dispersion and evaporation behaviors of MDO and also indicates if chemical dispersants are effective (Ref. [47]). MDO will disperse readily in high sea states and will also evaporate up to 50% in approximately 5 days in temperatures in the range of 15°C to 40°C.

	MDO
Evaporation	10% to 40% in 2 days, 50% in 5 days, depending on residuum content
Natural Dispersion	in high seas, will mostly disperse in 5 days
Chemical Dispersion	effective to a certain degree
Emulsification	forms unstable emulsions in high energy situations
In-situ Burning	effective; requires a minimum of 3 mm thickness

Table 19: Behavior of Marine Fuel Oils Spilled at Sea in temperatures in the range of 15°C to 40°C.

In cold Arctic temperatures, the evaporation rate slows significantly (Environment Canada - Emergency Sciences Division). This highly toxic diesel fuel would remain afloat on the Arctic waters for longer time.

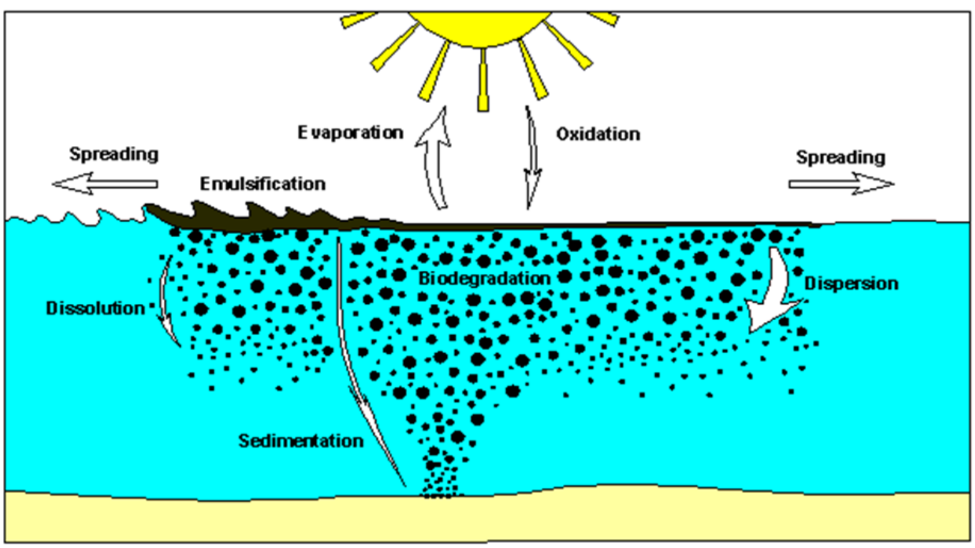

Figure 76: Fate and Effect of Spilled Oil

Figure 76 illustrates the fate and effect of the spilled oil. The processes that diesel spills may go through are spreading, evaporation, dissolution, dispersion, emulsification, sedimentation and degradation processes. A large portion of diesel in a small spill incident into the marine temperate environment is either evaporated or naturally dispersed into the column in times frames of a couple of hours to a couple of days. This is specially true for typical spills from a fishing vessel (500-5,000 gallons), even in cold water.

The weathering processes are described briefly below:

- **Oil spreading** refers to the motion of the oil fluid as it is spilled onto the more dense seawater. Advection is governed by geophysical forces (currents, wind). Spreading is important in the initial phase of the spill.
- **Evaporation** removes volatile components.
    - For some oil types (crudes) mass loss can be considerable, for other types insignificant
    - Density Increases
- **Dissolution**-Oil dissolve in water
- **Natural dispersion** forms oil-in-water mixture
    - Removes oil from the slick (under threshold concentration)
    - Enhances biodegradation
- **Emulsification** forms water-in-oil mixture
    - Increase in volume
    - Change in properties and color

These processes dominate in the first few days to weeks of a spill, and, except dissolution. These processes may dramatically change the nature of the oil.

A number of longer term weathering processes include the following:

- **Biodegradation** is the chemical dissolution of materials by bacteria or other biological means
- **Photo-oxidation** is sunlight promoted chemical reaction of oxygen in the air and oil.
- **Sedimentation (Absorption)**-The process by which one substance is attracted to and adheres to the surface of another substance without actually penetrating its internal structure

Evaporation and oil dispersion are the top two important processes after diesel is spread in the water. As regards solubility, diesel has a higher solubility than crude oil in the same salinity and temperature sea environment. The solubility of diesel decreases with lower temperature and higher salinity.

Photo-oxidation and biodegradation are the two most important factors involved in the transformation of diesel that are released into a marine environment. However, due to darkness and cold temperatures in the Arctic winter season, photo-oxidation and biodegradation of spilled oil will not be significant during this time.

6.7.2 Clean Up Method

The success of a cleanup method relies on the capability and availability of well-maintained equipment and products. Well-trained personnel to deploy the products are one of the crucial factors in the clean-up operations.

The clean up methods in general can be categorized as mechanical, biological/chemical and physical. Some of the equipment needed for oil cleanup methods are:

- Booms
- Skimmers
- Pumps
- Storage
- Dispersants and spray systems
- Response vessels
- Absorbents
- Other spill response equipment such as aircrafts and boats.

A boom is a floating barrier placed in water to contain and confine oil until it can be removed. A skimmer is a machine designed (different types for different scenarios are available) to recover floating oil from the water surface. Skimmers and pumps are needed for handling high viscosity emulsion and debris. The common performance parameters include the following:

- Slick thickness
- Oil type and viscosity
- Wave height and period
- Sweep width
- Sweep speed

Wind normally does not influence the performance of skimmer. Waves, specially chop & short type steep seas have a bigger effect on the skimmer collection. Waves may move the skimmer collection mechanism away from the oil floating on the water surface. A strong current may cause the oil to escape under collection booms.

Slick thickness is the most important factor in determining the effectiveness of skimmer systems. Any device can be effective if the slick is thick enough. Oil Recovery Rate is higher in crude than in diesel. Different skimmers work better with different oil types and viscosities. Details of the performance of weir skimmers, oleophilic and bucket skimmers in general environmental conditions are described in Ref. [64], while a comparison of performance of these three types of skimmers under dynamic conditions can be found in Ref. [55].

The effectiveness of dispersants is dependent on: Oil properties or oil type; Type of dispersant; oil weathering (window of opportunity); energy conditions (to initiate chemical dispersion) and oil availability for dispersant application (Ref. [26]). Dispersants are not an appropriate response to all types of spilled oil; spills of Marine Diesel Oil and other light oils will eventually evaporate and dissipate without intervention. Therefore, dispersants are unlikely to be used but will be retained as an option, subject to further investigation.

Absorbent materials are those chemicals such as oleophilic materials that have the capability of attracting oil and then removing the oil and absorbent together. Absorbents must be collected and removed at the end. Sorbents are primarily used on small spills, final cleanup of larger spills and to remove oil from areas that are inaccessible to skimmers. The quantity of sorbents required and the application method depends on the size and location of a spill. Sorbents are generally used near the shore (placed directly on the oil or ahead of advancing oil) and on deck or dock surfaces.

Storage devices are an important component of mechanical recovery, and can impede the recovery rate if insufficient capacity is available to store recovered liquids.

Response vessels are normally equipped with the standard oil containment and recovery devices and support equipment. Response vessels generally tow a boom in a U-shaped configuration that is commonly used either for skimming or in-situ burning. The most frequently reported shortages in spill response vessels were tank vessels (for temporary storage of recovered oil). Ice can also impact logistical aspects of spill response operations, such as safe operation of response vessels or positioning of equipment.

In-situ burning is another method with large potential to remove the oil from the sea surface. Combustion can be started by an igniter suspended from a helicopter and burning can go on as long as the slick thickness is over 3mm. When the slick thickness is less than 3mm, the in-situ burning will not continue to work (Ref. [25]). In addition, the decision to burn should be based on the following factors (Ref. [26]):

- Emulsions should be at least approximately 75% oil.
- Waves should be less than 2 m high and not breaking.
- Wind speed should be less than 35 km/h (20 knots).

An important part of the safety program for an in-situ burn operation is establishing minimal safety zones. Smoke dispersion modelling has been used frequently in the past decade to establish safe zones and obtain permits for large industrial sources. Calculations using historical data can provide a guide to safe distances (Ref. [10]). Table 20 provides minimal safe distances in kilometers.

Burn Area (m^2)	Diesel Fuel
50	0.03
100	0.06
150	0.1
250	0.3
400	2.1
500	7
750	>50
1000	>100

Table 20: Minimal safe distances in kilometers for in-situ Diesel Fuel Burning

6.7.3 Spills in Open Season

Diesel oil is not very sticky or viscous. When small spills do strand on the shoreline, the oil tends to penetrate porous sediments quickly, but also washed off quickly by wave and tidal flushing. Thus, shoreline cleanup is usually not needed.

Responding to spills from vessels in open season can involve controlling slicks at source and removing oil that escapes initial containment. The objective of both operations is to minimize the spreading of spills and subsequent environmental impacts. Control methods use similar approaches both at source and to deal with remote slicks.

The use of mechanical containment and recovery is often the primary and preferred method of response by many stakeholders wherever possible. 300-600 ft of booms can be towed by one or two vessels to capture and concentrate oil. Figure 77 shows a typical U shape boom configuration down current. Booms are effective in currents less than 0.5 m/s (1 knot) and winds less than 35 km/h (20 knots). If the current speed exceeds 1 knot, oil may escape the containment system deployed.

Figure 77: Containment techniques-U Shape Boom Configuration

When the containment boom is in place, the spilled diesel is recovered by placing the skimmer inside the boomed area. Skimmers that use adhesive surfaces (disc, belt, rope, and drum) and those that use gravity (weirs, vortex skimmers) can be effectively deployed. Disc, drum and rope mop skimmers can remove light and medium viscosity oils; brush and belt skimmers can collect heavy oils. Large volume skimming weirs can be used when oil/water separation is available or when there are large accumulations of thick, un-emulsified oil. The oil recovery rate is determined by the speed of the pump and the water conditions in which it is operating.

In-situ burning must be quickly implemented, usually by trained personnel. It is necessary to use caution with in-situ burning on marshes and determine effect on local vegetation and wildlife prior to use. In a remote area, the decision to burn should be based on factors included Section 6.7.2.

6.7.4 Spills in Transition Seasons

Response to spills in broken ice frequently requires strategies to deal with moving ice. Dramatic changes in ice concentration due to wind shifts should be expected. The standard approaches of mechanical operation and in-situ burning to a range of ice-concentration can be used. However, any spill response method would likely to be limited to a small window of opportunity due to the dynamic nature of the ice movement in transition seasons [57]. Examples of mechanical systems applied to spill response in ice conditions are shown in Figure 78, Ref. [83].

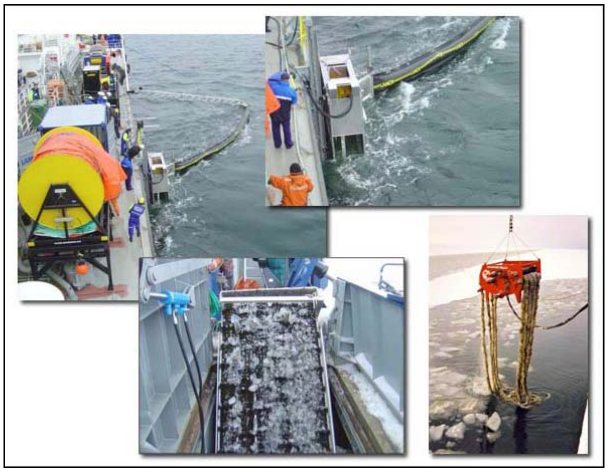

Figure 78: Examples of mechanical systems applied to spill response in ice conditions

During early freeze-up and the latter stages of breakup (up to 25- 30% ice cover), open-water response techniques are often used. However, diminishing open water, vessel mobility and mechanical recovery potential are concerns. During late freeze-up, cold temperatures may also limit operations.

Ice pieces must be small enough to be contained or deflected by booms; booms are of little or no use in large, moving ice floes or in ice concentrations greater than 30%. Skimmers function best if positioned in oil concentration in open water and in leads between ice floes.

In-situ burning is the optimum response strategy for most spills in broken ice when the conditions in Section 6.7.2 are met.

6.7.5 Spills in Frozen Conditions

The behavior of diesel spills depends on the environment that it is spilled into. Water and air temperature, water and wind speed and wave conditions all play big roles. Sea ice will impact the weathering and transport of spilled fuel, and has the potential to complicate spill tracking, containment, and recovery operations. Diesel spilled during freeze-up conditions will be subject to evaporation, dissolution, emulsification and natural dispersion to certain degrees.

Frozen conditions help response operations in many ways, providing a solid working platform, reduced oil mobility and naturally formed on and under-ice oil storage. Ice topography can be modified to contain spills. However, darkness and extreme weather conditions make it necessary to maintain awareness of many safety factors including [26]:

- Personnel must wear appropriate cold weather clothing, footwear and protective gear, and be able to recognize signs of frostbite, hypothermia and fatigue.
- In extremely low temperatures, engines are often run continuously, necessitating preplanning of fuel, lubricants and spare parts inventories.
- Winter darkness requires responders to take precautions, even when traversing short distances on ice: Pedestrian and machine travel should be restricted to safe, identified routes; operation of machinery requires strict attention.

Due to darkness and cold temperatures, chemical degradation processes will not be significant. Diesel spilled during freeze-up will either stay on or drift to the surface of the ice being formed. Diesel oil can stay unweathered and can be burned several months after being spilled.

Although the cold temperatures during freeze-up reduce evaporation rate, the amount of oil lost due to evaporation will be the same as in warmer water given enough time. Snow could be adsorbed into surface oil and eventually cover the oil. So the snow will add an additional resistance to evaporation (Dickins, 2011).

USCG conducted a series of small-scale spills (one to two barrels each) on fast ice in the Chukchi Sea in July 1970. The surface spills (diesel and North Slope crude) quickly drained through a permeable, recrystalized upper layer and collected on the melt pools. The researchers concluded that the presence of ridges and under hanging blocks under the ice would be able to contain fairly large oil volumes as long as currents and turbulence in the water column were low (Glaeser and Vance, 1971) .

A series of experimental spills of diesel and gasoline on ice floes in the Russian Arctic showed that light distilled fuels evaporate to completion rapidly on the surface of ice floes in spring and summer and that photo-oxidation is a more significant process in the 24-hour daylight than in more temperate climates (Serova 1992, Ivanov et al. 2005).

Mechanical equipment functions less efficiently in cold weather; condensation, freezing and other problems occur. Burning oil on solid ice is usually feasible. When burning oil on ice, it is important to trench to contain the oil as large volumes of melt water are created.

Most ice-covered areas have ice-free seasons when technology developed for open waters can be used. Oil recovery operations in ice covered waters will however be confronted with totally different problems than in open waters, e.g. limited flow of oil to the recovery device; limited access to the oil; deflection of oil together with ice; separation of oil from ice; contamination of ice; cleaning of ice; increased oil viscosity; icing /freezing of equipment; strength considerations and detection of oil in various ice conditions (Ref. [57]).

In-situ burning is particularly suited for use in ice conditions, sometimes offering the only option for removal of surface oil. The fundamentals of in-situ burning are: oil properties or oil type, oil weathering (“window of opportunity”); environmental conditions (especially wind and waves); safety hazards (human and the environment); oil availability for ignition/burning; igniters and fire-proof boom systems.

6.8 Mitigation and Response Measures

Response measures require frequent adjustments reflecting: environmental changes, spill distribution and weathering processes, proximity to shore & shallow water, personnel fatigue, resource availability etc.

6.8.1 Vessel Fuel Spill Emergency Response

In case of a spill, the master of the vessel shall notify the Qualified Individual (QI) who is responsible for reporting a spill to federal (USCG) and State Emergency Management Agency-ADEC. The USCG National Response Center is the single initial point of reporting for a spill or threat of a spill of oil or hazardous substances into coastal water. Reporting is required by law and must be done immediately. The QI will also determine if notification of Oil Spill Response Organizations /Response Action Contractors is necessary.

An example of spill response field guide is offered in Ref. [75]. The emergency procedures detailed mitigation measures for oil discharges including:

- Pipe/Hose Leak
- Tank Overflow
- Hull Failure/Structural Damage
- Unintended Grounding
- Collision
- Wreck/Stranding
- Excessive List
- Fire prevention and Control
- Submerged/Foundered
- Containment System Failure
- Hazardous Vapor Release

Pipe/Hose Leak, tank overflow and hull failure/structural damage can be categorized as operational discharge incidents. To minimize the potential for adverse effects on human health and the environment, it is important to stop the flow and initiate containment in case of a diesel spill. The following steps should be taken:

- Shut down pumps
- Close pipe, hose or other valves
- Isolate source of leak
- Apply temporary patch
- Deploy containment boom and response equipment, if safe and as time allows, and maintain containment efforts until assistance arrives

Grounding, collision, wreck, excessive list, fire/explosion prevention and control, submerge, containment failure, and hazardous vapor release are categorized vessel causality discharge incidents. When an incident happens, the first priority of the Master/Person-in-Charge is to ensure the safety of the vessel's personnel, and then take immediate action to mitigate the spill. Mitigating activities that can be considered are transfer of liquid from damaged compartments, and containment and isolation of on-board deck spills.

The main hazard associated with a vapor release is the safety of the crew. It is important to stop any cargo-transfer in progress and close all tank values and pipeline master valves.

Loading and unloading operations specifically related to oil and fuelling operations have a higher risk of discharges [6]. The owner or operator of a tank vessel or oil barge is responsible for meeting the applicable requirements of Alaska Statutes and for preventing the discharge of oil into waters or onto land of the state. The Oil Discharge Prevention and Contingency Plan (ODPCP) requirements are specified by the ADEC contained in 18 AAC 75 for tank vessels and oil barges operating in AK state waters (Ref. [77]). Review and approval are done by the ADEC.

Barges need to follow with skimming capabilities (limited quantities of oil spill). Permits from the Alaska State to operate are on case by case bases. The minimum requirements are based on assessment by the state.

6.8.2 Vessel Self Inspection Program for Preventing Pollution

The best way of responding to oil pollution is to prevent it from happening, rather than responding to it once it has occurred.

The following is a sample for vessel self inspection program:

- Diesel Oil transfers – Vessels over 400 GT. A proper Oil Record book CG-4602A should be filled out and kept on board for 3 years.

- Fuel Oil/Cargo Containment
  - Verify that each fixed container or enclosed deck area under or around each fuel oil, lubricating oil or hydraulic oil tank vent, overflow and fill pipe is intact.
  - Verify that each portable container is intact and had a capacity of at least 5 U.S. Gallons.
  - Verify that all welds are not deteriorated and that the containment area is clean.
  - Verify that the means of closing a containment area (plugs, valves, etc.) is present and/or properly working.
  - Verify that Pollution containment railing around deck is intact and that plugs are secured in place when elevated or fueling operations are commenced.
    - Plugs in deck containment should not be secured when vessel is in the afloat mode.

- Oily waste prevention
  - Check Bilges
    - Verify that bilge area is free of debris (rags, filters, etc.)
    - Verify that drip pans under all engines are free of excess oil and water; that drip pans are in good condition and serving their intended purpose.
  - Tank
    - Verify that oily waste tank piping, valves, and fittings are intact and free of leaks.
    - Verify that waste tank pump emergency shutdown is operational.
  - Barrels
    - Verify that barrels are marked for content.

        - Verify that waste put into the barrels is oil waste only.
        - Verify that the barrels are in good condition with all caps and plugs available.
        - Verify that the barrels are secured.

- Bilge and Ballast Discharge
    - Piping
        - The accessible bilge and ballast piping are in good condition and free of leaks.
    - Stop Valves
        - The overboard discharge gate valves operate freely and close completely.
        - All overboard discharge valves should remain closed when not in use.
    - Outlets
        - All welds are intact for all overboard discharge penetrations above and below the main deck.
        - Verify that fitted hose connections above the main deck close tight and are free of leaks.
    - Pump Stops
        - Verify that all local, remote and/or emergency pump stops secure the respective pumps.
    - Verify that all valves are labeled.

- Placards- Implementation of MARPOL 73/78
    - ANNEX V – "Garbage Placard"
        - The master or person in charge of each vessel shall ensure that one or more placards meeting the requirements are displayed in prominent locations.
    - ANNEX I – "Discharge of oil prohibited placard"
        - The master or person in charge of each vessel shall ensure that placard is displayed in each machinery space and at each bilge and ballast discharge station.
        - Placard should also be displayed so that persons in addition to the crew are aware of it.

- Oil Transfer Procedure
    - A copy of the USCG approved oil transfer procedures' pertaining to the vessel is on board.
    - It must be legible and contain all piping diagrams.
    - The oil transfer procedures must be posted or kept in a location readily accessible to all crewmembers.
    - The vessel operation shall have oil transfer procedures current and require vessel personnel to use them for each transfer.
    - A current Material Safety Data Sheet is on board pertaining to all hazardous material transferred on and off the vessel.

    - The declaration of inspections are being filled out properly and signed.

- IOPP Certificate MARPOL 73/78
    - Verify that the International Oil Pollution Prevention Certificate is on board the vessel.
    - Verify that oily water separating equipment and associated pumps and piping systems are satisfactory for the service intended, and no unauthorized alterations have been made.
    - Verify that the 100 or 15-PPM visual and or audible alarm is operational as per the manufacturer's specifications.

- Waste Management Plan-Annex V of MARPOL 73/78 Compliance (33 CFR 151.59)
    - Confirm that the Waste Management Plan is on board and the crew is well aware of the plan.
    - There is designated person responsible to carry out the plan.
    - Shipboard control of garbage
        - The master shall ensure that all garbage retained on board the vessel is transported from the ship by shipboard personnel and is properly deposited into a port or terminal's reception facility.

- Transfer Hoses
    - Verify the Certificate:
        - Hose test certificate or records available for inspection
    - Hoses to be used have been checked for:
        - Correct diameter & length
        - Chafing, cracks or other deformation,
        - Damaged fittings,
        - Blanking of hoses,
        - Continuity.

- Type II or III Sewage Treatment/Retention
    - Installation – verify that the tank is intact, free of deterioration and leaks.
    - Vents – verify that all vents are not clogged and flame screen in intact.
    - Wiring – verify that all electrical wiring is intact.
    - Motors and pumps – verify that all motors and pumps are mounted to foundations with guards in place and functional.
    - Piping – Verify that piping is intact and free of leaks, so as not to impose a health hazard.
    - Overboard Discharge valve – verify that this valve is closed and disabled (locked) to prevent the overboard discharge of sewage in U.S. waters.
    - Placard – verify that Operating instructions, Safety precautions and Warnings are posted
    - Emergency Shutdowns – verify that the emergency shutdown is operational.
    - Type II MSD only – verify that the proper chemicals are on board and expiration dates valid.

- Ship Emission
    - Verify International Air Pollution Prevention Certificate is up-to-date.

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