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Viggo Jean-Hansen
TØI report 1036/2009

Institute of Transport Economics
Norwegian Centre for Transport Research

Effects of proposed ship routeing off the Norwegian coast

Part 1 Røst - Utsira

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Summary:

The effects of transferring large vessels (> 5000 Gross Tonnes) and vessels carrying hazardous goods to a proposed shipping route along the Norwegian coastline from Røst to Utsira have been studied. The aim of the routeing measure is to separate the traffic and route the ships farther away from the coast to reduce oil spills. The effects of the routing measure have been analyzed by use of accident simulations and case scenarios. The results reveal that one may expect substantial reductions in oil spill volumes when traffic is transferred to the proposed route. The effects are even greater when ship traffic forecasts for 2025 are used. The reduction in total oil spill volumes is predominantly a result of an expected decline in tanker oil spills.

Sammendrag:

Effektene av å etablere en ny farled for skip over 5000 brutto tonn samt skip som fører farlig last langs norskekysten mellom Røst og Utsira er analysert. Målet med tiltaket er å separere skipstrafikken og lede trafikken lengre ut fra kysten for å redusere faren for oljeutslipp og oljesøl. Effektene av tiltaket er analysert ved hjelp simuleringer av ulykker og ulykkeskonsekvenser og gjennom analyser av to case-scenarioer. Resultatene viser at man kan forvente en kraftig reduksjon i omfanget av oljeutslipp og oljesøl ved å innføre den nye farleden. Effektene er enda større når trafikkprognoser for 2025 benyttes i simuleringene. Reduksjonene i omfang av oljeutslipp er særlig sterke for tankskip.

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Preface

Ship routeing schemes have been established in most of the major, congested shipping areas of the world. The number of accidents has often been dramatically lowered. The Norwegian Coastal Administration has proposed a routeing measure for transferring ship traffic above 5000 GT and vessels carrying dangerous or polluting goods in international voyage off the Norwegian coast all the way from Røst to the Oslo fjord. The present report investigates the effects of this proposed routeing measure from Røst to Utsira. The effects of the proposed routeing measure for the fairway from Utsira to the Oslo fjord are presented in a separate report.

The study was funded by The Norwegian Coastal administration (NCA). Project manager at the NCA was Trond Langemyr.

The principal author of this report is Research Engineer Juned Akhtar, who has been project manager at the Institute of Transport Economics (TØI). Senior Researcher Viggo Jean-Hansen (TØI) has been responsible for the ship traffic forecasts presented. M. Sc. Jørn Harald S. Andersen at Norconsult and Cand. Scient. Elisabeth Lundsør performed the oil spill analyses linked to the two case scenarios studied. Managing Director John Evensen at Maritime Preparedness Operations AS has given valuable comments on the methodology used. Principal Consultant Tim Fowler at Det Norske Veritas, London performed the accident and oil spill simulations in the report.

Comments to earlier drafts of this report have been given by Chief Researcher Torkel Bjørnskau (TØI) and Øystein Linnestad and Trond Langemyr from NCA. Torkel Bjørnskau has been responsible for formal quality assurance. Secretary Trude Rømming has been responsible for the final editing of the manuscript.

Oslo, December 2009
Institute of Transport Economics

Lasse Fridstrøm
Managing Director

Torkel Bjørnskau
Chief Researcher

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Summary:

Effects of proposed ship routeing off the Norwegian coast

Part 1 Røst-Utsira

The Norwegian Coastal Administration (NCA) commissioned The Institute of Transport Economics (TØI) to conduct a risk assessment of a proposed ship routeing measure off the Norwegian coast from Røst to Utsira.

The proposed measure is to route tankers and other heavy ship traffic (over 5.000 gross tonnes (GT)) with high environmental risk potential farther away from the coastline from Røst to Utsira. The proposed measure includes a traffic separation scheme separating traffic going in the different directions (north/south).

The idea behind the proposal is that when ships travel on the proposed route any emergencies or possible oil spills will occur farther away from the coast, giving the authorities more time to react and enable emergency towing or oil spill response that may significantly reduce the overall environmental impact. Another effect is that possible oil spills from ship accidents will to a greater extent evaporate before reaching the coast.

The study has compared accident probabilities and consequences for the present routes and for the proposed route using traffic data for 2008 and traffic forecasts for the year 2025. The effects of transferring ship traffic to the proposed route have also been illustrated by use of two case scenarios.

Reduced accident and oil spill probabilities

Today's traffic and a route model were charted by using data from the Automatic Identification System (AIS). A marine traffic simulation programme called MARCS, developed by DNV Technica, was used to simulate accidents and oil spill volumes both for today's route and for the proposed route, in both 2008 and 2025. Table S.1 and figure S.1 summarizes the results for all vessels.

Table S.1. Effects of proposed routeing on the expected number of all accidents, on oil spill accidents, and on the expected volume of oil spills, with traffic data for 2008 and 2025.

All vessels	All accidents [freq. per year]	Spill Accidents [freq. per year]	Oil spill + bunkers oil [tonnes per year]
Today's routes 2008	3.17	0.55	3224
Proposed route 2008	3.00	0.47	2799
Difference	0.17	0.08	425
Significance	Not sig.	Not sig.	Significant
Today's routes 2025	3.82	0.78	5059
Proposed route 2025	3.58	0.66	3577
Difference	0.24	0.12	1482
Significance	Not sig.	Not sig.	Significant

Source: TØI-report 1036/2009

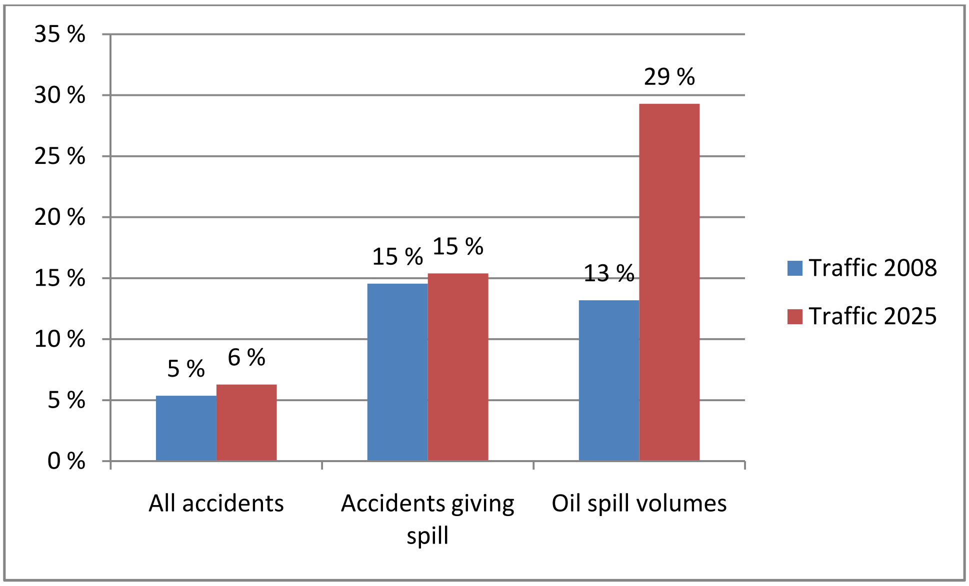

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Figure S.1. Expected effects of proposed routeing. Per cent change in all accidents, oil spill accidents and the volume of oil spills with traffic data for 2008 and 2025.

The proposed routeing of the ship traffic between Røst and Utsira reduces the expected number of accidents and the expected oil spill volumes, both with ship traffic volumes as in 2008 and 2025. The expected reduction in oil spill volumes is particularly great when traffic forecasts for 2025 are used in the simulations.

Tankers are the major contributor to potentially large oil spill volumes, and when tankers are analyzed separately the effects are even stronger. This is revealed in table S.2 and figure S.2.

Table S.2. Effects of proposed routeing on the expected number of all tanker accidents, on oil spill accidents for tankers, and on the expected volume of oil spills for tankers, with traffic data for 2008 and 2025.

Tankers only	All accidents [freq. per year]	Spill Accidents [freq. per year]	Oil spill + bunkers oil [tonnes per year]
Today's routes 2008	0.86	0.32	3120
Proposed route 2008	0.62	0.23	2670
Difference	0.24	0.09	456
Significance	Not sig.	Not sig.	Significant
Today's routes 2025	1.52	0.55	4930
Proposed route 2025	1.17	0.42	3479
Difference	0.35	0.13	1450
Significance	Not sig.	Not sig.	Significant

Source: TØI-report 1036/2009

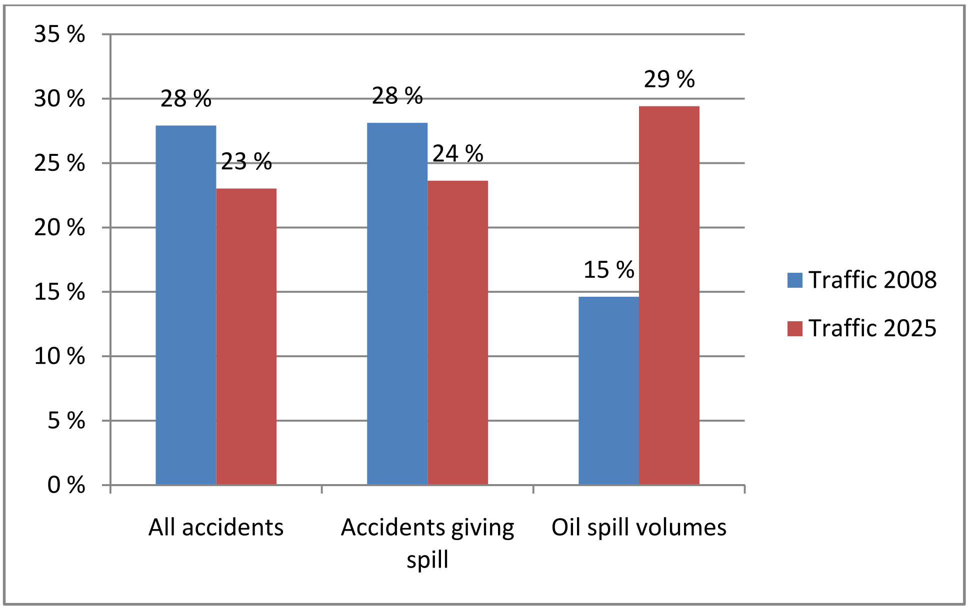

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Figure S.2. Expected effects of proposed routeing. Per cent change in tanker accidents, oil spill accidents for tankers, and the expected volume of oil spills for tankers, with traffic data for 2008 and 2025.

Transferring tanker traffic to the proposed new route gives nearly 30 per cent reductions in accidents and 15 per cent reduction in oil spill volumes when traffic figures for 2008 are used in the simulations. When traffic forecasts for 2025 are used accidents are reduced by over 20 per cent and oil spill volumes are reduced by almost 30 per cent.

Environmental effects illustrated by oil spill scenarios

To oil spill scenarios, at Stad and Sotra, have been constructed in order to analyze the effects of having oil spill accidents on the proposed route instead of on one of the routes used today. The scenarios clearly reveal that the probability of spill accidents decreases with the proposed measure. Also the probability of oil tanker collisions is smaller on the proposed new route than on today's routes, and given an oil spill accident the portion of the fuel or bunker oil reaching the shore is substantially reduced.

There are few adverse environmental effects of adopting the proposed routeing measure. The most important factor is a potentially larger coastline impact area for oil spills. For crude oil, this negative effect is counterbalanced by increased evaporation and natural degradation of oil resulting from increased distance to the cost. Fuel oil spills from locations along the proposed traffic lane may hit a larger impact area. It is, however, possible that this risk will be mitigated by increased time for oil spill response by the authorities, given an accident.

Conclusion

In sum it seems clear that the proposed routeing measures reduces both the probability of accidents and the consequences of possible accidents. Thus, adopting the proposed routeing measures will give a significant risk reduction.

The expected reduction in total oil spill volumes is predominantly a result of an expected decline in tanker oil spills. The proposed measure is in particular addressed towards managing these environmental risks mitigating the effects of the expected tanker traffic increase along the Norwegian coast. It seems, accordingly, reasonable to conclude that the proposed new route is a quite appropriate counter measure.

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Sammendrag:

Konsekvenser av forslag til ny farled utenfor norskekysten
Del 1 Røst-Utsira

På oppdrag for Kystverket har Transportøkonomisk Institutt (TØI) utført kvantitative risikoanalyser som viser effekten av å innføre en alternativ farled for skip over 5000 brutto tonn, samt skip som fører farlig og/eller forurensende last utenfor norskekysten fra Røst til Utsira. Den nye farleden som inkluderer systemer for separasjon av trafikk, vil føre skipstrafikken i større avstand fra kysten.

I analysene er sannsynligheter for og konsekvenser av ulykker sammenlignet ved bruk av dagens farled og den alternative farleden med trafikkdata fra 2008 og med prognostiserte trafikkdata for 2025. To scenarioer for oljeutslipp i utsatte områder har også blitt simulert og drøftet.

Færre ulykker og mindre utslipp med ny farled

Trafikkdata for 2008 ble samlet fra Automatic Identification System (AIS) database. Trafikkdata for 2025 er basert på prognoser for skipstrafikk beregnet av Transportøkonomisk institutt. Et dataprogram for ulykker og utslipp utviklet av Det Norske Veritas, MARCS, ble brukt for å simulere hhv. totalt antall forventede ulykker, forventet antall ulykker som gir utslipp, forventet mengde oljeutslipp og forventet mengde utslipp av bunkersolje. Tabell S.1 og figur S.1 gir et sammendrag av resultatene fra simuleringene.

Tabell S.1. Forventet antall ulykker, antall ulykker som gir oljeutslipp og omfang av utslipp for alle fartøyer med dagens led og med foreslått ny led med trafikk for 2008 og prognostisert trafikk for 2025.

Alle fartøyer	Alle ulykker [antall per år]	Ulykker som gir utslipp [antall per år]	Oljeutslipp (inkl. bunkersolje) [tonn per år]
Dagens led 2008	3,17	0,55	3224
Foreslått led 2008	3,00	0,47	2799
Differanse	0,17	0,08	425
Signifikans	Ikke sig.	Ikke sig.	Signifikant
Dagens led 2025	3,82	0,78	5059
Foreslått led 2025	3,58	0,66	3577
Differanse	0,24	0,12	1482
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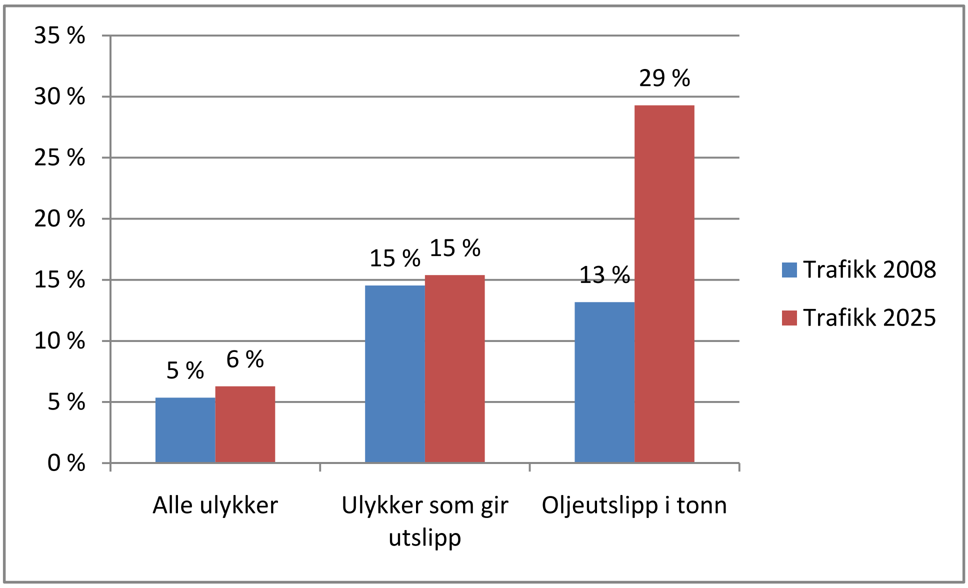

Figur S.1. Prosentvis endring i antall ulykker, antall ulykker som gir oljeutslipp og omfang av utslipp med dagens led og med foreslått ny led, med trafikk for 2008 og prognostisert trafikk for 2025.

Den foreslåtte alternative farleden gir signifikant mindre oljeutslipp sammenlignet med dagens led. Ser man på tankskip isolert, som gir det største bidraget til risikoen for oljeutslipp, er forbedringen enda større. Beregningene er basert på at den nye trafikkleden vil være obligatorisk for tankskip, noe som bidrar til den høye effekten, se tabell S.2 og figur S.2.

Tabell S.2. Forventet antall ulykker, antall ulykker som gir oljeutslipp og omfang av utslipp for tankskip med dagens led og med foreslått ny led, med trafikk for 2008 og prognostisert trafikk for 2025.

Tankskip	Alle ulykker [antall per år]	Ulykker som gir utslipp [antall per år]	Oljeutslipp (inkl. bunkersolje) [tonn per år]
Dagens led 2008	0,86	0,32	3120
Foreslått led 2008	0,62	0,23	2670
Differanse	0,24	0,09	456
Signifikans	Ikke sig.	Ikke sig.	Signifikant
Dagens led 2025	1,52	0,55	4930
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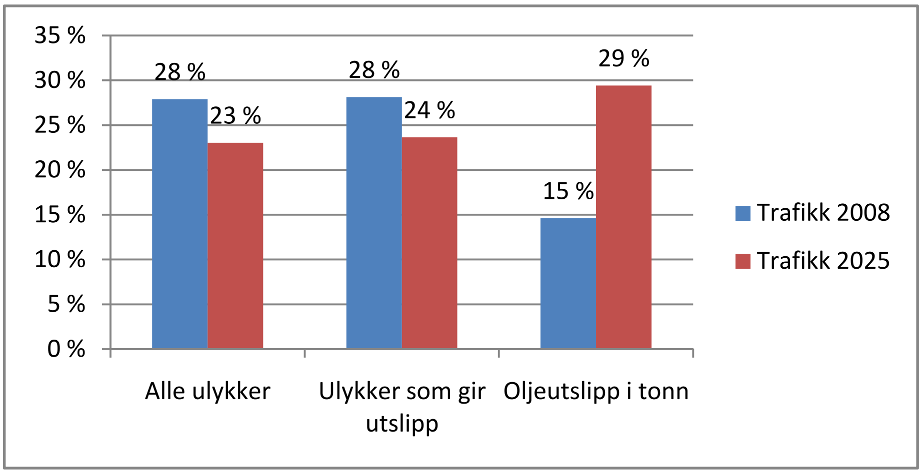


Figur S.2. Effekten av ny farled for tankskip. Forventet prosentvis reduksjon i antall ulykker totalt, ulykker som gir utslipp og omfang av utslipp av olje og bunkersolje, beregnet for trafikk i 2008 og prognostisert trafikk i 2025.

Ved å overføre tankskiptrafikken til den foreslåtte farleden kan man forvente en reduksjon i antall ulykker tankskip på nesten 30 prosent og en nedgang i omfanget av oljeutslipp på 15 prosent, når trafikktall for 2008 er benyttet i simuleringene. Når prognostiserte tall for 2025 er brukt forventes en reduksjon i ulykker på over 20 prosent og en reduksjon i omfang av oljeutslipp på nesten 30 prosent.

Miljøkonsekvenser illustrert med to utslippsscenarioer

To scenarioer ble valgt for å simulere effekter av oljeutslipp ved hhv. Stad og Sotra for å illustrere konsekvenser av å føre trafikk over i den nye farleden. I begge scenarioene ble sannsynlighet for ulykker som gir utslipp og sannsynlighet for kollisjon for tankskip redusert i den nye farleden. Mengde olje som nådde kysten gikk også ned, og det tok lenger tid før oljen nådde land. De negative miljøkonsekvensene av oljesøl var betraktelig mindre med den foreslåtte farleden enn med dagens farled.

Det er få negative konsekvenser av å overføre trafikk til den foreslåtte farleden. En mulig uheldig virkninger kan være at oljesøl som når land kan gi skade på et større område når utslippet skjer lenger fra land, men dette vil motvirkes både av at mer av oljen blir oppløst i sjø og luft samt at myndighetene også får lenger tid til å håndtere utslippet.

Konklusjon

Å føre de relevante skipene over i den nye farleden langs norskekysten fra Røst til Utsira reduserer både sannsynligheten for skipsulykker og sannsynligheten for oljeutslipp betraktelig. De to scenarioene i rapporten indikerer at den nye farleden også reduserer forventet mengde olje som treffer land gitt en ulykke med oljeutslipp. Resultatene viser at effekten på tankskipulykker og utslipp fra tankskip er svært gunstig. Dette har også vært en hovedintensjon bak det foreslåtte tiltaket. Det er følgelig grunn til å konkludere med at lede tankskiptrafikken over i den foreslåtte farleden er et svært godt tiltak for å møte miljøutfordringene som tankskiptrafikken langs norskekysten representerer.

Definition of terms

AIS: Automatic Identification System. A ship-borne transponder broadcasting information about the ship, the voyage, and several other safety related issues.

Collision: An event type that occurs when a ship is struck by another ship.

Drift grounding: An event type that occurs when a ship loses its ability to navigate, through loss of steering or propulsion, and is blown onto the shoreline before it is either taken in tow or is repaired.

DWT: Dead weight tonnage

Event frequency: The number of events, such as inter-ship collisions, that occur per year at a specified location or within a defined area.

GT: Gross tonnage

Historical frequency: A frequency derived from historical data.

IMO: International Maritime Organization

MARCS: Marine Accident Risk Calculation System. An accident and risk simulation programme developed by DNV Technica.

NCA: The Norwegian Coastal Administration

NM: Nautical Mile = 1.852 kilometers

Powered grounding: An event type that occurs when a tanker collides with the shoreline whilst underway.

Risk: The frequency of a hazard multiplied by its consequence. The term is however often used as the mere probability of an accident/incident with adverse consequences.

SOLAS: International Convention for the Safety of Life at Sea

Structural failure: An event type that occurs when a ship sinks in heavy weather or loses its structural integrity due to mechanical failure.

VTS: Vessel traffic services

1 Introduction

1.1 Background

Commercial shipping has important impacts on the wider environment, due to the ordinary release of exhaust gases etc., but in particular due to the risk of accidents with the unintended release of toxic chemicals and oil spills. Unfortunately shipping accidents may have very severe negative impacts, particularly to coastal regions, due to the potential release of very large quantities of hazardous or eco-toxic cargo materials such as crude oil.

Thus, prudent authorities who have the responsibility for pollution response in coastal regions seek to estimate the risks to which they may need to respond, and to prepare appropriate contingency plans and response options in order to manage the risks imposed.

In order to deal with ship accidents promptly and effectively, spill response is considered to be a very important mitigation measure. Norwegian authorities having for a long time been concerned about the risk of oil spills, they have implemented a series of measures in order to reduce the likelihood of accidents, for instance a new Vessel Traffic Service (VTS) service for North Norway located in Vardø, and reinforced tugboat preparedness.

One of the key measures adopted to reduce the risk of ship accidents and oil spills is to impose sailing routes farther away from the coast. Along the northern Norwegian coastline between Vardø and Røst such a more remote sailing route has been imposed. According to the Norwegian Coastal Administration (NCA), the experiences so far have been positive.

1.1.1 Increased oil transport

Since 2002 the oil transport in the Barents Sea from Russia has increased significantly. In 2002, 4 million tonnes of oil were shipped westward through the Barents Sea. In 2008 the number had increased to 10.8 million tonnes. Forecasts for 2025 estimate a 60 per cent increase in the oil transport and a tenfold increase in the gas tanker transport (Hovi & Madslien 2008; Bambulyak & Frantzen, 2009).

All oil transport imposes a risk of acute oil pollution. Consequently an increase in the maritime and off shore petroleum activity will increase the risk. Experience shows that only 10-15% of oil spills in the Arctic Sea can be removed by the current level of preparedness (Bambulyak & Frantzen, 2009). The rest will have to be left to the natural evaporation or breakdown over time. The major contributor to this risk is tankers transporting oil from Russia along the Norwegian coast (Kystverket, 2006a).

1.1.2 Risk of an environmental crisis

Since 2000 Norway has experienced several adverse events that could have resulted in major environmental crises. One example was when the ship "John R" stranded and broke into two pieces. Most of the oil carried by the ship was removed before the ship broke, thus inflicting only minor environmental damages. Another example was the near-accident of a 100 000 tonnes Russian oil tanker with engine failure that drifted towards the coast.

There have also been ship accidents leading to oil spills and pollution. One example is the “MS Server” grounding north-west of Bergen in January 2007. The bad weather the following days made the recovery of heavy fuel oil difficult. Around 400 tonnes of heavy fuel oil was released into the environment.

The most recent event took place in July 2009 when the Panama registered vessel “Full City” grounded south of Langesund in Southern Norway. The ship suffered severe damage to her hull, and bunker oil escaped to the sea and polluted the shorelines. Some of the affected areas were special protected areas and bird sanctuaries.

It is worth mentioning that Norway has experienced a steady rise in the number of groundings since 2004. In 2008 103 groundings were registered. Although the majority of these groundings involve medium size vessels, i.e. 500-5000 gross tonnage (GT), the trend is alarming (Sjøfartsdirektoratet, 2009).

1.1.3 The Norwegian Sea

The Norwegian Sea is rich in natural resources, thus being of great economic interest. Along with the fishery resources it also has huge recourses of gas and oil, resulting in high transport activity. Recently launched projects such as the gas production from the world’s largest offshore gas reserve, Shtockman, and the production of LNG from Snøhvit and oil from Goliat, will add to today’s already high maritime activity along the coast of Norway and thus increase the risk of environmental damages. The marine flora and fauna are vulnerable; the Norwegian coast line is home to approximately 19.5 million individual sea birds and 4.5 million breeding pairs (Loeng & Drinkwater, 2007).

1.1.4 The proposed measure

The proposed measure is to route tankers and other heavy ship traffic (over 5.000 GT) with high environmental risk potential farther away from the coastline from Røst to Utsira. The idea behind the proposal is that any emergencies or possible oil spills will then occur farther away from the coast, giving the authorities more time to react and enable emergency towing or oil spill response that may significantly reduce the overall environmental impact. Another effect is that possible oil spills from ship accidents will then to a greater extent evaporate before reaching the coast.

1.2 Research objective

The overall objective of this study is to produce quantitative risk analyses in order to estimate the effects of the proposed measure. The main research objective is thus to compare the accident risks and accident consequences with and without the proposed route measures implemented.

Risk calculations will be conducted both by use of current ship traffic volumes and by use of traffic forecasts for the year 2025.

1.3 Report structure

This report is structured as follows. In chapter 2 we describe the methodological approach chosen and in chapter 3 the data base used. Chapters 4 and 5 explain the routes used today and the proposed new route. In chapter 6 traffic forecasts are presented, while chapter 7 exhibits the results of the risk calculations. In chapter 8 we present the results of two case scenarios. A discussion of results and a conclusion follow in chapter 9.

In general the current main report summarises the model approach, presents the results and discusses their implications. Further information about the data used and the calculations made can be found in the appendices. Also the two case scenarios of accidents producing oil spills are presented in more detail in an appendix.

The appendices are as follows:

1. Traffic on today's routes and on the proposed route
2. Vessel velocity and length
3. Obstacles on or near the routes
4. Description of the Marine Accident Risk Calculation System (MARCS)
5. Data input in MARCS
6. MARCS results
7. Calculation of confidence intervals
8. Two case scenarios. Report from Norconsult
9. Accident figures for the scenario areas
10. Risk assessment of alternative tanker routing. Report from DNV

2 The approach

The approach adopted is to compare the proposed recommended route with today's routes given traffic data of 2008 and 2025. An accident and risk simulation programme called MARCS, developed by DNV Technica, was used for this purpose. The MARCS programme is described in detail in Appendix 4.

2.1 Traffic forecasts

The traffic data from 2008 was used to develop a forecast for 2025. The forecast allows for differentiated traffic developments according to ship types, coastline sections etc. along various parts of the coast. Chapter 6 describes in detail how the forecast has been made.

Traffic data both for 2008 and for 2025 have been entered into the MARCS model in order to calculate accident and oil spill probabilities.

2.2 Risk simulations

The primary focus of the risk simulations was to assess the risk of oil spills per year. Historical data for the North Sea from the Det Norske Veritas' (DNV) database on oil spill events from tankers was used to identify the major causes of oil spills. These input data, which were entered into the MARCS model, are described in more detail in Appendix 5.

The major causes of oil spill were according to the DNV database identified as:

- Inter-ship collisions
- Tanker grounding (powered and drifts events)
- Collisions between tankers and offshore platforms
- Fire and explosions whilst underway
- Structural failure/foundering
- Cargo transfer operations in open waters (lightering).

The simulation combines statistical data with information about the lanes, marine traffic data, environmental data, and operational data, in order to calculate the risk of accident and the risk of oil spills. The details of the data and the simulation are given in chapter 7.

The Norwegian coast is long with varying climatic conditions. The probabilities that have been estimated in this study are accumulated probabilities that are helpful to assess the total impact of the measure. Plots of the study area are also generated and illustrated in the report.

2.3 Case scenarios

Two case scenarios have been selected in order to simulate the consequences given specific accidents. These cases were carefully selected in co-operation with the Norwegian Coastal Administration (NCA), Maritime Preparedness Operations AS (MAPO) and Norconsult. They are intended to serve as examples and are described in detail in Appendix 8.

The scenarios were selected based on the following criteria:

- The national dimensioning of oil spill scenarios defined by the Ministry of Fisheries and Coastal Affairs (20 000 m^3 crude oil, 1000 m^3 or 5000 m^3 heavy fuel oil)
- AIS data and identification of high density traffic "hot spots"
- Potential threat to coastline and vulnerable marine resources
- Prevailing wind and sea current conditions, and inside operational window for oil spill response

As part of the national emergency response system an oil drift model service is provided by the Norwegian Meteorological Institute, Marine Forecasting Centre (DNMI). Based on sophisticated ocean and weather models, end users such as NCA and major private contingency organisations can access this tool through a web interface. By use of this tool NCA has provided the oil drift simulations to this report.

3 Marine traffic data

3.1 AIS data

The universal Automatic Identification System – AIS – is a ship-borne transponder that broadcasts information about the ship, the voyage, and several safety-related issues.

The coverage of the system is similar to other VHF applications, i.e. it depends on the range to the horizon from the antenna. A total of 37 stations form the AIS network in Norway. Typically the range is 45 NM from the coast. Research is currently in progress in order to increase this range by using a space-based AIS receiver which will have a range of up to 1000 NM. (Eriksen, Høye, Narheim, & Meland, 2006). AIS carriage requirements are given in the SOLAS convention chapter V, regulation 19, paragraph 2.4.

Ships transmit updated AIS information with 2-30 seconds' intervals. The frequency varies by type of ship. Information from AIS can be used to construct advanced data bases on ship movements, forming the basis of the ship traffic data used in our analyses.

3.2 Data selection

The proposed route was designed for vessels carrying hazardous/polluting cargo and for all vessels above 5000 GT. Our AIS data files did, however, not contain information about vessel weight (GT and DWT). Yet, by using the IMO number, NCA was able to utilize Lloyd's register to collect the vessel weights.

We specified the following six relevant vessel types according to their potential for bunker and cargo spills:

- Chemical tanker
- Gas tanker
- Oil tanker
- Cargo ships larger than 5000 GT
- Other ships larger than 5000 GT
- All other vessels

3.3 Traffic volumes in 2008

By first defining the routes of today's traffic we could define specific crossing sections on the routes. Data from the AIS database were utilized in order to collect information on all vessels on the crossing sections in the year 2008. For our analyses we required AIS data of traffic volumes sorted by weight (GT and DWT), tanker type, IMO number and speed. These data were then used as input into the MARCS program.

4 Today's traffic pattern

The traffic data was used to plot all vessels of 100 metres length or more for the period 2008-2009. 100 metres was chosen after checking the AIS files and confirming that all tankers were at least 100 metres. The average length of the entire fleet was calculated to be 165 metres.

The plots in figure 4.1 and 4.2 yield the typically used routes for large vessels today. A single sailing is marked with a yellow line. Areas with high density are marked red. On the basis of these traffic data, today's routes could be determined. Caution was taken to define a new lane at every shift of traffic density or angle. At every corner of these lines, a new lane was defined and the AIS data extension was made. In total 9 main lanes and 6 crossing lanes were defined for routes from Røst to Utsira. In the plots, today's routes are indicated by the parallel lines running along the coast. The crossing lanes are indicated as shaded grey areas.

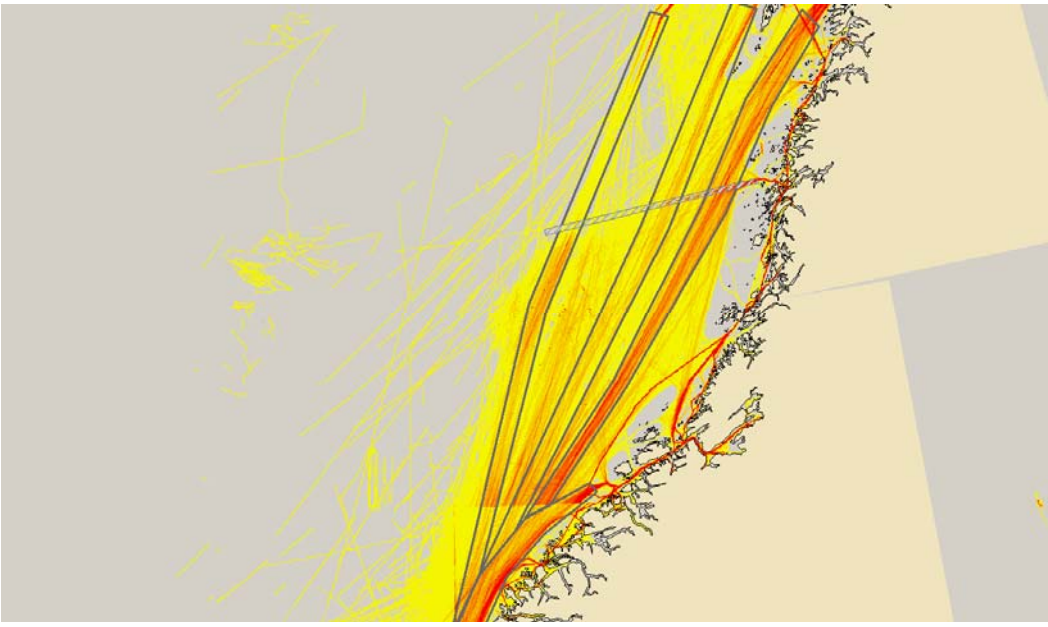


Figure 4.1 Today's routes Røst – Stad. Source: NCA

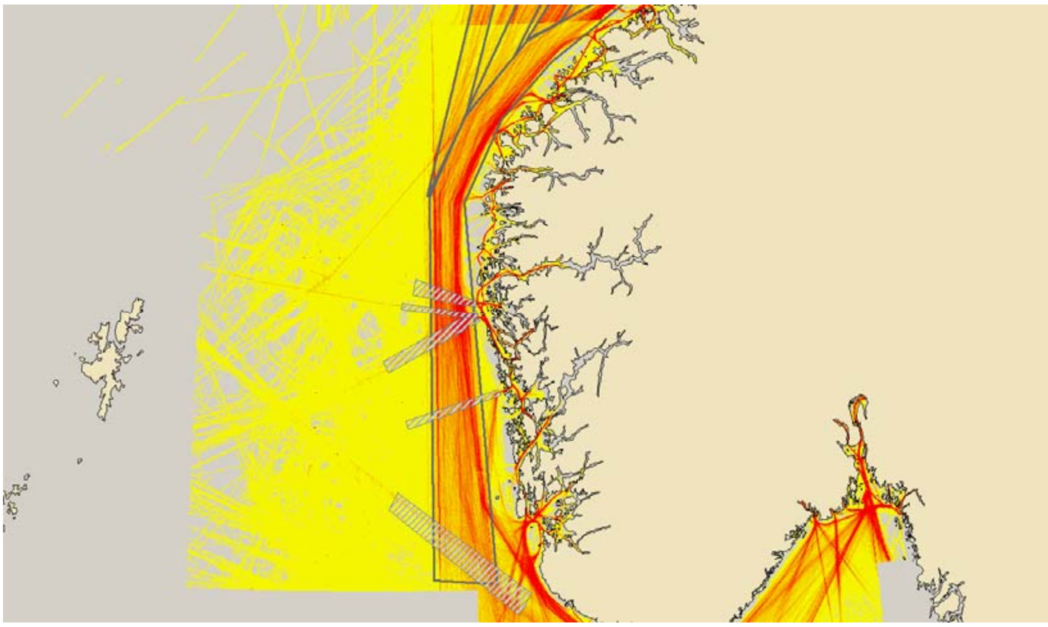


Figure 4.2 Today's routes Stad – Utsira. Source: NCA

4.1 Two-way traffic

Today's routes have no separation schemes. However the oil transport flow in the Norwegian Sea goes from north to south and from the offshore oil platforms to the plants onshore. Hence two lanes were defined on top of each other for the tankers, one fully loaded (north-south) and one mainly empty going back towards north. The rest of the traffic was defined as constantly half loaded.

4.2 Objects on or near the routes

Platforms, wind parks etc. are installations at sea that vessels have to navigate past. In the case of drifting or other emergency situations there can be collisions with these structures leading to oil spill, loss of ship etc. The Norwegian Coastal Administration provided a list of all the installations in our study area, 421 in total between Røst and Utsira. These are mainly oil platforms. This information was also entered into the MARCS model. The list of the installations is given in Appendix 3.

5 The proposed route

The proposed route has been identified by an expert group consisting of relevant stakeholders. The following points were considered while constructing the proposed ship routeing for tankers and vessels above 5000 GT:

1. IMO "design criteria" for the ships' routeing measures

2. Environmental considerations
   a. Routeing traffic as far from shore as practicable, but limited by the AIS range.
   b. Special concern has been given to areas along the route and off the coast that are vulnerable to oil spills

3. Industry and commerce – permanent and stationary activity.
   a. Consideration for stationary fishing areas
   b. Consideration of solid surface offshore installations (including future installations that will be in place when the proposed route measures will be effective in 2011)
   c. Considerations for shipping – avoiding disproportionate large changes to the distance travelled and safeguarding the current permanent cross-traffic.

4. Industry and commerce – activities that are not fixed or stationary
   a. Pelagic fishing
   b. Potential high-activity areas, i.e. areas with a high probability of becoming places of extensive commercial activity that may affect the shipping industry within the next 5 years.

5.1 Traffic on the proposed route

Today's routes and the proposed route differ with respect to vessel density, width and length. Our analysis is based on a scenario where vessels above 5000 GT and vessels carrying dangerous and/or polluting goods are transferred to the proposed route, leaving the rest of the ships on today's routes. In other words, all ship types except the last defined category ("all other vessels") in section 3.2 will be transferred to the proposed route in our risk simulations.

The plots in figure 5.1 show the proposed route. For co-ordinates please see Appendix 1.

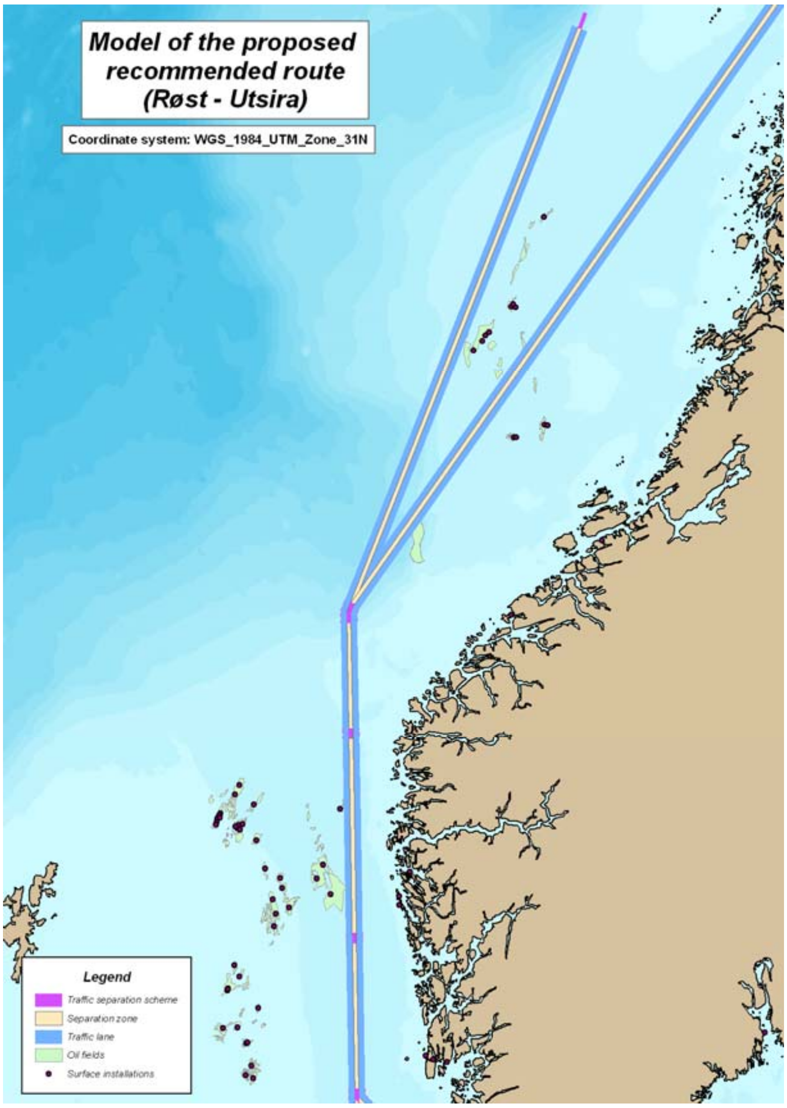


Figure 5.1 Proposed route Røst-Utsira. Source: NCA

5.2 Ship laden

Northbound tankers tend to sail in ballast, while southbound tankers are fully loaded. For the crossing traffic from the offshore installations, the tankers have been defined as being fully loaded going from the installations and empty to the installations.

6 Traffic forecast

TØI has established a forecast for the ship traffic from 2008 to 2025 for the whole fairway between Røst and the Oslo fjord. This chapter presents the basis of the forecast and some additional comments.

6.1 Types of vessels

We identified six types of relevant ships in section 3.2: Chemical tankers, gas tankers, oil tankers, cargo ships >5000 GT, other ships > 5000 GT and all other vessels.

The ships sailing in the fairway will be of many different nationalities, but the traffic is dominated by vessels linked to the offshore activities in Norwegian and Russian areas. Along the fairway outside the Norwegian coastline, ships to and from the Norwegian ports dominate the traffic. Sea freight typically consists of long haul transport of goods having low value per tonne.

Passenger traffic will be limited and predominantly consist of cruise ships (> 5000 GT) coming from Europe and America visiting Norwegian fjords, North Cape and the coast around Svalbard.

Oil and gas fields are currently being developed in the northern area of the fairway in question, and further developments both on Russian and Norwegian fields are likely in the period 2008-2025. Most of the oil and gas produced in these areas has to be exported by ship from the fields to the markets in Europe and North America. Thus, oil and gas tanker traffic is expected to increase.

In addition small tankers carrying fuel to the fishing fleet, oil and gas for residential heating etc. and other types of cargo ships will be travelling along the coast.

The last group of ships ("all other vessels") is dominated by fishing vessels going to the fishing fields and mostly to Norwegian fishing ports for further export by ship, road or air. Russian trawlers also deliver fish to Norwegian ports.

6.2 The parts of the route

The traffic forecast for the whole fairway, i.e. from Røst to the Oslo fjord, is split geographically into six sections due to the differing traffic developments expected. Sections 4-6 are relevant for the present study, whereas sections 1-3 are relevant for the study of the effects of the routeing measure between Utsira and the Oslo fjord which is presented in a separate report (Akhtar & Jean-Hansen 2009). The six geographical sections are:

1. From the Swedish border to Brevik (the VTS centre where the fairway into Grenland port in Telemark County is located)
2. From Brevik to Lindesnes (Lindesnes is the southernmost point of the Norwegian mainland in Vest-Agder County)
3. From Lindesnes to Fedje in Hordaland County (Fedje is in the middle of the western coast, approximately 50 km north of Bergen)
4. From Fedje to Stad in Møre and Romsdal County (Stad is the northwesternmost point of southern Norway and a spot with particularly hard winds and rough sea most of the year)
5. From Stad to Rørvik (Rørvik is a small port north of the Trondheim fjord and an important port used by Hurtigruten)
6. From Rørvik to Røst (Røst is a small inhabited island just outside the waters of Lofoten in Nordland County).

Figure 6.1 gives a picture of the profile of the present ship traffic on parts of the fairway. These six registration points depicted in figure 6 are all located between Lindesnes and Stad, i.e. in the geographical sections 3 and 4 in the list given above. Måløy is close to Stad (the northwesternmost point), whereas Farsund is close to Lindesnes (the southernmost point). Thus the six registration points give a picture of the ship traffic along the west coast of Norway.

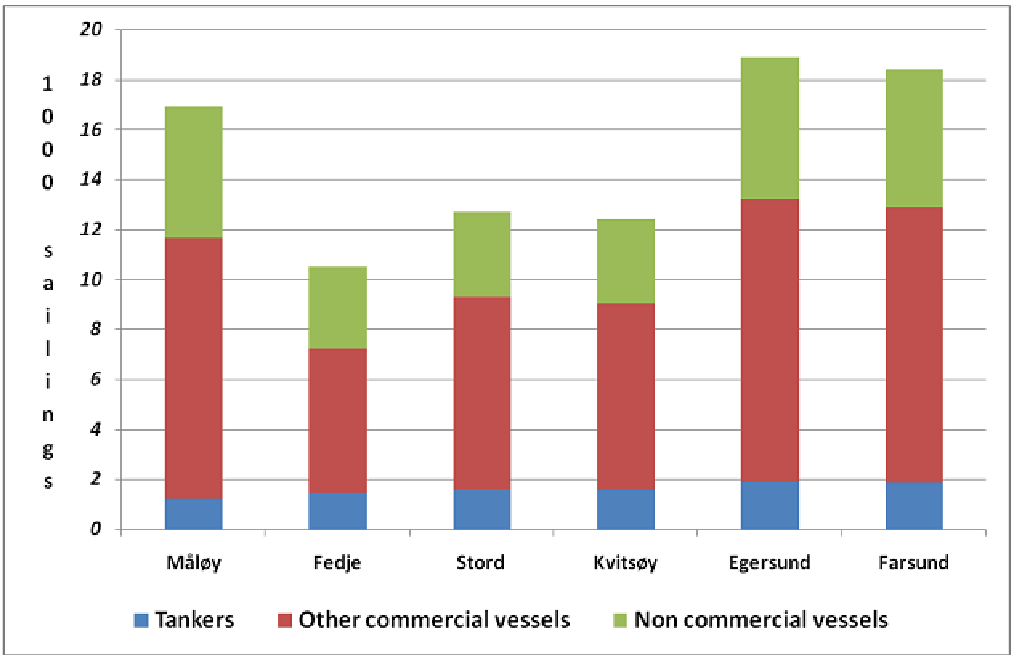


Figure 6.1 The number of sailings per year for ships and vessels distributed ship types and geographical registration points on the Norwegian west coast. Source: Safetec (2007).

The ship traffic volume differs along the western coast according to figure 6.1. The southernmost registration points, i.e. Egersund and Farsund, have the largest amount of traffic, but also by Måløy there are relatively large traffic volumes. It is also clear from figure 6.1 that “Other commercial vessels” (cargo ships) constitute the major part of the ship traffic passing through the registration points on the Norwegian west coast. Non-commercial traffic constitutes between 27 and 31 per cent of all sailings. The number of tankers passing is substantially lower, and fairly stable between the registration points. There is however a slight increase in the number of tankers from the left-hand to the right-hand side in the figure, implying that the number of tankers increases the further south we go.

6.3 Traffic forecasts by type of ship

By utilizing the traffic data from the registration points given in figure 6.1 and by analyzing the oil and gas shipments plan from the NCA and from internationally published reports, a traffic forecast for 2025 was developed for various sections of the route. The forecast was divided into two, one for tankers and one for non-tankers larger than 5000 GT (i.e. cargo vessels). The forecast for cargo vessels for sections 3, 4 and 5 of the route between Røst and Utsira is given in figure 6.2.

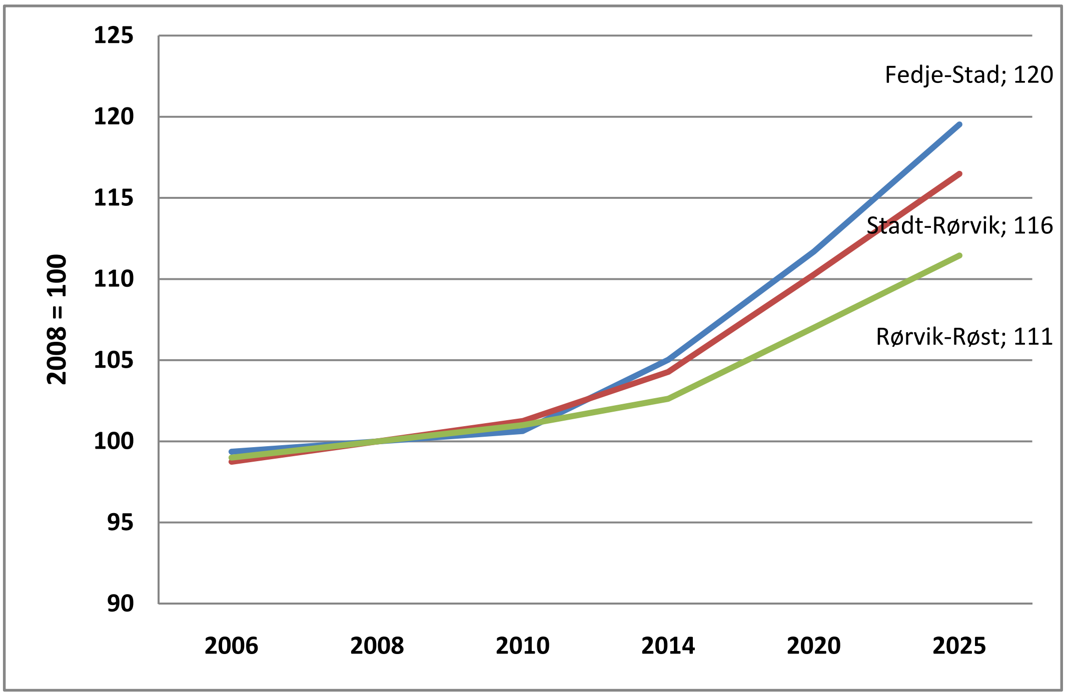


Figure 6.2 Traffic forecasts for cargo vessels on various geographical sections along the Norwegian coast, from 2006 to 2025. Index, 2008=100. Source: Hovi & Madslien(2008).

According to the forecasts given in figure 6.2 traffic volumes for cargo vessels will increase on all three sections of the route. Cargo vessel traffic is however expected to increase more on the west coast (Fedje-Stad) then on the north coast (Rørvik-Røst).

Also for tankers traffic volumes are expected to increase according to our forecasts. The traffic volume for tankers is heavily influenced by the developments of the gas and oil fields in the Barents Sea. The development of the large Shtokman oil and gas field will in particular generate more tanker traffic. Also the oil and gas fields in the

Norwegian sector (Snøhvit, Askeladd, Albatross and Goliat) will contribute to the expected tanker traffic increase. Traffic forecasts for oil and gas tankers are given in figure 6.3

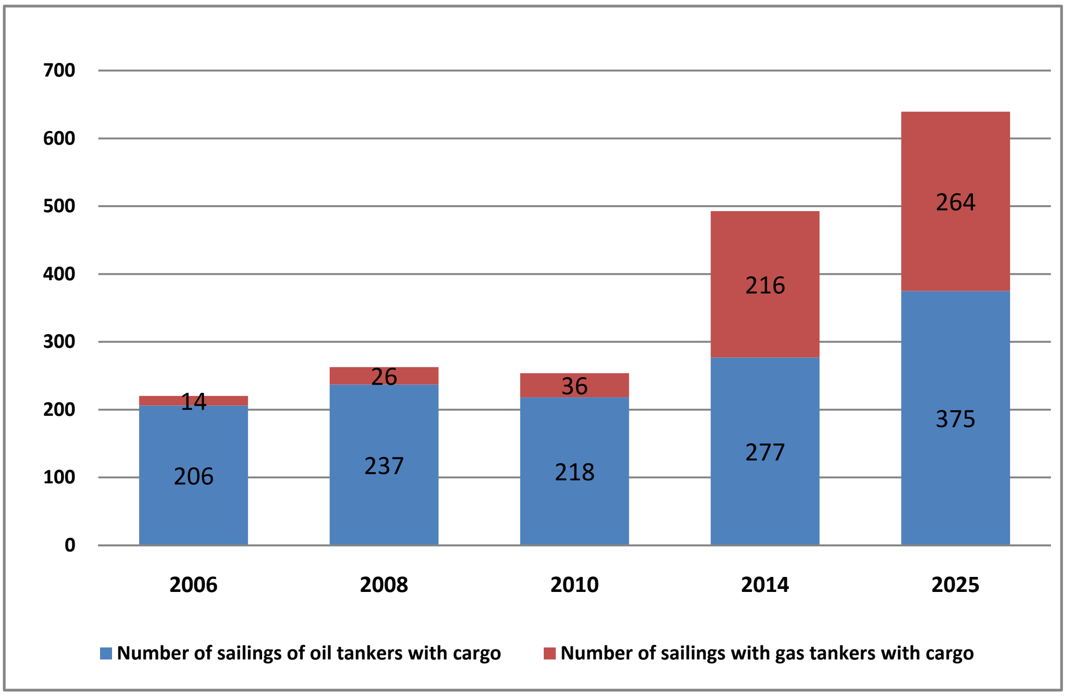


Figure 6.3 The forecasts for the number of sailings of oil and gas tankers along the west coast of Norway from 2006 to 2025. Source: Bambulyak and Frantzen (2009) and Hovi & Madslien (2008).

The forecast given in figure 6.3 is based on expected export figures from the Shtokman field given by Bambulyak and Frantzen (2009), as well as on forecasts of the transport of oil and gas from the Norwegian oil and gas fields given by Hovi and Madslien (2008). According to the prognosis, tanker traffic is expected to increase from 2014 onward, notably gas tanker traffic. This is closely related to the planned development of the gas production from the Shtokman field. Oil tanker traffic is also expected to increase, but to a lesser extent.

In addition to the tanker transit traffic given in figure 6.3 there is also tanker traffic to and from the oil and gas fields in the North and Norwegian Sea and product tankers trafficking Norwegian refinery ports. Figure 6.4 presents the forecast of the total tanker traffic between Utsira and Røst distributed by traffic types.

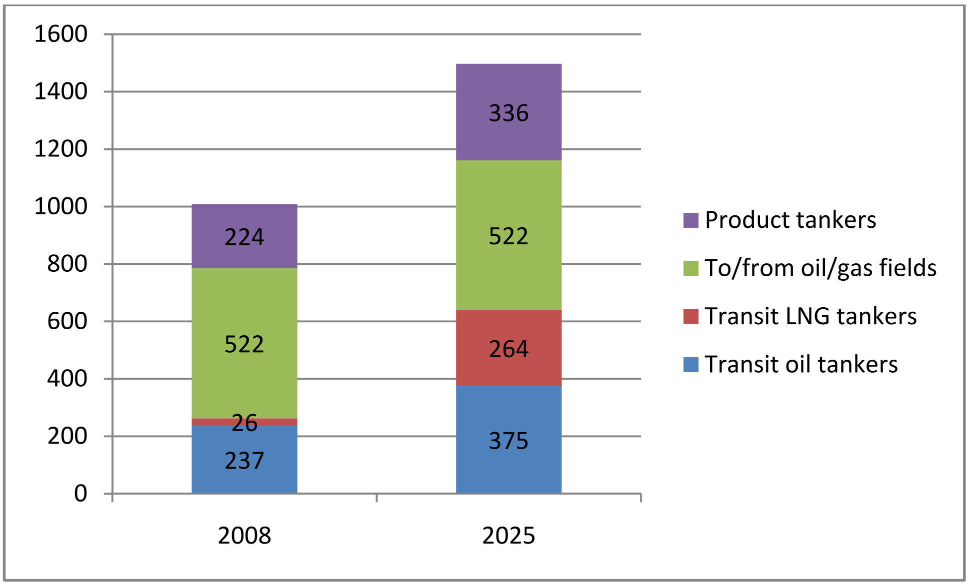


Figure 6.4 The total number of sailings of oil and gas tankers between Røst and Utsira in 2008 with forecasts for 2025. Source: NCA

In addition to the increase in the transit traffic of oil and notably gas tankers (cf. also figure 6.3) we expect an increase in the product tanker traffic going to and from Norwegian ports. Traffic to and from the oil and gas fields in the Norwegian and North Sea is, however, expected to remain stable.

We have defined six relevant types of vessels for the accident and oil spill simulations, cf. chapter 3, section 3.2. The change in traffic (number of sailings) within each of the six types of vessels from 2008 to 2025 is estimated by means of data from Hovi and Madslien (2008)[1] for Norwegian movements and from Bambulyak and Frantzen (2009) for Russian and (some) Norwegian tanker traffic. In Hovi and Madslien (2008), the forecast is specified by country but not differentiated by type of traffic.

For crossing lanes we have assumed a larger increase in the number of sailings with LPGs compared to oil tankers. The reason is that we expect an increase in household gas consumption compared to oil consumption, because gas is more environmentally friendly and clean. In addition, gas is easily available and cheap for the populations of the North Sea countries.

Table 6.1 gives the traffic volume data for today's route and the proposed route both for 2008 and 2025 distributed by type of ship. The numbers are aggregated per ship type by MARCS. These traffic figures are used as the basis for the risk calculations presented later in the report.

[1] Hovi and Madslien (2008) estimate the development in sea transport volumes (tonne-kilometres). We have assumed a similar development in the number of sailings.

Table 6.1 The total traffic volume (in 1000 nautical miles) in 2008 and 2025 distributed by type of ship on today's routes and on the proposed route.

	Today's routes 2008	Proposed route 2008	Today's routes 2025	Proposed route 2025
Chemical Tanker	958	1210	1420	1570
Gas Tanker	327	385	1450	2110
Oil Tanker	609	863	903	1570
Cargo ships >5000 GT	1250	2210	1500	2730
Other ships >5000 GT	464	691	554	817
All other vessels	4430	4520	4020	4090
Total	8040	9880	9850	12900

Source: DNV: In TØI-report 1036/2009, Appendix 10

According to table 6.1 implementing the proposed route will increase the traffic volume of all ship types, but only marginally for "all other vessels". The forecast for 2025 reveals a substantial increase in the traffic volume of tankers, notably gas tankers, corresponding to the picture given in figure 6.3. Traffic volumes of "all other vessels" are expected to decrease, due to a decreasing number of fishing vessels.

6.4 Total traffic forecasts

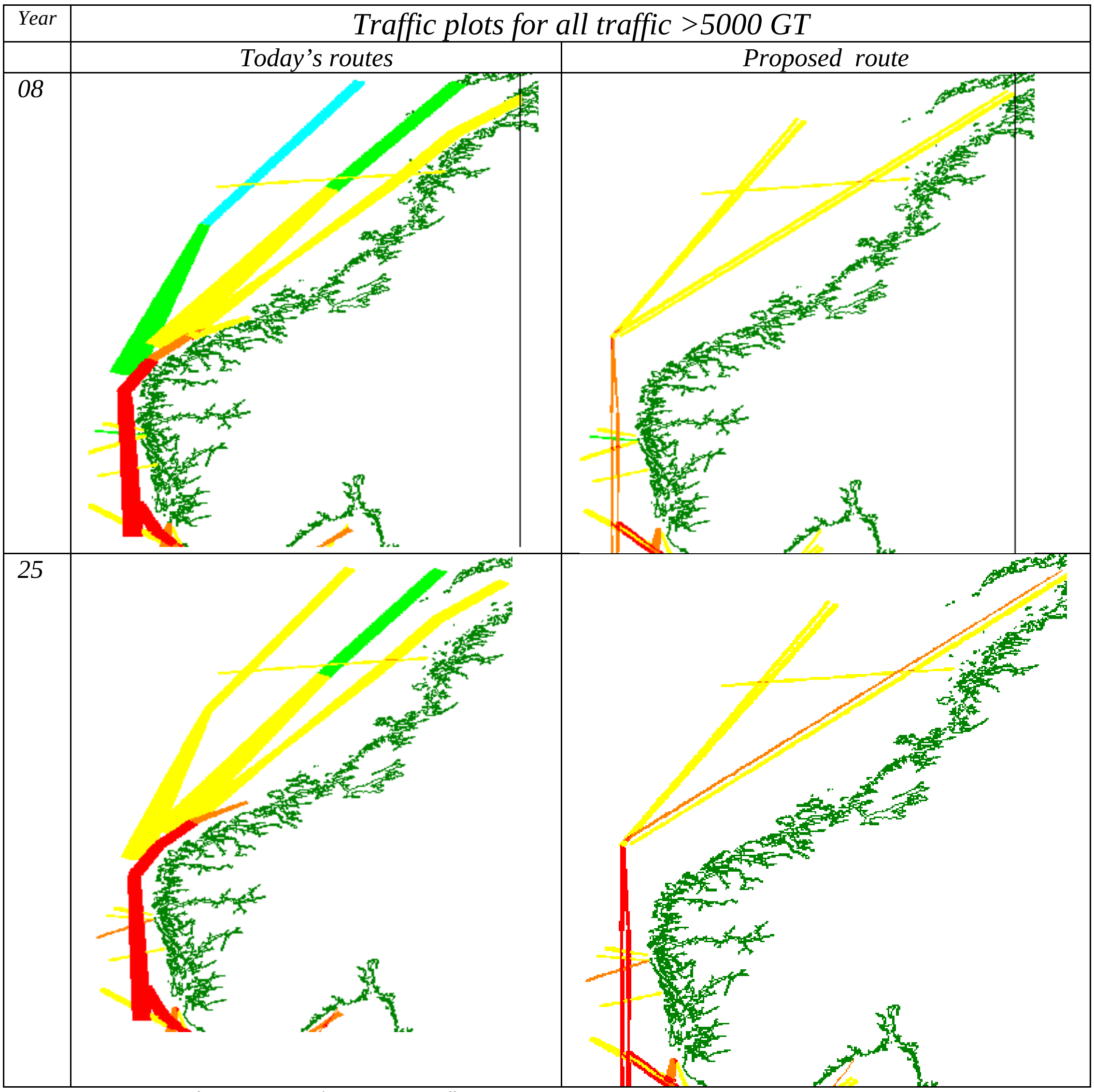
Using the forecasts for various sections and ship types, we have estimated the total traffic volumes on the entire route as of the year 2025. The expected ship traffic volumes are visualized in figures 6.3 and 6.4. Table 6.2 shows the keys for reading these plots. Vessels smaller than 5000 GT have been excluded from the diagrams, but they are of course included in the simulation results.

Table 6.2. lists the colours used in the traffic plots. Red colour indicates dense traffic with over 10 movements per day, while green, blue and grey colours indicate low levels of traffic. Yellow colour indicates traffic of 1-5 movements per day while orange indicates 5-10 movements per day.

Table 6.2 Key to Ship Traffic Plots

Colour	Traffic frequency (ship movements per day within each location)
(grey)	**0.05 to 0.1**
(cyan)	**0.1 to 0.5**
(green)	**0.5 to 1**
(yellow)	**1 to 5**
(orange)	**5 to 10**
(red)	**> 10**

Source: DNV: In TØI-report 1036/2009, Appendix 10

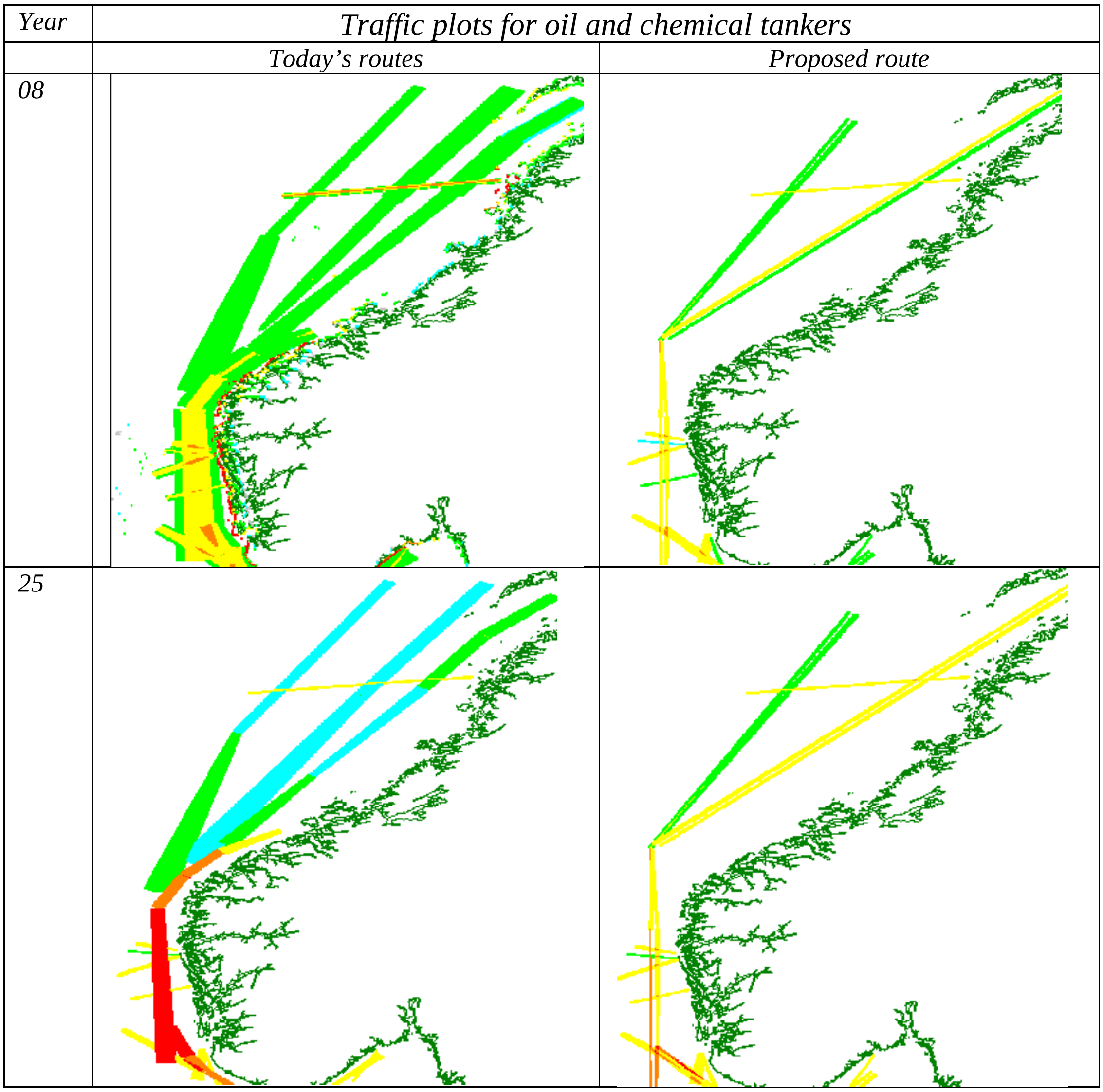


Source: DNV: In TØI-report 1036/2009, Appendix 10

Figure 6.5 Traffic plots for all vessels above 5000 GT in 2008 and 2025 on today's route and on the proposed route. Today's traffic (2008) is given in the top left diagram; estimated traffic on the proposed route in 2008 is given in top right diagram. Traffic forecasts for 2025 on today's route are given in the bottom left diagram and on the proposed route in the bottom right diagram.

The plots clearly show that the proposed new route directs the traffic farther away from the coast. The plots also visualize how the proposed new route segregates ships moving in different directions. The proposed route seems more lucid with fewer crossings and accordingly lower probability of collisions. Fewer crossings may also give make ship crews more alert at each crossing and thereby reduce collision probabilities even more. This possible increase in alertness is, however, not included in our simulation

Tankers are of particular interest in this study due to their high potential of oil spills. Figure 6.6 gives traffic plots for oil and chemical tankers alone in a fashion similar to figure 6.5.



Source: DNV: In TØI-report 1036/2009, Appendix 10

Figure 6.6 Traffic plots for oil and chemical tankers in 2008 and 2025 for today's routes and the proposed route. Today's traffic (2008) is given in the top left diagram; estimated traffic on the proposed route in 2008 is given in top right diagram. Traffic forecasts for 2025 on today's route are given in the bottom left diagram and on the proposed route in the bottom right diagram

Figure 6.6 reveals that tanker traffic will increase substantially and large parts of the coast will have more than 10 tanker movements per day in 2025. The plots reveal that on today's routes the tanker traffic will go quite close to the coast. The proposed route moves the traffic farther away from the coast and with the traffic separation schemes adopted the proposed new route seems to cope with the increased tanker traffic reasonably well.

7 Accident and oil spill probabilities

7.1 Scope of the study

In the following, accident probability figures will be calculated both for today's route and for the proposed new route, relying on historical accident data and on the traffic forecasts given above.

In order to estimate the expected number of accidents and oil spills for the two routes, DNV was engaged to perform probability calculations based on the MARCS model. The Institute of Transport Economics (TØI) was responsible for input data quality and for the interpretation of the results. Shipping patterns and other input data characteristics of shipping operations in the year 2008 have been extrapolated to the year 2025 by TØI.

The calculations are restricted to accidents affecting the marine environment, while accidents in port approach and port areas are excluded from the scope of this work. The accident and oil spill calculations are confined to the release of the following materials due to accidental events:

- Crude oil and refined products carried as cargo by tankers.
- Bunker fuel oil carried by all ships.

In addition to the accident and oil spill probabilities presented in this chapter, two separate oil spill case scenarios have been developed by Norconsult for accidents at two separate locations along the coast: Stad and Sotra. The results from these scenarios are presented in Appendix 8.

7.2 Description of the MARCS model

MARCS was developed by DNV to support their marine risk management consultancy business. The MARCS model provides a general framework for the performance of marine risk calculations. A block diagram of the model is shown in figure 7.1.

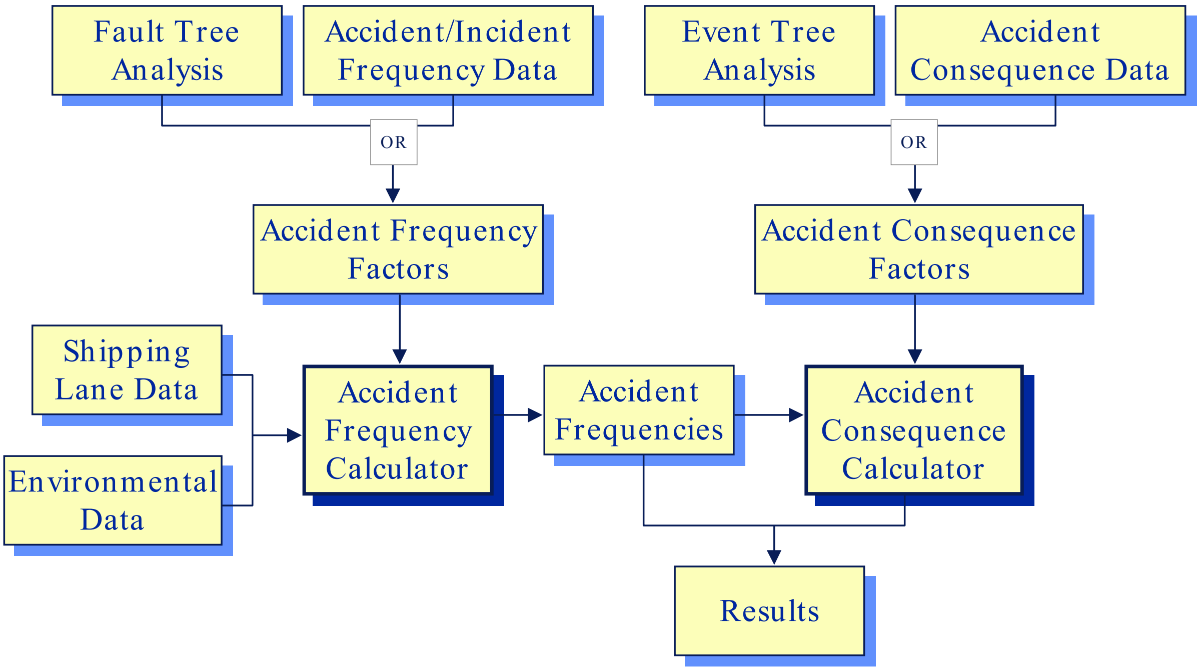


Figure 7.1 Block diagram of MARCS Source: DNV Appendix 4

The MARCS model classifies data into 4 main types:

- Shipping lane data describes the movements of various marine traffic types within the study area;
- Environment data describes the conditions within the calculation area, including the location of geographical features (land, offshore structures etc.) and meteorological data (visibility, wind rose, currents and sea state);
- Internal operational data describes operational procedures and equipment installed onboard ship – such data can affect both accident frequency and accident consequence factors;
- External operational data describes factors external to the ship that can affect ship safety, such as VTMS (Vessel Traffic Management Systems), TSS (Traffic Separation Schemes), and the location and performance of emergency tugs – such data can affect both accident frequency and accident consequence factors.

As indicated in figure 7.1, accident frequency and consequence factors can be derived in two ways. If a coarse assessment of accident risk is required, the factors may be taken from worldwide historical accident data. Alternatively, if a more detailed study is required, these factors may be derived from generic fault trees or event trees which have been modified to take account of specific local factors, as in our case.

7.3 Data input

A range of data sets are used by MARCS to simulate the traffic, the various accidents frequencies and the oil spills. A brief summary of the type of data input entered into the model will be described in this chapter. More details of these data can be found in Appendix 5.

7.3.1 Traffic image data

The marine traffic image data used by MARCS is a representation of the actual flows of traffic within the calculation area. Marine traffic data are represented through lane data structures. Various traffic types are divided into separate marine data bases in order to facilitate data verification and the computation of various types of risk (for example, crude oil spill risk versus human safety).

7.3.2 Internal operational data

Internal operational data are represented within MARCS using location specific survey data. Examples of internal operational data include:

- The probability of a collision given an encounter;
- The probability of a powered grounding given that a ship's course is close to the shoreline;
- The frequency (per hour at risk) of fires or explosions.

7.3.3 External operational data

External operational data generally represent controls external to the traffic image, which affect marine risk. In MARCS they relate mainly to the location of VTS zones (which influence the collision and powered grounding frequencies by external vigilance, where external vigilance means that an observer external to the ship may alert the ship to prevent an accident), and to the presence and performance of emergency towing vessels (tugs) which can save a ship from drift grounding.

7.3.4 Wind rose and sea state data

The severity of the Norwegian Sea weather is well known. A noteworthy characteristic is the seasonal and year-to-year variations. An accurate estimation of the wind climatology must therefore be based upon long time series of high-quality wind data.

Wind rose data is defined within 8 compass points (north, north-east, east etc.) in 4 wind speed categories: 1) calm (0 to 20 knots); 2) fresh (20 to 30 knots); 3) gale (30 to 45 knots); and 4) storm (greater than 45 knots). Sea state (wave height) within MARCS is inferred from the wind speed and the nature of the sea area (classified as sheltered, semi-sheltered or open water).

To simplify our simulation in relation to wind, four wind states were defined as shown in table 7.1. The sea state or the wave height is determined from a combination of the wind speed and the nature of the sea area, i.e. if the water is open, semi-sheltered or sheltered. For our study the routes were naturally defined as open waters (cf. Appendix 5 for details).

Table 7.1 Wind states and corresponding sea states

Wind state	Sea state
Calm	Flat – Moderate waves of some length.
Fresh	Long waves begin to form – Sea heaps up
Gale	Moderately high waves with breaking crests forming spindrift
Storm	Very high waves with overhanging crests – huge waves. Sea is completely white with foam and spray.

7.3.5 Visibility

Poor visibility arises when fog, snow, rain or other phenomena restrict visibility to less than two nautical miles. It should be noted that night-time is categorized as good visibility unless restricted by fog, snow etc.

Visibility data was provided by the Norwegian Meteorological Institute (Met.no). On average, from 1971 to 2000, the winter months from December to March are those with poorest visibility. In this period, visibility along the coast is categorized as good (defined as range of vision of 10 km) 80 per cent of the time. Visibility is best during May to September, with good visibility 90 % of the time.

Visibility between 4 and 10 kms is rare for this coast line. The visibility assumptions entered into MARCS was that visibility was better than 4 km 95% of the time and poorer than 4 km 5 % of the time all year round.

7.3.6 Hazards

Analyses of historical ship accident data indicate that almost all open-water shipping losses (excepting causes such as war or piracy) can be categorized into seven generic accident types as listed in table 7.2. (The table also gives the abbreviations used in the simulation. These will be useful for reading the detail statistics in Appendix 6.)

Table 7.2 Generic ship accident types

Accident type	**Abbreviation**
Ship-ship collision	Collis
Powered grounding (groundings which occur when the ship has the ability to navigate safely yet goes aground, such as the *Exxon Valdez*):	PGrd
Drift grounding (groundings which occur when the ship is unable to navigate safely due to mechanical failure, such as the *Braer*):	DGrd
Structural failure/foundering whilst underway	Struc
Fire/explosion whilst underway	Fex
Powered ship collision with fixed marine structures such as platforms or wind turbines (similar definition to powered grounding):	PPlat
Drifting ship collision with fixed marine structures such as platforms or wind turbines (similar definition to drift grounding)	DPlat

Source: DNV: In TØI-report 1036/2009, Appendix 10

These generic accident types effectively represent the results of a high level marine transportation hazard identification (HAZID) exercise and are applicable for most marine transportation systems. DNV considers this high level HAZID to be sufficient for the risk calculations in this project.

7.4 Accident analyses

In the following we present three types of figures on expected numbers of accidents:

1. Expected accident frequencies (accidents per year) by ship and accident type, for today's routes and the proposed new route in 2008.
2. Expected spill accident frequencies (cargo and bunker oil spills) by ship type for today's route and the proposed new route in 2008 and 2025
3. Expected oil spill volumes (cargo and bunker oil spills) by ship type for today's route and the proposed new route in 2008 and 2025

7.4.1 Accident frequencies in 2008

Tables 7.3 and 7.4 presents the expected accident frequency per year given traffic volumes and ship type distributions of 2008 for the routes travelled today and for the proposed new route. The accident figures are also distributed according to accident and ship types.

Table 7.3 Expected accident frequency per year in 2008. Today's routes Røst–Utsira.

	Total	Chemical Tanker	Gas Tanker	Oil Tanker	Cargo > 5000 GT	Other vessels >5000 GT	Rest
Collis	**0.150**	0.021	0.005	0.013	0.023	0.007	0,080
Struc	**0.177**	0.022	0.004	0.016	0.029	0.010	0,096
FEX	**0.155**	0.019	0.003	0.014	0.026	0.009	0,084
PGrd	**0.415**	0.068	0.010	0.092	0.090	0.032	0,122
DGrd	**2.253**	0.345	0.057	0.165	0.345	0.107	1,236
PPlat	**0.007**	0.000	0.000	0.004	0.001	0.000	0,001
DPlat	**0.012**	0.001	0.000	0.003	0.002	0.001	0,004
Total	**3.170**	0.477	0.079	0.308	0.517	0.167	1,623

Source: TØI-report 1036/2009 (Appendix 6: MARCS results)

Table 7.4 Expected accident frequency per year in 2008. Proposed route Røst–Utsira.

	Total	Chemical Tanker	Gas Tanker	Oil Tanker	Cargo > 5000 GT	Other vessels >5000 GT	Rest
Collis	**0.120**	0.013	0.002	0.011	0.024	0.007	0.064
Struc	**0.219**	0.026	0.003	0.024	0.054	0.015	0.097
FEX	**0.192**	0.023	0.003	0.021	0.047	0.013	0.085
PGrd	**0.360**	0.043	0.006	0.077	0.065	0.026	0.143
DGrd	**2.090**	0.177	0.026	0.160	0.377	0.091	1.260
PPlat	**0.006**	0.000	0.000	0.004	0.001	0.000	0.001
DPlat	**0.017**	0.002	0.000	0.004	0.005	0.002	0.004
Total	**3.000**	0.283	0.040	0.300	0.573	0.152	1.650

Source: TØI-report 1036/2009 (Appendix 6: MARCS results)

In total, 3.2 accidents are expected to take place in 2008 on today's route. The estimated figure if the proposed new route is implemented is 3.0 accidents. There is a reduction in the expected number of most accident types and ship types, in particular for chemical tankers and gas tankers. For the other types of ship the expected number of accidents is only marginally changed.

According to table 7.3 and 7.4, grounding accidents are those that will be most reduced by imposing the new route. This is hardly surprising since the routing scheme moves the ship traffic farther away from the shore.

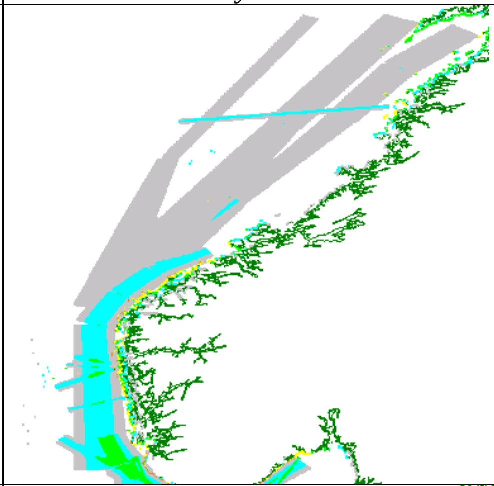
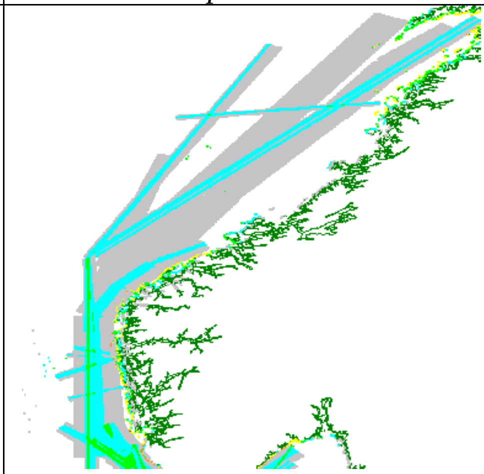
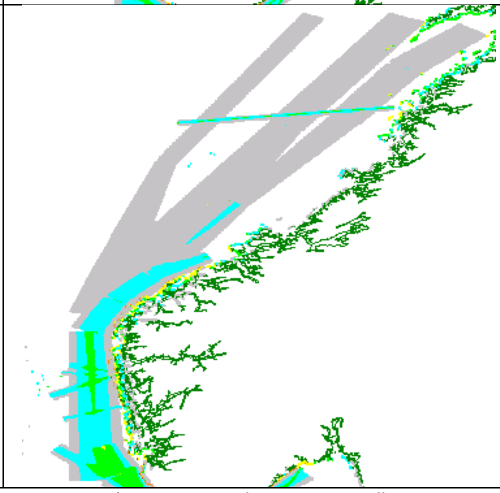
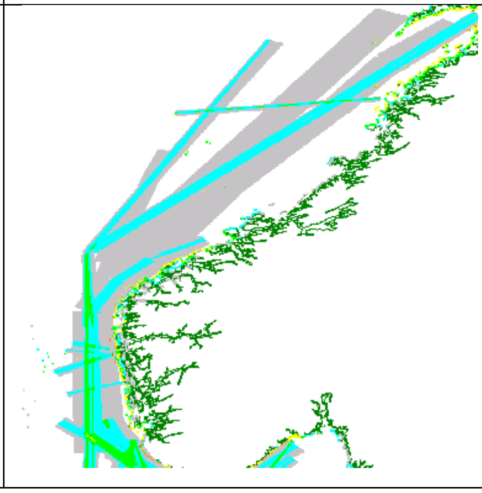
7.4.2 Expected spill accident frequencies in 2008 and 2025

Not all accidents result in oil spills. Figure 7.2 presents plots of the expected bunker oil spill accidents plus cargo spill accidents for chemical tankers and oil tankers on today's route and on the proposed route in 2008 and 2025. Details can be found in Appendix 6. Table 7.5 explains the colour code used in the plot. As in the plots presented above, today's routes are presented on the left-hand side and the proposed new route on the right-hand side.

Table 7.5 Key to accident frequency plots

Colour	Accident frequency (accidents per year within each calculation location)
(grey)	1.0 E-08 - 1.0 E-06
(cyan)	1.0 E-06 - 1.0 E-05
(green)	1.0 E-05 - 1.0 E-04
(yellow)	1.0 E-04 - 1.0 E-03
(orange)	1.0 E-03 - 1.0 E-02
(red)	> 1.0 E-02

Source: DNV: In TØI-report 1036/2009, Appendix 10

	Spill accidents: Bunker spill from all traffic plus cargo oil spill from chemical tankers and oil tankers	
Year	*Today's routes*	*Proposed route*
08		
25		

Source: DNV: In TØI-report 1036/2009, Appendix 10

Figure 7.2 Expected frequencies of spill accidents: bunker and cargo oil spills on today's route and the proposed new route in 2008 and 2025.

In the plots in figure 7.2, the lanes of today's routes are mainly coloured grey and blue in the north, whereas there are some green areas in the south. For the proposed route, the effect of having traffic concentrated in the proposed lanes is quite clearly indicated by the blue lines. Expected oil spill accidents on the crossing lanes are not affected by the implementation of the proposed route.

By merely looking at the plots it is difficult to draw any clear conclusions about expected oil spill frequencies of redirecting ship traffic to the proposed new route. This is however revealed in table 7.6, which gives the total spill accident frequencies distributed by vessel types for the four scenarios depicted in figure 7.2.

Table 7.6 Spill accident frequencies for today's route and for the proposed route in 2008 and 2025 distributed by ship type. Røst – Utsira

	Total	Chemical Tanker	Gas Tanker	Oil Tanker	Cargo > 5000 GT	Other vessels >5000 GT	Rest
Today's routes 2008	**0.55**	0.18	0.02	0.12	0.05	0.02	0.16
Proposed route 2008	**0.47**	0.10	0.01	0.12	0.06	0.02	0.17
Today's routes 2025	**0.78**	0.27	0.09	0.19	0.06	0.02	0.15
Proposed route 2025	**0.66**	0.14	0.06	0.22	0.07	0.02	0.15

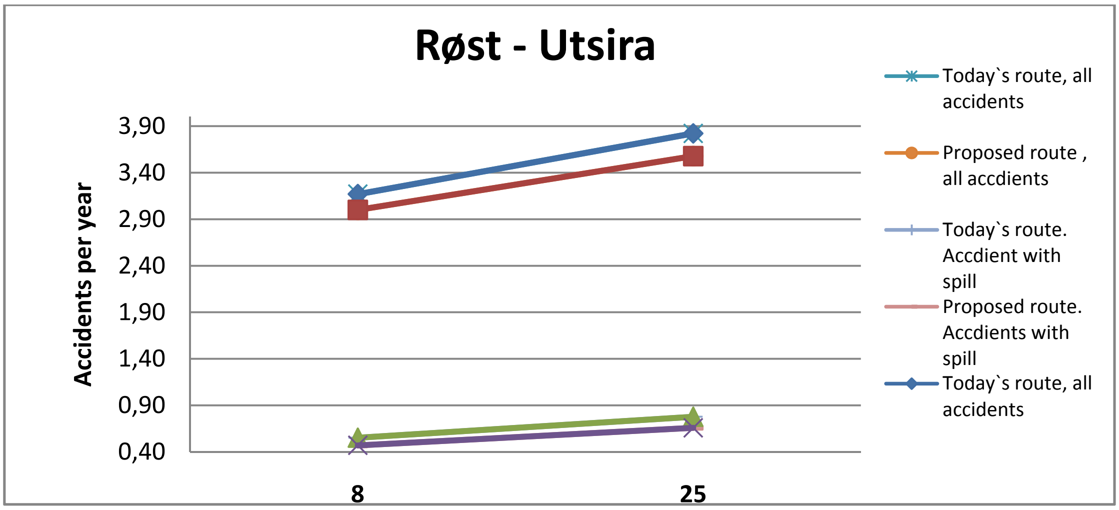
Source: TØI-report 1036/2009 (Appendix 6: MARCS results)

Table 7.6 clearly shows that the expected number of spill accidents is decreased when adopting the proposed new route. This is true both for the total number of accidents and for accidents involving chemical tankers and gas tankers. For oil tankers there is, however, a small increase in the expected number of oil spill accidents when the proposed route is adopted, given the traffic forecasts of 2025.

The main reason for this effect is probably that lanes in the proposed new route narrows the traffic and thus increases the probability of a collision. However, the simulation does not take into account the possible higher alertness of the crew and easier navigation which follows by the separation of the traffic. Neither does the simulation adjust for the positive experiences derived from traffic separations schemes elsewhere in the world. Accordingly it is possible that our simulation overestimates the accident frequency of oil tankers in 2025.

The vessels in the category "Rest" will not follow the proposed new route, and thus the changes in accident probabilities are small. The small reduction can be attributed to the fact that when other vessels are rerouted, the vessels in the "Rest" category have fewer other vessels to collide with.

Figure 7.3 gives a picture of the expected accident frequencies both for all accidents and for oil spill accidents for today's route and for the proposed new route, in 2008 as well as in 2025.



Source: TØI-report 1036/2009

Figure 7.3 Effects on all accidents and on oil spill accidents for the present route and for the proposed new route in 2008 and 2025

The expected number of accidents both with and without oil spills is lower for the proposed new route both in 2008 and 2025, but the differences seem rather moderate. However, when, in the next section, we compare the two alternative routes with respect to the expected oil spill volumes, the picture is altered and the proposed new route is seen to have a substantial beneficial effect.

7.4.3 Expected oil spill volumes in 2008 and 2025

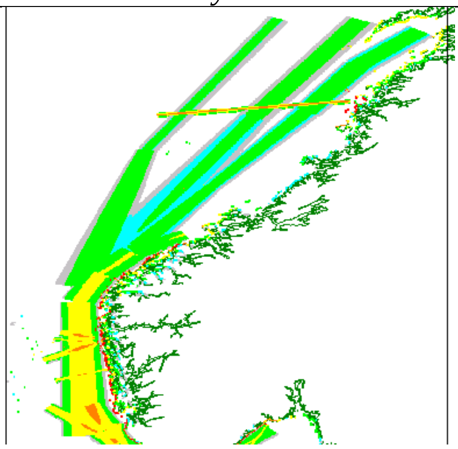
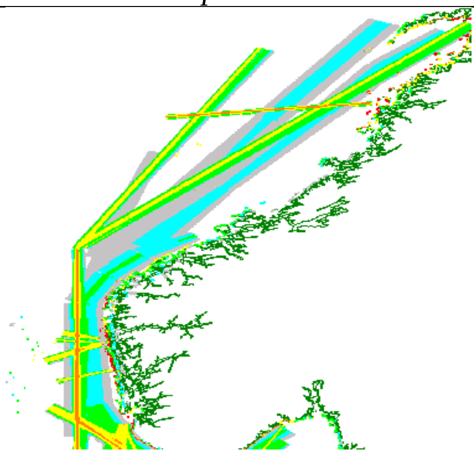
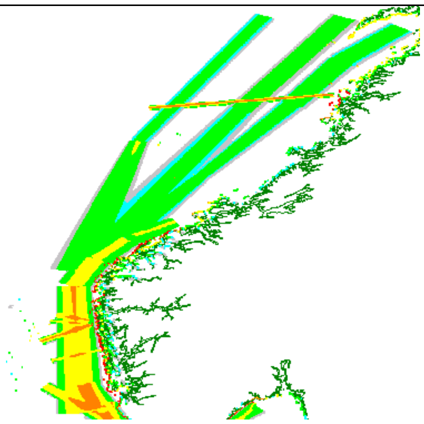
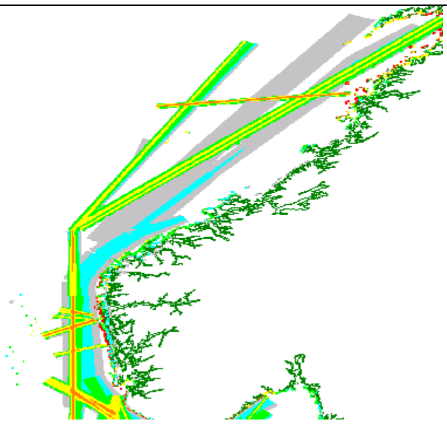
Not all accidents are spill accidents, and not all spill accidents lead to huge oil spills. The cargo and bunker fuel oil risks (average tonnes of oil lost from containment per year) depend on ship type and accident type. Figure 7.4 presents plots of the expected cargo oil spill volumes for chemical tankers and oil tankers on today's route and on the proposed new route in 2008 and 2025.

Details are presented in Appendix 6. Table 7.7 explains the colour code used in the plot. As in the plots previously presented, today's routes are presented on the left-hand side and the proposed new route on the right-hand side of figure 7.4.

Table 7.7 Key to accident risk plots

Colour	Cargo spill risk (tonnes cargo spilt per year within each location)
(grey)	**1.0 E-06 – 1.0 E-05**
(cyan)	**1.0 E-05 – 1.0 E-04**
(green)	**1.0 E-04 – 1.0 E-02**
(yellow)	**1.0 E-02 – 1.0 E-01**
(orange)	**1.0 E-01 – 1.0**
(red)	**> 1.0**

Source: DNV: In TØI-report 1036/2009, Appendix 10

	Bunker oil spills from all ship types and cargo oil spill from chemical tankers and oil tankers	
Year	*Today's routes*	*Proposed route*
08		
25		

Source: DNV: In TØI-report 1036/2009, Appendix 10

Figure 7.4 Bunker and cargo oil spills in 2008 and 2025 for today's route and for the proposed new route. The spills for today's route/2008 is given in the top left diagram; the proposed new route/2008 in the top right quadrant; the spills for today's route in 2025 is presented in the bottom left diagram and for the proposed route in the bottom right diagram.

The red stripes sketched along the coast indicate large oil spills caused by grounding accidents. From comparing the plots it is evident that the proposed new route reduces oil spill volumes from grounding accidents both in 2008 and in 2025.

Overall, it is clear that with the proposed new route, the oil spill will be concentrated within the lanes, and the oil spill in the rest of the sea and on the shore will lowered. Detailed oil spill figures are given in table 7.8.

Table 7.8 Expected oil spills in tonnes per year on the fairway Røst – Utsira for today's routes and the proposed route distributed by ship types and traffic estimates for 2008 and 2025.

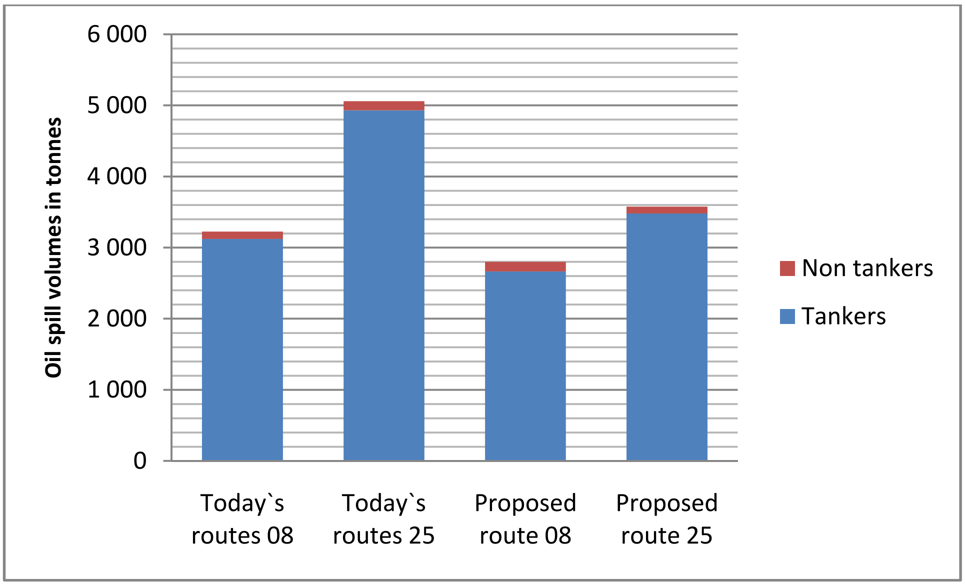
	Total	Chemical Tanker	Gas Tanker	Oil Tanker	Cargo > 5000 GT	Other >5000 GT	Rest
Today's routes 2008	3224.4	513.8	78.5	2543.3	63.6	4.9	20.4
Proposed route 2008	2799.0	385.9	48.7	2240.9	97.8	4.7	20.9
Today's routes 2025	5059.4	781.3	314.6	3862.1	76.4	5.9	18.6
Proposed route 2025	3576.9	366.1	148.7	2977.9	71.2	3.5	9.7

Source: TØI-report 1036/2009 (Appendix 6: MARCS results)

It is clear that the oil spill probability is reduced for all vessel types for both traffic scenarios by adopting the proposed route. In total, the proposed routing is expected to reduce oil spills by 425 tonnes per year in 2008 and by 1483 tonnes in 2025. The main reason for this substantial reduction is that the number of groundings is reduced. The reduction is particularly strong for tankers. More detailed analyses of tankers are presented in section 7.4.4.

7.4.4 Expected accident frequencies and oil spill volumes for tankers

Tankers are of particular interest in the present study because they contribute to the vast majority of oil spills. Tankers include oil tankers, chemical tankers and gas tankers. For oil tankers and chemical tankers the proposed new route has particularly beneficial effects. One important reason for this is that grounding accidents are reduced as seen in table 7.3. Figure 7.5 presents the expected oil spill volumes that can be attributed to tankers and non-tankers on today's route and on the proposed new route in 2008 and 2025, cf. also table 7.8.



Source: TØI-report 1036/2009

Figure 7.5 Expected oil spill volumes from tankers and non-tankers in tonnes, including bunkers oil on today's route and the proposed route with traffic data for 2008 and 2025. Tankers include oil tankers, chemical tankers and gas tankers.

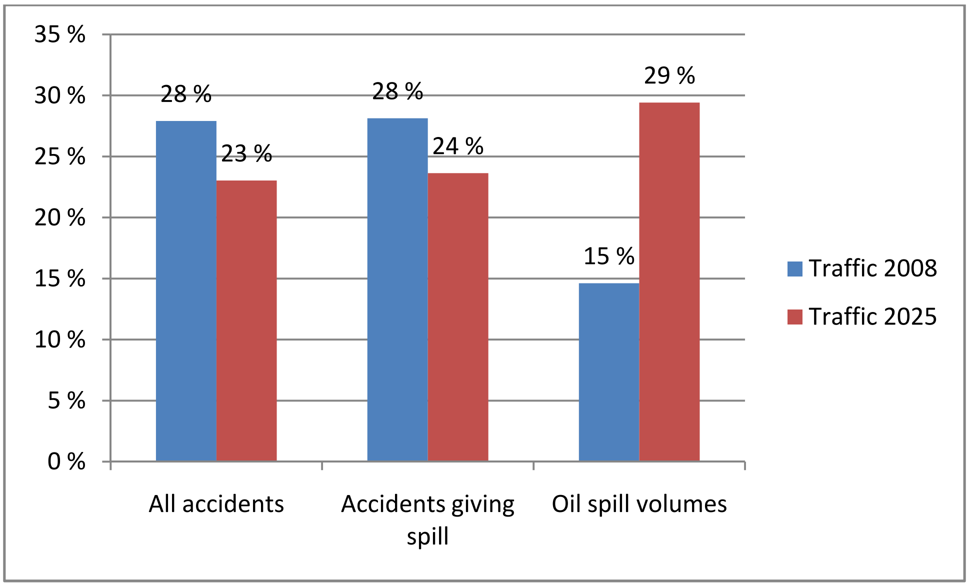
Figure 7.5 clearly reveals that tankers are responsible for almost all oil spills. Accordingly the effect of the proposed new route for tanker accidents and spills are of particular interest, and especially oil tankers and chemical tankers (gas tankers can only spill their bunkers oil).

It is also important to note that it is the expected oil spill *volumes* that are of particular interest, because the environmental risk follows from oil spills rather than from the accidents per se. Table 7.9 and figure 7.6 present the effects of applying the proposed new route on the expected number of tanker accidents, on the expected number of spill accidents for tankers, and on the expected oil spill volumes for tankers in 2008 and 2025. Details on expected accidents and oil spill volumes can be found in Appendix 6.

Table 7.9 Effects of proposed routeing on the expected number of all tanker accidents, on oil spill accidents for tankers, and on the expected volume of oil spills for tankers, with traffic data for 2008 and 2025.

Tankers only	All accidents [freq. per year]	Spill Accidents [freq. per year]	Oil spill + bunkers oil [tonnes per year]
Today's routes 2008	0.86	0.32	3120
Proposed route 2008	0.62	0.23	2670
Difference	0.24	0.09	456
Significance	Not sig.	Not sig.	Significant
Today's routes 2025	1.52	0.55	4930
Proposed route 2025	1.17	0.42	3479
Difference	0.35	0.13	1450
Significance	Not sig.	Not sig.	Significant

Source: TØI-report 1036/2009



Source: TØI-report 1036/2009

Figure 7.6 Expected effects of proposed routeing. Per cent change in tanker accidents, on oil spill accidents for tankers, and the expected volume of oil spills for tankers, with traffic data for 2008 and 2025.

The proposed route reduces both the expected number of accidents and the expected oil spill volumes from tanker accidents. The effects on the expected oil spill volumes are statistically significant at the 5 % level. See Appendix 7 for details regarding the calculation of confidence intervals and significance levels.

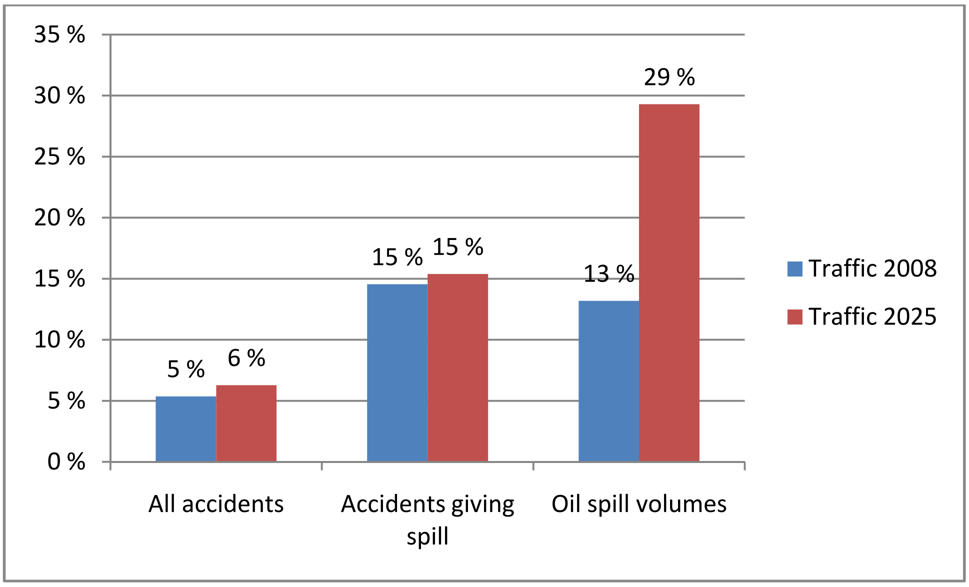
7.5 Aggregate results

The results given above clearly reveal that adopting the proposed new route can be expected to reduce the number of ship accidents, the number of oil spill accidents and especially the expected oil spill volumes for tankers. The effects are particularly strong for tanker accidents and spills. Table 7.10 and figure 7.7 present the aggregate effects for all ships (not only tankers) for the proposed new route compared with today's routes. For details, please see Appendix 6.

Table 7.10 Effects of proposed routeing on the expected number of all accidents, on oil spill accidents, and on the expected volume of oil spills, with traffic data for 2008 and 2025.

All vessels	All accidents [freq. per year]	Spill Accidents [freq. per year]	Oil spill + bunkers oil [tonnes per year]
Today's routes 2008	3.17	0.55	3224
Proposed route 2008	3.00	0.47	2799
Difference	0.17	0.08	425
Significance	Not sig.	Not sig.	Significant
Today's routes 2025	3.82	0.78	5059
Proposed route 2025	3.58	0.66	3577
Difference	0.24	0.12	1482
Significance	Not sig.	Not sig.	Significant

Source: TØI-report 1036/2009



Source: TØI-report 1036/2009

Figure 7.7 Expected effects of proposed routeing. Per cent change in all accidents, oil spill accidents and the volume of oil spills with traffic data for 2008 and 2025.

Transferring ship traffic to the proposed new route gives a five per cent reduction in all accidents and a 15 per cent reduction in oil spill accidents. These effects are independent of whether traffic data of 2008 or 2025 are used. For oil spill volumes (both cargo and bunkers spills), there is a considerable effect of almost 30 per cent reduction when the proposed route is adopted with traffic data of 2025.

Another effect of the transfer of ship traffic to the proposed new route is that possible oil spills will occur farther away from the coast, giving the authorities more time to react and enable emergency towing or oil spill response that may significantly reduce the overall environmental impact, cf. the results of the two oil spill scenarios presented in Appendix 8.

However, when oil spills occur farther away from the coast a higher number of sites may be exposed to the spill. Experience shows nevertheless that the number of impact sites is not proportionate with the total impact area and may also be counterbalanced by the lower concentration of oil (severity of impact) on each site. During past spills oil it has been observed that oil tends to accumulate in patches. The extended drifting distance may decrease the impact intensity and hence ease the effect for the local populations within a region.

Summing up the results, it seems clear that implementing the proposed route for tankers and vessels above 5000 GT will lower probabilities for oil spills including bunkers oil spills and reduce the volumes of oil spills reaching the coast. Thus the proposed new route will significantly reduce the environmental impacts of the shipping traffic along the Norwegian coast.

8 Environmental impacts illustrated by two case scenarios - Stad and Sotra

In this chapter we present two case scenarios of the environmental impacts of a major oil spill on the coast outside the two locations, Stad and Sotra. Both are situated on the west coast of Norway. On both locations the consequences of a major oil spill are simulated for the proposed new route and for one of today's routes. To ensure comparable results, the scenarios at the locations are identical for the two routes except for the location of the spill accident. All estimations are conducted by use of identical simulation tool, input data and methodology. The scenarios were selected based on the following criteria:

- The national dimensioning oil spill scenarios defined by the Ministry of fisheries and coastal affairs
- AIS data and identification of high density traffic "hot spots"
- Potential threat to coastline and vulnerable marine resources
- Typical wind and sea current, and inside operational window for oil spill response

8.1 The accident probabilities at Stad and Sotra

By running the MARCS simulation with the same assumptions as in chapter 7, but this time shrinking the study area to include only the areas around Stad and Sotra, we obtain the expected number of spill accidents per year for the two locations. The results are shown in table 8.1.

For Stad it is evident that the expected number of spill accidents is considerably lowered for all vessel types. For Sotra the effects are more ambiguous. The total expected number of spill accidents is reduced also at Sotra, but not for all vessel types. Accident frequencies are expected to increase on the proposed new route for oil tankers and cargo ships in 2008 and for gas tankers in 2025. However these increases are negligible. For oil tankers the spill accident rate is increased with 0,003 accidents per year for 2008 traffic. The reason is that in the fairway outside Sotra the proposed route is quite close to where the ships sail today. Thus the proposed route will not have significant effects on traffic patterns here.

Table 8.1 Spill accident frequencies for today's routes and for the proposed route in 2008 and 2025 distributed by ship type for Stad and Sotra.

		Total	Chemical Tanker	Gas Tanker	Oil Tanker	Cargo > 5000 GT	Other vessels >5000 GT
Stad	**Today's routes 08**	**0.089**	0.0333	0.0016	0.0073	0.0085	0.0033
	Proposed route 08	**0.049**	0.0064	0.0003	0.0024	0.0035	0.0012
	Today's routes 25	**0.110**	0.0500	0.0038	0.0111	0.0102	0.0039
	Proposed route 25	**0.055**	0.0105	0.0033	0.0042	0.0047	0.0016
Sotra							
	Today's routes 08	**0.050**	0.017	0.003	0.006	0.001	0.011
	Proposed route 08	**0.039**	0.011	0.002	0.009	0.004	0.001
	Today's routes 25	**0.069**	0.025	0.006	0.019	0.007	0.002
	Proposed route 25	**0.060**	0.016	0.012	0.013	0.005	0.001

Source: TØI-report 1036/2009 (Appendix 9: Accident figures for the scenario areas)

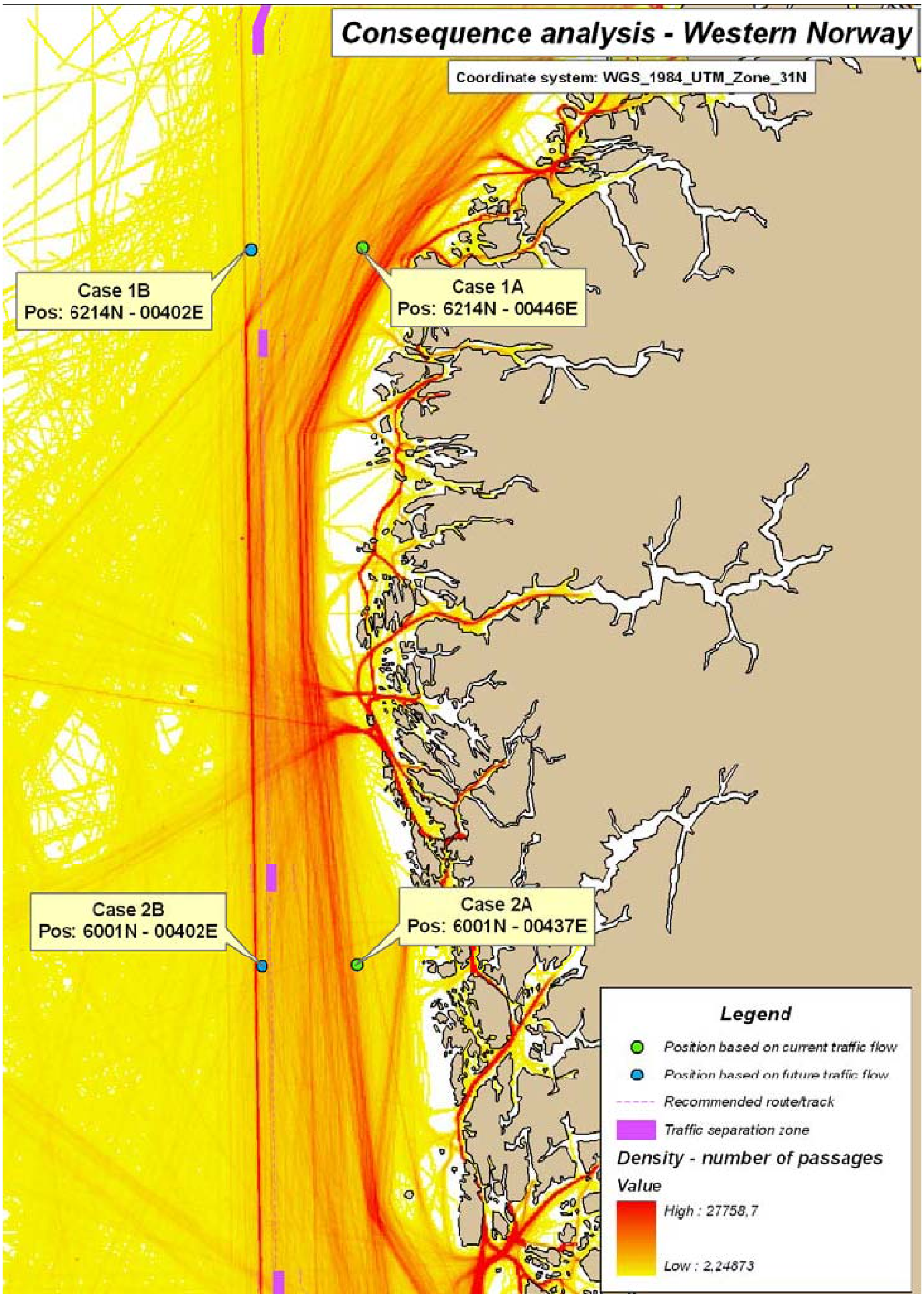
8.2 The scenarios

In the two case scenarios it is assumed that a collision takes place releasing oil into the sea. In the Stadt scenario it assumed to be 1000 m^3 bunker oil; in the Sotra scenario it is assumed to be 20 000 m^3 crude oil. In the Stadt scenario the accident happens in spring; in the Sotra scenario the accident happens in the autumn. The two case scenarios are described in detail in Appendix 8. Details about the assumptions etc. are also given in tables 8.2 and 8.3.

By using the oil drift simulation model developed by The Norwegian Meteorological Institute (DNMI), the *initial* shoreline impact length as well as the oil mass balance (evaporation, dispersion, on surface) has been calculated by NCA. Please note that the figures in this chapter show one dataset (time-step) only for comparison. Hour-by-hour simulation data has been utilized to obtain the results.

To assess the potential for emergency towing preventing ship grounding (and spill), time from propulsion failure (at position A and B for each scenario) until grounding has been calculated and compared with tug boat response times.

The location of the case scenarios is given in figure 8.1.

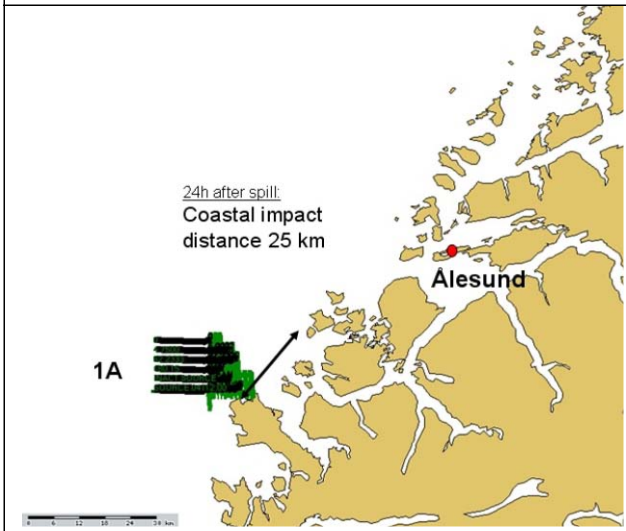
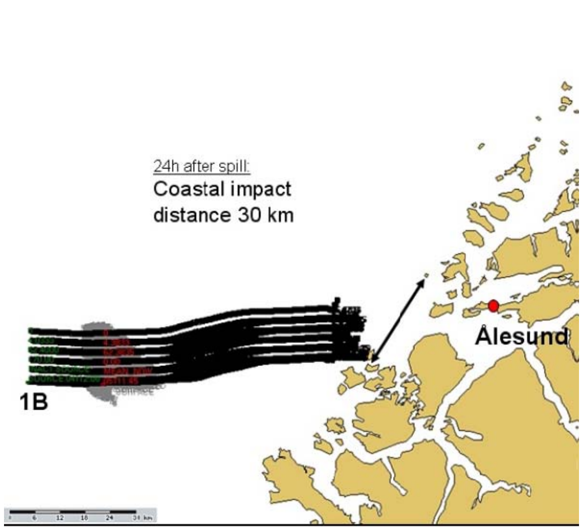


Source: Norconsult: In TØI-report 1036/2009, Appendix 8

Figure 8.1 Location of the two scenarios where oil spill consequences are simulated. Case 1A and 2A are on today's routes; Case 1B and 2B are on the proposed route.

Table 8.2 and 8.3 presents the details of the simulations of accidents and consequences including type of incident, time of year, release type, oil type and release volumes. The tables also include the simulation results.

Table 8.2 Scenario at Stad. Illustration of the oil drift 24 hours after the release of 1000 m3 bunker oil on one of today's routes and on the proposed route ,with key data concerning the scenario and simulation results.

<table>
<tr><th>Today's routes
Situation after 24 hours</th><th>Proposed route
Situation after 24 hours</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">Key data concerning the scenario:
• Location A: N62o14', E004o46' - a high density traffic spot based on AIS data
• Location B: N62o14', E004o02' - closest point to (A) given proposed recommended routeing, south bound
• Type of incident: Collision, ore carrier
• Time of year: Spring
• Release type: From sea bed (A: -174 m, B; -360 m), during 6 hours
• Oil type: Bunker, IF260
• Release volume: 1000 m3
• Weather: Wind, 8 m/sec from 240 degrees, coastal current 0,15 m/s towards north</td></tr>
<tr><td>Simulation results
• Time from release to shoreline impact:16 h
• Initial shoreline impact length: 25 km
• Oil volume reaching shoreline, first batch: 978 m3
(Given no oil spill response)</td><td>Simulation results
• Time from release to shoreline impact:87 h
• Initial shoreline impact length: 30 km
• Oil volume reaching shoreline, first batch:370 m3
(Given no oil spill response)</td></tr>
</table>

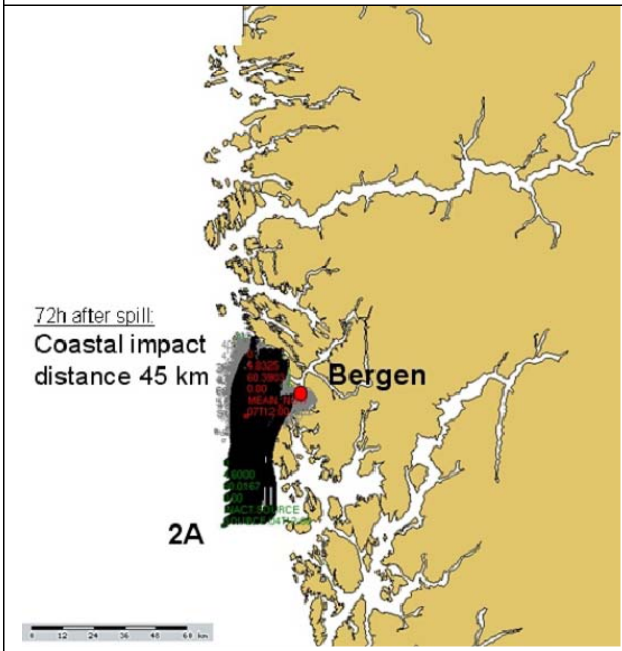
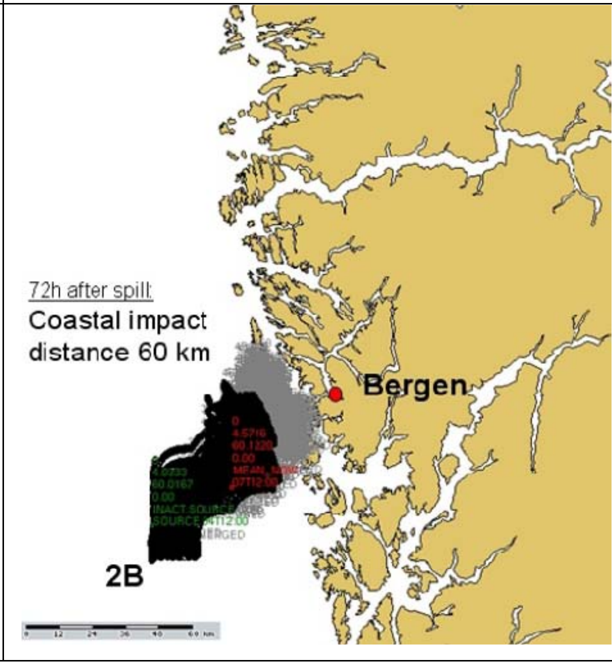
Source: Norconsult: In TØI-report 1036/2009, Appendix 8

For the Stad scenario there is a major effect of adopting the proposed route on the time from oil release to shoreline impact. Also the oil volumes reaching the shoreline, given no oil spill response, are significantly reduced from 978 m^3 to 370 m^3. The reason for this is that when time to impact increases more oil is degraded in the sea and the air. As a consequence of the oil spill accident being farther from the coast if the proposed route is adopted, the size of the potential impact area is, however, somewhat larger if the accident happens on the proposed route.

As the accident type, weather conditions and the amount of oil spilled are the same for today's route and the proposed route, we assume the costs of the ship loss, cargo, human lives and injuries to also be equal for today's route and the proposed route. We will therefore not include these costs in our comparison.

Table 8.3 gives the simulation results from the case scenario at Sotra.

Table 8.3 Scenario at Sotra. Illustration of the oil drift 72 hours after the release of 20 000 m3 crude oil on one of today’s routes and on the proposed route ,with key data concerning the scenario and simulation results.

Today`s routes *Situation after 72 hours*	**Proposed route** *Situation after 72 hours*
	
Key data concerning the scenario: • Location 2A: N60°01’, E004°37’ - a high density traffic spot based on AIS data • Location B: N60°01’, E004°02’ - closest point to (A) given proposed recommended routeing, south bound • Type of incident: Collision • Time of year: Autumn • Release type: Surface, during 5 hours • Oil type: Crude oil, light (Draugen field) • Release volume: 20 000 m^3 • Wind, 12 m/sec from 270 degrees, coastal current 0,15 m/s towards north-east	
Simulation results • Time from release to shoreline impact: 24 h • Initial shoreline impact length: 45 km • Oil volume reaching shoreline, first batch: 8600 m^3 (Given no oil spill response)	**Simulation results** • Time from release to shoreline impact:81 h • Initial shoreline impact length: 60 km • Oil volume reaching shoreline, first batch: 6800 m^3 (Given no oil spill response)

Source: Norconsult: In TØI-report 1036/2009, Appendix 8

In general the results from the case scenario at Sotra are similar to those from Stad. One of the major benefits from adopting the proposed route is the increase in time from an oil spill release to shoreline impact resulting in more natural degradation and allowing authorities more time to react. In the Sotra scenario the time for oil spill release to shoreline impact is expected to increase from 24 hours to 81 hours. As for the Stad case, the potential impact area will, however, increase.

8.3 Environmental consequences of oil spills

The marine environment and its inhabitants are threatened by many factors. Utilization, habitat destruction and climate changes are just some of them. An oil spill incident may harm populations or ecosystems in different ways and to different degrees according to the environmental pressure the area or population are already experiencing. The toxic components of oil, the polycyclic aromatic hydrocarbons may cause physical, physiological or behavioral damages to the flora and fauna affected. This may lead to lethal or sub lethal effects.

Fish and invertebrates are vulnerable to oil spills. Due to the nature of oil, where it is transported and spread on the surface before it hits the shore; the bottom living animals in the open sea are less vulnerable than pelagic living, but in the coastal area both pelagic and bottom living may be affected. They are mostly exposed to water soluble components as their main source of contact would be through respiration from water through their gills.

Seabirds are probably one of the most vulnerable animal groups to oil spills. Oil polluted birds are often the most prominent picture from a spill incident, but studies also conclude that oil spills have contributed to decreased populations of seabird species. This has not yet been shown for other animal groups. As for some mammals, the external pollution is the most acute. Oil in the feathers results in clogging and reduction of the water resistance, and it prevents the insulation ability of the feathers and reduces the ability for heat regulation.

Sea living mammals may be affected by oil spills in different ways. They should be able to swim out of an area, and whales have in experiments learned to avoid areas of oil spills after first encounter with the spill. However, common seals have shown the opposite behavior during the Exxon Valdez accident, rather seemed to be attracted by the spill.

Adult animals are protected from external contamination by their thick skin, but the infants may be vulnerable, especially just after birth. For whales, heavy oil may cause temporarily reduction in the water flow through the baleens, but this is not seen to cause any severe effect for the animal. However, whales and seals may be affected by inhalation of hydrocarbons that can lead to death due to high levels of adrenalin and hydrocarbons in the blood, and due to its narcotic effect that can lead to instant drowning.

8.4 Environmental impacts at Stad and Sotra

To assess the environmental consequences for each case we have chosen to use the relative difference of impact areas as the main parameter. This is due to the fact that the actual oil spill concentration and distribution within the archipelago is highly dependent on a wide range parameters not part of today's model tools.

MOB (Miljø og beredskap ≈ Environmental Contingency) is the national regime for the prioritization of environmental resources during oil spills emergency response in Norwegian waters. The prioritizing is made up by a system of parameters e.g. oil pollution vulnerability, conservation value, the resource's natural occurrence as well as whether the environmental loss can be compensated economically or not. These parameters form the basis for the priority category, which range from A-D; with A being the highest level of priority. The prioritizing work has been conducted by the local environmental authority.

Our quantification is performed by summarizing the MOB areas of different categories within the scenario impact areas. The data used for these scenarios are based upon the data from *Kystinfo*, the public GIS tool of the Norwegian Coastal Administration.

Most of the MOB areas that may be affected by oil spill at Stad or Sotra are seabird habitats where birds breed and feed. There is a wide range of different seabird species and some are diving for food while others are surface feeders. All these strategies may make the birds vulnerable for injuries and subjected to prey deficiency in case of an oil spill that covers large parts of their target area. The area is also home to common seals and sea otters. An incident happening in the spring coinciding with hatching and birth of seals may cause severe injuries and increase the mortality.

There are also valuable wetlands that may be severely impacted from an oil spill. Otherwise there are also many sites dedicated for human recreational activities in this area, but these are categorized with the priority C or D.

There are registered observations of deep water corals (*Lophelia pertusa)* in the areas affected by both scenarios. This specie is red listed but live below 40 m depth and will probably therefore not be directly exposed. The effect of oil pollution on deep water corals are not yet well known but some ongoing project may give more information in the future. The areas is also home to common seals and sea otters and are valuable wetlands that may be severely impacted from an oil spill. There are also many sites dedicated to recreational activities in these areas, but these are categorized with the priority C or D. For details about environmental impacts please see Appendix 8.

Summing up the environmental impacts for scenario Stad, the total number of MOB areas affected with today's routes are 467 and with the proposed route 447. In other words, environmental damages around Stad will obtain less damage with the proposed route compare to today's route given our scenario. For scenario outside Sotra the MOB for today's routes are 122 and for the proposed route 273. This is of course a considerable increase owing to the much larger potential impact area. Still, an increase in MOB areas does not necessarily imply increased environmental damages. This will be heavily influenced by the amount of spill actually reaching the shores, depending on oil spill response and natural degradation.

8.5 Clean-up costs

The oil spill response may reduce the volume of oil reaching the coast. The efficiency of open ocean oil spill response is highly dependent on prevailing weather and coastal currents. In Norway, there are 16 governmental oil spill response depots, and off-shore oil spill response equipment (booms and skimmers) are located on board Royal Norwegian Coastguard vessels patrolling the coastline. The depots are dependent on use of vessels of opportunity. In the vicinity of scenario Stad, oil spill response depots are located in Ålesund and Fedje. Closest depot to scenario Sotra is Bergen.

When assessing the consequence reducing effect of oil spill response, a generic approach was adopted based on experience from oil spill operations in Norway during the last 20 years was used. A range of assumption and parameters were used (see Appendix 8 for details).

For scenario Stad oil recovered at sea is expected to be 385 m^3, and the oil reaching shore to be 593 m^3 for today's routes. For the proposed route the oil recovered at sea is expected to be 734 m^3 and 244 m^3 is expected to reach the shores. Based on this the clean-up costs are calculated to be 118.5 million NOK for today's routes and 49 million NOK for the proposed route.

For scenario Sotra oil recovered at sea is expected to be 980 m^3, and the oil reaching shore to be 7620 m^3 for today's routes. For the proposed route the oil recovered at sea is expected to be 5100 m^3 and 1700 m^3 is expected to reach the shores. Clean-up costs are calculated to be 610 million NOK for today's routes and 136 million NOK for the proposed route.

8.6 Emergency towing

To assess the potential for emergency towing preventing ship grounding (and spill), time from propulsion failure (at position A and B for each scenario cf. figure 8.1) until grounding has been calculated and compared with tug boat response times.

According to NCA (Kystverket 2006b) drifting speed for large vessels varies between 1.2 to almost 4 knots, depending on ship dimensions, wind and ocean current. For this comparative analysis, the shortest drifting distance and 2.5 knot (wind above 10 m/s) and 2.0 knot (wind below 10 m/s) drift speed was used to calculate maximum tug boat response times.

Actual tug boat availability per 2008 in the vicinity of the scenario areas was used for this analysis. Results show that tug boat response times would be too great to prevent grounding for the Stad scenario with today's routes. For the proposed route tug boat response time would be sufficient to prevent grounding for the Stadt scenario. For the Sotra scenario tug boat response times are sufficiently small to assist the drifting ship in either case. Again, for the details see Appendix 8.

8.7 Conclusion scenario Stad

The results of the accident scenario outside Stad where 1000 tonnes of bunker oil was leaked out are summed up in table 8.4.

Table 8.4 clearly reveals that the probability of a spill accident decreases with the proposed measure. Also the probability of oil tanker collisions is smaller on the proposed new route than on today's routes, and the portion of the fuel or bunker oil of 1000 m3 reaching the shore is more than halved. The number of vulnerable areas affected given the above spill is also lowered. A main improvement is the availability of tugs for vessels if moved farther away from the coast.

Table 8.4 Environmental consequences of implementing the proposed new route at Stad.

	Today's routes	Proposed route
Spill accidents per year 2008/2025	0.0880/0.1100	0.0485/0.0540
Oil tanker collisions (causing oil spills) per year 2008/2025	0.0073/0.011	0.0024/0.0042
Proportion of the released oil that reaches the shore	59%	24%
Recovery costs (saving and cleaning) mill. NOK	118,5	49
Time from oil release to shoreline impact	16 hours	87 hours
Tug in time	No	Yes
Number of MOB (vulnerable) areas affected	467	447

Source: Norconsult: In TØI-report 1036/2009, Appendix 8

8.8 Conclusion scenario Sotra

The results of the accident scenario outside Sotra where 20 000 tons crude oil was assumed to be leaked out are summed up in table8.5.

Table 8.5 Environmental consequences of implementing the proposed new route at Sotra.

	Today's routes	Proposed route
Spill accident per year 2008/2025	0,050/0,069	0,039/0,060
Oil tanker collisions (causing oil spills) per year 2008/2025	0,006/0,019	0,009/0,013
Proportion of the released oil that reaches the shore	38%	9%
Recovery costs (Saving and cleaning) mill. NOK	104	23
Time from oil release to shoreline impact	24 hours	81 hours
Tug in time	Yes	Yes
Number of MOB (vulnerable) areas affected	122	273

Source: Norconsult: In TØI-report 1036/2009, Appendix 8

According to the results in 8.5 the probability of spill accidents increases somewhat for the proposed route in the Sotra scenario. Also, the number of vulnerable areas potentially damaged by oil spills is increased. Nevertheless, also for the Sotra scenario the proposed route reduces the amount of oil reaching the shores substantially. The increased time from oil release to shoreline impact allows for better oil spill response by the authorities.

9 Discussion and conclusion

9.1 Reduced oil spills

Our findings show that implementing a routeing measure for tankers and vessels above 5000 GT off the Norwegian coast will significantly reduce the probability of accidents, including those causing oil spills. The proposed routeing measure will reduce oil and bunkers spills for all vessels by an estimated 13 per cent (456 tonnes) as of 2008 and by 29 per cent (1450 tonnes) as of 2025.

Our results also indicate that very large oil spills will occur less often and farther away from the coast, thus allowing authorities more time to react. More efficient natural degradation of oil will also occur through evaporation and natural dispersion causing (in most cases) significantly reduced environmental impact. This general conclusion is also supported by the two case studies, where two different oil spill scenarios were analyzed.

The highest benefit of routeing vessels farther away from the coast will be related to crude oil spills from tanker accidents. This is exactly the type of risk at which the proposed routeing measure is addressed, hence it seems to be a quite effective countermeasure. The favourable effect of routeing holds true for various traffic density levels. Given the traffic density forecast for 2025 the proposed measure gives stronger positive effects than with today's traffic.

There is of course a strong correlation between oil spills and spilling accidents. However, not all spilling accidents result in huge oil spills. Even if the calculated changes in accident frequencies did not reach statistical significance, the significant change in oil spill volumes indicates that large spilling accident involving oil tankers will also be substantially reduced by adopting the proposed routeing measures.

There are few adverse environmental effects of adopting the proposed routeing measure. The most important factor is a potentially larger coastline impact area for oil spills. For crude oil, this negative effect is counterbalanced by increased evaporation and natural degradation of oil resulting from increased distance to the cost. Fuel oil spills from locations along the proposed traffic lane may hit a larger impact area. It is, however, possible that this risk will be mitigated by increased time for oil spill response by the authorities, given an accident.

9.2 Increased shipping costs

The main argument against the proposed routeing measure is on the cost side. The proposed new route being longer than most routes followed today, it will lead to an increase in total ship miles travelled between Røst and Utsira. However, for the tanker traffic to and from the Barents Sea and for the traffic to and from the oil installations in the Norwegian Sea, the proposed route will only give minor increases in shipping distances.

The overall increase in traffic volume translates into a corresponding increase in shipping costs. Our study has not, unfortunately, had access to sufficiently reliable unit cost data for the accurate calculation of shipping cost increases. In addition we do not know how many of the domestic ships that will follow the proposed route. In our accident simulation model we have assumed that all ships above 5000 GT will move to the proposed route. Ships travelling between Norwegian ports will however not be obliged to follow the proposed route if this route is adopted. Some domestic tankers will, due to the companies' risk management policies, travel the proposed route even though they are not obliged to do so and in spite of the resulting cost increase.

For the tanker traffic from the Barents Sea along the Norwegian coast and for the traffic to and from the oil installations in the Norwegian Sea the proposed routeing measure will only generate a minor cost increase. For these ships the proposed route is only marginally longer than the route they normally travel today and one major benefit of the proposed route is the segregation scheme adopted.

9.3 Conclusion

In sum it seems clear that the proposed routeing measure reduces both the probability of accidents and the consequences of possible accidents. Thus, adopting the proposed routeing measures will give a significant risk reduction.

In our simulations and calculations, all traffic above 5000 GT has been moved to the proposed route. As domestic traffic will not be obliged to follow the new route, it is likely that the traffic density on the proposed route will be lower than assumed in our simulations. Accordingly the risk of collisions and oil pollution may be reduced even more than our estimates indicate.

Due to lack of sufficient details on costs and benefits, it has not been possible to determine whether the benefits of the proposed measure outweigh the cost. For the tanker traffic along the coast it seems however clear that benefits outweigh the costs by far. For the total ship traffic chances are, however, that in an average year the savings in accident and oil spill costs do not outweigh the increase in shipping costs. This possible negative benefit-cost differential could, however, be regarded as an insurance premium against the consequence of very large oil spills, of which the figures on expected (average) annual cost savings would not be representative.

The expected reduction in total oil spill volumes is predominantly a result of an expected decline in tanker oil spills. The proposed measure is in particular addressed towards managing these environmental risks mitigating the effects of the expected tanker traffic increase along the Norwegian coast. It seems, accordingly, reasonable to conclude that the proposed new route is a quite appropriate counter measure.

References

Akhtar, J., & Jean-Hansen V. (2009). Effects of proposed ship routeing off the Norwegian coast. Part 2 Utsira – Oslo fjord. *TØI report 1037/2009.*

Bambulyak, A., & Frantzen, B. (2009). *Oil transport from the Russian part of the Barents Region.*

Borresen, J. A. (1997). Wind Atlas for the North Sea and Norwegian Sea. *Norwegian University Press, Norwegian Meteorological*

Eriksen, T., Høye, G., Narheim, B., & Meland, B. J. (2006). Maritime traffic monotoring using a space-based AIS.

Hovi, I., & Madslien, A. (2008). Revised forecast for Norwegian freigth transport 2006-2040. *TØI report 1001/2008.*

Kystverket (2006a). Stamnettsutredning - Kystverket Troms og Finnmark

Kystverket (2006b). Nasjonal slepeberedskap (National emergency tug preparedness).

Loeng, H., & Drinkwater, K. (2007). An overview of the ecosystems of the Barents and Norwegian Seas and their response to climate variability. *Deep-Sea research, 54.*

Norconsult (2006). *Forventet skipsutvikling de neste 30 årene.* Trondheim.

Safetec (2007). RKU Nordsjøen. Beskrivelse av skipstrafikken i Nordsjøen.

Sjøfartsdirektoratet (2009). 103 grunnstøtninger i 2008. Faktaark.

Appendices

Appendix 1: Traffic on today's routes and on the proposed route

Table 1 shows the transfer of traffic from the today's routes (see figure 1-4) to the proposed route (figure 5-6). The traffic in the crossing lanes are kept unchanged.

Table 1Waypoints

Proposed lane (one way)	Today's lane (two ways)
[Waypoints]	
0-1 and reverse	27-33 33-41 28-32 32-38 And reverse
1-2 and reverse	39-40 33-41 and reverse
2-3 and reverse	40-42 and reverse
3-4 and reverse	21-22and reverse
31-30 (north)	29-30 30-31 31-34 34-36
21-20 (north)	Reverse of above

Today’s routes

FID	Shape *	Id	Name	ET ID	ET X	ET Y	ET ORDER	ET IDR	ET IDP	X DMS	Y DMS
0	Point	0		0	9,66179	65,87203	0	0_0	0	9°39'42"	65°52'19"
1	Point	0		0	5,50276	62,83993	0,0734	0_0	0	5°30'10"	62°50'24"
2	Point	0		0	7,88506	64,34075	0,1116	0_0	0	7°53'06"	64°20'27"
3	Point	0		0	10,55887	66,11079	0,1552	0_0	0	10°33'32"	66°06'39"
4	Point	0		0	12,07688	67,14896	0,1802	0_0	0	12°04'37"	67°08'56"
5	Point	0		0	14,00742	67,98122	0,2034	0_0	0	14°00'27"	67°58'52"
6	Point	0		0	14,40037	67,77582	0,2087	0_0	0	14°24'01"	67°46'33"
7	Point	0		0	12,74569	67,02609	0,2292	0_0	0	12°44'44"	67°01'34"
8	Point	0		0	11,13867	65,97946	0,2548	0_0	0	11°08'19"	65°58'46"
9	Point	0		0	8,21901	64,2655	0,2987	0_0	0	8°13'08"	64°15'56"
10	Point	0		0	6,2352	63,03255	0,3302	0_0	0	6°14'07"	63°01'57"
11	Point	0		0	7,17871	63,2766	0,3404	0_0	0	7°10'43"	63°16'36"
12	Point	0		0	7,34603	63,17512	0,3431	0_0	0	7°20'46"	63°10'30"
13	Point	0		0	6,05688	62,75842	0,358	0_0	0	6°03'25"	62°45'30"
14	Point	0		0	5,16314	62,31855	0,3706	0_0	0	5°09'47"	62°19'07"
15	Point	0		0	4,48515	61,66037	0,3858	0_0	0	4°29'07"	61°39'37"
16	Point	0		0	4,85566	58,62063	0,4491	0_0	0	4°51'20"	58°37'14"
17	Point	0		0	3,89033	58,66092	0,4596	0_0	0	3°53'25"	58°39'39"
18	Point	0		0	3,81882	61,69613	0,5226	0_0	0	3°49'08"	61°41'46"
19	Point	0		0	5,94697	65,20489	0,5982	0_0	0	5°56'49"	65°12'18"
20	Point	0		0	9,7628	68,1862	0,6678	0_0	0	9°45'46"	68°11'10"
21	Point	0		0	10,2954	68,12339	0,6721	0_0	0	10°17'43"	68°07'24"
22	Point	0		0	6,3567	65,09517	0,743	0_0	0	6°21'24"	65°05'43"
23	Point	0		0	4,51969	62,3306	0,8029	0_0	0	4°31'11"	62°19'50"
24	Point	0		0	8,93842	65,94222	0,8881	0_0	0	8°56'18"	65°56'32"
25	Point	0		0	12,10684	68,18295	0,9414	0_0	0	12°06'25"	68°10'59"
26	Point	0		0	12,82812	68,0697	0,9474	0_0	0	12°49'41"	68°04'11"
27	Point	0		0	10,02947	68,155	0		0	10°01'46"	68°09'18"
28	Point	0		0	12,46839	68,12671	0		0	12°28'06"	68°07'36"
29	Point	0		0	14,20476	67,87862	0		0	14°12'17"	67°52'43"
30	Point	0		0	12,41215	67,08787	0		0	12°24'44"	67°05'16"
31	Point	0		0	10,84953	66,04539	0		0	10°50'58"	66°02'43"
32	Point	0		0	9,30062	65,90755	0		0	9°18'02"	65°54'27"
33	Point	0		0	6,15226	65,15017	0		0	6°09'08"	65°09'01"
34	Point	0		0	8,05227	64,30322	0		0	8°03'08"	64°18'12"
35	Point	0		0	7,26252	63,22588	0		0	7°15'45"	63°13'33"
36	Point	0		0	5,86778	62,93672	0		0	5°52'04"	62°56'12"
37	Point	0		0	5,78021	62,79945	0		0	5°46'49"	62°47'58"
38	Point	0		0	5,00701	62,58615	0		0	5°00'25"	62°35'10"
39	Point	0		0	4,84149	62,32495	0		0	4°50'29"	62°19'30"
40	Point	0		0	4,15218	61,67865	0		0	4°09'08"	61°40'43"
41	Point	0		0	4,1656	62,01383	0		0	4°09'56"	62°00'50"
42	Point	0		0	4,37329	58,64168	0		0	4°22'24"	58°38'30"

FID	Shape *	Id	ET From	ET To	ET Length nm	ET Length meter	ET Angle degree	Width meters	Width nm
0	Polyline	0	0	24	18,292	33900,3	278	16950,1	9,146
1	Polyline	0	1	10	23,17	42940,6	57	21470,3	11,585
2	Polyline	0	1	13	16,021	29691	105	14845,5	8,01
3	Polyline	0	1	23	40,992	75970,1	220	37985,1	20,496
4	Polyline	0	2	9	9,83	18216,8	113	9108,4	4,915
5	Polyline	0	3	8	16,251	30118,1	112	15059,1	8,126
6	Polyline	0	4	7	17,368	32188,4	107	16094,2	8,684
7	Polyline	0	5	6	15,275	28309,1	134	14154,6	7,638
8	Polyline	0	11	12	7,608	14099,3	140	7049,6	3,804
9	Polyline	0	14	23	18,008	33373,6	271	16686,8	9,004
10	Polyline	0	15	18	19,152	35493,5	275	17746,7	9,576
11	Polyline	0	16	17	30,336	56220,7	273	28110,4	15,168
12	Polyline	0	18	23	42,973	79641,2	26	39820,6	21,487
13	Polyline	0	19	22	12,292	22780,3	120	11390,1	6,146
14	Polyline	0	20	21	12,531	23222,7	101	11611,3	6,265
15	Polyline	0	25	26	17,59	32599,2	104	16299,6	8,795

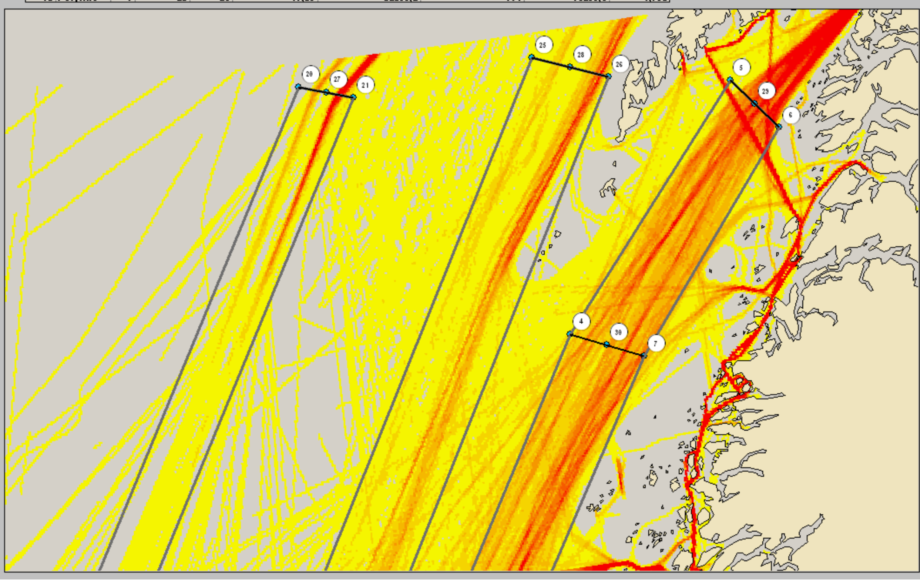


Figure 1 Today’s routes - Røst

FID	Shape *	Id	Name	ET ID	ET X	ET Y	ET ORDER	ET IDR	ET IDP	X DMS	Y DMS
0	Point	0		0	9,66179	65,87203	0	0_0	0	9°39'42"	65°52'19"
1	Point	0		0	5,50276	62,83993	0,0734	0_0	0	5°30'10"	62°50'24"
2	Point	0		0	7,88506	64,34075	0,1116	0_0	0	7°53'06"	64°20'27"
3	Point	0		0	10,55887	66,11079	0,1552	0_0	0	10°33'32"	66°06'39"
4	Point	0		0	12,07688	67,14896	0,1802	0_0	0	12°04'37"	67°08'56"
5	Point	0		0	14,00742	67,98122	0,2034	0_0	0	14°00'27"	67°58'52"
6	Point	0		0	14,40037	67,77582	0,2087	0_0	0	14°24'01"	67°46'33"
7	Point	0		0	12,74569	67,02609	0,2292	0_0	0	12°44'44"	67°01'34"
8	Point	0		0	11,13867	65,97946	0,2548	0_0	0	11°08'19"	65°58'46"
9	Point	0		0	8,21901	64,2655	0,2987	0_0	0	8°13'08"	64°15'56"
10	Point	0		0	6,2352	63,03255	0,3302	0_0	0	6°14'07"	63°01'57"
11	Point	0		0	7,17871	63,2766	0,3404	0_0	0	7°10'43"	63°16'36"
12	Point	0		0	7,34603	63,17512	0,3431	0_0	0	7°20'46"	63°10'30"
13	Point	0		0	6,05688	62,75842	0,358	0_0	0	6°03'25"	62°45'30"
14	Point	0		0	5,16314	62,31855	0,3706	0_0	0	5°09'47"	62°19'07"
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16	Point	0		0	4,85566	58,62063	0,4491	0_0	0	4°51'20"	58°37'14"
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18	Point	0		0	3,81882	61,69613	0,5226	0_0	0	3°49'08"	61°41'46"
19	Point	0		0	5,94697	65,20489	0,5982	0_0	0	5°56'49"	65°12'18"
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21	Point	0		0	10,2954	68,12339	0,6721	0_0	0	10°17'43"	68°07'24"
22	Point	0		0	6,3567	65,09517	0,743	0_0	0	6°21'24"	65°05'43"
23	Point	0		0	4,51969	62,3306	0,8029	0_0	0	4°31'11"	62°19'50"
24	Point	0		0	8,93842	65,94222	0,8881	0_0	0	8°56'18"	65°56'32"
25	Point	0		0	12,10684	68,18295	0,9414	0_0	0	12°06'25"	68°10'59"
26	Point	0		0	12,82812	68,0697	0,9474	0_0	0	12°49'41"	68°04'11"
27	Point	0		0	10,02947	68,155	0		0	10°01'46"	68°09'18"
28	Point	0		0	12,46839	68,12671	0		0	12°28'06"	68°07'36"
29	Point	0		0	14,20476	67,87862	0		0	14°12'17"	67°52'43"
30	Point	0		0	12,41215	67,08787	0		0	12°24'44"	67°05'16"
31	Point	0		0	10,84953	66,04539	0		0	10°50'58"	66°02'43"
32	Point	0		0	9,30062	65,90755	0		0	9°18'02"	65°54'27"
33	Point	0		0	6,15226	65,15017	0		0	6°09'08"	65°09'01"
34	Point	0		0	8,05227	64,30322	0		0	8°03'08"	64°18'12"
35	Point	0		0	7,26252	63,22588	0		0	7°15'45"	63°13'33"
36	Point	0		0	5,86778	62,93672	0		0	5°52'04"	62°56'12"
37	Point	0		0	5,78021	62,79945	0		0	5°46'49"	62°47'58"
38	Point	0		0	5,00701	62,58615	0		0	5°00'25"	62°35'10"
39	Point	0		0	4,84149	62,32495	0		0	4°50'29"	62°19'30"
40	Point	0		0	4,15218	61,67865	0		0	4°09'08"	61°40'43"
41	Point	0		0	4,1656	62,01383	0		0	4°09'56"	62°00'50"
42	Point	0		0	4,37329	58,64168	0		0	4°22'24"	58°38'30"

FID	Shape *	Id	ET From	ET To	ET Length nm	ET Length meter	ET Angle degree	Width meters	Width nm
0	Polyline	0	0	24	18,292	33900,3	278	16950,1	9,146
1	Polyline	0	1	10	23,17	42940,6	57	21470,3	11,585
2	Polyline	0	1	13	16,021	29691	105	14845,5	8,01
3	Polyline	0	1	23	40,992	75970,1	220	37985,1	20,496
4	Polyline	0	2	9	9,83	18216,8	113	9108,4	4,915
5	Polyline	0	3	8	16,251	30118,1	112	15059,1	8,126
6	Polyline	0	4	7	17,368	32188,4	107	16094,2	8,684
7	Polyline	0	5	6	15,275	28309,1	134	14154,6	7,638
8	Polyline	0	11	12	7,608	14099,3	140	7049,6	3,804
9	Polyline	0	14	23	18,008	33373,6	271	16686,8	9,004
10	Polyline	0	15	18	19,152	35493,5	275	17746,7	9,576
11	Polyline	0	16	17	30,336	56220,7	273	28110,4	15,168
12	Polyline	0	18	23	42,973	79641,2	26	39820,6	21,487
13	Polyline	0	19	22	12,292	22780,3	120	11390,1	6,146
14	Polyline	0	20	21	12,531	23222,7	101	11611,3	6,265
15	Polyline	0	25	26	17,59	32599,2	104	16299,6	8,795

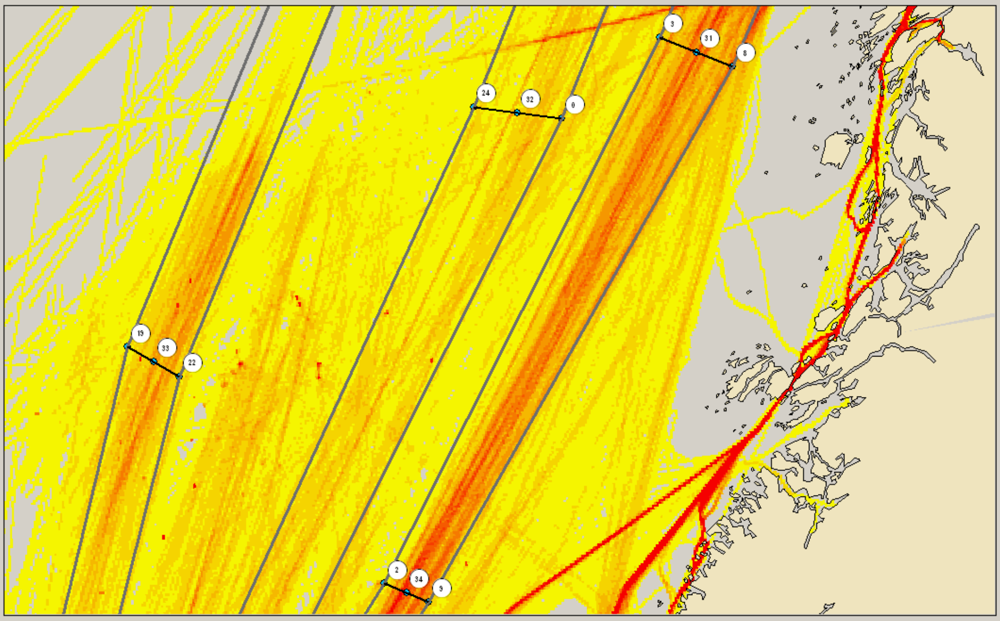


Figure 2 Today's routes Nordland

FID	Shape *	Id	Name	ET ID	ET X	ET Y	ET ORDER	ET IDR	ET IDP	X DMS	Y DMS
0	Point	0		0	9,66179	65,87203	0	0_0	0	9°39'42"	65°52'19"
1	Point	0		0	5,50276	62,83993	0,0734	0_0	0	5°30'10"	62°50'24"
2	Point	0		0	7,88506	64,34075	0,1116	0_0	0	7°53'06"	64°20'27"
3	Point	0		0	10,55887	66,11079	0,1552	0_0	0	10°33'32"	66°06'39"
4	Point	0		0	12,07688	67,14896	0,1802	0_0	0	12°04'37"	67°08'56"
5	Point	0		0	14,00742	67,98122	0,2034	0_0	0	14°00'27"	67°58'52"
6	Point	0		0	14,40037	67,77582	0,2087	0_0	0	14°24'01"	67°46'33"
7	Point	0		0	12,74569	67,02609	0,2292	0_0	0	12°44'44"	67°01'34"
8	Point	0		0	11,13867	65,97946	0,2548	0_0	0	11°08'19"	65°58'46"
9	Point	0		0	8,21901	64,2655	0,2987	0_0	0	8°13'08"	64°15'56"
10	Point	0		0	6,2352	63,03255	0,3302	0_0	0	6°14'07"	63°01'57"
11	Point	0		0	7,17871	63,2766	0,3404	0_0	0	7°10'43"	63°16'36"
12	Point	0		0	7,34603	63,17512	0,3431	0_0	0	7°20'46"	63°10'30"
13	Point	0		0	6,05688	62,75842	0,358	0_0	0	6°03'25"	62°45'30"
14	Point	0		0	5,16314	62,31855	0,3706	0_0	0	5°09'47"	62°19'07"
15	Point	0		0	4,48515	61,66037	0,3858	0_0	0	4°29'07"	61°39'37"
16	Point	0		0	4,85566	58,62063	0,4491	0_0	0	4°51'20"	58°37'14"
17	Point	0		0	3,89033	58,66092	0,4596	0_0	0	3°53'25"	58°39'39"
18	Point	0		0	3,81882	61,69613	0,5226	0_0	0	3°49'08"	61°41'46"
19	Point	0		0	5,94697	65,20489	0,5982	0_0	0	5°56'49"	65°12'18"
20	Point	0		0	9,7628	68,1862	0,6678	0_0	0	9°45'46"	68°11'10"
21	Point	0		0	10,2954	68,12339	0,6721	0_0	0	10°17'43"	68°07'24"
22	Point	0		0	6,3567	65,09517	0,743	0_0	0	6°21'24"	65°05'43"
23	Point	0		0	4,51969	62,3306	0,8029	0_0	0	4°31'11"	62°19'50"
24	Point	0		0	8,93842	65,94222	0,8881	0_0	0	8°56'18"	65°56'32"
25	Point	0		0	12,10684	68,18295	0,9414	0_0	0	12°06'25"	68°10'59"
26	Point	0		0	12,82812	68,0697	0,9474	0_0	0	12°49'41"	68°04'11"
27	Point	0		0	10,02947	68,155	0		0	10°01'46"	68°09'18"
28	Point	0		0	12,46839	68,12671	0		0	12°28'06"	68°07'36"
29	Point	0		0	14,20476	67,87862	0		0	14°12'17"	67°52'43"
30	Point	0		0	12,41215	67,08787	0		0	12°24'44"	67°05'16"
31	Point	0		0	10,84953	66,04539	0		0	10°50'58"	66°02'43"
32	Point	0		0	9,30062	65,90755	0		0	9°18'02"	65°54'27"
33	Point	0		0	6,15226	65,15017	0		0	6°09'08"	65°09'01"
34	Point	0		0	8,05227	64,30322	0		0	8°03'08"	64°18'12"
35	Point	0		0	7,26252	63,22588	0		0	7°15'45"	63°13'33"
36	Point	0		0	5,86778	62,93672	0		0	5°52'04"	62°56'12"
37	Point	0		0	5,78021	62,79945	0		0	5°46'49"	62°47'58"
38	Point	0		0	5,00701	62,58615	0		0	5°00'25"	62°35'10"
39	Point	0		0	4,84149	62,32495	0		0	4°50'29"	62°19'30"
40	Point	0		0	4,15218	61,67865	0		0	4°09'08"	61°40'43"
41	Point	0		0	4,1656	62,01383	0		0	4°09'56"	62°00'50"
42	Point	0		0	4,37329	58,64168	0		0	4°22'24"	58°38'30"

FID	Shape *	Id	ET From	ET To	ET Length nm	ET Length meter	ET Angle degree	Width meters	Width nm
0	Polyline	0	0	24	18,292	33900,3	278	16950,1	9,146
1	Polyline	0	1	10	23,17	42940,6	57	21470,3	11,585
2	Polyline	0	1	13	16,021	29691	105	14845,5	8,01
3	Polyline	0	1	23	40,992	75970,1	220	37985,1	20,496
4	Polyline	0	2	9	9,83	18216,8	113	9108,4	4,915
5	Polyline	0	3	8	16,251	30118,1	112	15059,1	8,126
6	Polyline	0	4	7	17,368	32188,4	107	16094,2	8,684
7	Polyline	0	5	6	15,275	28309,1	134	14154,6	7,638
8	Polyline	0	11	12	7,608	14099,3	140	7049,6	3,804
9	Polyline	0	14	23	18,008	33373,6	271	16686,8	9,004
10	Polyline	0	15	18	19,152	35493,5	275	17746,7	9,576
11	Polyline	0	16	17	30,336	56220,7	273	28110,4	15,168
12	Polyline	0	18	23	42,973	79641,2	26	39820,6	21,487
13	Polyline	0	19	22	12,292	22780,3	120	11390,1	6,146
14	Polyline	0	20	21	12,531	23222,7	101	11611,3	6,265
15	Polyline	0	25	26	17,59	32599,2	104	16299,6	8,795

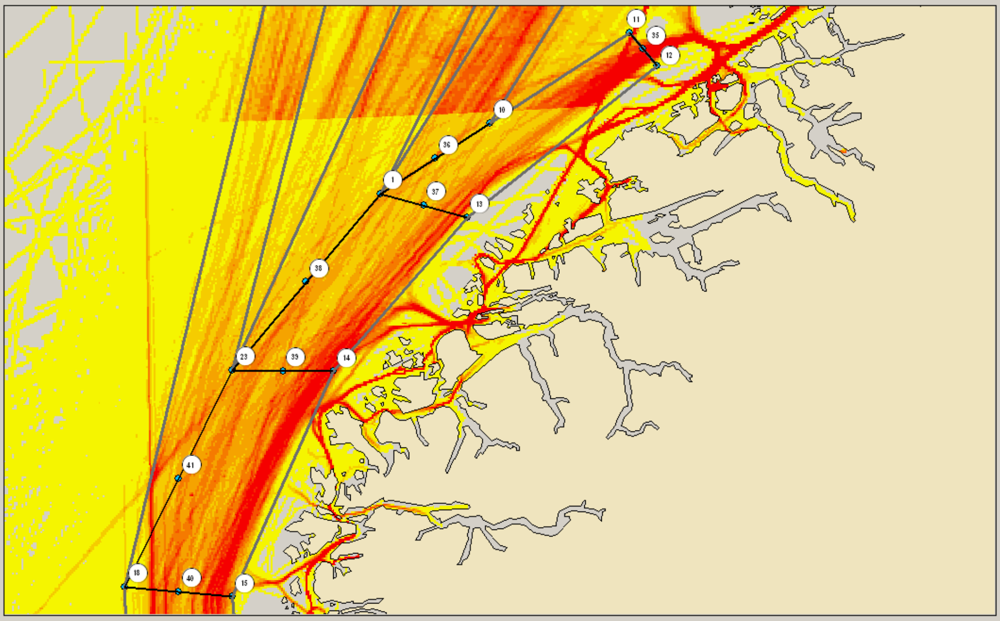


Figure 3 Today's routes Stad

FID	Shape *	Id	Name	ET ID	ET X	ET Y	ET ORDER	ET IDR	ET IDP	X DMS	Y DMS
0	Point	0		0	9,66179	65,87203	0	0_0	0	9°39'42"	65°52'19"
1	Point	0		0	5,50276	62,83993	0,0734	0_0	0	5°30'10"	62°50'24"
2	Point	0		0	7,88506	64,34075	0,1116	0_0	0	7°53'06"	64°20'27"
3	Point	0		0	10,55887	66,11079	0,1552	0_0	0	10°33'32"	66°06'39"
4	Point	0		0	12,07688	67,14896	0,1802	0_0	0	12°04'37"	67°08'56"
5	Point	0		0	14,00742	67,98122	0,2034	0_0	0	14°00'27"	67°58'52"
6	Point	0		0	14,40037	67,77582	0,2087	0_0	0	14°24'01"	67°46'33"
7	Point	0		0	12,74569	67,02609	0,2292	0_0	0	12°44'44"	67°01'34"
8	Point	0		0	11,13867	65,97946	0,2548	0_0	0	11°08'19"	65°58'46"
9	Point	0		0	8,21901	64,2655	0,2987	0_0	0	8°13'08"	64°15'56"
10	Point	0		0	6,2352	63,03255	0,3302	0_0	0	6°14'07"	63°01'57"
11	Point	0		0	7,17871	63,2766	0,3404	0_0	0	7°10'43"	63°16'36"
12	Point	0		0	7,34603	63,17512	0,3431	0_0	0	7°20'46"	63°10'30"
13	Point	0		0	6,05688	62,75842	0,358	0_0	0	6°03'25"	62°45'30"
14	Point	0		0	5,16314	62,31855	0,3706	0_0	0	5°09'47"	62°19'07"
15	Point	0		0	4,48515	61,66037	0,3858	0_0	0	4°29'07"	61°39'37"
16	Point	0		0	4,85566	58,62063	0,4491	0_0	0	4°51'20"	58°37'14"
17	Point	0		0	3,89033	58,66092	0,4596	0_0	0	3°53'25"	58°39'39"
18	Point	0		0	3,81882	61,69613	0,5226	0_0	0	3°49'08"	61°41'46"
19	Point	0		0	5,94697	65,20489	0,5982	0_0	0	5°56'49"	65°12'18"
20	Point	0		0	9,7628	68,1862	0,6678	0_0	0	9°45'46"	68°11'10"
21	Point	0		0	10,2954	68,12339	0,6721	0_0	0	10°17'43"	68°07'24"
22	Point	0		0	6,3567	65,09517	0,743	0_0	0	6°21'24"	65°05'43"
23	Point	0		0	4,51969	62,3306	0,8029	0_0	0	4°31'11"	62°19'50"
24	Point	0		0	8,93842	65,94222	0,8881	0_0	0	8°56'18"	65°56'32"
25	Point	0		0	12,10684	68,18295	0,9414	0_0	0	12°06'25"	68°10'59"
26	Point	0		0	12,82812	68,0697	0,9474	0_0	0	12°49'41"	68°04'11"
27	Point	0		0	10,02947	68,155	0		0	10°01'46"	68°09'18"
28	Point	0		0	12,46839	68,12671	0		0	12°28'06"	68°07'36"
29	Point	0		0	14,20476	67,87862	0		0	14°12'17"	67°52'43"
30	Point	0		0	12,41215	67,08787	0		0	12°24'44"	67°05'16"
31	Point	0		0	10,84953	66,04539	0		0	10°50'58"	66°02'43"
32	Point	0		0	9,30062	65,90755	0		0	9°18'02"	65°54'27"
33	Point	0		0	6,15226	65,15017	0		0	6°09'08"	65°09'01"
34	Point	0		0	8,05227	64,30322	0		0	8°03'08"	64°18'12"
35	Point	0		0	7,26252	63,22588	0		0	7°15'45"	63°13'33"
36	Point	0		0	5,86778	62,93672	0		0	5°52'04"	62°56'12"
37	Point	0		0	5,78021	62,79945	0		0	5°46'49"	62°47'58"
38	Point	0		0	5,00701	62,58615	0		0	5°00'25"	62°35'10"
39	Point	0		0	4,84149	62,32495	0		0	4°50'29"	62°19'30"
40	Point	0		0	4,15218	61,67865	0		0	4°09'08"	61°40'43"
41	Point	0		0	4,1656	62,01383	0		0	4°09'56"	62°00'50"
42	Point	0		0	4,37329	58,64168	0		0	4°22'24"	58°38'30"

FID	Shape *	Id	ET From	ET To	ET Length nm	ET Length meter	ET Angle degree	Width meters	Width nm
0	Polyline	0	0	24	18,292	33900,3	278	16950,1	9,146
1	Polyline	0	1	10	23,17	42940,6	57	21470,3	11,585
2	Polyline	0	1	13	16,021	29691	105	14845,5	8,01
3	Polyline	0	1	23	40,992	75970,1	220	37985,1	20,496
4	Polyline	0	2	9	9,83	18216,8	113	9108,4	4,915
5	Polyline	0	3	8	16,251	30118,1	112	15059,1	8,126
6	Polyline	0	4	7	17,368	32188,4	107	16094,2	8,684
7	Polyline	0	5	6	15,275	28309,1	134	14154,6	7,638
8	Polyline	0	11	12	7,608	14099,3	140	7049,6	3,804
9	Polyline	0	14	23	18,008	33373,6	271	16686,8	9,004
10	Polyline	0	15	18	19,152	35493,5	275	17746,7	9,576
11	Polyline	0	16	17	30,336	56220,7	273	28110,4	15,168
12	Polyline	0	18	23	42,973	79641,2	26	39820,6	21,487
13	Polyline	0	19	22	12,292	22780,3	120	11390,1	6,146
14	Polyline	0	20	21	12,531	23222,7	101	11611,3	6,265
15	Polyline	0	25	26	17,59	32599,2	104	16299,6	8,795

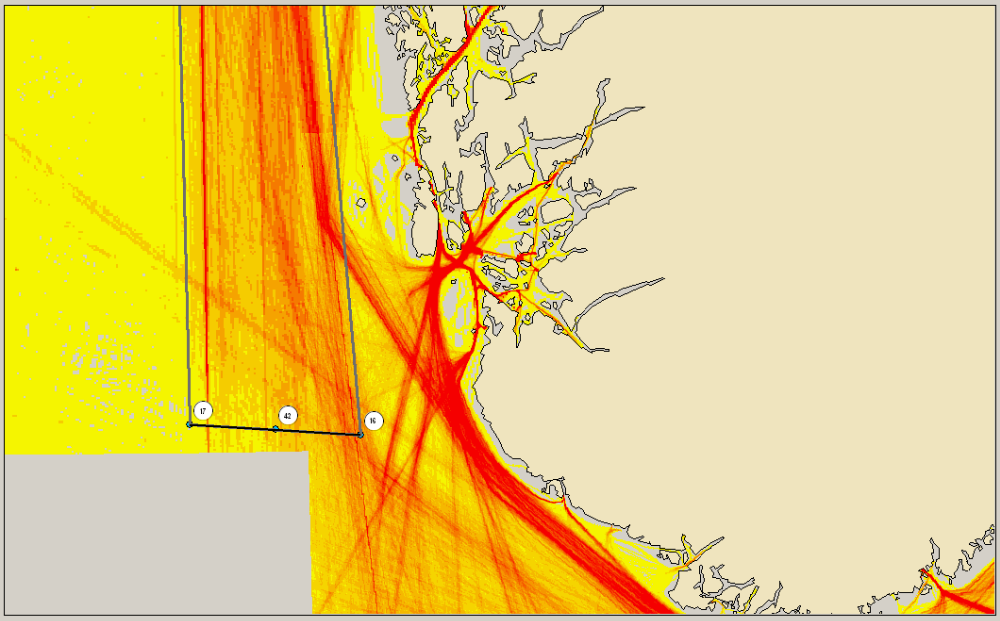
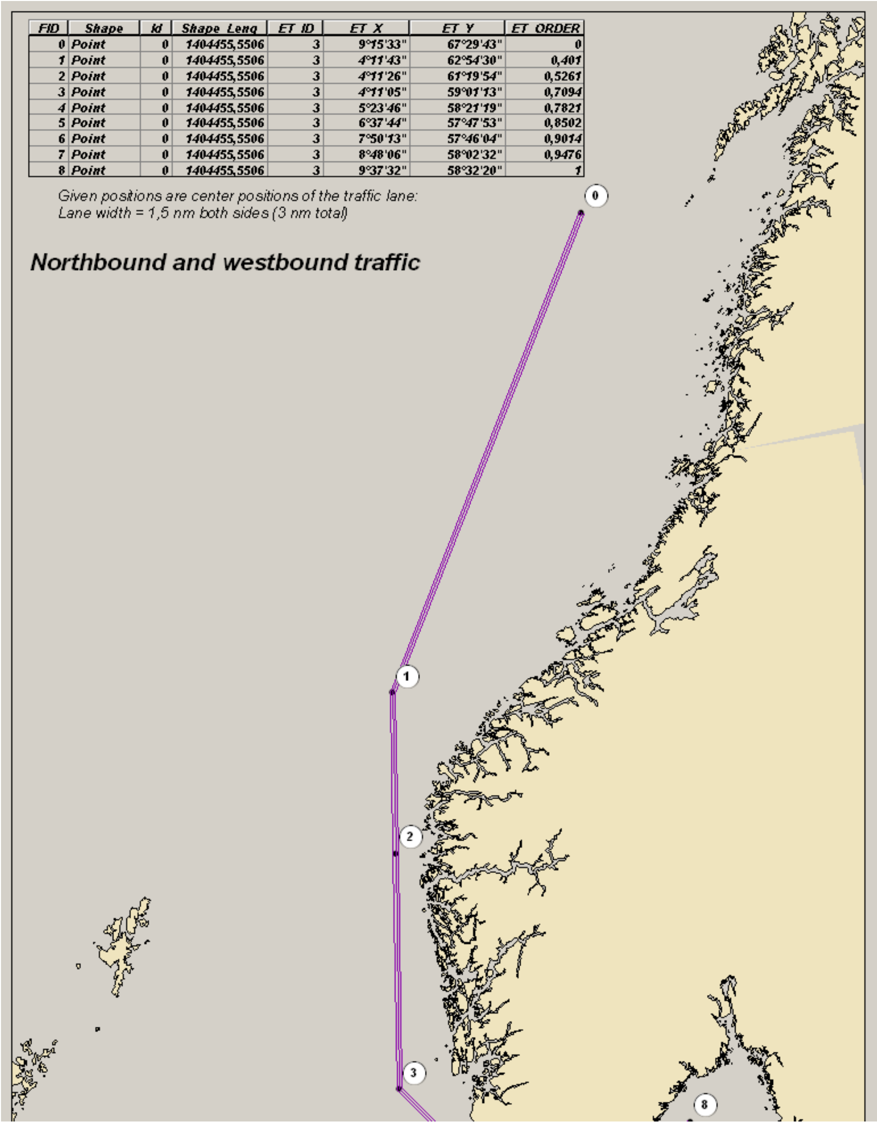


Figure 4 Today's routes Utsira

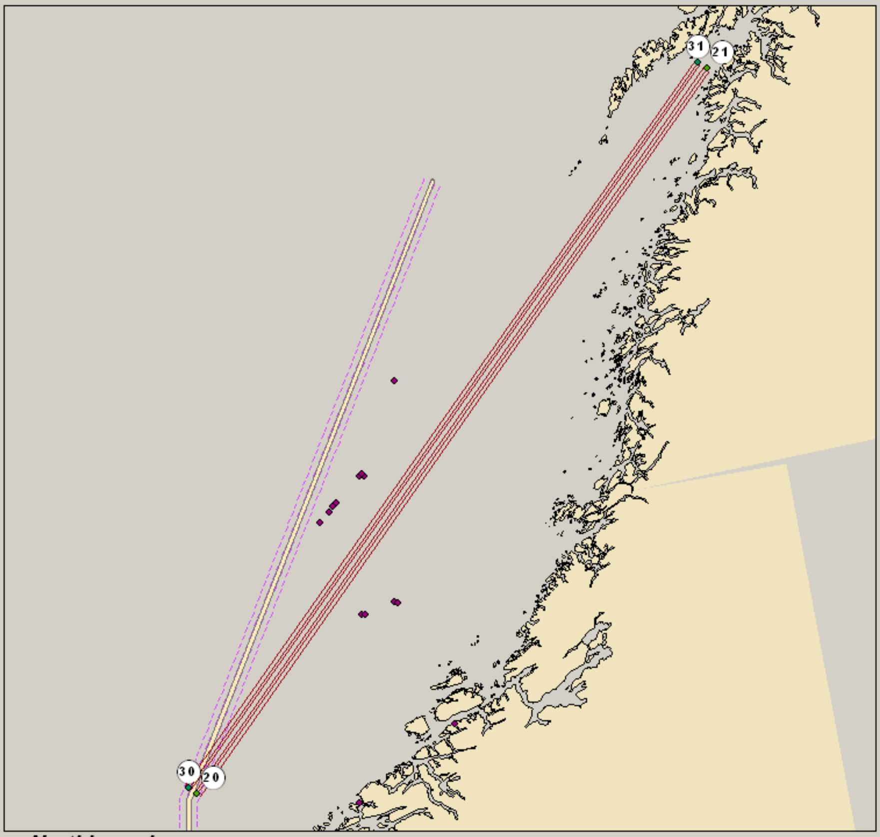
Proposed route



FID	Shape	Id	Shape Leng	ET ID	ET X	ET Y	ET ORDER
0	Point	0	1404455,5506	3	9°15'33"	67°29'43"	0
1	Point	0	1404455,5506	3	4°11'43"	62°54'30"	0,401
2	Point	0	1404455,5506	3	4°11'26"	61°19'54"	0,5261
3	Point	0	1404455,5506	3	4°11'05"	59°01'13"	0,7094
4	Point	0	1404455,5506	3	5°23'46"	58°21'19"	0,7821
5	Point	0	1404455,5506	3	6°37'44"	57°47'53"	0,8502
6	Point	0	1404455,5506	3	7°50'13"	57°46'04"	0,9014
7	Point	0	1404455,5506	3	8°48'06"	58°02'32"	0,9476
8	Point	0	1404455,5506	3	9°37'32"	58°32'20"	1

Figure 5 Proposed route Røst - Utsira

Merging traffic to/from Vestfjorden



Northbound

FID	Shape *	Id	OBJECTID	Shape_Leng	ET_ID	ET_X	ET_Y
0	Point	0	2	751801,994525	0	4°15'09"	62°57'50"
1	Point	0	2	751801,994525	0	14°56'49"	68°03'28"

Southbound

FID	Shape *	Id	OBJECTID	Shape_Leng	ET_ID	ET_X	ET_Y
0	Point	0	3	751801,994525	0	4°06'17"	63°00'47"
1	Point	0	3	751801,994525	0	14°47'35"	68°07'02"

Numbering (example); Number 21 means objectid 2 and FID 1

Given positions are center positions of a lane of total 3 nm wide (1,5 nm on each side)

Figure 6 Proposed route Vestfjorden - Stad

Appendix 2: Vessel velocity and length

Vessel velocity

Figures 2.1-2.2 are plots of velocity of vessels of 100 meters and above for the year 2008. Different velocities are indicated by different colours in the plots. The colour keys can be read in the appurtenant colour boxes.

Most of the coast is coloured green indicating that most vessels of 100 metres and above travel with speeds around 12 knots. The number of vessels in the area can also be read on the appurtenant colour boxes, indicated by the numbers given. The average speed for the entire areas is calculated to be 12.0 knots for vessels above 100 meters (assuming that the last speed category (coloured red) is 17 knots in average).

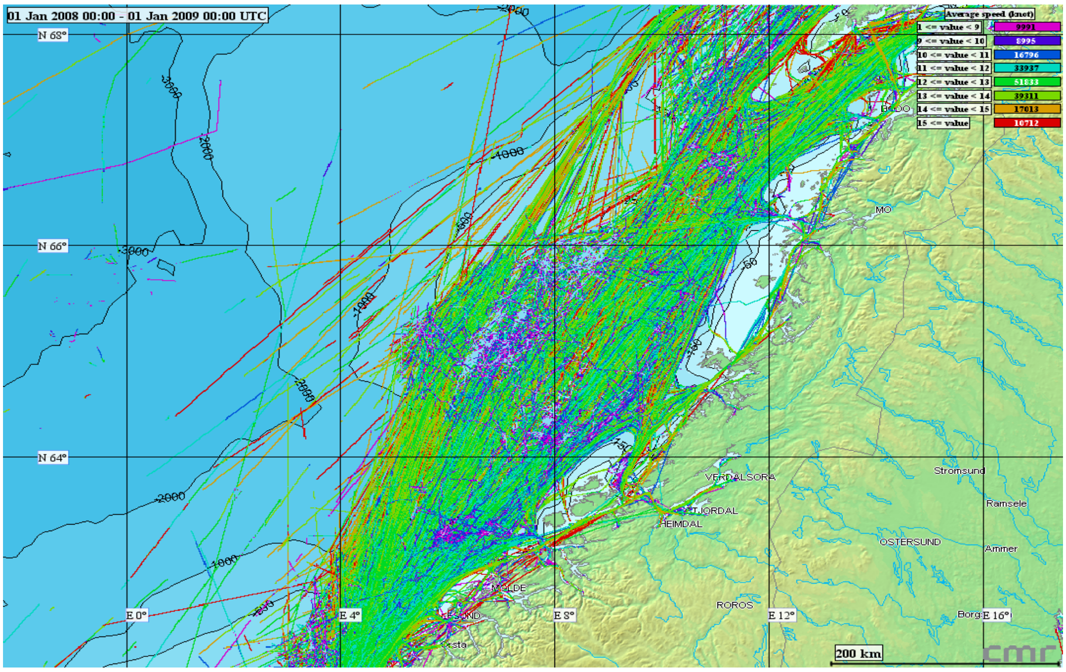


Figure 2.1 Vessel velocities Røst - Stad

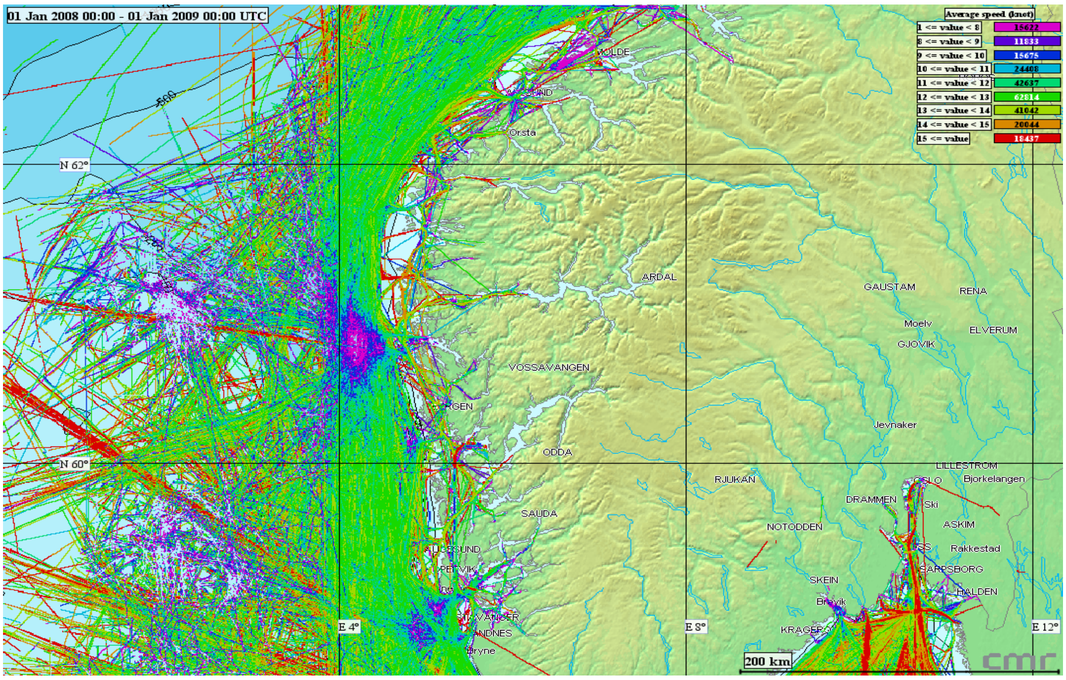


Figure 2.2 Vessel velocities Stad - Utsira

Vessel lengths

Figures 2.3-2.4 are plots of vessel lengths for the year 2008. Different vessel lengths are indicated by different colours in the plots. The colour keys can be read in the appurtenant colour boxes.

Most of the coast is coloured green indicating that most vessels of 100 metres and above travel with speeds around 12 knots. The number of vessels of different lengths the area can also be read on the appurtenant colour boxes, indicated by the numbers given. The average length of vessels above 100 meters is calculated to be 172 meters (assuming the red category to be 250 meters long on average).

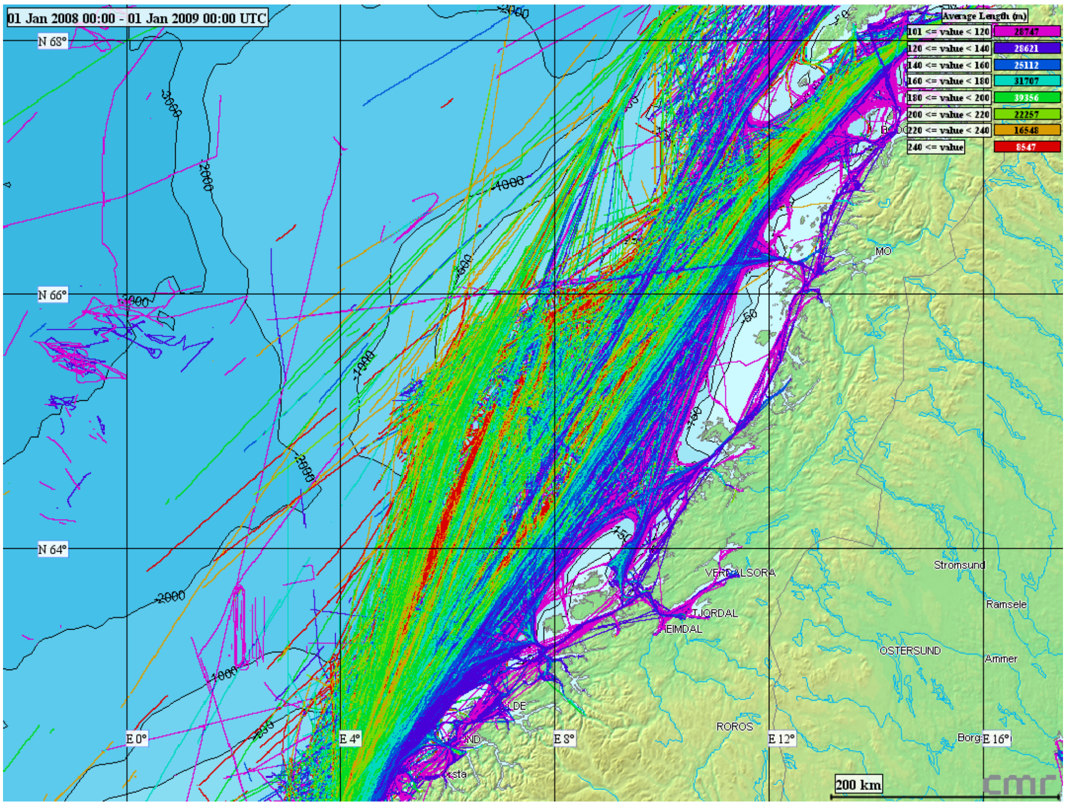


Figure 2.3 Vessel lengths Røst - Stad

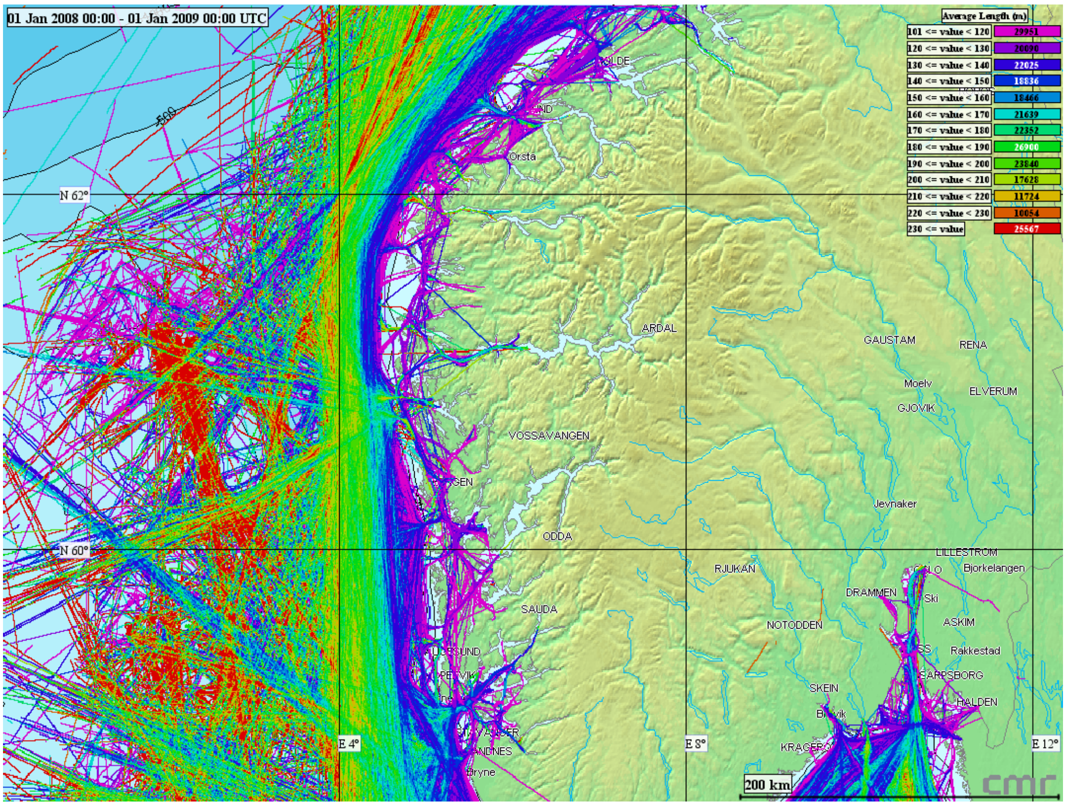


Figure 2.4 Vessel length Stad - Utsira

Appendix 3 Obstacles on or near the routes

Name	NS_decimal degrees	EW_decimal degrees
25/11-A-19 H	59.191692	2.358800
25/11-A-20 H	59.190944	2.360047
25/11-A-21 H	59.191206	2.359703
25/11-A-4 H	59.191469	2.359853
25/11-A-5 H	59.191728	2.359497
25/11-A-6 H	59.191203	2.360392
25/11-A-8 H	59.191619	2.359064
25/11-B-11 H	59.178483	2.378889
25/11-B-14 H	59.178542	2.379403
25/11-B-18 H	59.177553	2.379458
25/11-B-7 H	59.178014	2.379572
25/11-C-12 H	59.183314	2.410072
25/11-C-13 H	59.183297	2.409617
25/11-C-17 H	59.183064	2.409856
25/11-C-3 H	59.183478	2.409036
25/11-D-1 H	59.200286	2.410283
25/11-D-10 H	59.200103	2.409781
25/11-D-2 H	59.199889	2.409211
25/4-D1 H	59.656122	2.278028
25/4-E1 H	59.656369	2.278400
25/4-J-1 H	59.581797	2.057828
25/4-J-2 H	59.581561	2.058558
30/6-B-51 H	60.533292	2.740253
30/6-C-27 H	60.541011	2.719256
30/8-A-21 H	60.457350	2.608061
30/9-B-49 H	60.542236	2.837436
30/9-B-50 H	60.541214	2.806556
31/2-B-3 H	60.777756	3.436672
31/2-D-1 H	60.867547	3.436708
31/2-D-2 H	60.858467	3.445436
31/2-D-3 H	60.858467	3.445408
31/2-D-4 H	60.856847	3.448978
31/2-D-5 H	60.857147	3.442911
31/2-D-6 H	60.856594	3.441375
31/2-D-7 H	60.855839	3.442831
31/2-D-8 H	60.855228	3.445467
31/2-E-1 H	60.800347	3.443517
31/2-E-3 H	60.799811	3.449375

31/2-E-4 H	60.798944	3.442178
31/2-E-5 H	60.797894	3.442958
31/2-E-6 H	60.797594	3.445294
31/2-F-1 H	60.776789	3.435886
31/2-F-4 H	60.775447	3.434653
31/2-F-5 H	60.766722	3.424139
31/2-F-6 H	60.774483	3.437953
31/2-G-1 H	60.751311	3.439494
31/2-G-3 H	60.755322	3.441039
31/2-G-4 H	60.752603	3.439381
31/2-G-6 H	60.752408	3.443333
31/3-Q-21 H	60.831994	3.716522
31/5-H-1 H	60.716108	3.510936
31/5-H-2 H	60.730292	3.513231
31/5-H-3 H	60.714264	3.513711
31/5-H-4 H	60.715319	3.507353
31/5-H-5 H	60.714514	3.506814
31/5-H-6 H	60.713014	3.509433
31/5-I-32 H	60.716678	3.598700
33/12-N-5	61.043878	1.982189
34/10-A-1 H	61.184647	2.220975
34/10-A-2 A	61.180136	2.218453
34/10-A-3 H	61.187294	2.211461
34/10-A-4 H	61.188203	2.224297
34/10-A-5 H	61.178369	2.210675
34/10-A-9 H	61.176728	2.149289
34/4-C H	61.525061	2.211225
34/4-D H	61.525750	2.211111
34/4-K H	61.525408	2.212250
34/4-L H	61.525556	2.212500
34/7-C-5 H	61.379783	2.106158
34/7-E-5 H	61.366050	2.120975
34/7-I-1 H	61.275931	2.119611
34/7-I-10 H	61.276297	2.119328
34/7-I-11 H	61.276172	2.119344
34/7-I-2 H	61.275931	2.119692
34/7-I-3 H	61.276175	2.117111
34/7-I-4 H	61.275786	2.116731
34/7-I-5 H	61.276456	2.117644
34/7-R-1 H	61.275617	2.115192
34/8-A-1 H	61.370158	2.459758
34/8-A-10 H	61.370408	2.458731
34/8-A-11 H	61.370419	2.458592
34/8-A-13 H	61.370431	2.458311
34/8-A-14 H	61.369903	2.458733
34/8-A-18 AH/H	61.369900	2.458733

34/8-A-19 H	61.369919	2.458864
34/8-A-2 H	61.370219	2.459736
34/8-A-20 H	61.369939	2.458994
34/8-A-21 H/AH	61.369961	2.459119
34/8-A-22 H/AH	61.369972	2.459250
34/8-A-23 H	61.370003	2.459383
34/8-A-24 H	61.370031	2.459517
34/8-A-25 H/AH	61.370056	2.459631
34/8-A-26 H	61.370094	2.459739
34/8-A-3 H	61.370256	2.459625
34/8-A-4 H/AH	61.370283	2.459511
34/8-A-5 H	61.370308	2.459381
34/8-A-6 H	61.370331	2.459236
34/8-A-7 H	61.370350	2.459119
34/8-A-8 H	61.370369	2.458986
34/8-A-9 H	61.370389	2.458864
35/11-B-31 H	61.040294	3.576089
35/11-R		
36/22	55.291106	0.203406
36/22-BP	55.290889	0.203889
37/4	55.900167	1.612222
37/4-BP	55.900161	1.612222
6407/7-A-1 H	64.270986	7.201522
6407/7-A-10 H	64.271050	7.202622
6407/7-A-11 H	64.271089	7.202417
6407/7-A-12 H	64.271133	7.202189
6407/7-A-13 H	64.271172	7.201989
6407/7-A-14 H	64.271211	7.201781
6407/7-A-15 H	64.271258	7.201550
6407/7-A-16 H	64.271303	7.201361
6407/7-A-17 H	64.271347	7.201142
6407/7-A-18 H	64.271369	7.200933
6407/7-A-4 H	64.270719	7.201603
6407/7-A-5 H	64.270764	7.201797
6407/7-A-6 H	64.270814	7.202008
6407/7-A-7 H	64.270864	7.202203
6407/7-A-8 H	64.270903	7.202411
6407/7-A-9 H	64.270944	7.202639
6407/9-A-53 H	64.330261	7.775253
6407/9-A-58 H	64.385469	7.960408
6407/9-D-1 H	64.342425	7.723842
6407/9-D-2 H	64.342403	7.723294
6407/9-D-3 H	64.360889	7.712722
6407/9-E-1 H	64.262472	7.730842
6407/9-E-2 H	64.262019	7.730861
6407/9-E-3 H	64.262250	7.732050

6507/11-8 H	65.111611	7.509222
ALBUSKJELL A	56.642886	2.940008
ALBUSKJELL A-BS	56.641819	2.940639
ALBUSKJELL A-FL	56.641019	2.941222
ALBUSKJELL F	56.620536	3.053947
ALBUSKJELL F-BS	56.619419	3.054581
ALBUSKJELL F-FL	56.618600	3.055161
ALVE	65.968444	7.810103
ALVHEIM FPSO	59.567517	1.998450
B-11	55.462314	4.551647
BALDER FPU	59.191214	2.359683
BOA	59.576550	1.923706
BRAE A	58.692483	1.281950
BRAGE	60.542558	3.046797
BRAGE-T	60.560633	2.898056
BYGGVE	59.609228	2.475575
BYGNES	59.299164	5.304764
COD	57.069553	2.434722
COD FL	57.068481	2.435422
DRAUGEN	64.353172	7.782606
DRAUGEN B	64.400264	7.795817
DRAUGEN C	64.310711	7.738408
DRAUGEN D	64.342333	7.724467
DRAUGEN E	64.278431	7.737406
DRAUGEN FLP	64.347000	7.840694
DRAUGEN PLEM 105	64.347197	7.837172
DRAUGEN PLEM-106	64.346803	7.844228
DRAUGEN T	64.233256	6.441258
FLORÏ T	61.401519	4.132678
FRAM A1	61.084772	3.516464
FRAM A2	61.085469	3.516992
FRAM B1	61.039378	3.575736
FRAM B2	61.042783	3.599775
FRAM T-1	61.024236	3.573558
FRAM T-2	61.024431	3.573969
FRANPIPE T	53.094747	3.130108
FRIGG DP1	59.874028	2.060833
FRIGG DP2	59.886131	2.072389
FRIGG QP	59.880133	2.066500
FRIGG TCP2	59.880122	2.066536
FRÏY	59.734167	2.557778
GRANE	59.165239	2.487389
GRANE SSIV	59.167414	2.487281
GULLFAKS A	61.176106	2.189150
GULLFAKS A SSIV	61.176106	2.189194
GULLFAKS A-SPM 1	61.191606	2.157508

GULLFAKS A-SPM 2	61.167253	2.229728
GULLFAKS B	61.202917	2.201300
GULLFAKS C	61.214944	2.273869
GULLFAKS C SSIV	61.214944	2.273897
GULLFAKS SÏR D	61.124042	2.244292
GULLFAKS SÏR E	61.110667	2.260658
GULLFAKS SÏR F	61.097503	2.276806
GULLFAKS SÏR G	61.097286	2.276736
GULLFAKS SÏR H	61.055647	2.073947
GULLFAKS SÏR I	61.055389	2.036911
GULLFAKS SÏR J	61.064122	2.003297
GULLFAKS SÏR K	61.136072	2.015494
GULLFAKS SÏR L	61.096747	2.192775
GULLFAKS SÏR M	61.097053	2.192675
GULLFAKS T	61.096331	2.016267
HEIDRUN	65.325833	7.317500
HEIDRUN B	65.312778	7.262500
HEIDRUN C	65.286350	7.303081
HEIDRUN D	65.361889	7.335989
HEIDRUN E	65.383294	7.369383
HEIDRUN F	65.369439	7.357031
HEIDRUN PLEM-1	65.321731	7.378411
HEIDRUN PLEM-2	65.341847	7.365508
HEIDRUN RISER-BASE	65.323469	7.317500
HEIDRUN SDU	65.325556	7.317222
HEIDRUN STL-I	65.320781	7.403008
HEIDRUN STL-II	65.343619	7.365869
HEIDRUN TEMPLATE	65.325764	7.317631
HEIDRUN UMBILCAL BASE	65.324022	7.309994
HEIMDAL	59.574161	2.228806
HEIMDAL HRP	59.575300	2.228306
HULDRA	60.855825	2.650325
JOTUN A	59.455256	2.386358
JOTUN B	59.451019	2.366908
JOTUN SSIV	59.457528	2.364486
JOTUN T	59.477222	2.233056
KALSTÏ	59.333397	5.195147
KNELER A	59.547817	2.019069
KNELER B	59.546536	1.988650
KOLLSNES	60.548331	4.845403
KOLLSNES T	60.604978	4.263133
KRISTIN	64.993956	6.551342
KRISTIN N	65.028111	6.479606
KRISTIN P	65.014631	6.438214
KRISTIN Q	64.881161	6.434936
KRISTIN R	64.960211	6.438553

KRISTIN S	64.977522	6.434914
KRISTIN T	64.966614	6.769781
KVITEBJÏRN	61.080306	2.499719
K┼RSTÏ	59.273361	5.521358
LILLE-FRIGG	59.961639	2.390833
LILLE-FRIGG A	59.972353	2.385078
LILLE-FRIGG B	59.966153	2.388381
MELKÏYA	70.687450	23.599450
MIKKEL A	64.712619	7.680722
MIKKEL B	64.647083	7.663642
MIME	57.120142	2.486267
MONGSTAD	60.814792	5.036756
MOR-A	65.136972	6.477875
MOR-B	65.163153	6.497247
MTS SSIV		
MÏRE T	63.599981	5.993603
NATURKRAFT GASSKRAFTVERK K┼RSTÏ	59.273361	5.521358
NAVION SAGA	58.441417	1.887500
NJORD A	64.270989	7.201522
NJORD BRAVO	64.272061	7.253081
NJORD SDU-1	64.270986	7.201244
NJORD SDU-2	64.270986	7.201522
NJORD STL	64.272061	7.253081
NJORD T	64.205378	7.259961
NORDÏST FRIGG	59.986511	2.249317
NORDÏST FRIGG A	59.986511	2.249317
NORNE B	66.015169	8.054200
NORNE C	66.014414	8.056033
NORNE D	66.013719	8.057867
NORNE E	66.045472	8.098236
NORNE ERB	66.027306	8.088389
NORNE F	66.044747	8.100072
NORNE FPSO	66.027292	8.088358
NORNE G	66.078325	8.248819
NORNE H	66.077628	8.250828
NORNE J	66.049122	8.171356
NORNE K	66.013611	8.053889
NORNE/HEIDRUN T	65.084517	6.801461
NYHAMNA	62.847794	6.953700
ODIN	60.076933	2.165750
ORMEN LANGE A	63.502222	5.399444
ORMEN LANGE B	63.524167	5.399444
OSEBERG A	60.491864	2.827314
OSEBERG B	60.493339	2.828253
OSEBERG C	60.608339	2.775597
OSEBERG D	60.490667	2.828986

OSEBERG DELTA	60.468119	2.681594
OSEBERG SÏR	60.390172	2.796961
OSEBERG SÏR J	60.354489	2.900078
OSEBERG SÏR K	60.264506	2.776169
OSEBERG VESTFLANKE	60.537628	2.685606
OSEBERG ÏST	60.700497	2.935219
OSEBERG-Y	60.581039	2.799267
PETROJARL 1	58.713306	1.668136
PETROJARL VARG	58.077881	1.890458
RINGHORNE	59.266058	2.449858
SAGE-T	59.478489	1.390039
SKINFAKS N	61.078994	1.989853
SKIRNE	59.585558	2.629706
SLAGENTANGEN	59.318456	10.530986
SNORRE A	61.449336	2.144344
SNORRE B	61.525439	2.211506
SNORRE B SBV	61.522850	2.212575
SNORRE MDU	61.525556	2.211944
SNORRE SDU-1	61.525833	2.212222
SNORRE SDU-2	61.525833	2.211667
SNORRE UPA	61.489328	2.226344
SNÏHVIT CDU-1	71.569300	21.227533
SNÏHVIT D	71.592167	21.273000
SNÏHVIT E	71.594528	21.183531
SNÏHVIT F	71.611028	21.058039
SNÏHVIT N	71.488528	21.084861
SNÏHVIT PLEM-1	71.571336	21.226536
ST. FERGUS	57.553331	1.850000
STATFJ-NORD SSIV	61.296808	1.908986
STATFJORD A	61.255683	1.853875
STATFJORD A-OLS	61.263511	1.887231
STATFJORD B	61.206911	1.830636
STATFJORD B-OLS	61.224417	1.838644
STATFJORD C	61.296583	1.902547
STATFJORD C-SPM	61.281056	1.883833
STATFJORD G	61.365714	1.934983
STATFJORD NORD D	61.447361	1.914167
STATFJORD NORD E	61.434250	1.925111
STATFJORD NORD F	61.444722	1.956333
STATFJORD ÏST K	61.343944	1.972778
STATFJORD ÏST L	61.329403	1.986522
STATFJORD ÏST M	61.341256	1.999897
STATFJORD-A-ALP	61.263503	1.887228
STATFJORD-B-SPM	61.206944	1.830833
STAT-SSTC	61.185831	1.845936
STT-IN	60.560875	2.896869

STURE	60.621111	4.851111
SYGNA N	61.466942	1.991850
TJELDBERGODDEN	63.394653	8.654947
TOGI	60.574250	3.657528
TOR II Y	60.848958	4.060278
TORDIS EXTENSION	61.274872	2.119906
TORDIS ÏST K	61.276153	2.120244
TORDIS-MS	61.275633	2.118114
TORSIS SSIB		
TROLL A	60.645639	3.726494
TROLL B	60.774375	3.503181
TROLL C	60.886322	3.611444
TROLL D	60.856728	3.444803
TROLL E	60.799217	3.445739
TROLL ERB	60.772500	3.510833
TROLL ERS	60.773500	3.506344
TROLL F	60.776169	3.438244
TROLL G	60.753522	3.442142
TROLL H	60.714497	3.510378
TROLL I1	60.741011	3.581725
TROLL I2	60.728542	3.577597
TROLL J1	60.743236	3.608000
TROLL J2	60.729297	3.656547
TROLL K1	60.768314	3.611350
TROLL K2	60.755839	3.639794
TROLL L1	60.785122	3.556042
TROLL L2	60.808772	3.555953
TROLL M1	60.915603	3.626553
TROLL M2	60.931419	3.664239
TROLL N1	60.915689	3.586608
TROLL N2	60.946339	3.580369
TROLL O1	60.889572	3.566389
TROLL P1	60.866994	3.557942
TROLL P2	60.876578	3.494208
TROLL PILOT	60.896339	3.653758
TROLL PRB	60.775833	3.497500
TROLL PRBN	60.773208	3.510625
TROLL PRBS	60.772169	3.509578
TROLL PRS	60.774947	3.501172
TROLL PTG	60.882175	3.618272
TROLL PTO	60.882417	3.618436
TROLL Q1	60.844672	3.627228
TROLL R	60.862942	3.710408
TROLL RB1	60.888978	3.608492
TROLL RB2	60.884136	3.617828
TROLL RB3	60.887922	3.606253

TROLL RB4	60.883006	3.615306
TROLL RSS1	60.887036	3.610128
TROLL RSS2	60.885014	3.613886
TROLL S1	60.895050	3.654642
TROLL S2	60.892981	3.671869
TROLL T1	60.832575	3.603978
TROLL T2	60.808086	3.593197
TROLL U1	60.849328	3.581667
TROLL U2	60.831050	3.572594
TUNE	60.467522	2.653308
TYRIHANS A	64.888958	7.071344
TYRIHANS B	64.811606	7.056781
TYRIHANS C	64.789861	7.011728
TYRIHANS D	64.779739	6.990717
TYRIHANS W	64.834914	7.015317
UK-NL	61.167483	1.659428
VALE	59.706231	2.310508
VESLEFRIKK A	60.782706	2.897858
VESLEFRIKK B	60.781389	2.898611
VESLEFRIKK T	60.560536	2.898056
VEST EKOFISK	56.563208	3.085600
VESTERLED T	59.643314	1.318975
VIGDIS B	61.397081	2.117650
VIGDIS C	61.380431	2.103392
VIGDIS D	61.345614	2.072869
VIGDIS E	61.398561	2.067925
VIGDIS F	61.320681	2.066700
VIGDIS G	61.379189	2.106233
VIGDIS-Y	61.184678	2.172264
VISUND	61.370156	2.458917
VISUND NORD	61.430833	2.567583
VISUND SDU-1	61.369722	2.459167
VISUND SDU-2	61.370000	2.459444
VÏRING T	62.219386	4.599142
ÏST FRIGG A	59.919069	2.364442
ÏST FRIGG B	59.890667	2.361928
ÏST FRIGG CMS	59.904642	2.362911
ÏST KAMELEON	59.585867	2.086322
ÅSGARD A	65.064417	6.727444
ÅSGARD B	65.110372	6.791186
ÅSGARD C	65.131369	6.865786
ÅSGARD E	65.068319	6.611367
ÅSGARD ERB	65.106686	6.799053
ÅSGARD F	65.029528	6.601250
ÅSGARD G	65.088264	6.662000
ÅSGARD H	65.118572	6.674278

ÅSGARD I	65.085361	6.681750
ÅSGARD J	65.166333	6.733083
ÅSGARD K	65.133833	6.707000
ÅSGARD L	65.138250	6.782694
ÅSGARD M	65.173444	6.800889
ÅSGARD N	65.173917	6.851444
ÅSGARD O	65.138900	6.784739
ÅSGARD P	65.022994	6.879389
ÅSGARD Q	65.040172	6.941875
ÅSGARD R	65.033403	6.901956
ÅSGARD RB	65.066639	6.727306
ÅSGARD S	65.016111	6.945889
ÅSGARD T	65.043442	6.655031
ÅSGARD X	65.067639	7.492972
ÅSGARD Y	65.005167	7.557000
ÅSGARD Z	64.970806	7.622139

APPENDIX 4

DESCRIPTION OF THE MARCS MODEL

APPENDIX 4 – DESCRIPTION OF THE MARCS MODEL

Contents

I. DESCRIPTION OF THE MARCS MODEL

I.1 BACKGROUND

Transportation by sea using conventional shipping operations results in both economic benefits and associated ship accident risks, which can result in safety and environmental impacts. Analysis of historical ship accident data indicates that almost all open-water shipping losses (excepting causes such as war or piracy) can be categorised into the following generic accident types:

- Ship-ship collision;
- Powered grounding (groundings which occur when the ship has the ability to navigate safely yet goes aground, such as the *Exxon Valdez*);
- Drift grounding (groundings which occur when the ship is unable to navigate safely due to mechanical failure, such as the *Braer*);
- Structural failure/ foundering whilst underway;
- Fire/ explosion whilst underway;
- Powered ship collision with fixed marine structures such as oil platforms or wind turbines (similar definition to powered grounding);
- Drifting ship collision with fixed marine structures such as oil platforms or wind turbines (similar definition to drift grounding).

These generic accident types effectively represent the results of a high level marine transportation hazard identification (HAZID) exercise and are applicable for most marine transportation systems. However, each marine risk analysis should consider if additional locally specific accident modes apply. For example, in Prince William Sound, Alaska laden oil tankers are tethered to a tug for part of the transit to mitigate grounding accidents. However, the presence of the tug also introduces an extra accident mode (tanker grounds because tug actions are inappropriate). The presence or absence of such additional geographically specific accident modes should be verified on a project specific basis.

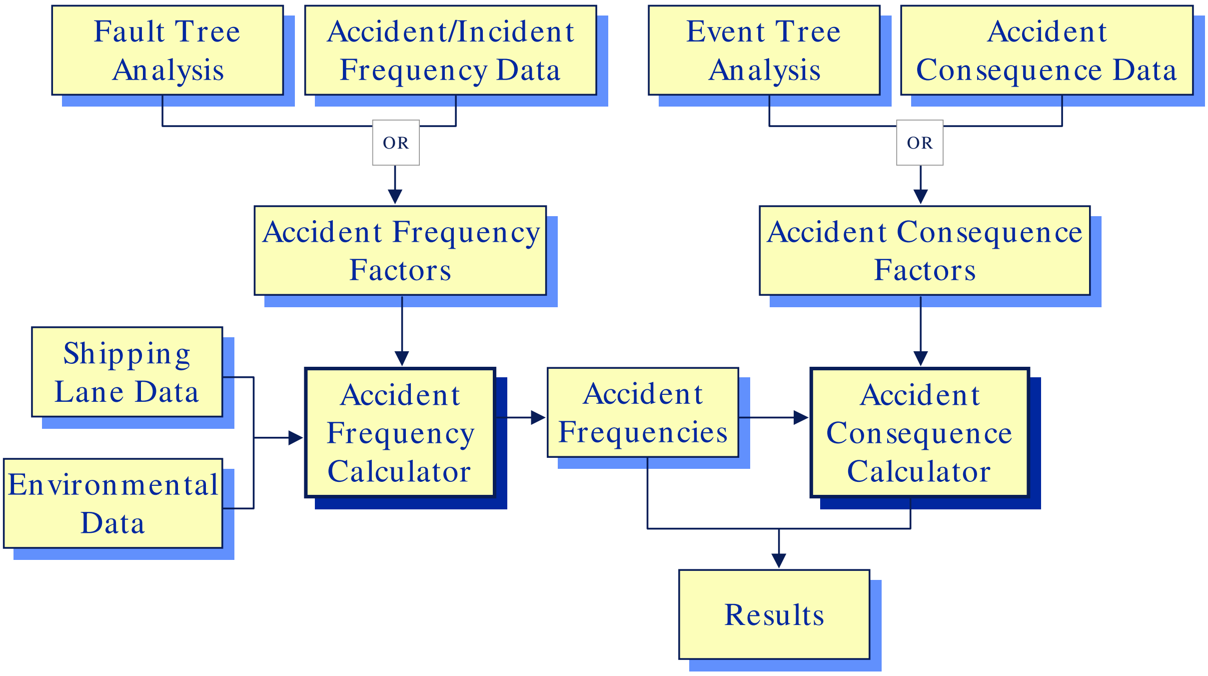
Marine transport risk analysis can be performed by assessing the frequency of the above accident types, followed by an assessment of the accident consequences, typically in terms of cargo spill, lives lost or in financial terms. DNV has developed the MARCS (Marine Accident Risk Calculation System) model to perform such marine transport risk analyses in a structured manner. The risk analysis results can then be assessed to determine if the estimated risks are acceptable or if risk mitigation is justified or required (risk assessment).

I.2 INTRODUCTION TO MARCS

I.2.1 Overview

The Marine Accident Risk Calculation System (MARCS) was developed by DNV to support our marine risk management consultancy business. The MARCS model provides a general framework for the performance of marine risk calculations. A block diagram of the model is shown in Figure I.1.

Figure I.1 Block Diagram of MARCS



The MARCS model classifies data into 4 main types:

- Shipping lane data describes the movements of different marine traffic types within the study area;
- Environment data describes the conditions within the calculation area, including the location of geographical features (land, offshore structures etc) and meteorological data (visibility, windrose, currents and seastate);
- Internal operational data describes operational procedures and equipment installed onboard ship – such data can affect both accident frequency and accident consequence factors;
- External operational data describes factors external to the ship that can affect ship safety, such as VTMS (Vessel Traffic Management Systems), TSS (Traffic Separation Schemes), and the location and performance of emergency tugs – such data can affect both accident frequency and accident consequence factors.

As indicated in Figure I.1, accident frequency and consequence factors can be derived in two ways. If a coarse assessment of accident risk is required, the factors may be taken from worldwide historical accident data. Alternatively, if a more detailed study is required, these factors may be derived from generic fault trees or event trees which have been modified to take account of specific local factors.

I.2.2 Critical Situations

MARCS calculates the accident risk in stages. It first calculates the location dependent frequency of critical situations (the number of situations which could result in an accident – "potential accidents" – at a location per year; a location is defined as a small part of the study area, typically about 1 nautical mile square, but depending on the chosen calculation resolution). The definition of a critical situation varies with the accident mode, see Section I.4. MARCS then assesses the location dependent frequency of serious accidents for each accident mode via "probability of an accident given a critical situation" parameters. A "serious accident" is defined by Lloyds as any accident where repairs must be made before the ship can continue to trade. Finally, the location dependent accident consequence, and hence risk, is assessed.

Analysis of these results for a specified area or trade enables the derivation of conclusions and recommendations on topics such as risk acceptability, risk reduction measures and cost-benefit analysis of alternative options.

I.2.3 Fault Tree Analysis

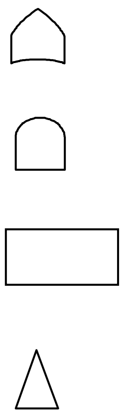
Fault tree analysis (see, for example, Henley E.J. and Kumamoto H., 1981 or Cooke R.M., 1995) can be described as an analytical technique, whereby an undesired state of a system is specified, and the system is then analysed in the context of its environment and operation to find all credible ways in which the undesired event can occur. This undesired state is referred to as the top event of the fault tree. It expresses the frequency or probability for the occurrence of this event or incident.

The basic events of a fault tree are those events that make up the bottom line of the fault tree structure. To perform calculations of the top frequency or probability of a fault tree, these basic events needs to be quantified.

The fault tree structure is built up by basic events, and logical combinations of these events which are expressed by AND and OR gates. The output of these gates are new events, which again may be combined with other events/basic events in new gates. The logic finally results in the top event of the fault tree. For example, fire occurs if combustible material AND air/oxygen AND an ignition source is present.

The different symbols in the fault tree are defined in Figure I.2.

Figure I.2 Fault tree symbols



OR - gate

AND - gate

description of initial event, gate or top event

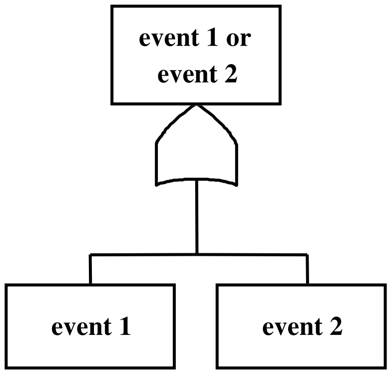
Transfer symbol to another part of the tree

The OR gate, see Figure I.3, expresses the probability of occurrence of event 1 or event 2, and is calculated as the sum minus the intersection of the two events;

$$P(\text{event 1 OR event 2}) = P1 + P2 - P1 * P2$$

Usually the intersection probability can be neglected, as it will be a very small number (if P1 = P2 = 10^{-2}, then P1*P2 = 10^{-4}).

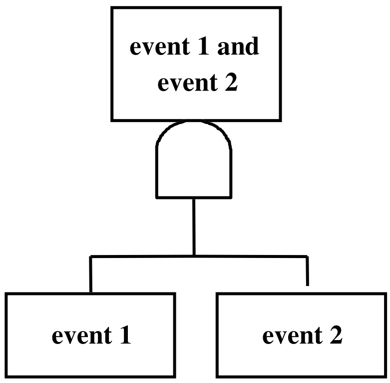
Figure I.3: OR - gate



The AND gate, see Figure I.4, expresses the probability that event 1 and event 2 occur simultaneously, and is calculated as the product of the two events;

P(event 1 AND event 2)= P1*P2

Figure I.4: AND - gate



It should be emphasised that the quality of the results produced by fault tree analysis is dependent on how realistically and comprehensively the fault tree model reflects the causes leading to the top event. Of course, it is never possible to fully represent reality, and therefore the models will always only represent a simplified picture of the situation of interest. The top event frequencies will generally be indicative, and hence relative trends are more secure than the absolute values.

Fault tree models have been constructed to assess a number of parameters within MARCS, including collision per encounter probabilities (collision model) and failure to avoid a powered grounding given a critical situation probabilities (powered grounding model) (SAFECO I; SAFECO II).

I.3 DATA USED BY MARCS

I.3.1 Traffic Image Data

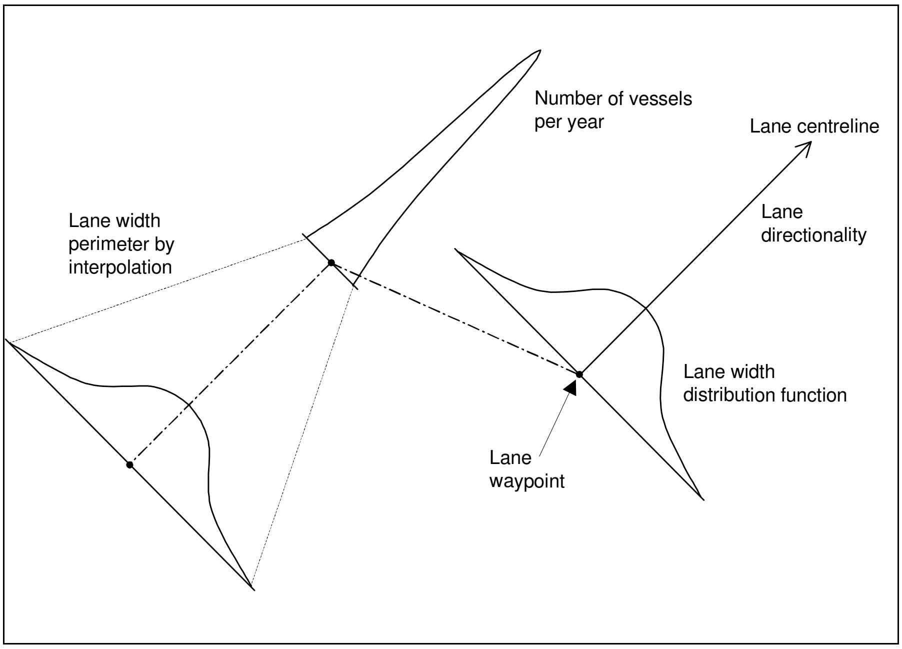
The marine traffic image data used by MARCS is a representation of the actual flows of traffic within the calculation area. Marine traffic data is represented using lane data structures. Different traffic types are divided into separate marine databases in order to facilitate data verification and the computation of different types of risk (for example, crude oil spill risk versus human safety).

A typical traffic lane is shown in Figure I.5. The following data items are defined for all lanes:

1. The lane number (a unique identifier used as a label for the lane);
2. The lane width distribution function (Gaussian or truncated Gaussian);
3. The lane directionality (one-way or two-way);
4. The annual frequency of ship movements along the lane;
5. A list of waypoints, and an associated lane width parameter at each waypoint;
6. The vessel size distribution on the lane.

Additional data may be attached to the lane, such as: the hull type distribution (single hull, double hull, etc) for tankers; the loading type (full loading, hydrostatic loading) for tankers; ship type etc..

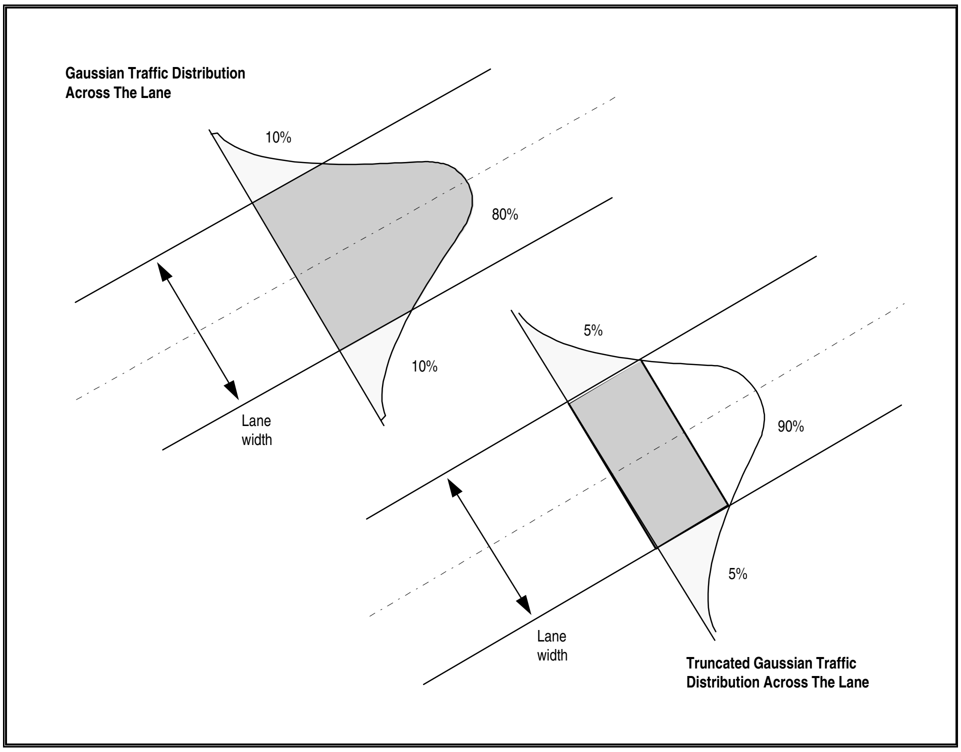
Figure I.5 Shipping Lane representation used in MARCS



Detailed surveys of marine traffic in UK waters in the mid 1980s (e.g. HMSO, 1985) concluded that commercial shipping follows fairly well defined shipping lanes, as opposed to mainly random tracks of individual ships. Further detailed analysis of the lanes showed that the lateral distribution across the lane width was approximately Gaussian, or truncated

Gaussian for traffic arriving in coastal waters from long haul voyages (e.g. from the US or Canada). The shipping lane distributions used in MARCS are shown in Figure I.6.

Figure I.6 Shipping Lane Width Distribution Functions used in MARCS



The marine traffic description used by MARCS is completed by the definition of four additional parameters for each type of traffic:

1. Average vessel speed (generally 8 to 18 knots);
2. Speed fraction applied to faster and slower than average vessels (generally plus/minus 20%);
3. Fraction of vessels travelling faster and slower than the average speed (generally plus/minus 20%);
4. Fraction of vessels that exhibit "rogue" behaviour (generally set to 0%, though historical accident data in many geographical areas shows a small proportion of (usually) smaller vessels undergo accidents through lack of watch keeping (bridge personal absent or incapacitated)).

A rogue vessel is defined as one that fails to adhere (fully or partially) to the Collision Avoidance Rules (Cockcroft, 1982). Such vessels are assumed to represent an enhanced collision hazard. These four parameters can be specified as a function of location within the study area for each traffic type.

The marine traffic image is made up by the superposition of the defined traffic for each contributing traffic type.

I.3.2 Internal Operational Data

Internal operational data is represented within MARCS using either worldwide data or frequency factors obtained from fault tree analysis or location specific survey data. Fault tree parameters take into consideration factors such as crew watch-keeping competence and internal vigilance (where a second crew member, or a monitoring device, checks that the navigating officer is not incapacitated by, for example, a heart attack). Examples of internal operational data include:

1. The probability of a collision given an encounter;
2. The probability of a powered grounding given a ship's course is close to the shoreline;
3. The frequency (per hour at risk) of fires or explosions.

Internal operational data may be defined for different traffic types and/ or the same traffic type on a location specific basis.

I.3.3 External Operational Data

External operational data generally represents controls external to the traffic image, which affect marine risk. In MARCS it relates mainly to the location of VTS zones (which influence the collision and powered grounding frequencies by external vigilance, where external vigilance means that an observer external to the ship may alert the ship to prevent an accident) and the presence and performance of emergency towing vessels (tugs) which can save a ship from drift grounding.

I.3.4 Environment Data

The environment data describes the location of geographical features (land, offshore structures etc.) and meteorological data (visibility, wind rose, sea currents and seastate).

Poor visibility arises when fog, snow, rain or other phenomena restricts visibility to less than 2 nautical miles. It should be noted that night-time is categorised as good visibility unless fog, for example, is present.

Windrose data is defined within 8 compass points (north, north-east, east etc) in 4 wind speed categories denoted: calm (0 – 20 knots); fresh (20 to 30 knots); gale (30 to 45 knots); and storm (greater than 45 knots). Seastate (wave height) within MARCS is inferred from the windspeed and the nature of the sea area (classified as sheltered, semi-sheltered or open water).

Sea currents are represented as maximum speeds in a defined direction within an area.

I.4 DESCRIPTION OF ACCIDENT FREQUENCY MODELS

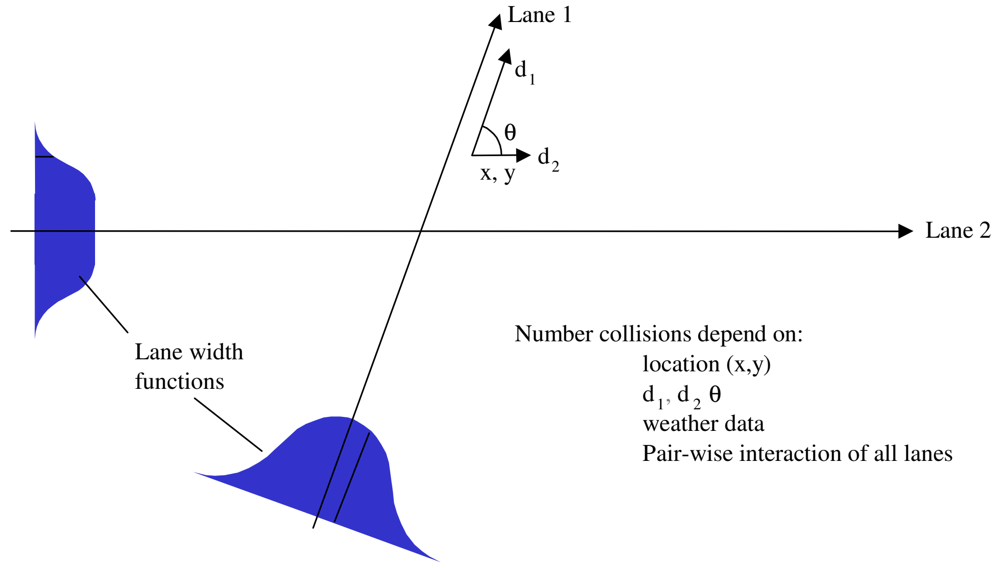
The section describes how MARCS uses the input data (traffic image, internal operational data, external operational data and environment data) to calculate the frequency of serious accidents in the study area.

I.4.1 The Collision Model

The collision model calculates the frequency of serious inter-ship powered collisions at a given geographical location in two stages. The model first estimates the frequency of encounters (critical situations for collision - when two vessels pass within 0.5 nautical miles of each other) from the traffic image data using a pair-wise summation technique, assuming no collision avoiding actions are taken. This enables the calculation of either total encounter frequencies, or encounter frequencies involving specific vessel types.

The model then applies a probability of a collision for each encounter, obtained from fault tree analysis, to give the collision frequency. The collision probability value depends on a number of factors including, for example, the visibility or the presence of a pilot. Figure I.7 shows a graphical representation of the way in which the collision model operates.

Figure I.7 Graphical representation of the collision model



Frequency = (Frequency of encounters) x (probability of collision given an encounter)

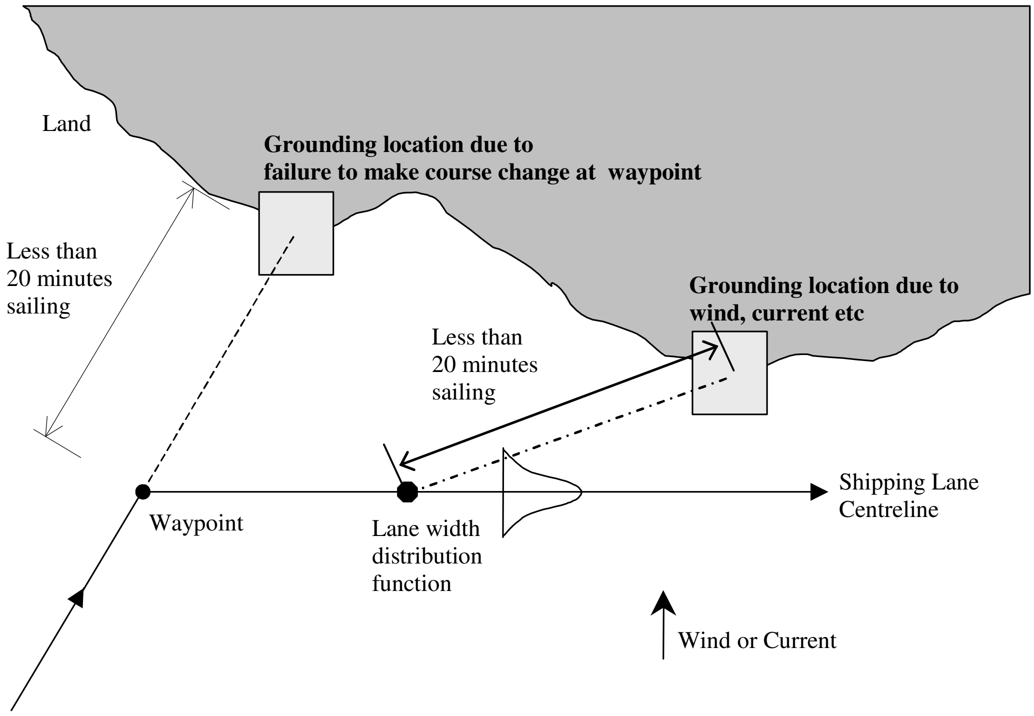
In Figure I.7, d_1 refers to the density of traffic associated with lane 1 at the location x,y. The frequency of encounters at location x,y through the interaction of lanes 1 and 2 is proportional to the product of d_1, d_2 and the relative velocity between the lane densities.

I.4.2 The Powered Grounding and Powered Collision Models

The powered grounding frequency model calculates the frequency of serious powered grounding accidents in two stages. The model first calculates the frequency of critical situations (sometimes called “dangerous courses” for powered grounding accidents). Two types of critical situation are defined as illustrated in Figure I.8. The first critical situation arises when a course change point (waypoint) is located such that failure to make the course change would result in grounding within 20 minutes navigation from the planned course change point if the course change is not made successfully. The second critical situation results when a grounding location is within 20 minutes navigation of the course centreline. In this case crew inattention combined with wind, current or other factors could result in a powered grounding.

The frequency of serious powered groundings is calculated as the frequency of critical situations multiplied by the probability of failure to avoid grounding.

Figure I.8 Graphical representation of the powered grounding model



The powered grounding probabilities are derived from the fault tree analysis of powered grounding. The powered grounding fault tree contains 2 main branches:

1. Powered grounding through failure to make a course change whilst on a dangerous course. A dangerous course is defined as one that would ground the vessel within 20 minutes if the course change were not made.
2. Powered grounding caused by crew inattention and wind or current from the side when the ship lane runs parallel to a shore within 20 minutes sailing.

Both these branches are illustrated in Figure I.8. The powered grounding frequency model takes account of internal and external vigilance, visibility and the presence of navigational aids (radar) in deducing failure parameters.

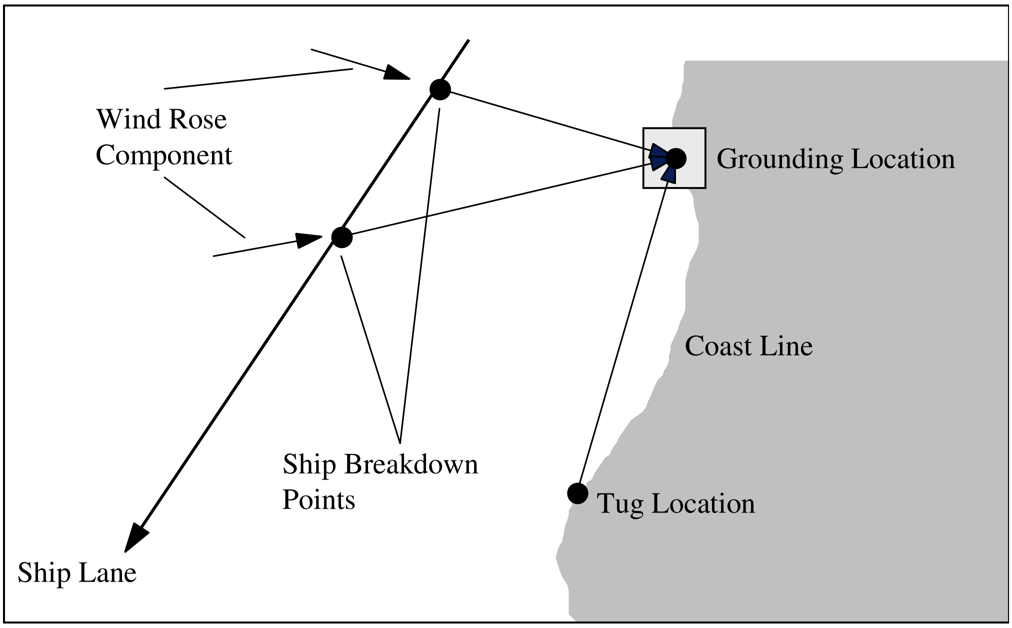
The powered collision with fixed objects model works is similar to the powered grounding model.

I.4.3 The Drift Grounding and Drift Collision Models

The drift grounding frequency model consists of two main elements as follows: first, the ship traffic image is combined with the ship breakdown frequency factor to generate the location and frequency of vessel breakdowns; second, the recovery of control of drifting ships can be regained by one of 3 mechanisms: a) repair, b) emergency tow assistance, or c) anchoring. Those drifting ships that are not saved by one of these three mechanisms (and do not drift out into the open sea) contribute to the serious drift grounding accident frequency results.

The number and size distribution of ships which start to drift is determined from the ship breakdown frequency, the annual number of transits along the lane and the size distribution of vessels using the lane. The proportion of drifting vessels which are saved (fail to ground) is determined from the vessel recovery models. The drift grounding frequency model is illustrated in Figure I.9.

Figure I.9 Graphical representation of the drift grounding model

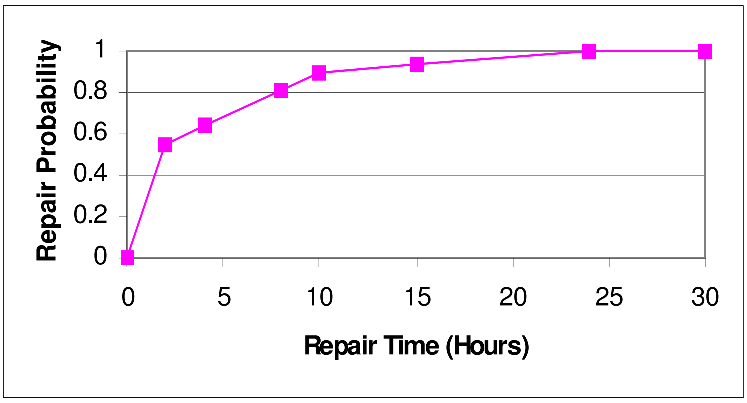


Implicit in Figure I.9 is the importance of the time taken for the ship to drift aground. When this time is large (because the distance to the shore is large and/ or because the drift velocity is small) then the probability that the ship will recover control before grounding (via repair or tug assistance) will be increased.

Repair Recovery Model

Vessels which start to drift may recover control by effecting repairs. For a given vessel breakdown location, grounding location and drift speed there is a characteristic drift time to the grounding point. The proportion of drifting vessels which have recovered control by self-repair is determined from this characteristic drift time and the distribution of repair times.

Figure I.10 Graphical representation of the self repair save mechanism



Recovery of Control by Emergency Tow

Drifting vessels may be brought under control (saved from grounding) by being taken in tow by an appropriate tug. It should be noted that the tug save model assumes a save is made when the ship is prevented from drifting further towards the shoreline by the attachment of a suitable tug. In practice, two or more tugs would be required to complete the ship save, by towing the vessel to a safe location, but this aspect of the save is not modelled in MARCS.

Two types of tug can be represented within MARCS. Close escort tugs move with ships through their transit, thus their time to reach a drifting ship is always small. Pre-positioned tugs are located at strategic points around the study area. The model works by calculating for each tug:

- If the tug can reach the drifting vessel in time to prevent it grounding. This time consists of the time to reach the ship (almost zero when close escorting) and the time to connect and take control of the ship (which is a function of seastate);
- If the tug can reach the ship before it grounds, then the adequacy of the tug with regard to control of the ship is evaluated. (The presence of several tugs of differing power is assumed to be represented by the presence of one tug of the largest power. This is because only one tug is usually used to exert the main "saving" pull. Other tugs present are used to control the heading of the disabled ship, and to bring the ship to a safe location.)
- When several tugs of various capabilities can reach the drifting ship in time, then the tug with the best performance is assumed to be connected to the ship and takes control of the largest proportion of the drifting vessels.

The tug model contains parameters to take explicit account of:

- The availability of the tug (some tugs have other duties);
- The tugs response time (delay before assistance is summoned);
- The tug speed (as a function of seastate);
- The time to connect a line and exert a controlling influence on the ship (as a function of seastate);
- The performance of the tug (identified as the maximum control tonnage for the tug) as a function of wind speed and location (since the wind speed and the fetch control sea state).

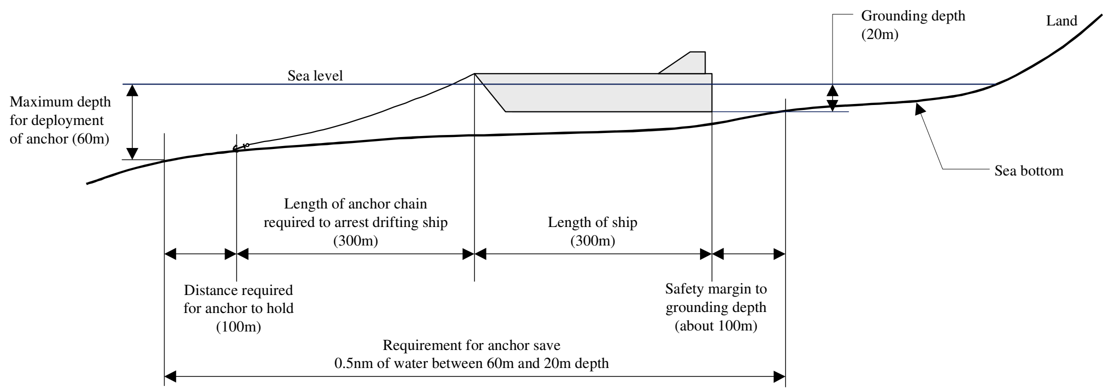
Tug performance parameters can take account of ship wind and wave resistance, tug wind and wave resistance and tug length and propulsion arrangement (open versus nozzle) which influences the propulsion efficiency.

Recovery of Control by Anchoring

The anchor save model is derived with reference to the following reasoning:

1. Anchoring is only possible if there is a sufficient length of suitable water to prevent the ship running aground. Suitable water is defined as a depth of between 30 fathoms (about 60m - maximum for deployment of anchor) and 10 fathoms (about 20m - minimum for ship to avoid grounding). Sufficient length is calculated as 100m for anchor to take firm hold of the seabed + 300m to stop ship + 300m for length of ship + 100m for clearance = 800m, or 0.5 nautical miles (to be slightly conservative).
2. If such a track exists, then the probability that the anchor holds is calculated as a function of the wind speed and the sea bottom type (soft sea beds consist predominantly of sands, silts and muds). If the anchor hold, then an anchor save is made.

Figure I.11 Graphical representation of the Anchor save mechanism



The anchor save model can also specify a time required to deploy the anchoring system as this may be significant for ships without main power.

The anchor save model is conservative in that it under-predicts the effectiveness of this save mechanism for average and smaller ships.

The drift collision with fixed objects model works is similar to the drift grounding model.

I.4.4 The Structural Failure Model

The structural failure/foundering accident frequency model applies accident frequency parameters derived from accident data or fault tree analysis with calculations of the ship exposure time to obtain the serious accident frequency. The structural failure/foundering parameters take account of the greater structural strength of some hull designs, such as double hulled vessels.

The total ship exposure time (number of vessel hours) in any area for a given wind speed category (used by MARCS to infer the seastate) can be calculated from the traffic image parameters (locations of lanes, frequencies of movements and vessel speeds) and the local wind speed parameters. The serious structural failure/foundering frequency is then obtained by multiplying these vessel exposure times by the appropriate structural failure frequency factor for the wind speed (seastate) category.

I.4.5 The Fire and Explosion Model

The fire/explosion accident frequency model applies the accident frequency parameters derived from accident data or fault tree analysis with calculations of the ship exposure time to obtain the serious accident frequency. The total ship exposure time (number of vessel hours) in any area can be calculated from the traffic image parameters (locations of lanes, frequencies of movements and vessel speeds). The fire/explosion serious accident frequency is then obtained by multiplying these vessel exposure times by the appropriate fire/explosion frequency factor (accidents per ship-hour). It should be noted that fire/explosion frequency factors assumed to be independent of environmental conditions outside the ship.

I.5 DESCRIPTION OF ACCIDENT CONSEQUENCE MODELS

I.5.1 Introduction

MARCS evaluates the consequences of an accident in terms of, for example, the loss of containment of any fluid stored within a ship. This loss of containment can be in the form of either a bunker (fuel) oil spillage, a loss of liquid cargo stored in atmospheric tanks (tanks at the same pressure as the atmosphere), or a loss of gas cargo from pressurised or refrigerated tanks. It should be noted that MARCS does not calculate any consequences based upon the dispersion of fluid that might result from a loss of containment, though DNV is able to assess such consequences using other DNV tools.

Marine accident consequences are typically expressed in terms of cargo spilled, lives lost or financial loss. They are used with the frequency of a marine accident to estimate the resulting marine accident risk(s).

I.5.2 Factors affecting Cargo Loss Risk

There are various factors or events that can affect the risk of loss of containment following an accident ranging from those that relate to accident frequencies to those that relate to accident locations. Listed below are the factors which may be referenced by MARCS, depending on the situation, when evaluating the consequence(s) of a particular scenario.

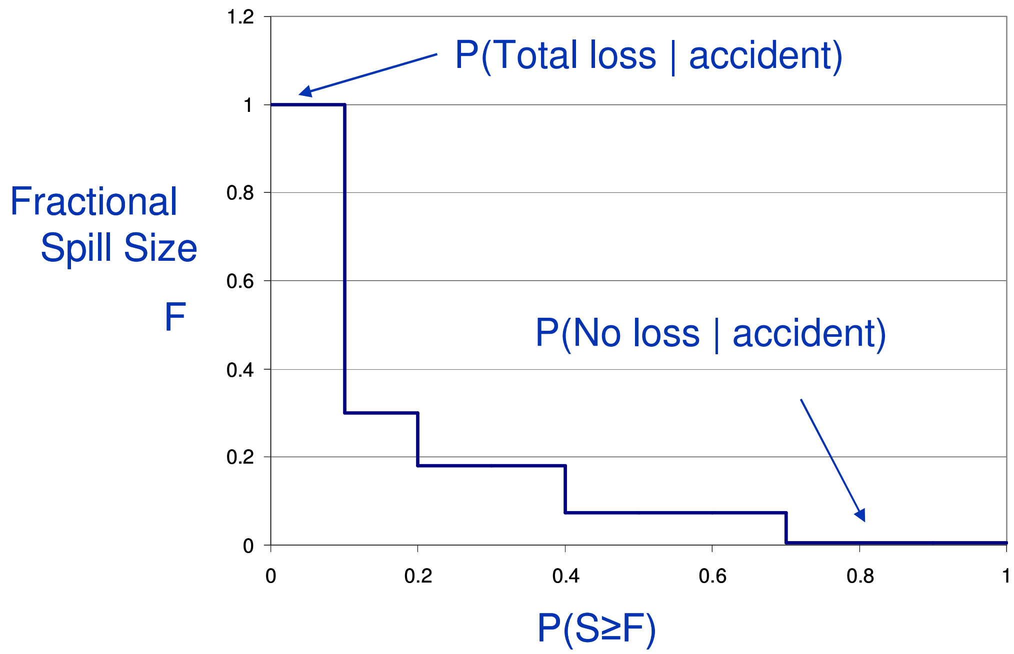
- Frequency of serious accidents. This is taken from the accident frequency models based upon historical accident data, as described in Section IV.4 above, and is one of the main factors that affect risk.
- The probability of loss of containment given a serious accident. This could be a function of:
  - Ship Type. A laden crude tanker has both cargo and bunker oil that could spill compared with, for example, a container ship that has only bunker oil.
  - Ship Structure. Ships may be single or double hulled, or a variation of either.
  - Probability of grounding on rocks. Grounding on rocks will increase the likelihood of a loss of containment.
  - Severity of accident. For example, an increase in the momentum of a colliding ship will increase the severity of an accident because of the resulting increase in energy that needs to be dissipated.
  - Location of accident. For example, high wave energy shore lines lead to an increased risk of ship damage during grounding and hence increased risk of loss of containment or, if the loss of containment has already occurred, then an increased risk in total loss of the ship.
- Probability of outflow of a specific quantity given a serious accident. This is the probability that there is a spillage of certain mass following a serious accident.
- Probability of the total loss of a ship given a serious accident. This assumes a total loss of cargo, though in practice some cargo may be recovered without spillage or without total spillage.

I.5.3 Generic Spill Model

The spill models developed for use by MARCS are based upon one or more of 3 main sources of information. These are historical accident analysis, engineering calculations, and judgements based upon other sources of data. Historical accident analysis, where available, can provide information on the number of accidents per ship category and the size of spillage in each case. This is usually the most robust source of data and is often complemented by further calculations to obtain spill models. In certain cases it is necessary to make judgements where relevant data is lacking; this can be the least robust method available.

Previous projects performed by DNV have developed crude oil outflow models for different accident types (collision, fire/explosion etc) and different hull configurations (single hull, double hull etc). These models (normalised cumulative probability distributions) take the generic form shown in Figure IV.12. This shows a typical spill model as used by MARCS. The fractional spill size is defined as the size of the spillage divided by the total cargo capacity of the ship in DWT and the value on the x-axis is the probability that an actual spill (as a fraction of the total capacity) is greater than a certain defined fractional spill size.

Figure I.12 Generic MARCS Spill Model



DNV has also developed bunker fuel oil spill models for all ship types, using a similar form to that shown in Figure IV.12. It should be noted that, in general, double hulled ships do not have “double skin” protection for their bunker fuel.

I.5.4 MARCS Spill Model Parameters

There are various parameters that MARCS utilises to reference a particular spill model in order to correctly estimate the marine accident risks. These are listed below along with examples:

- Accident Type. For example, collision, powered grounding, etc.
- Vessel Type and Size. For example, oil tanker with a cargo capacity of 100,000 DWT.
- Accident Severity. For example, collision energy.
- Accident Location. For example, high wave energy shore line.
- Hull Type. For example, single hull, double hull, double bottom, double side.
- Loading Type. For example, fully laden, part laden, empty (contains bunker oil only).
- Probability of vessel being laden for each cargo type. For example, a vessel might be laden 50% of the time and empty the other 50% of the time resulting in the vessel having a 0.5 probability of being laden.

These parameters are used to access the correct spill model in MARCS.

I.6 REFERENCES

Cockcroft, 1988: "A guide to the collision avoidance rules", Cockcroft, A N and Lameijar J N F, Stanford Maritime, 1982.

Cooke R.M., 1995: "Methods and Code for Uncertainty Analysis", UNICORN, AE Technology, TUDelft,

Henley E.J., Kumamoto H., 1981: "Reliability Engineering and Risk Assessment", Prentice-Hall Inc.

HMSO, 1985: "Shipping routes in the area of the UK continental shelf: Offshore technology report", OTH 85 213, HMSO, March 1985.

SAFECO I: "Safety of Shipping in Coastal Waters (SAFECO I) Summary Report", DNV 98-2038, 1998.

SAFECO II: "Safety of Shipping in Coastal Waters (SAFECO II) Summary Report", DNV 99-2032, 1999.

Appendix 5   Data input in MARCS

Contents

II. DATA USED BY THE MARCS MODEL

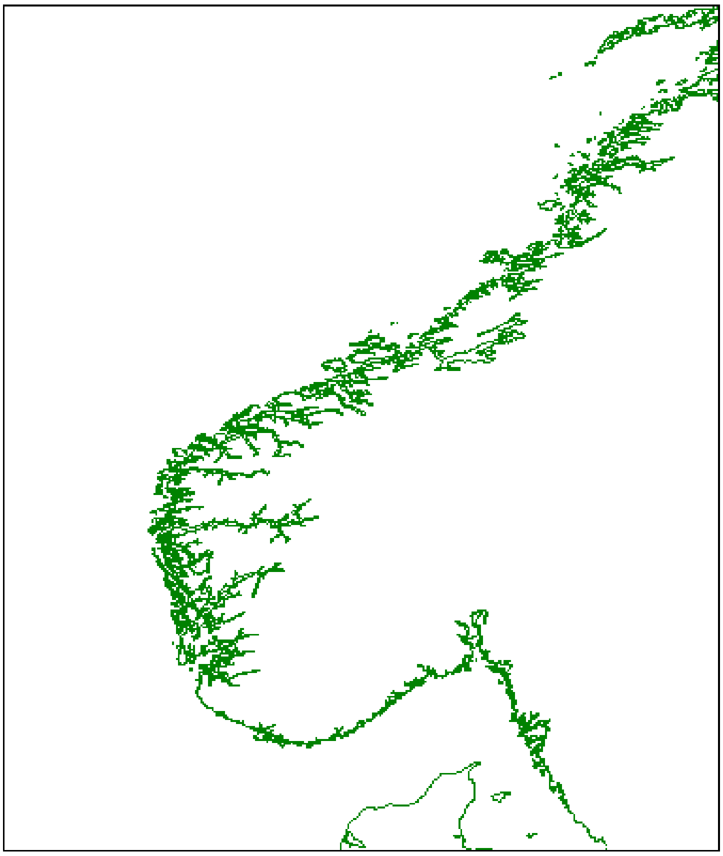
This appendix describes the data and reasoning behind the risk analysis parameters used to generate the marine risk results used in this project.

II.1 RISK MODELLING APPROACH

This section describes the overall approach to the modelling of the risks of alternative tanker routings off the coast of Norway. The marine risk model (MARCS, or Marine Accident Calculation System) is described in detail in Appendix I.

The study area is shown in Figure II.1. This has been chosen so that all ship routes within 50nm (nautical miles) of the Norwegian coast are included within the study area. This limit is selected because in previous marine projects performed by DNV it has been judged that 50nm is the highest credible drift distance for a mechanically disabled ship. It should be noted that any ships outside the defined study area cannot influence the marine risk analysis, or the risk results obtained.

Figure II.1 Definition of the Project Study Area



The co-ordinates of the study area are between 68° 30' and 56° 30' north to south and between 2° and 15° west to east. The calculation resolution is 1 minute by 1 minute; each small area defined by the calculation resolution is called a calculation location, see Appendix I.

Other inputs that contribute to the definition of the project study area, such as the location of offshore wind turbines and the location of the grounding line, are described in Section II.4 below.

II.2 MARINE TRAFFIC IMAGE DATA

II.2.1 Traffic Characteristics

MARCS represents marine traffic in terms of up to 8 traffic types and traffic routes for each traffic type. For most projects, traffic types are defined in terms of the similarity of risks that each ship type poses and other similarities (for example, ferries tend to trade faster so may be grouped separately from general cargo ships). Non-hazardous traffic types, such as general cargo ships, container ships and ferries will also be defined. This is because these non-hazardous ships can collide with hazardous cargo ships, and because all ships carry bunker oil. In this study NCTR were responsible for the collection of ship traffic data.

The traffic types defined in this study are as follows:

- Type 1: Chemical tankers and refined product tankers;
- Type 2: Gas tankers;
- Type 3: Oil (crude) tankers;
- Type 4: Not used;
- Type 5: Not used;
- Type 6: Cargo > 5000bt;
- Type 7: Other >5000bt;
- Type 8: All other.

For each ship lane defined it is necessary to define a range of parameters which describe:

- The lane number and ship type (as above);
- The cargo type that is being transported (see below);
- The annual frequency of ship movements along the lane (ships/year);
- The lane type (all lanes in this study are one-way Gaussian – see Appendix I);
- Any tug escorts that may be present (none in this study);
- The type of ship loading (characterised by 3 parameters);
- The proportion of ships on the lane in each ship size (DWT) and hull type (single hull, double hull etc) category;
- The number of waypoints, the location of each waypoint and the lane width (twice the standard deviation) at each waypoint.

These parameters are provided in the spreadsheet NCTRInput 12Oct09.xls. Four traffic patterns were defined as follows:

- "Gammel2008". Shipping traffic prior to deep water routing for the year 2008. This is denoted as Case A.
- "Ny2008". New shipping traffic after the implementation of deep water routing for the year 2008. This is denoted as Case B.
- "Gammel2025". Estimated shipping traffic prior to deep water routing for the year 2025. This is denoted as Case C.
- "Ny2008". Estimated new shipping traffic after the implementation of deep water routing for the year 2025. This is denoted as Case D.

The cargo type carried by each vessel type corresponds to the traffic type in this project. That is, chemical tankers carry chemicals (assumed to be hydrocarbons and immiscible with sea water), gas carriers contain hydrocarbon gases, oil tankers carry crude oil. The remaining traffic types do not carry hazardous cargo that is within the scope of this work.

In addition, it is assumed that all ships carry bunker fuel oil in their bunker fuel oil tanks (distinct from bunker fuel oil as a cargo). Spills of bunker oil are within the scope of this work.

II.2.2 Internal Operational Data

In DNV's previous marine risk analysis projects we have derived internal operational data, such as ship-ship collision probabilities given an encounter, from North Sea fleet data. This is assumed to apply to marine traffic in Norwegian waters. Table II.1 shows the internal operational data which DNV normally applies for North Sea average ships [DNV, 1997; DNV, 1998].

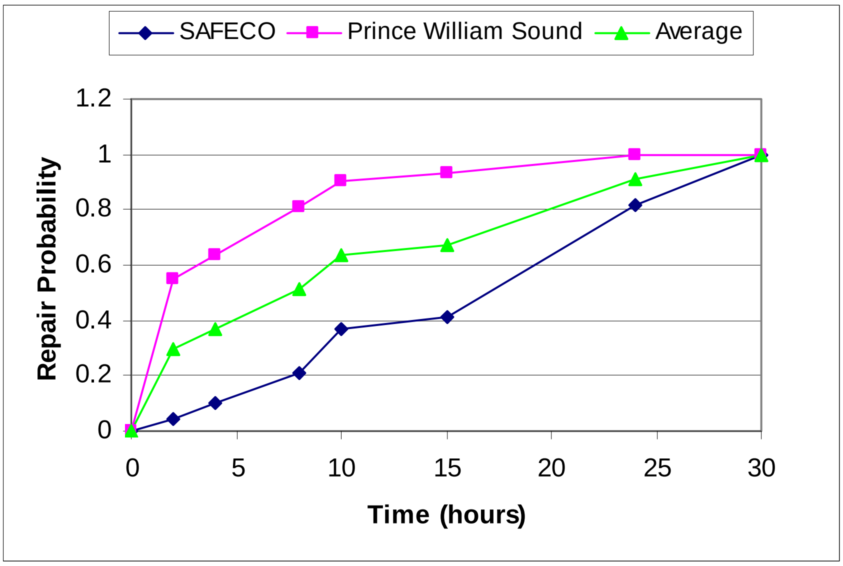
Table II.1 Risk Parameters for North Sea Average Ships

Risk Parameter		**Average ship probability (all ship types)**
Accident Type	**Visibility**	
Collision with VTS support	Good	6.83e-5
Collision with VTS support	Poor	4.64e-4
Powered Grounding with VTS support	Good	2.47e-4
Powered Grounding with VTS support	Poor	6.87e-4

Accident Type and Parameter Description	**Ship Type**	**Average ship frequency (per hour)**
Drift Grounding Ship breakdown frequency per hour	Type 1: Chemical tankers; Type 2: Gas tankers; Type 3: Oil (crude) tankers; Type 6: Cargo > 5000bt; Type 7: Other >5000bt; Type 8: All other.	2.50e-4 2.50e-4 2.50e-4 2.50e-4 2.50e-4 2.50e-4
Structural Failure Structural failure frequency per hour in calm/ fresh, gale and storm seastates respectively	Type 1: Chemical tankers; Type 2: Gas tankers; Type 3: Oil (crude) tankers; Type 6: Cargo > 5000bt; Type 7: Other >5000bt; Type 8: All other.	4.62e-7 4.62e-7 9.23e-7 4.62e-7 4.62e-7 9.23e-7 4.62e-7 4.62e-7 9.23e-7 4.62e-7 4.62e-7 9.23e-7 4.62e-7 4.62e-7 9.23e-7 4.62e-7 4.62e-7 9.23e-7
Fire/Explosion	Type 1: Chemical tankers; Type 2: Gas tankers; Type 3: Oil (crude) tankers; Type 6: Cargo > 5000bt; Type 7: Other >5000bt; Type 8: All other.	4.08e-7 4.08e-7 4.08e-7 4.08e-7 4.08e-7 4.08e-7

Figure II.2 shows the distribution of self-repair times derived from these two projects (Prince William Sound Risk Assessment and SAFECO respectively). As shown in Figure II.2, there is considerable uncertainty regarding the time required to repair mechanical failures onboard ship. In the current project the average curve from both projects is assumed to apply to all ships.

Figure II.2 Self Repair Distribution Function used in SAFECO project and used in Prince William Sound (PWS) project and the average of both curves used in this project



II.2.3 Traffic speeds

Table II.2 shows the average speed of each vessel type in the study area as used in the risk calculation. This speed is uniform throughout the study area.

Table II.2 Average Vessel Speed (knots) applied in the Study Area

Ship Type	All Locations (knots)
Type 1: Chemical tankers;	12
Type 2: Gas tankers;	12
Type 3: Oil (crude) tankers;	12
Type 6: Cargo > 5000bt;	12
Type 7: Other >5000bt;	12
Type 8: All other.	12

II.3 EXTERNAL OPERATIONAL DATA FOR STUDY AREA

The support of Vessel Traffic Service (VTS) can reduce the frequency of collision, powered grounding and powered collision with fixed obstacles due to the additional surveillance provided. In this study the entire study area is assumed to be supported by VTS and the accident parameters shown in Table II.1 are applied.

Table II.3 summarises the emergency tows which are potentially available (data from NCTR, see NCTRInput 12Oct09.xls, sheet Tugs). Tugs with bollard pull less than 40 tonnes are assumed to have insignificant capability of taking control of ships in the open sea.

Table II.3 Locations and Performances of Emergency Tows

Location	North	East	Number	Bollard pull (tonne)
Oslo/Brevik	59°22`	9°41`	5	< 40
Kristiansand	58°08`	7°59`	1	< 40
Farsund	58°03`	6°44`	1	< 40
Kårstø	59°17`	5°31`	1	42- 50
Slagentangen	59°19`	10°31`	1	53
Sture	60°38`	4°49`	1	53- 92
Stavanger	58°57`	5°43`	3	43-90
Bergen	60°23`	5°19`	1	64
Mongstad	60°48`	5°02`	1	53-95
Kristiansund	63°07`	7°41`	2	< 40
Trondheim	63°26`	10°23`	2	< 40
Ålesund	62°28`	6°05`	3	< 40
Sandnessjøen	66°01`	12°36`	1	50
Narvik	68°23`	17°41`	2	43-47

Due to the high levels of traffic in the area, it is possible that other tugs or salvage vessels might fortuitously be in the vicinity of a drifting ship and therefore be able to offer assistance. This eventuality has not, however, been included in the drift grounding frequency calculator within MARCS, to ensure that a conservative approach to the risk modelling is maintained throughout the study.

The tug input data to the MARCS model is shown in Table II.4. Each tug type in Table II.3 is assigned to a tug performance class by reference to previous tug performances characterised by DNV. The availability of each tug is determined by assuming that each individual tug is available for only 20% of the time. Thus the availability for controlling a drifting vessel is estimated from the equation:

$$\text{Availability} = 1.0 - 0.8^{(\text{number of tugs of similar performance at the location})}$$

Table II.4 Tug Input Data

Class	Availability	N	E
1	0.488	59.28333	17.08333
1	0.200	59.31667	19.16667
1	0.360	60.63333	38.06667
3	0.200	60.63333	38.06667
1	0.360	58.95000	57.08333
3	0.200	58.95000	57.08333
3	0.200	60.80000	48.08333
2	0.200	60.80000	48.08333

1	0.360	60.8000 0	48.0833 3
1	0.200	66.0166 7	1.20000
1	0.360	68.3833 3	23.2833 3

As noted above, tugs with less than 40 tons of bollard pull are judged to be ineffective in open water.

The performance (speed of the tug and the maximum size of ship it can control in kdwt) of each tug type, taken from previous work by DNV, is shown in Table II.5.

Table II.5 Tug Performance Data for a Open Sea Location (Save = Maximum size of ship in kdwt that can be controlled by the tug in the specified conditions)

Wind	Calm				Fresh			
	Speed knots	Save	Speed knots	Save	Speed knots	Save	Speed knots	Save
Type 1	14	999	11	999	8	0	5	0
Type 2	14	999	11	999	8	0	5	0
Type 3	14	999	11	999	8	49	5	0
Type 4	14	999	11	999	8	142	5	0
Type 5	14	999	11	999	8	999	5	147

The locations of 157 offshore oil platforms were included in the risk assessment. The data used is recorded in spreadsheet NCTRInput 12Oct09.xls, sheet Platforms.

II.4 ENVIRONMENTAL DATA FOR THE STUDY AREA

Typical values of visibility and wind speed/ direction for the North Sea from a previous project were used in this project as shown in Tables II.7 and II.8.

Table II.7 Visibility Data used in this Project

Sea Area	Good Visibility (time fraction greater than 2 nm)	Poor Visibility (time fraction less than 2 nm)	Data Source
North Sea Average	0.95	0.05	DNV, 1998
Data applied in this study	0.95	0.05	

Table II.8 Windrose Data for the Study Area (DNV, 1998)

Wind State	Wind speed (knots)	Wind Direction - North Sea Average (DNV, 1998)							
		N	NE	E	SE	S	SW	W	NW
Calm	0 – 20	0.058	0.028	0.042	0.053	0.090	0.090	0.08	0.08
Fresh	20 – 30	0.029	0.014	0.021	0.027	0.045	0.045	0.04	0.04
Gale	30 - 45	0.023	0.011	0.017	0.021	0.036	0.036	0.032	0.032
Storm	> 45	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002

The significant wave height observed is a function of the wind speed, the time for which that wind speed has been observed and the "fetch" of the location (the sea distance over which the wind acts and the wave heights are built). In previous work (DNV, 1997), DNV defined 3 types of sea location and approximate significant wave heights as a function of wind speed, as shown in Table II.9. Within Table II.9, the "Open Ocean" location considered was the northern Pacific Ocean (i.e. a large body of water with some very large waves).

Table II.9 Approximate Significant Wave Height as a function of Wind Speed and Location Characteristics

Wind State	Wind Speed	Sheltered Wave Height	Semi-Sheltered Wave Height	Open Ocean Wave Height
Calm	20 knots	1.2m	1.6m	2m
Fresh	30 knots	2.4m	3.2m	4m
Gale	45 knots	4.2m	5.6m	7m
Storm	58 knots	5.4m	7.2m	9m

In order to be conservative, the study area in this project was characterised as open ocean, as the Norwegian Sea cannot be considered to be semi-sheltered.

The navigation charts were examined for sea current data but no significant currents were found (excluding tidal currents which cannot be represented adequately by a statistical model such as MARCS) and so none were included in the risk analysis calculations.

The grounding line for the marine traffic was assumed to be the same as the coastline in this project. That is, the sea depth increases rapidly as distance from the coastline increases.

The sea bottom and shoreline that predominates within the study area is mainly rock. Thus, in the case of grounding, the probability of a cargo or fuel oil release is relatively high compared to a sandy or muddy sea-bottom or shoreline. Thus a uniform probability of a cargo spill (or more precisely a puncture of the outer hull) given a grounding of 1.0 is applied throughout the study area. (Note that this probability does not take account of additional risk controls. For example, if a tanker is double hulled a spill may not always result from grounding on rocks.)

A drifting ship can save itself from grounding by deploying its anchoring systems, provided that the sea bottom geometry is suitable. For anchor saves to be effective, the sea depth should lie between 60 and about 20m for a distance of half a nautical mile, see Appendix I. Anchor saves are more effective at low wind speeds and for softer sea bottoms. In this study area it was assumed that anchoring would be an ineffective save mechanism at all locations in the study area.

II.5 REFERENCES

DNV, 1997: "Prince William Sound Risk Assessment", Final Report to the Prince William Sound risk assessment steering committee, December 1996.

DNV, 1998: "Demonstration of risk analysis techniques for ship transportation in European waters", Report 98-2021, Final report to SAFECO project.

Appendix 6: MARCS results

The different table categories have been given the following colour keys:

White	Accident frequency per year
Light cyan	Spill accident frequency per year
Light blue	Oil spill volumes in tonnes per year

Today's route 2008

All accidents

	Total	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	1.50E-01	2.12E-02	4.85E-03	1.34E-02	2.32E-02	6.92E-03	8.03E-02
Struc	1.77E-01	2.22E-02	3.83E-03	1.62E-02	2.94E-02	1.01E-02	9.55E-02
FEX	1.55E-01	1.94E-02	3.35E-03	1.42E-02	2.57E-02	8.84E-03	8.36E-02
PGrd	4.15E-01	6.82E-02	1.04E-02	9.19E-02	9.00E-02	3.24E-02	1.22E-01
DGrd	2.25E+00	3.45E-01	5.66E-02	1.65E-01	3.45E-01	1.07E-01	1.24E+00
PPlat	7.34E-03	2.50E-04	1.80E-05	3.92E-03	1.33E-03	4.80E-04	1.35E-03
DPlat	1.17E-02	8.49E-04	1.31E-04	3.37E-03	2.43E-03	1.34E-03	3.56E-03
Total	3.17E+00	4.77E-01	7.91E-02	3.08E-01	5.17E-01	1.67E-01	1.62E+00

Accidents with cargo oil spills

	Accident	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	2.62E-02	8.46E-03	1.33E-03	5.37E-03	2.32E-03	6.92E-04	8.02E-03
Struc	3.38E-02	1.11E-02	1.05E-03	8.11E-03	2.94E-03	1.01E-03	9.55E-03
FEX	2.95E-02	9.71E-03	9.20E-04	7.10E-03	2.57E-03	8.84E-04	8.35E-03
PGrd	9.71E-02	2.55E-02	2.50E-03	4.46E-02	9.00E-03	3.24E-03	1.22E-02
DGrd	3.65E-01	1.22E-01	1.66E-02	5.80E-02	3.44E-02	1.07E-02	1.24E-01
PPlat	7.85E-04	3.74E-05	2.66E-06	5.87E-04	6.63E-05	2.40E-05	6.76E-05
DPlat	1.02E-03	1.27E-04	1.97E-05	5.05E-04	1.21E-04	6.69E-05	1.78E-04
Total	5.53E-01	1.77E-01	2.24E-02	1.24E-01	5.15E-02	1.66E-02	1.62E-01

Cargo oil spill volumes

	Risk	Area:	2	**Røst-Utsira**			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	1.06E+02	1.91E+01	4.13E+00	8.06E+01	1.35E+00	1.09E-01	5.02E-01
Struc	3.35E+02	5.52E+01	3.40E+00	2.74E+02	1.99E+00	1.47E-01	6.18E-01
FEX	2.10E+02	3.44E+01	2.97E+00	1.70E+02	1.74E+00	1.29E-01	5.41E-01
PGrd	1.11E+03	1.02E+02	1.38E+01	9.88E+02	5.84E+00	4.58E-01	8.12E-01
DGrd	1.35E+03	2.90E+02	5.20E+01	9.74E+02	2.06E+01	1.59E+00	7.71E+00
PPlat	1.43E+00	2.38E-02	9.12E-03	1.30E+00	7.51E-02	7.95E-03	1.09E-02
DPlat	1.47E+00	5.73E-02	8.64E-02	1.06E+00	2.16E-01	2.07E-02	2.90E-02
Total	3.11E+03	5.01E+02	7.64E+01	2.49E+03	3.18E+01	2.46E+00	1.02E+01

Proposed route 2008

All accidents

	Total	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	1.20E-01	1.29E-02	1.80E-03	1.05E-02	2.37E-02	6.97E-03	6.42E-02
Struc	2.19E-01	2.58E-02	3.20E-03	2.40E-02	5.40E-02	1.47E-02	9.71E-02
FEX	1.92E-01	2.26E-02	2.80E-03	2.10E-02	4.72E-02	1.29E-02	8.50E-02
PGrd	3.60E-01	4.32E-02	6.13E-03	7.66E-02	6.49E-02	2.56E-02	1.43E-01
DGrd	2.09E+00	1.77E-01	2.56E-02	1.60E-01	3.77E-01	9.05E-02	1.26E+00
PPlat	6.37E-03	1.44E-04	1.19E-06	3.77E-03	9.58E-04	8.29E-05	1.42E-03
DPlat	1.73E-02	1.94E-03	2.46E-04	4.37E-03	5.43E-03	1.61E-03	3.66E-03
Total	3.00E+00	2.83E-01	3.98E-02	3.00E-01	5.73E-01	1.52E-01	1.65E+00

Accidents with cargo oil spills

	Accident	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	1.88E-02	4.85E-03	4.55E-04	4.03E-03	2.37E-03	6.97E-04	6.42E-03
Struc	4.24E-02	1.29E-02	8.75E-04	1.20E-02	5.40E-03	1.47E-03	9.71E-03
FEX	3.71E-02	1.13E-02	7.65E-04	1.05E-02	4.72E-03	1.29E-03	8.49E-03
PGrd	8.19E-02	1.77E-02	1.41E-03	3.95E-02	6.49E-03	2.56E-03	1.43E-02
DGrd	2.89E-01	5.68E-02	7.12E-03	5.23E-02	3.77E-02	9.05E-03	1.26E-01
PPlat	7.08E-04	2.08E-05	6.03E-08	5.65E-04	4.79E-05	4.15E-06	7.08E-05
DPlat	1.53E-03	2.94E-04	3.83E-05	6.58E-04	2.72E-04	8.04E-05	1.83E-04
Total	4.71E-01	1.04E-01	1.07E-02	1.20E-01	5.70E-02	1.52E-02	1.65E-01

Cargo oil spill volumes

	Risk	Area:	2	**Røst-Utsira**			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	8.11E+01	1.55E+01	2.08E+00	6.12E+01	1.74E+00	1.41E-01	4.10E-01
Struc	4.11E+02	7.78E+01	4.13E+00	3.23E+02	4.53E+00	2.93E-01	6.30E-01
FEX	2.58E+02	4.84E+01	3.61E+00	2.01E+02	3.96E+00	2.56E-01	5.51E-01
PGrd	9.96E+02	8.14E+01	9.94E+00	8.99E+02	4.44E+00	3.37E-01	9.65E-01
DGrd	9.29E+02	1.54E+02	2.74E+01	7.06E+02	3.37E+01	1.29E+00	7.85E+00
PPlat	1.33E+00	1.72E-02	1.88E-05	1.26E+00	3.71E-02	2.35E-03	1.15E-02
DPlat	2.06E+00	1.08E-01	1.44E-01	1.21E+00	5.30E-01	4.15E-02	2.99E-02
Total	2.68E+03	3.77E+02	4.73E+01	2.19E+03	4.89E+01	2.36E+00	1.05E+01

Today's route 2025

All accidents

	Total	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	2.46E-01	4.00E-02	4.23E-02	2.59E-02	3.51E-02	1.04E-02	9.20E-02
Struc	2.10E-01	3.37E-02	1.89E-02	2.49E-02	3.50E-02	1.20E-02	8.59E-02
FEX	1.84E-01	2.95E-02	1.65E-02	2.18E-02	3.06E-02	1.05E-02	7.52E-02
PGrd	5.19E-01	1.02E-01	2.24E-02	1.38E-01	1.07E-01	3.86E-02	1.10E-01
DGrd	2.64E+00	5.17E-01	2.26E-01	2.47E-01	4.10E-01	1.27E-01	1.11E+00
PPlat	9.68E-03	3.76E-04	8.38E-05	5.87E-03	1.57E-03	5.62E-04	1.22E-03
DPlat	1.46E-02	1.27E-03	6.68E-04	5.05E-03	2.86E-03	1.57E-03	3.21E-03
Total	3.82E+00	7.24E-01	3.27E-01	4.69E-01	6.22E-01	2.01E-01	1.48E+00

Accidents with cargo oil spills

	Accident	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	5.17E-02	1.60E-02	1.16E-02	1.04E-02	3.50E-03	1.04E-03	9.19E-03
Struc	4.78E-02	1.69E-02	5.19E-03	1.24E-02	3.49E-03	1.20E-03	8.59E-03
FEX	4.18E-02	1.48E-02	4.54E-03	1.09E-02	3.06E-03	1.05E-03	7.51E-03
PGrd	1.36E-01	3.82E-02	5.49E-03	6.70E-02	1.07E-02	3.86E-03	1.10E-02
DGrd	4.99E-01	1.83E-01	6.41E-02	8.70E-02	4.10E-02	1.27E-02	1.11E-01
PPlat	1.12E-03	5.61E-05	1.23E-05	8.80E-04	7.86E-05	2.81E-05	6.09E-05
DPlat	1.43E-03	1.91E-04	1.00E-04	7.58E-04	1.43E-04	7.84E-05	1.60E-04
Total	7.79E-01	2.69E-01	9.11E-02	1.89E-01	6.20E-02	1.99E-02	1.48E-01

Cargo oil spill volumes

	Risk	Area:	2	**Røst-Utsira**			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	2.28E+02	3.61E+01	3.44E+01	1.55E+02	2.00E+00	1.65E-01	5.73E-01
Struc	5.27E+02	8.47E+01	2.24E+01	4.17E+02	2.36E+00	1.77E-01	5.56E-01
FEX	3.35E+02	5.27E+01	1.96E+01	2.60E+02	2.07E+00	1.54E-01	4.86E-01
PGrd	1.68E+03	1.53E+02	3.31E+01	1.48E+03	6.96E+00	5.46E-01	7.31E-01
DGrd	2.12E+03	4.35E+02	1.96E+02	1.46E+03	2.45E+01	1.89E+00	6.94E+00
PPlat	2.16E+00	3.57E-02	6.32E-02	1.95E+00	8.86E-02	9.32E-03	9.82E-03
DPlat	2.54E+00	8.59E-02	5.60E-01	1.59E+00	2.54E-01	2.43E-02	2.61E-02
Total	4.90E+03	7.62E+02	3.06E+02	3.78E+03	3.82E+01	2.97E+00	9.32E+00

Proposed route 2025

All accidents

	Total	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	1.78E-01	2.23E-02	2.06E-02	2.17E-02	3.72E-02	1.10E-02	6.50E-02
Struc	2.75E-01	3.15E-02	2.91E-02	4.33E-02	6.67E-02	1.72E-02	8.74E-02
FEX	2.41E-01	2.76E-02	2.54E-02	3.79E-02	5.84E-02	1.51E-02	7.65E-02
PGrd	4.35E-01	6.36E-02	1.22E-02	1.20E-01	7.95E-02	3.06E-02	1.29E-01
DGrd	2.42E+00	2.00E-01	1.62E-01	3.31E-01	4.84E-01	1.08E-01	1.13E+00
PPlat	8.40E-03	2.16E-04	1.08E-05	5.66E-03	1.14E-03	9.81E-05	1.28E-03
DPlat	2.39E-02	2.51E-03	2.04E-03	7.42E-03	6.78E-03	1.84E-03	3.30E-03
Total	3.58E+00	3.47E-01	2.52E-01	5.67E-01	7.34E-01	1.84E-01	1.49E+00

Accidents with cargo oil spills

	Accident	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	3.41E-02	9.08E-03	5.40E-03	8.31E-03	3.72E-03	1.11E-03	6.49E-03
Struc	6.36E-02	1.69E-02	8.02E-03	2.16E-02	6.67E-03	1.72E-03	8.73E-03
FEX	5.56E-02	1.47E-02	7.01E-03	1.89E-02	5.84E-03	1.51E-03	7.64E-03
PGrd	1.14E-01	2.60E-02	2.80E-03	6.12E-02	7.95E-03	3.06E-03	1.29E-02
DGrd	3.88E-01	6.78E-02	3.85E-02	1.10E-01	4.84E-02	1.08E-02	1.13E-01
PPlat	1.00E-03	3.12E-05	5.39E-07	8.47E-04	5.70E-05	4.91E-06	6.38E-05
DPlat	2.42E-03	3.89E-04	3.20E-04	1.12E-03	3.39E-04	9.22E-05	1.65E-04
Total	6.59E-01	1.35E-01	6.21E-02	2.22E-01	7.30E-02	1.83E-02	1.49E-01

Cargo oil spill volumes

	Risk	Area:	2	**Røst-Utsira**			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	1.23E+02	1.73E+01	1.31E+01	9.04E+01	1.47E+00	1.21E-01	2.15E-01
Struc	4.32E+02	5.88E+01	1.97E+01	3.50E+02	2.93E+00	1.78E-01	2.89E-01
FEX	2.75E+02	3.66E+01	1.72E+01	2.18E+02	2.57E+00	1.56E-01	2.53E-01
PGrd	1.50E+03	1.20E+02	1.97E+01	1.36E+03	4.99E+00	3.85E-01	5.03E-01
DGrd	1.13E+03	1.25E+02	7.37E+01	8.98E+02	2.32E+01	9.03E-01	3.58E+00
PPlat	1.97E+00	2.58E-02	8.04E-05	1.90E+00	4.34E-02	2.56E-03	5.46E-03
DPlat	2.75E+00	9.80E-02	6.27E-01	1.62E+00	3.74E-01	2.59E-02	1.40E-02
Total	3.46E+03	3.58E+02	1.44E+02	2.92E+03	3.56E+01	1.77E+00	4.86E+00

Today's route 2008

All accidents

	Total	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	1.50E-01	2.12E-02	4.85E-03	1.34E-02	2.32E-02	6.92E-03	8.03E-02
Struc	1.77E-01	2.22E-02	3.83E-03	1.62E-02	2.94E-02	1.01E-02	9.55E-02
FEX	1.55E-01	1.94E-02	3.35E-03	1.42E-02	2.57E-02	8.84E-03	8.36E-02
PGrd	4.15E-01	6.82E-02	1.04E-02	9.19E-02	9.00E-02	3.24E-02	1.22E-01
DGrd	2.25E+00	3.45E-01	5.66E-02	1.65E-01	3.45E-01	1.07E-01	1.24E+00
PPlat	7.34E-03	2.50E-04	1.80E-05	3.92E-03	1.33E-03	4.80E-04	1.35E-03
DPlat	1.17E-02	8.49E-04	1.31E-04	3.37E-03	2.43E-03	1.34E-03	3.56E-03
Total	3.17E+00	4.77E-01	7.91E-02	3.08E-01	5.17E-01	1.67E-01	1.62E+00

Accidents with bunker oil spills

	Accident	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	1.50E-02	2.12E-03	4.85E-04	1.34E-03	2.32E-03	6.92E-04	8.02E-03
Struc	1.77E-02	2.22E-03	3.83E-04	1.62E-03	2.94E-03	1.01E-03	9.55E-03
FEX	1.55E-02	1.94E-03	3.35E-04	1.42E-03	2.57E-03	8.84E-04	8.35E-03
PGrd	4.15E-02	6.82E-03	1.03E-03	9.19E-03	9.00E-03	3.24E-03	1.22E-02
DGrd	2.25E-01	3.45E-02	5.66E-03	1.65E-02	3.44E-02	1.07E-02	1.24E-01
PPlat	3.67E-04	1.25E-05	9.01E-07	1.96E-04	6.63E-05	2.40E-05	6.76E-05
DPlat	5.84E-04	4.24E-05	6.55E-06	1.68E-04	1.21E-04	6.69E-05	1.78E-04
Total	3.16E-01	4.76E-02	7.91E-03	3.04E-02	5.15E-02	1.66E-02	1.62E-01

Bunkers oil spill volumes

	Risk	Area:	2	**Røst-Utsira**			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	4.96E+00	5.51E-01	1.24E-01	2.33E+00	1.35E+00	1.09E-01	5.02E-01
Struc	6.47E+00	6.06E-01	1.02E-01	3.01E+00	1.99E+00	1.47E-01	6.18E-01
FEX	5.66E+00	5.30E-01	8.90E-02	2.63E+00	1.74E+00	1.29E-01	5.41E-01
PGrd	2.85E+01	2.36E+00	4.08E-01	1.86E+01	5.84E+00	4.58E-01	8.12E-01
DGrd	6.82E+01	8.45E+00	1.41E+00	2.85E+01	2.06E+01	1.59E+00	7.71E+00
PPlat	2.36E-01	2.56E-03	1.37E-04	1.40E-01	7.51E-02	7.95E-03	1.09E-02
DPlat	3.87E-01	6.17E-03	1.26E-03	1.13E-01	2.16E-01	2.07E-02	2.90E-02
Total	1.14E+02	1.25E+01	2.14E+00	5.53E+01	3.18E+01	2.46E+00	1.02E+01

Proposed route 2008

All accidents

	Total	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	1.20E-01	1.29E-02	1.80E-03	1.05E-02	2.37E-02	6.97E-03	6.42E-02
Struc	2.19E-01	2.58E-02	3.20E-03	2.40E-02	5.40E-02	1.47E-02	9.71E-02
FEX	1.92E-01	2.26E-02	2.80E-03	2.10E-02	4.72E-02	1.29E-02	8.50E-02
PGrd	3.60E-01	4.32E-02	6.13E-03	7.66E-02	6.49E-02	2.56E-02	1.43E-01
DGrd	2.09E+00	1.77E-01	2.56E-02	1.60E-01	3.77E-01	9.05E-02	1.26E+00
PPlat	6.37E-03	1.44E-04	1.19E-06	3.77E-03	9.58E-04	8.29E-05	1.42E-03
DPlat	1.73E-02	1.94E-03	2.46E-04	4.37E-03	5.43E-03	1.61E-03	3.66E-03
Total	3.00E+00	2.83E-01	3.98E-02	3.00E-01	5.73E-01	1.52E-01	1.65E+00

Accidents with bunker oil spills

	Accident	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	1.20E-02	1.29E-03	1.80E-04	1.05E-03	2.37E-03	6.97E-04	6.42E-03
Struc	2.19E-02	2.59E-03	3.20E-04	2.40E-03	5.40E-03	1.47E-03	9.71E-03
FEX	1.91E-02	2.26E-03	2.80E-04	2.10E-03	4.72E-03	1.29E-03	8.49E-03
PGrd	3.60E-02	4.32E-03	6.13E-04	7.66E-03	6.49E-03	2.56E-03	1.43E-02
DGrd	2.09E-01	1.77E-02	2.56E-03	1.60E-02	3.77E-02	9.05E-03	1.26E-01
PPlat	3.19E-04	7.19E-06	5.93E-08	1.89E-04	4.79E-05	4.15E-06	7.08E-05
DPlat	8.63E-04	9.69E-05	1.23E-05	2.18E-04	2.72E-04	8.04E-05	1.83E-04
Total	2.99E-01	2.82E-02	3.97E-03	2.96E-02	5.70E-02	1.52E-02	1.65E-01

Bunkers oil spill volumes

	Risk	Area:	2	**Røst-Utsira**			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	4.71E+00	4.81E-01	6.91E-02	1.87E+00	1.74E+00	1.41E-01	4.10E-01
Struc	9.97E+00	8.53E-01	1.24E-01	3.55E+00	4.53E+00	2.93E-01	6.30E-01
FEX	8.72E+00	7.46E-01	1.09E-01	3.10E+00	3.96E+00	2.56E-01	5.51E-01
PGrd	2.36E+01	1.67E+00	2.88E-01	1.59E+01	4.44E+00	3.37E-01	9.65E-01
DGrd	7.21E+01	5.21E+00	8.25E-01	2.32E+01	3.37E+01	1.29E+00	7.85E+00
PPlat	1.88E-01	1.89E-03	1.55E-05	1.36E-01	3.71E-02	2.35E-03	1.15E-02
DPlat	7.43E-01	1.19E-02	2.28E-03	1.27E-01	5.30E-01	4.15E-02	2.99E-02
Total	1.20E+02	8.97E+00	1.42E+00	4.79E+01	4.89E+01	2.36E+00	1.05E+01

Today's route 2025

All accidents

	Total	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	2.46E-01	4.00E-02	4.23E-02	2.59E-02	3.51E-02	1.04E-02	9.20E-02
Struc	2.10E-01	3.37E-02	1.89E-02	2.49E-02	3.50E-02	1.20E-02	8.59E-02
FEX	1.84E-01	2.95E-02	1.65E-02	2.18E-02	3.06E-02	1.05E-02	7.52E-02
PGrd	5.19E-01	1.02E-01	2.24E-02	1.38E-01	1.07E-01	3.86E-02	1.10E-01
DGrd	2.64E+00	5.17E-01	2.26E-01	2.47E-01	4.10E-01	1.27E-01	1.11E+00
PPlat	9.68E-03	3.76E-04	8.38E-05	5.87E-03	1.57E-03	5.62E-04	1.22E-03
DPlat	1.46E-02	1.27E-03	6.68E-04	5.05E-03	2.86E-03	1.57E-03	3.21E-03
Total	3.82E+00	7.24E-01	3.27E-01	4.69E-01	6.22E-01	2.01E-01	1.48E+00

Accidents with bunker oil spills

	Accident	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	2.46E-02	4.00E-03	4.23E-03	2.59E-03	3.50E-03	1.04E-03	9.19E-03
Struc	2.10E-02	3.37E-03	1.89E-03	2.49E-03	3.49E-03	1.20E-03	8.59E-03
FEX	1.84E-02	2.95E-03	1.65E-03	2.18E-03	3.06E-03	1.05E-03	7.51E-03
PGrd	5.19E-02	1.02E-02	2.24E-03	1.38E-02	1.07E-02	3.86E-03	1.10E-02
DGrd	2.64E-01	5.17E-02	2.26E-02	2.47E-02	4.10E-02	1.27E-02	1.11E-01
PPlat	4.84E-04	1.88E-05	4.19E-06	2.94E-04	7.86E-05	2.81E-05	6.09E-05
DPlat	7.32E-04	6.36E-05	3.34E-05	2.53E-04	1.43E-04	7.84E-05	1.60E-04
Total	3.81E-01	7.23E-02	3.26E-02	4.63E-02	6.20E-02	1.99E-02	1.48E-01

Bunkers oil spill volumes

	Risk	Area:	2	**Røst-Utsira**			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	9.28E+00	1.04E+00	1.03E+00	4.47E+00	2.00E+00	1.65E-01	5.73E-01
Struc	9.28E+00	9.30E-01	6.73E-01	4.58E+00	2.36E+00	1.77E-01	5.56E-01
FEX	8.11E+00	8.13E-01	5.89E-01	4.01E+00	2.07E+00	1.54E-01	4.86E-01
PGrd	4.07E+01	3.54E+00	9.41E-01	2.80E+01	6.96E+00	5.46E-01	7.31E-01
DGrd	9.43E+01	1.27E+01	5.58E+00	4.27E+01	2.45E+01	1.89E+00	6.94E+00
PPlat	3.22E-01	3.84E-03	9.46E-04	2.09E-01	8.86E-02	9.32E-03	9.82E-03
DPlat	4.92E-01	9.26E-03	8.25E-03	1.70E-01	2.54E-01	2.43E-02	2.61E-02
Total	1.62E+02	1.90E+01	8.83E+00	8.41E+01	3.82E+01	2.97E+00	9.32E+00

Proposed route 2025

All accidents

	Total	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	1.78E-01	2.23E-02	2.06E-02	2.17E-02	3.72E-02	1.10E-02	6.50E-02
Struc	2.75E-01	3.15E-02	2.91E-02	4.33E-02	6.67E-02	1.72E-02	8.74E-02
FEX	2.41E-01	2.76E-02	2.54E-02	3.79E-02	5.84E-02	1.51E-02	7.65E-02
PGrd	4.35E-01	6.36E-02	1.22E-02	1.20E-01	7.95E-02	3.06E-02	1.29E-01
DGrd	2.42E+00	2.00E-01	1.62E-01	3.31E-01	4.84E-01	1.08E-01	1.13E+00
PPlat	8.40E-03	2.16E-04	1.08E-05	5.66E-03	1.14E-03	9.81E-05	1.28E-03
DPlat	2.39E-02	2.51E-03	2.04E-03	7.42E-03	6.78E-03	1.84E-03	3.30E-03
Total	3.58E+00	3.47E-01	2.52E-01	5.67E-01	7.34E-01	1.84E-01	1.49E+00

Accidents with bunker oil spills

	Accident	frequency	Area:	2			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	1.78E-02	2.23E-03	2.06E-03	2.17E-03	3.72E-03	1.11E-03	6.49E-03
Struc	2.75E-02	3.15E-03	2.91E-03	4.33E-03	6.67E-03	1.72E-03	8.73E-03
FEX	2.41E-02	2.76E-03	2.54E-03	3.78E-03	5.84E-03	1.51E-03	7.64E-03
PGrd	4.35E-02	6.36E-03	1.22E-03	1.20E-02	7.95E-03	3.06E-03	1.29E-02
DGrd	2.42E-01	2.00E-02	1.62E-02	3.31E-02	4.84E-02	1.08E-02	1.13E-01
PPlat	4.20E-04	1.08E-05	5.38E-07	2.83E-04	5.70E-05	4.91E-06	6.38E-05
DPlat	1.19E-03	1.26E-04	1.02E-04	3.71E-04	3.39E-04	9.22E-05	1.65E-04
Total	3.56E-01	3.46E-02	2.51E-02	5.60E-02	7.30E-02	1.83E-02	1.49E-01

Bunkers oil spill volumes

	Risk	Area:	2	**Røst-Utsira**			
	Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
Collis	5.42E+00	4.94E-01	4.18E-01	2.70E+00	1.47E+00	1.21E-01	2.15E-01
Struc	8.45E+00	6.05E-01	5.89E-01	3.85E+00	2.93E+00	1.78E-01	2.89E-01
FEX	7.39E+00	5.29E-01	5.15E-01	3.37E+00	2.57E+00	1.56E-01	2.53E-01
PGrd	3.30E+01	2.45E+00	5.71E-01	2.41E+01	4.99E+00	3.85E-01	5.03E-01
DGrd	6.28E+01	3.88E+00	2.74E+00	2.85E+01	2.32E+01	9.03E-01	3.58E+00
PPlat	2.58E-01	2.81E-03	7.71E-05	2.03E-01	4.34E-02	2.56E-03	5.46E-03
DPlat	6.05E-01	1.06E-02	1.01E-02	1.71E-01	3.74E-01	2.59E-02	1.40E-02
Total	1.18E+02	7.97E+00	4.84E+00	6.29E+01	3.56E+01	1.77E+00	4.86E+00

Appendix 7: Calculation of confidence intervals

To calculate the reliability of the results, confidence intervals were estimated for the calculations of the accident frequencies and oil spill frequencies and their difference. Confidence intervals show the statistical uncertainties in numbers and risk figures. The calculations of statistical significance show whether or not risk differences between groups or periods are large enough to be considered real and not a result from random fluctuations. We have used the conventional significance level of 5%, which implies that the probability of the difference in risk figures being a result of random fluctuations is less than 0.05.

It is generally believed that the purely random variation in the accident rate complies with the so-called Poisson distribution. For large samples this is approximately equal to the normal distribution. The Poisson distribution is the standard deviation equal to square root of the century. A 95% confidence interval for an accident rate (n) is thus:

$$n \pm \left(1{,}96\sqrt{n}\right)$$

If the confidence interval for the two risk figures does not overlap, one concludes that the risk figures are significantly different. But also when the confidence intervals overlap, the two risk figures can be significantly different.

We use the formula below which takes into account the improbability of the two "true" risk numbers being in extreme of their confidence:

$$|D| \pm 1{,}96\sqrt{(s_1)^2 + (s_2)}^2$$

$|D|$ = Absolute value of difference between the risk figure 1 and risk figure 2

S_1 = standard deviation of the risk figure 1
S_2 = standard deviation of the risk figure 2

Reference:

Bjørnskau, T., *Risiko i trafikken 2005-2007.* TØI rapport 986/2008, 2008.

Appendix 8: Two case-scenarios. Report from Norconsult

The institute of transport economics (TØI)

Proposed ship's routing, TSS Røst to TSS Utsira

Comparative consequence analysis of representative ship accidents

October 27. 2009

Norconsult

D01	27.10.09	Final	JSA	ELLUN	GLE
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Client:

The institute of transport economics

Title:

Proposed ship's routing, TSS Røst to TSS Utsira

Comparative consequence analysis of representative ship accidents

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Content

1 REPRESENTATIVE SCENARIOS

1.1 Method

In the real world the variety of incidents and accidents involving ships is infinite. Statistical models provide quantitative probability (frequency) of incidents of a certain category, timeframe and area. However, the probability of a specific scenario (date, cause, location, release volume, pollutant characteristics, weather, current, sea state etc.) can not be calculated based on today's model and data. Hence a simplified approach is needed.

To demonstrate how the proposed ship's routing alters risk, we use a generic and comparative approach:

- Probability of collision (and other types of incidents) is calculated for TSS Røst to TSS Utsira, and for today's ship's routing in the same area.

  NOTE: Not all collisions cause release of pollutant. However, the relative change of probability (frequency) for collisions is regarded as a strong indicator for comparing today's traffic routing and the proposed new routing.

- Representative (typical) scenarios are then defined based on type of traffic, existing and future routing, type of cargo, typical weather etc.
- Each scenario is then positioned at two locations: (A) A high density traffic location where this type of ship is sailing today (based on AIS data), and (B) the expected position of the collision if that same ship had used the new routing. All positions were validated by the NCA.
- The sequence of events for that scenario located at two different positions is then simulated.
- A relative comparison of consequences between A and B is then performed.

To ensure comparable results, the scenario at location A and B are identical. All assessments are conducted using identical simulation tool, input data and assessment methodology. This methodology ensures that we can identify:

- Change of probability per year for today's and future routing for a given category of incident.
- Consequence differences between A and B locations for each scenario.

Although risk (probability x consequence) is not calculated, this methodology enables identification of relative change of both probability and consequence independently.

To assess environmental consequences for each scenario we have chosen to use the relative difference of impact areas as the main parameter. This is due to the fact that the actual oil spill concentration and distribution within the archipelago is highly dependent on a wide range parameters not part of today's model tools.

MOB (Miljø Og Beredskap) is the national regime for the prioritisation of environmental resources during oil spills emergency response in Norwegian waters. The prioritising is made up by a system of parameters e.g. oil pollution vulnerability, conservation value, the resource's natural occurrence as well as whether the environmental loss can be compensated economically or not. These parameters form the basis for the priority category, which range from A-D; with A being the highest level of priority. The prioritizing work has been conducted by the local environmental authority.

Our quantification is performed by summarising the MOB areas of different categories within the scenario impact areas. The data used for these scenarios are based upon the data from *Kystinfo*, the public GIS tool of the Norwegian Coastal Administration. The MOB-data in this tool was updated October 9. 2009. The data used for quantification of fish spawning areas is based upon the same tool but from the website of The Norwegian Directorate of Fisheries.

1.2 Acute oil pollution - emergency response

The Pollution Control Act states that the National Contingency System is divided into private, municipal and governmental contingency areas with specific responsibilities. In Norway, all contingency plans and organizations are standardized and co-ordinated. Hence, in the event of a major acute pollution incident, the national contingency system under the supervision of The Norwegian Coastal Administration (NCA) will work as a single integrated response organisation.

NCA is a directorate of the Ministry of Fisheries and Coastal Affairs responsible for sea transport, maritime safety, ports and emergency response to acute pollution. Large-scale incidents of acute pollution mainly relates to oil spills from ships, off-shore installations, shipwrecks or from unidentified sources. NCA has its own surveillance aircraft, 16 oil-spill depots and 9 intermediate depots with oil-spill recovery equipment. The Administration has also equipment stationed on board a number of vessels, including the Norwegian Coast Guard's vessels as well as the Administration's own vessels. As part of the national emergency response system an oil drift model service is provided by the Norwegian meteorological Institute, Marine Forecasting Centre (DNMI). Based on sophisticated ocean and weather models, the end user such as NCA and major private contingency organisations can access this tool through a web interface (Kilden). NCA has provided the oil drift simulations to this report.

1.3 Oil spill contingency and emergency towing

NCAs national emergency tow system constitutes the following resources from TSS Røst to TSS Risør:

Location of emergeny tows

Location	North	East	Number	Bollard pull (te)	Length	Speed
Oslo/Brevik	59°22`	9°41`	1	35	29,4	10
			2	29	26,2	N/A
			3	35	29,4	13
			4	25	N/A	N/A
			5	35	26,7	12
Kristiansand	58°08`	7°59`	1	22	25,2	N/A
Farsund	58°03`	6°44`	1	24	N/A	N/A
Kårstø	59°17`	5°31`	1	50	30,8	13
			2	42	29,7	12
			3	42	29,7	12
Slagentange	59°19`	10°31`	1	53	32,9	14,5
Sture	60°38`	4°49`	1	53	33,3	12
			2	65	37	15
			3	92	41,6	15
Stavanger	58°57`	5°43`	1	35	N/A	N/A
			2	43	30,26	12,5
			3	62	35	14,5
			4	90	45,5	14,5
Bergen	60°23`	5°19`	1	64	N/A	N/A
Mongstad	60°48`	5°02`	1	95	40,55	15
			2	67	38,85	15,5
			3	65	35	13
			4	53	36	N/A
Kristiansund	63°07`	7°41`	1	26	N/A	N/A
			2	26	N/A	N/A
Trondheim	63°26`	10°23`	1	39	N/A	N/A
			2	20	N/A	N/A
Ålesund	62°28`	6°05`	1	31	N/A	N/A
			2	20	N/A	N/A
			3	35	N/A	N/A
Sandnessjøe	66°01`	12°36`	1	50	N/A	N/A
Narvik	68°23`	17°41`	1	23	N/A	N/A
				47	N/A	N/A
				43	N/A	N/A

1.4 Scenarios - environmental impact areas

The scenarios were selected based on the following criteria:

- The national dimensioning oil spill scenarios defined by the Ministry of fisheries and coastal affairs (20 000 m^3 crude, 1000 m^3 & 5000 m^3 fuel oil)
- AIS data and identification of high density traffic "hot spots"
- Potential threat to coastline and vulnerable marine resources
- Typical wind and sea current, and inside operational window for oil spill response

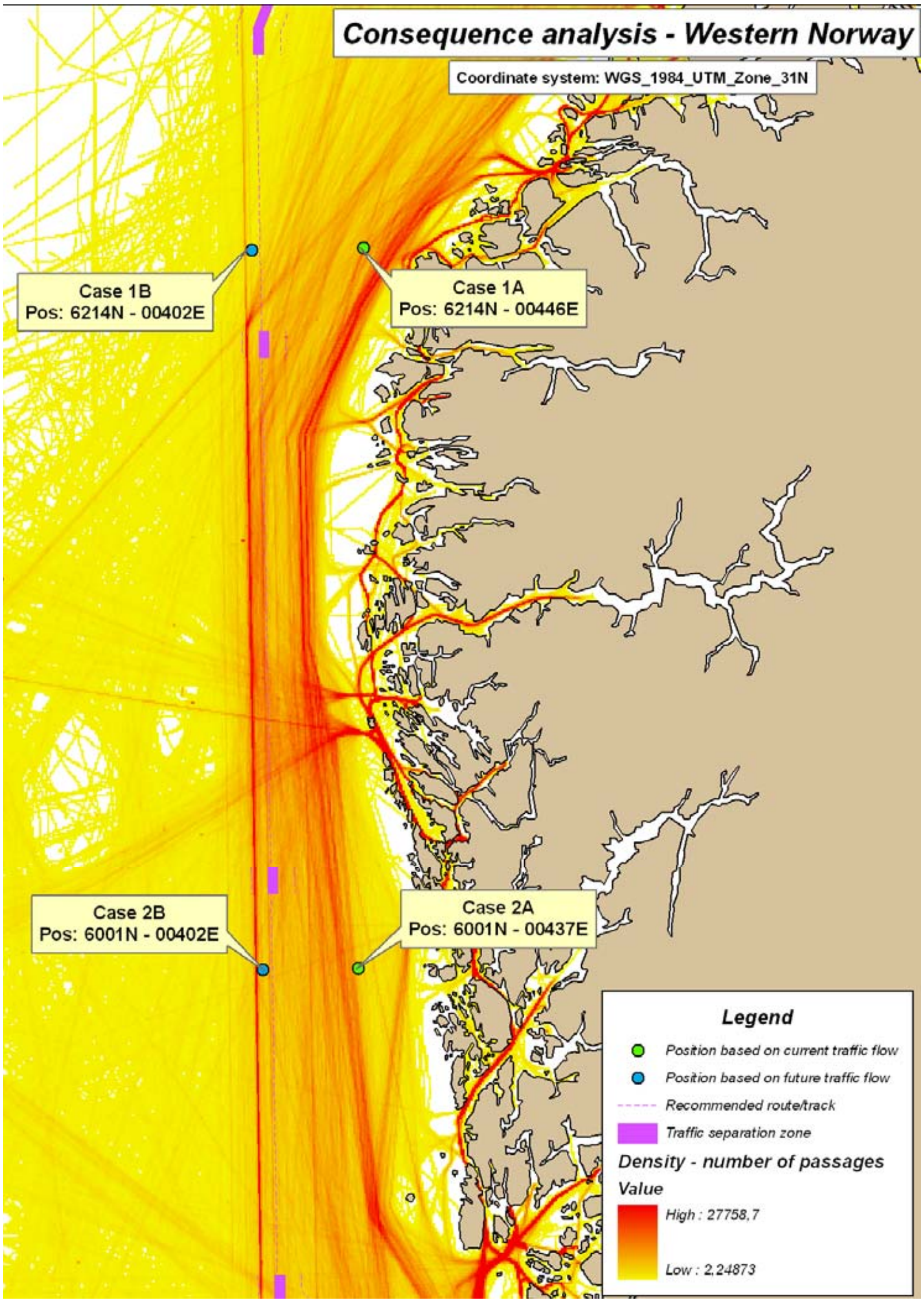


Figure 1.4A: AIS data from 2008, green circle show locations of scenarios in this report

Concerning environmental impact, the national Marine Resources DataBase (MRDB) has been developed by DNV with funding from authorities and private industry. Chapter 2.2 explains this data in more detail.

1.4.1 *Scenario 1A and 1B, bunker oil spill west of Stad*

Scenario 1A and 1B are identical except from location:

- Location A: N62^{0}14’, E004^{0}46’ - a high density traffic spot based on AIS data
- Location B: N62^{0}14’, E004^{0}02’ - closest point to (A) given new routing, south bound

Key data concerning the scenario:

- Type of incident: Collision, ore carrier
- Time of year: Spring
- Release type: From sea bed (A: -174 m, B; -360 m), during 6 hours
- Oil type: Bunker, IF260 (intermediate fuel oil)
- Release volume: 1000 m^3
- Weather: Wind, 8 m/sec from 240 degrees, coastal current 0,15 m/s towards north
  (Represents 15% of all wind direction measurements, 9,6% of wind speed measurements)

Simulation of initial shoreline impact

By using the DNMI oil drift simulation model, the <u>initial</u> shoreline impact length as well as the oil mass balance (evaporation, dispersion, on surface) has been calculated by NCA. Please note that the figures in this chapter are showing one dataset (time-step) only for comparison. Hour-by-hour simulation data has been utilized to obtain the results. The model is unable to simulate secondary oil spill impact that is re-migration of oil that already has reached the shoreline. However, qualitative data based on extensive experience from recent oil spill response operations is used in chapter 2 to assess the long-term shoreline impact.

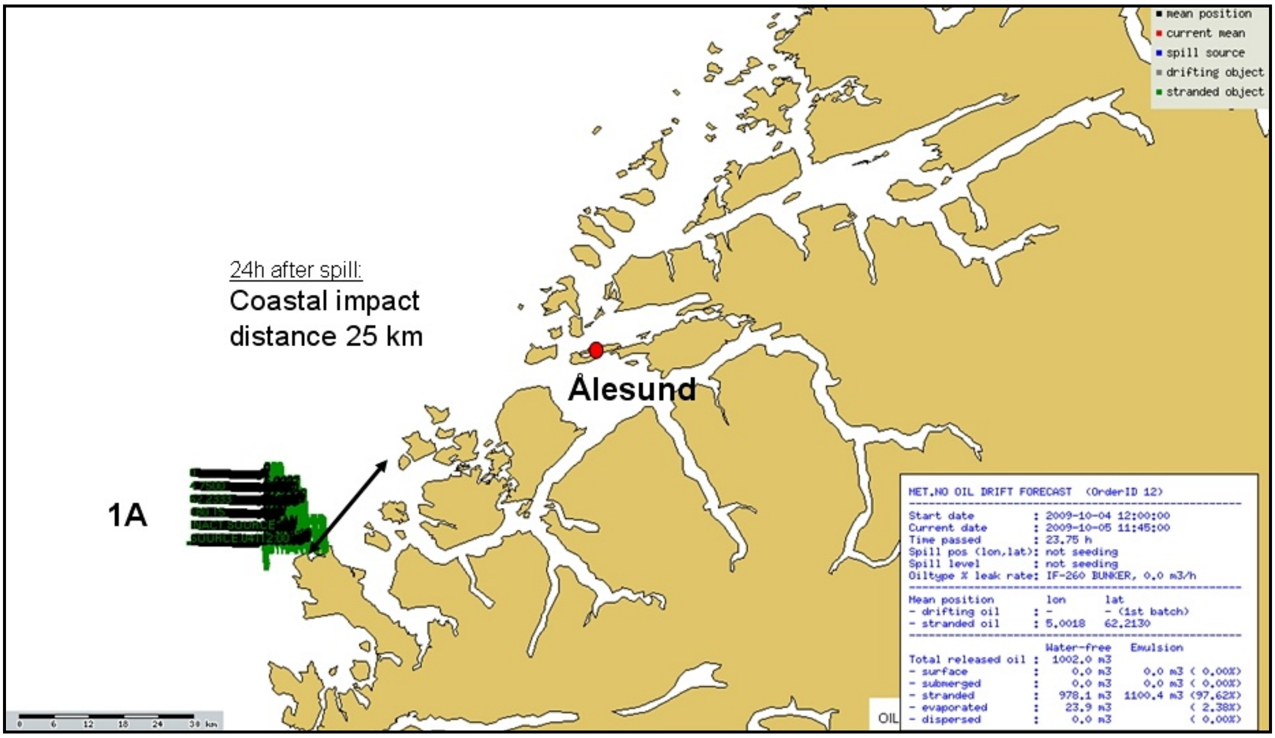


Fig 1.4.1A: Subsea release from position 1A situation after 24h (Courtesy of NCA/DNMI)

<u>Simulation results, scenario 1A</u>

- Time from release to shoreline impact: 16 h
- Initial shoreline impact length: 25 km
- Oil volume reaching shoreline, first batch: 978 m^3 (Given no oil spill response)

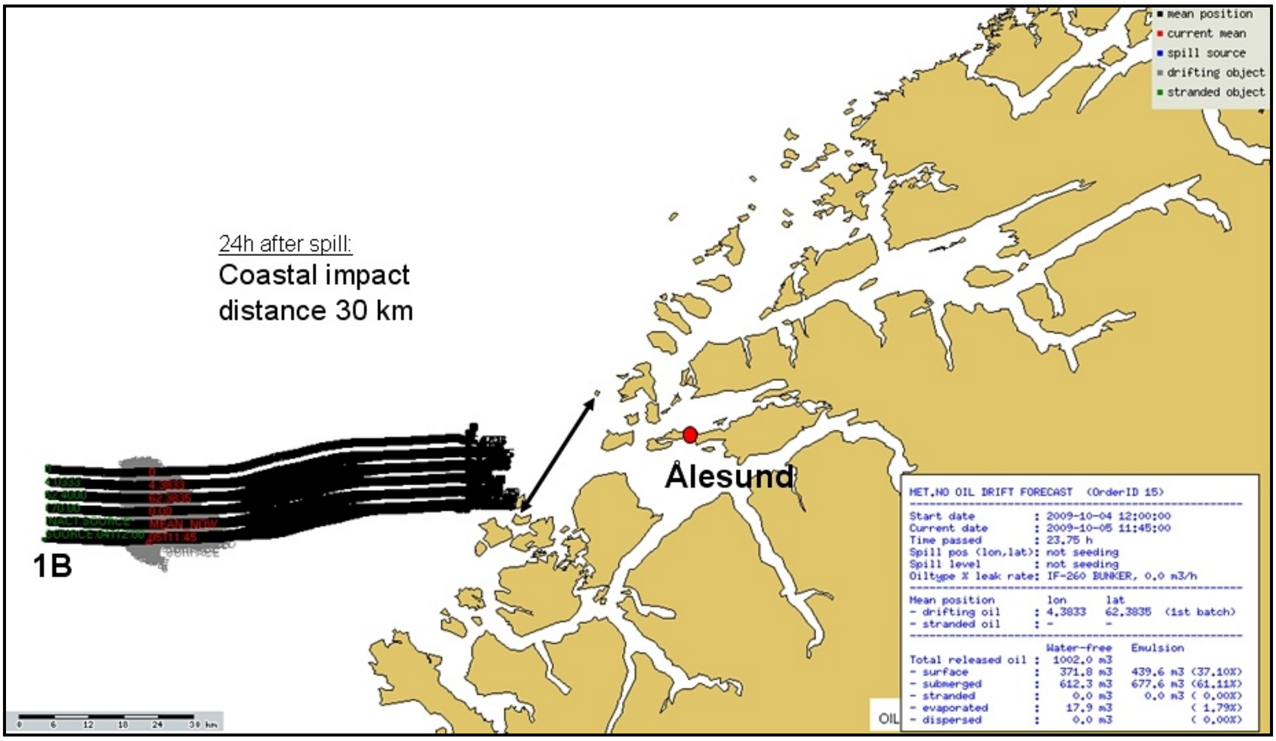


Fig 1.4.1B: Subsea release from position 1B (new route) situation after 24h (Courtesy of NCA/DNMI)

<u>Simulation results, scenario 1B</u>

- Time from release to shoreline impact: 87 h
- Initial shoreline impact length: 30 km
- Oil volume reaching shoreline, first batch: 370 m^3 (Given no oil spill response)

1.4.2 Scenario 2A and 2B, crude oil release west of Marstein

Scenario 2A and 2B are identical except from location:

- Location A: N60^{0}01', E004^{0}37' - a high density traffic spot based on AIS data
- Location B: N60^{0}01', E004^{0}02' - closest point to (A) given new routing, south bound

Key data concerning the scenario:

- Type of incident: Collision
- Time of year: Autumn
- Release type: Surface, during 5 hours
- Oil type: Light crude oil (Draugen field)
- Release volume: 20 000 m^3
- Wind, 12 m/sec from 270 degrees, coastal current 0.15 m/s towards north-east
  (Represents 17 % of all wind direction measurements, 7 % of wind speed measurements)

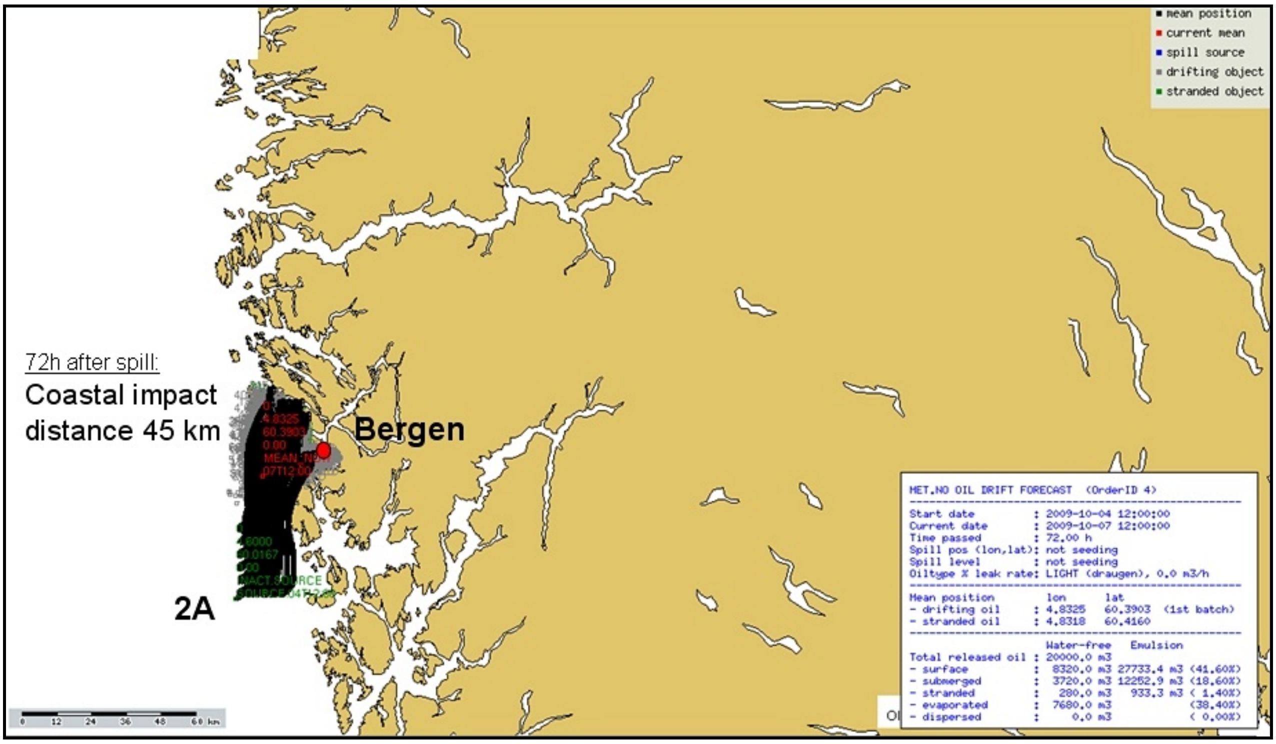


Fig 1.4.2A: Surface release from position 2A situation after 72h (Courtesy of NCA/DNMI)

<u>Simulation results, scenario 2A</u>

- Time from release to shoreline impact: 24 h
- Initial shoreline impact length: 45 km
- Oil volume reaching shoreline, first batch: 8600 m^3 (Given no oil spill response)

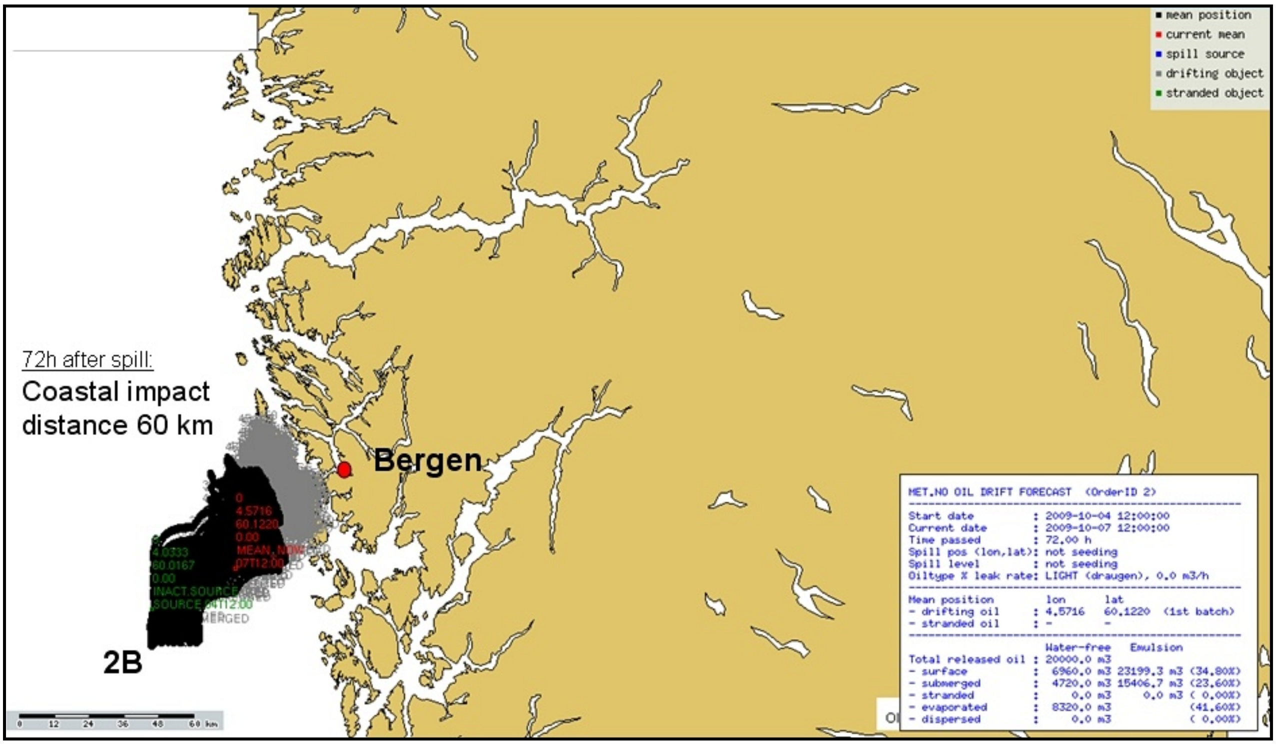


Fig 1.4.2B: Surface release from position 2B (new routing) situation after 72h (Courtesy of NCA/DNMI)

Simulation results, scenario 2B

- Time from release to shoreline impact: 81 h
- Initial shoreline impact length: 60 km
- Oil volume reaching shoreline, first batch: 6800 m^3 (Given no oil spill response)

1.5 Scenarios - ship grounding and emergency towing

To assess the potential for emergency towing preventing ship grounding (and spill), time from propulsion failure (at position A and B for each scenario) until grounding has been calculated and compared with tug boat response times.

In the document "Nasjonal slepeberedskap" (National emergency tug preparedness) issued by the Norwegian Coastal Administration (2006) thousands of ship drift simulations were conducted by DNV using the SHIPDRIFT model. It shows that drifting speed for large vessels varies between 1.2 to almost 4 knots, depending on ship dimensions, wind and ocean current. For this comparative analysis, we use shortest drifting distance and 2.5 knot (wind above 10 m/s) and 2.0 knot (wind below 10 m/s) drift speed.

1.5.1 Scenario 1A and B, ship drifting towards shore west of Stadt

For scenario 1A and 1B, the following tug boat availability exists, given that the tug boats are in port when request for assistance is received:

- Location: Kristiansund N:
- Tug boat speed: 12 kn (3 boats available, conservative speed estimate due to unavailable data)
- Distance to location 1A: 170 km
- Distance to location 1B: 190 km
- Response time to location 1A: 7.6 h
- Response time to location 1B: 8.5 h

- Location: Mongstad
- Tug boat speed: 15 kn (several boats available)
- Distance to location 1A: 165 km
- Distance to location 1B: 180 km
- Response time to location 1A: 5.9 h
- Response time to location 1B: 6.4 h

Given propulsion stop at location A or B, the minimum time to grounding is:

- Distance from location 1A to nearest shoreline: 16,5 km
- Distance from location 1B to nearest shoreline: 55,0 km
- Time from loss of propulsion to grounding, location 1A: 4.5 h
- Time from loss of propulsion to grounding, location 1B: 14.9 h
- Tug boat arrives in time, location 1A?: No
- Tug boat arrives in time, location 1B?: Yes (from both tug boat ports)

1.5.2 Scenario 2A and 2B, ship drifting towards shore west of Marstein

For scenario 2A and 2B, the following tug boat availability exists, given that the tug boats are in port when request for assistance is received:

- Location: Bergen
- Tug boat speed: 12 kn (conservative estimate)
- Distance to location 2A: 65 km
- Distance to location 2B: 98 km
- Response time to location 2A: 2.9 h
- Response time to location 2B: 4.4 h

Given propulsion stop at location 2A and 2B, the minimum drifting times to grounding are:

- Distance from location 2A to nearest shoreline: 25 km
- Distance from location 2B to nearest shoreline: 57 km
- Time from loss of propulsion to grounding, location 2A: 5.3 h
- Time from loss of propulsion to grounding, location 2B: 12.3 h
- Tug boat arrives in time, location 2A?: Yes
- Tug boat arrives in time, location 2B?: Yes

2 ENVIRONMENTAL CONSEQUENCES

2.1 Oil spill emergency response effectiveness and cost

The oil spill response may reduce the volume of oil reaching the coast. The efficiency of open ocean oil spill response is highly dependant on prevailing weather and coastal currents. In Norway, there are 16 governmental oil spill response depots, and off-shore oil spill response equipment (booms and skimmers) are located on board Royal Norwegian Coastguard vessels patrolling the coastline. The depots are dependant on use of vessels of opportunity.

In the vicinity of scenario 1A and 1B, an oil spill response depots are located in Ålesund and Fedje. Closest depot to scenario 2A and 2B is Bergen.

When assessing the consequence reducing effect of oil spill response, the following generic approach is established based on experience from oil spill operations in Norway during the last 20 years:

- One coastguard vessel will be first on site, 4 hours after accident. The 2nd after 12 hours.
- One oil spill response system will be on site after 5h (preparations) + time to reach site.
- For each additional 24 hours, number of response systems will double until the 3rd day.
- Crude oil recovery rate is 50 m^3 oil per hour for coastguard system below 10 m/s wind
  25 m^3 oil per hour for each coastguard system above 10 m/s and for all depot based systems.
- Fuel oil recovery rate is 10 m^3 oil per. hour for coastguard system below 10 m/s
  5 m^3 oil per. hour for each coastguard system above 10 m/s depot based systems.
- Max possible off-shore oil spill recovery: 75% (due to unrecoverable films, patchy structure etc).
- Clean-up cost per m^3 crude oil NOK 200 000, heavy fuel NOK 500 000.
- Natural degradation vs. manual clean-up of oil reaching shore: 60% / 40%.

The effect of oil spill response is related to volume only (volume of oil pr. km^2), not on impact area. For crude oil, actual recovered fluid volume will be doubled due to emulsification, hence the low rates related to non-emulsified oil (we have used the "20% of skimmer capacity" rule of thumb, used in North America)

Scenario 1A

Oil spill recovery

Time from incident to shoreline impact for 1A is 16 hours. During this timeframe the following oil spill response systems will be in action:

- One coastguard vessel, 16 - 4 = 12 hours of operation. Recovery: 12 x 10 m^3 = 120 m^3
- 2nd coastguard vessel, 16-12 = 4 hours of operation. Recovery: 4 x 10 m^3 = 40 m^3
- One system from Ålesund depot: 16-5-2 = 9 hours of operation: Rec: 9 x 5 m^3 = 225 m^3

The oil budget for shoreline impact is: 978 (from model) - 225 - 40 - 120 = 593 m^3

Clean up cost

- 40% of 593 m^3 equals 237 x 500 000 NOK = 118.5 mill. NOK

Scenario 1B

Oil spill recovery

Time from incident to shoreline impact for 1B is 71 hours. During this timeframe the following oil spill response systems will be in action:

- One coastguard vessel, 71 - 4 = 67 hours of operation. Recovery: 67 x 10 m^3 = 670 m^3
- 2nd coastguard vessel, 71-12 = 59 hours of operation. Recovery: 59 x 10 m^3 = 590 m^3
- One system from Ålesund depot: 71-5-2 = 64 hours of operation: Rec: 64 x 5 m^3 = 320 m^3

The oil budget for shoreline impact is: 978 (from model) - 75% rule = 244 m^3

Clean up cost

- 40% of 244 m^3 equals 98 m^3 x 500 000 NOK = 49 mill. NOK

Scenario 2A

Oil spill recovery

Time from incident to shoreline impact for 2A is 24 hours. During this timeframe the following oil spill response systems will be in action:

- One coastguard vessel, 24 - 4 = 20 hours of operation. Recovery: 20 x 25 m^3 = 500 m^3
- 2nd coastguard vessel, 24-12 = 12 hours of operation. Recovery: 12 x 25 m^3 = 300 m^3
- One system from Bergen depot: 24-5-1 =18 hours of operation: Rec: 18 x 10 m^3 = 180 m^3

The oil budget for shoreline impact is: 8600 (from model) - 500 - 300 - 180 = 7620 m^3

Clean up cost

- 40% of 7620 m^3 equals 3048 m^3 x 200 000 NOK = 610 mill. NOK

Scenario 2B

Oil spill recovery

Time from incident to shoreline impact for 2B is 81 hours. During this timeframe the following oil spill response systems will be in action:

First 24 hours:

- One coastguard vessel, 24 - 4 = 20 hours of operation. Recovery: 20 x 25 m^3 = 500 m^3
- 2nd coastguard vessel, 24 - 12 = 12 hours of operation. Recovery: 12 x 25 m^3 = 300 m^3
- One system from Bergen depot: 24-5-1 =18 hours of operation: Rec: 18 x 10 m^3 = 180 m^3
- Total, first 24 hours: 980 m^3

Doubling of capacity every 24 hours: 980 + 1960 + 3920 = 6860 after 72 hours, more than the initial release. Hence the 75% rule of thumb will be effective.

The oil budget for shoreline impact is: 25% of 6800 m^3 = 1700 m^3

Clean up cost

- 40% of 1700 m^3 equals 680 m^3 x 200 000 NOK = 136 mill. NOK

2.2 Environmental impact of oil spills

The actual coastal impact area is dependant on re-migrating of oil from shorelines, weather, effectiveness of the oil spill response and the complexity of the archipelago and fjord systems. In general, the initial impact area expands as distance between the spill and shoreline increases, given wind/current towards land. This is valid to a point where no oil reaches the shoreline due to evaporation and natural degradation.

The oil drift simulation model used in chapter 1 is unable to calculate re-migration of oil after initial shoreline impact. Therefore, a qualitative assessment of the impact area is made based on experiences from previous oil spills in Norway. The situation maps in this chapter show the potential impact area one week after release. For most vulnerable environmental resources, the concentration (thickness and coverage) of oil is not strongly correlated with actual environmental loss. This is due to the fact that oil is not even distributed, but concentrated in bays and areas of certain coastal currents. Usually, environmental damage is independent whether 2 cm or 4 cm of oil is on its surface. Therefore, in this generic and simplified comparison, we do not use oil quantity per. square kilometre as an indicator of environmental impact.

The marine environment and its inhabitants are threatened by many factors. Utilization, habitat destruction and climate changes are just some of them. An oil spill incident may harm populations or ecosystems in different ways and to different degrees according to the environmental pressure this area or population are already experiencing. The toxic components of oil, the polycyclic aromatic hydrocarbons may cause physical, physiological or behavioural damages to the flora and fauna affected. This may lead to lethal or sub lethal effects.

An environment or a population that has been decimated by oil spill may recover after a number of years. If decimated twice or more within a short time span the impact may be more severe. This is valid for some parts of the western coast of Norway, were the frequency of passing ships is high and the coastal environment and weather conditions are harsh. The possibility of accidents may therefore be relatively high. It is therefore of high importance to take measures to reduce the number of oil spills along Norway’s vulnerable coastline.

Severe injuries to the marine environment have been seen worldwide, and one of the most infamous is the “Exxon Valdez” grounding in Prince William Sound, Alaska, April 1989. A total of 40 000 m^3 of crude oil was released into the sea. The oil eventually covered 28,000,000 km^2 of the coastal zone. Thousands of animals died immediately; estimates range from 250,000 to as many as 500,000 seabirds, at least 1,000 sea otters, approximately 12 river otters, 300 harbor seals, 250 bald eagles, and 22 orcas, as well as the destruction of billions of salmon and herring eggs. The consequences are still present and overall reductions in population have been seen in various marine animals, including stunted growth in pink salmon populations. The shoreline may need 30 years or more to fully recover.

In Norway there have been several mid-size incidents causing extensive oil spills during the last decade. One example is the “MS Server” grounding north-west of Bergen in January 2007. The bad weather the following days made the heavy fuel oil recovery difficult. Around 400 tonnes of heavy fuel oil was released into the environment. Six months later, a total 230 sites including nine natural reserves (mainly seabird breeding colonies) had to been cleaned up manually before breeding season. In the Hellesøy natural reserve no Herring gulls, which normally breed here, did so the following summer. It is estimated that the spill killed between 3200-8000 seabirds. This incident alone may not cause long term effects, but the fact that the seabird populations in this area did experience a similar accident only three years earlier (the “MS Rocknes” grounding) may increase the total environmental effect.

Investigations of marine flora and fauna in the months after the “MS Server” accident showed a clear reduction in the density of certain seaweed species (*Pelvietia canaliculata).* The abundance of sessile fauna, filter feeders and snail species that are feeding on seaweed were clearly reduced in the affected areas. Similar reductions in flora and fauna were also reported after the oil spill following the accident of “Mercantil Marica” in Solund municipality in 1989.

Fish and invertebrates - oilspill vulnerability

Fish and invertebrates are vulnerable to oil spills. Due to the nature of oil, where it is transported and spread on the surface before it hits the shore; the bottom living animals in the open sea are less vulnerable than pelagic living, but in the coastal area both pelagic and bottom living may be affected. They are mostly exposed to water soluble components as their main source of contact would be through respiration from water through their gills. Dispersed oil components my also be taken up through the mouth or through prey organisms that have themselves taken up oil components. This may lead to accumulation of toxic components in the predator. Both invertebrates and fishes are most sensitive to toxic response in their larval stages, just after hatching and through the digestion of the yolk sack.

Physiological effects: reduced heart frequency, changes in the salinity balance and change in blood parameters; blood cells, hormone levels etc. There has also been observed problems for reproduction including increased infertility, reduced egg production and reduced survival for the offspring.

Behavioural effects: Changes in hunting and reproductive behaviour have been observed along with reduced anti predator behaviour like crabs that has been observed to change its normal behaviour for avoiding predators by digging itself down in the sediment.

Morphological effects: has been observed adult stages were damages to gills, intestine, pancreas, spinal cord and brain damages.

Fish can smell oil and if possible they may avoid areas of oil spill. Zooplankton has been shown to recover rather fast after an oil spill due to their short generation time. Benthos may be exposed to the toxic components for longer time due to storage and leaking of oil components in the bottom sediment.

Oil covered rocks and shores will also be a barrier for new recruitments of sessile organisms. Reduction of sessile organisms and filter feeders were also observed after the MS Server incident. It has been shown that amphipods and decapods are relatively more sensitive to oil spills than isopods that generally are more resistant.

Fish and crabs caught in the sea after the accidents and oil spill from MS Server outside Fedje in Hordaland, Norway, contained 20 times more PAH than the background concentrations.

Seabirds - oil spill vulnerability

Seabirds are probably one of the most vulnerable animal groups to oil spills. Oil polluted birds are often the most prominent picture from a spill incident, but studies also conclude that oil spills have contributed to decreased populations of seabird species. This has not yet been shown for other animal groups.

As for some mammals, the external pollution is the most acute. Oil in the feathers results in clogging and reduction of the water resistance, and it prevents the insulation ability of the feathers and reduces the ability for heat regulation. If exposed to water, the animal may freeze to death. If the bird reaches land it can probably escape the freezing, but it may have problems finding appropriate food. This may lead to starvation. Birds have also been observed efficiently cleaning their own feathers, but this may lead to digestion of heavy amounts of oil causing anaemia, disturbed osmoregulation, hormonal effects and reproductive effects as well as reduced and delayed lying of eggs and reduced thickness of the egg shell.

As for other animal groups the embryonic stages and juveniles are most sensitive. Just small amounts of oil may cause genetic and morphological injuries to the embryo, delay the embryonic development and increase the post hatching mortality. For the young birds the salinity balance may be disturbed, reduced intestine absorption and liver injuries may occur. This leads to reduced growth and increased mortality.

During moulting, seabirds gather in the open waters and they may be unable to fly for a period of up to two months. In this period they will be very vulnerable to external stress and pollution.

Indirect consequences for seabirds may also be that prey organisms may disappear from a polluted area and this will again decrease their survival.

Mammals - oil spill vulnerability

Sea living mammals may be affected by oil spills in different ways. They should be able to swim out of an area, and whales have in experiments learned to avoid areas of oil spills after first encounter with the spill. However, common seals have shown the opposite behaviour during the Exxon Valdez accident, rather seemed to be attracted by the spill.

Adult animals are protected from external contamination by their thick skin, but the infants may be vulnerable, especially just after birth. For whales, heavy oil may cause temporarily reduction in the water flow through the baleens, but this is not seen to cause any severe effect for the animal. However, whales and seals may be affected by inhalation of hydrocarbons that can lead to death due to high levels of adrenalin and hydrocarbons in the blood, and due to its narcotic effect that can lead to instant drowning. Also digestion of contaminated prey can cause liver injuries and negatively affect reproduction. The mortality of killer whales after the Exxon Valdez incident increased 5-6 times during the following two years, especially affecting young and female animals.

Sea otters are dependent on their fur for thermal insulation and the first effect of oil pollution will be clogging of the fur when externally exposed to oil. This will reduce the animal's ability for heat regulation and it may stay on lad for longer periods. On land it can not find food and will starve. It will also try to clean its fur, and this activity may reduce the time spent for hunting for food. Also this behaviour may cause the animal to digest a lot of the oil from the fur causing internal damages for the digestion system. Also stress, shock and respiratory effects have been observed.

Scenario 1A and B

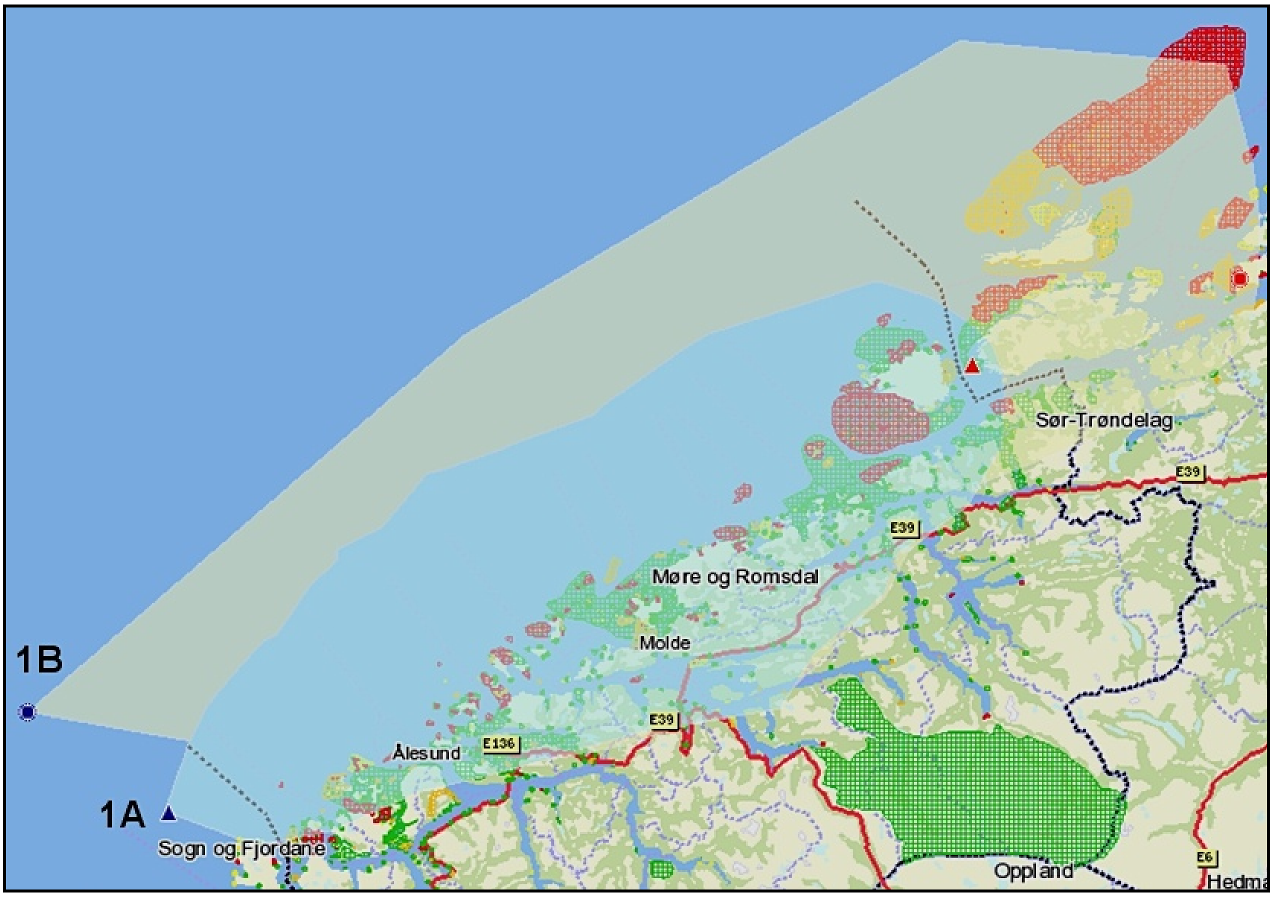


Figure 2.2A: Impact areas of 1A and 1B after 1 week based on experiences from past spills

Vulnerable environmental resources within the two areas:

No. of MOB areas (m^2)	1A	1B	Increase A>B
Mob A Summer	74	78	5 %
Mob A Winter	56	61	9 %
Mob B Summer	70	66	-6 %
Mob B Winter	36	46	28 %
Mob C Summer	129	109	-16 %
Mob C Winter	102	78	-24 %
Mob D Summer	194	194	0 %
Mob D Winter	530	517	-2 %
No. of protected areas			
Spawning areas			
Size of MOB-areas (m^2)	**1A**	**1B**	**Increase A>B**
Mob A Summer	5,2E+08	2,13E+09	309 %
Mob A Winter	4,63E+08	1,97E+09	324 %
Mob B Summer	1,33E+08	4,8E+08	260 %
Mob B Winter	74824451	5,09E+08	580 %
Mob C Summer	92657744	4,81E+08	419 %
Mob C Winter	88575188	1,94E+08	119 %
Mob D Summer	1,51E+08	1,52E+08	0 %
Mob D Winter	1,76E+09	1,77E+09	1 %

Most of the MOB areas that may be affected by an oil spill in this region are seabird habitats where birds breed and feed. There is a wide range of different seabird species and some are diving for food while others are surface feeders. All these strategies may make the birds vulnerable for injuries and subjected to prey deficiency in case of an oil spill that covers large parts of their target area. The area is also home to common seals and sea otters. An incident happening in the spring coinciding with hatching and birth of seals may cause severe injuries and increase the mortality.

There are also valuable wetlands that may be severely impacted from an oil spill. Otherwise there are also many sites dedicated for human recreational activities in this area, but these are categorized with the priority C or D.

There are registered observations of deep water corals (*Lophelia pertusa)* in the areas affected by both scenarios. This specie is red listed but live below 40 m depth and will probably therefore not be directly exposed. The effect of oil pollution on deep water corals are not yet well known but some ongoing project may give more information in the future. However, it should be mentioned that the extent of scenario B will geographically cover parts of the protected Sularevet (reef).

Scenario 2A and B

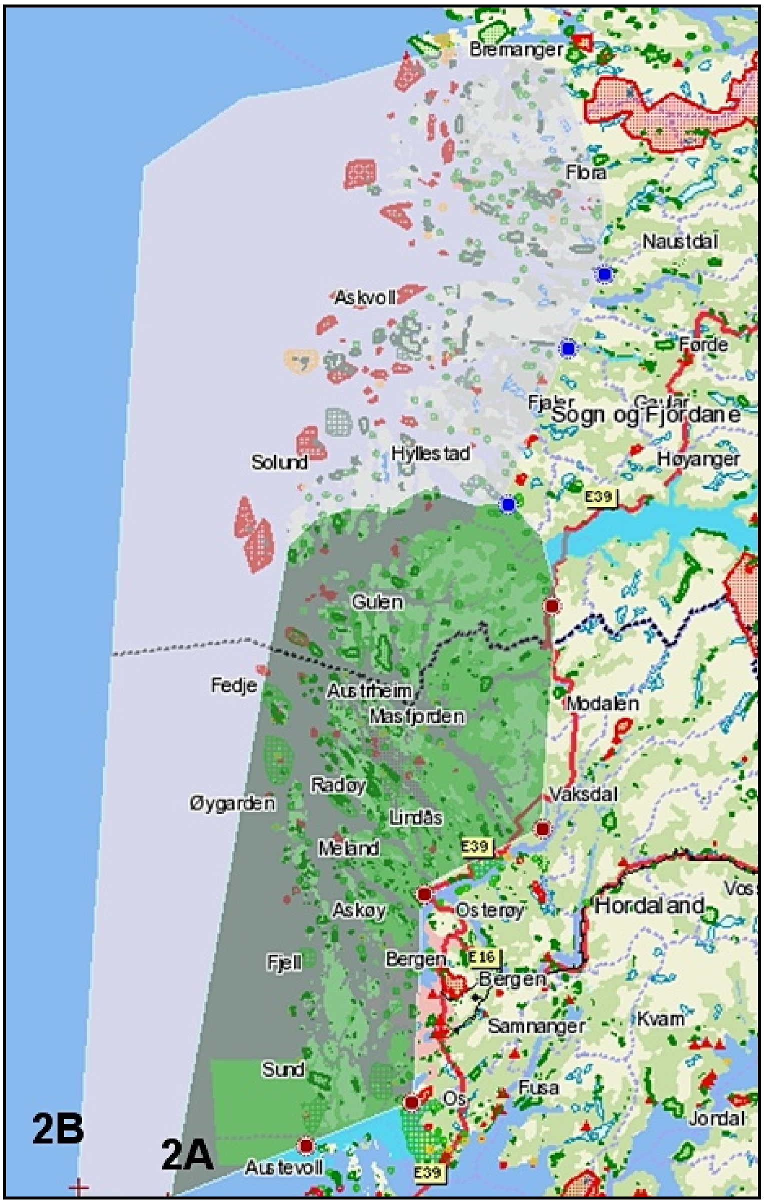


Figure 2.2B: Impact areas of 2A and 1B after 1 week based on experiences from past spills

Vulnerable environmental resources within the two areas:

No. of MOB areas (m^2)	2A	2B	Increase A>B
Mob A Summer	21	60	186 %
Mob A Winter	7	28	300 %
Mob B Summer	24	31	29 %
Mob B Winter	1	2	100 %
Mob C Summer	14	24	71 %
Mob C Winter	5	12	140 %
Mob D Summer	93	207	123 %
Mob D Winter	109	231	112 %
No. of protected areas	3	3	0 %
Spawning areas	100	134	34 %
Size of MOB-areas (m^2)	**2A**	**2B**	**Increase A>B**
Mob A Summer	25802907	1,59E+08	515 %
Mob A Winter	15543496	1,38E+08	789 %
Mob B Summer	18753921	29574244	58 %
Mob B Winter	781413	9210479	1079 %
Mob C Summer	12215211	36263546	197 %
Mob C Winter	6699891	28098413	319 %
Mob D Summer	72671435	1,62E+08	123 %
Mob D Winter	2,09E+08	3,42E+08	64 %

Most of the MOB areas within the potential impact area oil spill in these areas are seabird habitats where they breed and feed, and also some species spending the Winter in these areas. There are a wide range of different seabird species, some are diving for food, others surface feeders. All these strategies may make the birds vulnerable and subjected to prey deficiency in case of an oil spill that covers big parts of their target area.

Several locations in this area has already been hit by oil pollution several few times in the last 15-20 years (The vessels Azalea, Sonata, Arisan, Server, Rocknes, Green Aalesund, Mercantile Marica), and we must assume that this may have affected the seabird population.

The area is also home to common seals and sea otters. An incident occurring in the Autumn may be less lethal than one occurring in the early Spring, especially for the offspring that are more vulnerable just after birth. Also animals that are anyway planning to leave to spend the winter somewhere else will decrease the pressure on the feeding resources.

There are also valuable wetlands that may be severely impacted from an oil spill. There are also many sites dedicated to recreational activities in this area, but these are categorized with the priority C or D.

There are registered observations of deep water corals (*Lophelia pertusa)* in the area affected by both scenarios. This species are red listed but live below 40 m depth and will therefore not be directly exposed.

Scenario 2A covers 100 registered spawning areas including herring, cod, pollack, haddock, horse mackerel, blue whiting, ling, European plaice, turbot and European hake. Scenario 2B covers almost double the amount of areas and also includes spawning areas for herring blue whiting, haddock, Pollack, saithe and horse mackerel. In scenario B the spill may cover a larger area and therefore includes another 34 spawning areas with the same fish species in addition to tusk and European sprat. Most of these species spawn on bottom and/or in deep water, but the flatfish turbot and European plaice spawn in shallow water and the eggs float upwards. This behaviour may limit the risk for being affected by an oil spill in the early stages but when occurring in the autumn, the effect will mainly be on the young adults and adults. Then it is critical whether they can avoid the spill by actively swim away, and of the amount of toxic substances they may digest through their prey organisms.

3 CONCLUSIONS

3.1 Relative comparison of consequences

3.1.1 Scenario 1A and 1B

Based on this generic comparative consequence analysis, the following conclusions are made:

	Init. release	T to impact	Rec. at sea	Oil on shore	Rec. cost	No. of MOB	Tug in time
Scenario 1A	1000 m^3	16 h	385 m^3	593	118 MNOK	467	No
Scenario 1B	1000 m^3	87 h	734 m^3	244	49 MNOK	447	Yes

3.1.2 Scenario 2A and 2B

Based on this generic comparative consequence analysis, the following conclusions are made:

	Init. release	T to impact	Rec. at sea	Oil on shore	Rec. cost	No. of MOB	Tug in time
Scenario 2A	20 000 m^3	24 h	980 m^3	7620 m^3	610 MNOK	122	Yes
Scenario 2B	20 000 m^3	81 h	5100 m^3	1700 m^3	136 MNOK	273	Yes

3.1.3 Conclusion

An oil spill occurring along the new proposed route will have significantly more time (3 to 5 times) at sea until shoreline impact. The extended oil drift time at sea will enhance natural degradation of oil through evaporation and natural dispersion. It will also enable emergency towing or oil spill response that may significantly reduce the overall environmental impact. The highest benefit is expected to be for crude oil spills from tanker accidents.

The larger impact area of an oil spill occurring further away from the shore indicates that a higher number of sites may be exposed to the spill. However, experience shows that the number of impact sites is not proportionate with the total impact area and may also be counter balanced by the lower concentration of oil (severity of impact) on each site. During past spills oil has been observed accumulating in patches. The extended drifting distance may decrease the impact intensity and hence ease the effect for the local populations within a region. This means that e.g. neighboring bird populations may not be effected, directly or through polluted or shortage of prey, to the same degree and migration between them decrease the overall impact. The same may be the result for a local fish stock, a seal or otter population etc.

The impact areas for both scenario 1A/B and 2A/B have patchy coral occurrence. It is not well understood how they may be affected by oil pollution or whether oil released on the surface may affect them. However, the effect for fish spawning areas may be more severe. Fish larvae are very vulnerable to toxicity and stress during their early development. A longer oil spill emergency response time, allowing less oil to impact the shoreline will be critical for limiting the impact for fish populations and thereby the people depending on this resource for a living.

References

Heggøy E, Johansen P-O, 2007 Johannessen P. Marinbiologisk undersøkelse i forbindelse med forliset av MS Server i 2007. SAM-Unifob rapport nr. 14-2007

Lorentsen, S.-H. (ed.), Byrkjeland, S., Flagstad, Ø., Heggberget, T.M., Larsen, T., Røv, N., Balstad, T., Haugland, T. & Østborg, G.M. 2008. Etterkantundersøkelser sjøfugl og oter etter MS Server-forliset januar 2007. NINA Rapport 336: 64 pp.

SFT 2000. Beredskap mot akutt forurensning; Modell for prioritering av miljøressurser ved akutte oljeutslipp langs kysten. Overgjødsling og Oljeforurensning TA 1765/2000.

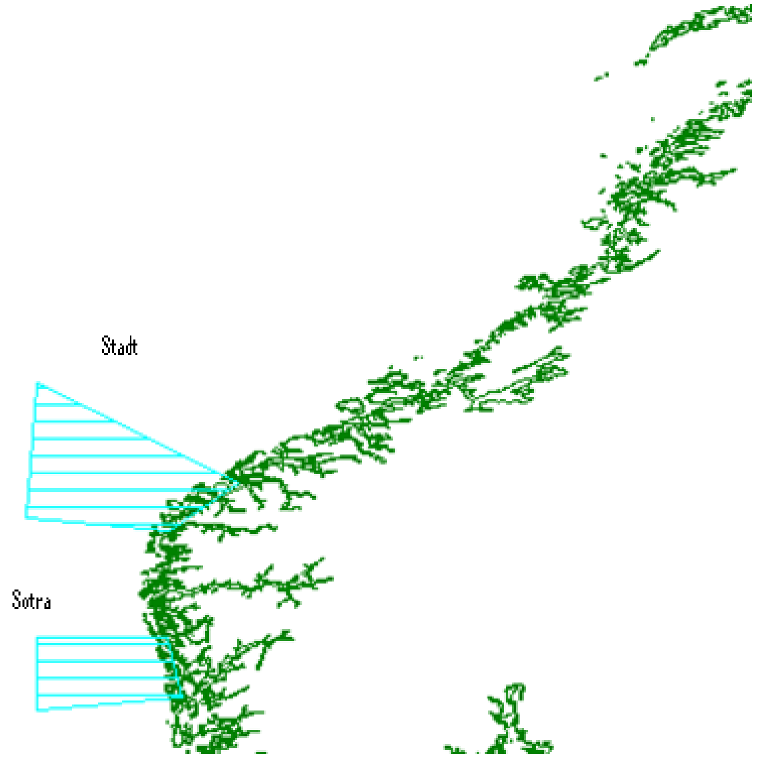
Electronic sources:

DNMI, kilden.no
Biologi.no: www.biologi.no
Directorate of Fisheries; www.fiskeridir.no
SFT; www.sft.no - spesielt Publikasjoner - Olje & gass - statlig dimensjonering
Institute for Marine Research: www.imr.no
The Norwegian Coastal Administration; www.kystverket.no
SEAPOP (SEAbird POPulations); www.seapop.no
Wikipedia: www.wikipedia.no

Appendix 9 Accident figures for the scenario areas

Accident figures for the scenario areas for 2008 and 2025 collected from MARCS are given in tables below. The different table categories have been given the following colour keys:

	Accident frequency per year
	Spill accident frequency per year
	Oil spill volumes in tonnes per year



Today's route 2008 - Stad	**Stad**							
Total accidents		Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
	Collis	1.40E-02	2.22E-03	1.36E-04	4.48E-04	2.04E-03	7.65E-04	8.39E-03
	Struc	1.98E-02	3.00E-03	1.68E-04	7.46E-04	3.05E-03	1.13E-03	1.17E-02
	FEX	1.73E-02	2.62E-03	1.47E-04	6.52E-04	2.66E-03	9.91E-04	1.02E-02
	PGrd	6.12E-02	8.28E-03	6.16E-04	3.57E-03	1.05E-02	4.37E-03	3.39E-02
	DGrd	4.73E-01	7.68E-02	4.88E-03	1.45E-02	6.67E-02	2.53E-02	2.84E-01
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	5.85E-01	9.30E-02	5.94E-03	2.00E-02	8.50E-02	3.26E-02	3.48E-01
Spill accidents	Collis	2.23E-03	8.91E-04	3.75E-05	1.79E-04	2.04E-04	7.65E-05	8.38E-04
	Struc	3.51E-03	1.50E-03	4.61E-05	3.73E-04	3.05E-04	1.13E-04	1.17E-03
	FEX	3.06E-03	1.31E-03	4.04E-05	3.26E-04	2.66E-04	9.91E-05	1.02E-03
	PGrd	9.03E-03	2.64E-03	1.62E-04	1.35E-03	1.05E-03	4.37E-04	3.39E-03
	DGrd	7.10E-02	2.69E-02	1.34E-03	5.09E-03	6.67E-03	2.53E-03	2.84E-02
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	8.88E-02	3.33E-02	1.63E-03	7.32E-03	8.50E-03	3.26E-03	3.48E-02
Oil spill in tonnes	Collis	4.09E+00	1.60E+00	7.11E-02	2.25E+00	1.15E-01	1.09E-02	5.19E-02
	Struc	1.67E+01	5.64E+00	8.71E-02	1.08E+01	1.81E-01	1.65E-02	7.27E-02
	FEX	1.05E+01	3.51E+00	7.62E-02	6.69E+00	1.58E-01	1.44E-02	6.36E-02
	PGrd	3.29E+01	6.59E+00	8.30E-01	2.45E+01	6.82E-01	6.69E-02	2.16E-01
	DGrd	1.32E+02	5.42E+01	2.68E+00	6.95E+01	3.71E+00	3.61E-01	1.75E+00
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	1.97E+02	7.16E+01	3.74E+00	1.14E+02	4.85E+00	4.69E-01	2.16E+00

Proposed route 2008 - Stad	**Stad**							
Total accidents		Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
	Collis	2.38E-02	4.12E-03	2.89E-04	1.51E-03	9.36E-03	3.21E-03	5.26E-03
	Struc	2.81E-02	3.59E-03	2.47E-04	1.43E-03	8.28E-03	2.82E-03	1.17E-02
	FEX	2.45E-02	3.14E-03	2.16E-04	1.25E-03	7.24E-03	2.46E-03	1.02E-02
	PGrd	3.40E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.40E-02
	DGrd	3.06E-01	4.62E-03	3.25E-04	1.56E-03	1.04E-02	3.53E-03	2.86E-01
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	4.17E-01	1.55E-02	1.08E-03	5.75E-03	3.53E-02	1.20E-02	3.47E-01
Spill accidents	Collis	4.11E-03	1.65E-03	7.90E-05	5.97E-04	9.36E-04	3.21E-04	5.26E-04
	Struc	4.87E-03	1.80E-03	6.82E-05	7.17E-04	8.28E-04	2.82E-04	1.17E-03
	FEX	4.26E-03	1.58E-03	5.96E-05	6.26E-04	7.24E-04	2.47E-04	1.02E-03
	PGrd	3.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.40E-03
	DGrd	3.19E-02	1.36E-03	7.67E-05	4.60E-04	1.04E-03	3.53E-04	2.86E-02
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	4.85E-02	6.39E-03	2.83E-04	2.40E-03	3.53E-03	1.20E-03	3.47E-02
Oil spill in tonnes	Collis	1.68E+01	6.41E+00	6.09E-01	8.98E+00	6.65E-01	6.93E-02	3.27E-02
	Struc	3.69E+01	1.45E+01	5.32E-01	2.11E+01	6.03E-01	6.06E-02	7.28E-02
	FEX	2.32E+01	9.00E+00	4.65E-01	1.31E+01	5.28E-01	5.30E-02	6.37E-02
	PGrd	2.17E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.17E-01
	DGrd	1.62E+01	5.54E+00	5.37E-01	7.59E+00	7.36E-01	7.50E-02	1.76E+00
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	9.33E+01	3.54E+01	2.14E+00	5.08E+01	2.53E+00	2.58E-01	2.15E+00

Today's route 2025 Stad		Stad						
Total accidents		Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
	Collis	1.66E-02	3.63E-03	3.21E-04	7.56E-04	2.65E-03	9.96E-04	8.20E-03
	Struc	2.17E-02	4.54E-03	4.89E-04	1.19E-03	3.63E-03	1.36E-03	1.05E-02
	FEX	1.90E-02	3.96E-03	4.28E-04	1.04E-03	3.18E-03	1.19E-03	9.20E-03
	PGrd	6.81E-02	1.24E-02	2.18E-03	5.36E-03	1.25E-02	5.18E-03	3.05E-02
	DGrd	5.13E-01	1.15E-01	1.02E-02	2.18E-02	7.97E-02	3.02E-02	2.56E-01
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	6.38E-01	1.40E-01	1.37E-02	3.02E-02	1.02E-01	3.90E-02	3.14E-01
Spill accidents	Collis	3.03E-03	1.45E-03	8.82E-05	3.02E-04	2.65E-04	9.95E-05	8.20E-04
	Struc	4.55E-03	2.27E-03	1.34E-04	5.92E-04	3.63E-04	1.36E-04	1.05E-03
	FEX	3.97E-03	1.98E-03	1.18E-04	5.18E-04	3.18E-04	1.19E-04	9.19E-04
	PGrd	1.15E-02	3.96E-03	6.62E-04	2.03E-03	1.25E-03	5.18E-04	3.05E-03
	DGrd	8.74E-02	4.04E-02	2.82E-03	7.63E-03	7.97E-03	3.02E-03	2.56E-02
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	1.10E-01	5.00E-02	3.82E-03	1.11E-02	1.02E-02	3.90E-03	3.14E-02
Oil spill in tonnes	Collis	6.88E+00	2.61E+00	2.25E-01	3.83E+00	1.50E-01	1.42E-02	5.08E-02
	Struc	2.68E+01	8.67E+00	6.57E-01	1.72E+01	2.16E-01	1.99E-02	6.54E-02
	FEX	1.69E+01	5.39E+00	5.74E-01	1.07E+01	1.89E-01	1.74E-02	5.72E-02
	PGrd	5.45E+01	9.89E+00	6.67E+00	3.68E+01	8.08E-01	7.91E-02	1.94E-01
	DGrd	1.99E+02	8.14E+01	6.99E+00	1.04E+02	4.43E+00	4.31E-01	1.58E+00
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	3.04E+02	1.08E+02	1.51E+01	1.73E+02	5.79E+00	5.61E-01	1.95E+00

Proposed route 2025 Stad		Stad						
Total accidents		Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
	Collis	4.20E-02	8.75E-03	4.27E-03	3.24E-03	1.59E-02	5.43E-03	4.37E-03
	Struc	3.40E-02	5.27E-03	2.55E-03	2.32E-03	9.94E-03	3.35E-03	1.05E-02
	FEX	2.97E-02	4.61E-03	2.23E-03	2.02E-03	8.70E-03	2.93E-03	9.20E-03
	PGrd	3.06E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.06E-02
	DGrd	2.87E-01	6.93E-03	3.34E-03	2.34E-03	1.25E-02	4.21E-03	2.57E-01
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	4.23E-01	2.56E-02	1.24E-02	9.92E-03	4.70E-02	1.59E-02	3.12E-01
Spill accidents	Collis	8.54E-03	3.51E-03	1.17E-03	1.28E-03	1.59E-03	5.43E-04	4.37E-04
	Struc	6.90E-03	2.65E-03	7.05E-04	1.16E-03	9.94E-04	3.36E-04	1.05E-03
	FEX	6.03E-03	2.32E-03	6.16E-04	1.02E-03	8.70E-04	2.93E-04	9.20E-04
	PGrd	3.06E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.06E-03
	DGrd	3.09E-02	2.04E-03	7.89E-04	6.89E-04	1.25E-03	4.22E-04	2.57E-02
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	5.54E-02	1.05E-02	3.28E-03	4.15E-03	4.70E-03	1.59E-03	3.12E-02
Oil spill in tonnes	Collis	1.37E+01	1.98E+00	1.88E+00	9.73E+00	1.18E-01	6.40E-03	3.04E-02
	Struc	5.76E+01	9.30E+00	3.72E+00	4.43E+01	1.97E-01	1.05E-02	3.23E-02
	FEX	3.68E+01	5.78E+00	3.26E+00	2.76E+01	1.72E-01	9.14E-03	2.83E-02
	PGrd	5.83E+00	6.57E-01	2.73E-01	3.76E+00	9.85E-01	6.89E-02	8.17E-02
	DGrd	1.11E+02	1.56E+01	1.17E+01	8.23E+01	9.84E-01	5.88E-02	2.44E-01
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	2.25E+02	3.33E+01	2.09E+01	1.68E+02	2.46E+00	1.54E-01	4.17E-01

Today-s route 2008 - Sotra

Total accidents	Todays 08	Total	frequency	Area:	3			
		Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
	Collis	1.49E-02	2.47E-03	5.35E-04	1.87E-03	2.76E-03	5.59E-04	6.72E-03
	Struc	2.25E-02	3.75E-03	7.80E-04	2.89E-03	4.23E-03	8.54E-04	1.00E-02
	FEX	1.97E-02	3.28E-03	6.82E-04	2.53E-03	3.70E-03	7.46E-04	8.78E-03
	PGrd	6.40E-02	1.62E-02	3.94E-03	1.31E-02	1.57E-02	5.12E-03	9.89E-03
	DGrd	1.71E-01	2.95E-02	6.62E-03	2.23E-02	3.21E-02	7.06E-03	7.31E-02
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	2.92E-01	5.52E-02	1.26E-02	4.27E-02	5.85E-02	1.43E-02	1.09E-01
Spill accidents	Collis	2.89E-03	9.88E-04	1.47E-04	7.49E-04	2.76E-04	5.59E-05	6.71E-04
	Struc	5.04E-03	1.88E-03	2.15E-04	1.45E-03	4.22E-04	8.55E-05	1.00E-03
	FEX	4.41E-03	1.64E-03	1.88E-04	1.26E-03	3.70E-04	7.47E-05	8.77E-04
	PGrd	6.56E-03	1.71E-03	4.07E-04	1.38E-03	1.57E-03	5.12E-04	9.88E-04
	DGrd	3.12E-02	1.03E-02	1.82E-03	7.79E-03	3.21E-03	7.07E-04	7.30E-03
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	5.01E-02	1.65E-02	2.78E-03	1.26E-02	5.84E-03	1.44E-03	1.08E-02
Oil spill in tonnes	Collis	1.50E+01	2.56E+00	5.20E-01	1.17E+01	1.82E-01	9.63E-03	4.54E-02
	Struc	5.90E+01	1.04E+01	7.66E-01	4.76E+01	2.81E-01	1.47E-02	6.78E-02
	FEX	3.70E+01	6.45E+00	6.70E-01	2.96E+01	2.46E-01	1.28E-02	5.93E-02
	PGrd	6.08E+00	7.95E-01	2.11E-01	4.07E+00	8.76E-01	6.04E-02	7.05E-02
	DGrd	1.76E+02	2.95E+01	6.60E+00	1.38E+02	2.07E+00	1.15E-01	4.94E-01
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	2.93E+02	4.96E+01	8.76E+00	2.30E+02	3.65E+00	2.12E-01	7.37E-01

Proposed route 2008 - Sotra

Total accidents	Proposed 08	Total	frequency	Area:	3			
		Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
	Collis	1.32E-0:	1.85E-03	3.95E-04	1.43E-03	2.07E-03	4.29E-04	7.00E-03
	Struc	2.30E-0:	3.81E-03	8.07E-04	2.94E-03	4.28E-03	8.70E-04	1.03E-02
	FEX	2.01E-0:	3.33E-03	7.06E-04	2.57E-03	3.75E-03	7.60E-04	9.02E-03
	PGrd	6.93E-0:	1.55E-02	3.78E-03	1.26E-02	1.49E-02	4.97E-03	1.75E-02
	DGrd	1.38E-0:	1.85E-02	4.15E-03	1.43E-02	1.99E-02	4.71E-03	7.65E-02
	PPlat	0.00E+0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	2.64E-0:	4.30E-02	9.84E-03	3.39E-02	4.49E-02	1.17E-02	1.20E-01
Spill accidents	Collis	2.20E-0:	6.52E-04	9.72E-05	5.07E-04	2.07E-04	4.29E-05	7.00E-04
	Struc	5.15E-0:	1.91E-03	2.23E-04	1.47E-03	4.28E-04	8.71E-05	1.03E-03
	FEX	4.51E-0:	1.67E-03	1.95E-04	1.29E-03	3.74E-04	7.61E-05	9.01E-04
	PGrd	6.93E-0:	1.55E-03	3.78E-04	1.26E-03	1.49E-03	4.97E-04	1.75E-03
	DGrd	2.06E-0:	5.36E-03	9.68E-04	4.20E-03	1.98E-03	4.71E-04	7.64E-03
	PPlat	0.00E+0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	3.94E-0:	1.12E-02	1.86E-03	8.73E-03	4.48E-03	1.17E-03	1.20E-02
Oil spill in tonnes	Collis	9.88E+0	1.65E+00	3.34E-01	7.71E+00	1.36E-01	7.23E-03	4.74E-02
	Struc	6.03E+0	1.06E+01	7.95E-01	4.85E+01	2.84E-01	1.50E-02	6.98E-02
	FEX	3.78E+0	6.58E+00	6.95E-01	3.02E+01	2.49E-01	1.31E-02	6.10E-02
	PGrd	4.09E+0	4.37E-01	1.37E-01	2.51E+00	8.24E-01	5.77E-02	1.25E-01
	DGrd	9.08E+0	1.42E+01	3.43E+00	7.13E+01	1.26E+00	7.19E-02	5.18E-01
	PPlat	0.00E+0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	2.03E+0	3.35E+01	5.39E+00	1.60E+02	2.75E+00	1.65E-01	8.22E-01

Today's route 2025 - Sotra								
		Total	frequency	Area:	3			
Total accidents		Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
	Collis	2.08E-02	4.39E-03	1.27E-03	3.34E-03	3.91E-03	7.95E-04	7.10E-03
	Struc	2.67E-02	5.64E-03	1.59E-03	4.35E-03	5.06E-03	1.02E-03	9.03E-03
	FEX	2.33E-02	4.93E-03	1.39E-03	3.80E-03	4.42E-03	8.95E-04	7.90E-03
	PGrd	8.57E-02	2.44E-02	7.87E-03	1.97E-02	1.88E-02	6.12E-03	8.90E-03
	DGrd	2.04E-01	4.42E-02	1.37E-02	3.34E-02	3.84E-02	8.44E-03	6.58E-02
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	3.60E-01	8.35E-02	2.58E-02	6.45E-02	7.05E-02	1.73E-02	9.87E-02
Spill accidents	Collis	4.62E-03	1.76E-03	3.48E-04	1.34E-03	3.90E-04	7.96E-05	7.09E-04
	Struc	6.94E-03	2.82E-03	4.37E-04	2.17E-03	5.05E-04	1.03E-04	9.02E-04
	FEX	6.07E-03	2.46E-03	3.82E-04	1.90E-03	4.42E-04	8.95E-05	7.90E-04
	PGrd	8.82E-03	2.57E-03	8.13E-04	2.06E-03	1.88E-03	6.12E-04	8.89E-04
	DGrd	4.22E-02	1.55E-02	3.77E-03	1.17E-02	3.83E-03	8.45E-04	6.57E-03
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	6.86E-02	2.51E-02	5.75E-03	1.92E-02	7.05E-03	1.73E-03	9.86E-03
Oil spill in tonnes	Collis	2.70E+01	4.57E+00	1.24E+00	2.09E+01	2.58E-01	1.37E-02	4.79E-02
	Struc	8.91E+01	1.56E+01	1.56E+00	7.15E+01	3.36E-01	1.76E-02	6.10E-02
	FEX	5.59E+01	9.69E+00	1.37E+00	4.45E+01	2.94E-01	1.54E-02	5.34E-02
	PGrd	8.90E+00	1.19E+00	4.22E-01	6.10E+00	1.05E+00	7.21E-02	6.34E-02
	DGrd	2.67E+02	4.42E+01	1.36E+01	2.06E+02	2.47E+00	1.37E-01	4.44E-01
	PPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	4.48E+02	7.52E+01	1.82E+01	3.49E+02	4.40E+00	2.56E-01	6.70E-01

Proposed route 2025- Sotra								
		Total	frequency	Area:	3			
Total accidents		Total	CTank1	GTank2	OTank3	Cargo6	Other7	Other8
	Collis	2.21E-0:	2.76E-03	4.27E-03	2.61E-03	3.00E-03	6.27E-04	8.78E-03
	Struc	3.22E-0:	4.75E-03	7.61E-03	4.41E-03	5.12E-03	1.04E-03	9.28E-03
	FEX	2.82E-0:	4.15E-03	6.66E-03	3.85E-03	4.48E-03	9.10E-04	8.12E-03
	PGrd	8.93E-0:	2.33E-02	7.56E-03	1.89E-02	1.78E-02	5.94E-03	1.57E-02
	DGrd	1.73E-0:	2.28E-02	3.01E-02	2.15E-02	2.37E-02	5.63E-03	6.88E-02
	PPlat	0.00E+0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	3.44E-0:	5.78E-02	5.62E-02	5.13E-02	5.41E-02	1.42E-02	1.11E-01
Spill accidents	Collis	4.46E-0:	1.18E-03	1.08E-03	9.66E-04	2.99E-04	6.28E-05	8.78E-04
	Struc	8.63E-0:	2.77E-03	2.10E-03	2.21E-03	5.11E-04	1.04E-04	9.27E-04
	FEX	7.55E-0:	2.43E-03	1.84E-03	1.94E-03	4.48E-04	9.10E-05	8.11E-04
	PGrd	8.93E-0:	2.33E-03	7.55E-04	1.89E-03	1.78E-03	5.94E-04	1.57E-03
	DGrd	3.02E-0:	7.55E-03	6.51E-03	6.30E-03	2.37E-03	5.63E-04	6.88E-03
	PPlat	0.00E+0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	5.97E-0:	1.63E-02	1.23E-02	1.33E-02	5.41E-03	1.42E-03	1.11E-02
Oil spill in tonnes	Collis	1.37E+0	1.98E+00	1.88E+00	9.73E+00	1.18E-01	6.40E-03	3.04E-02
	Struc	5.76E+0	9.30E+00	3.72E+00	4.43E+01	1.97E-01	1.05E-02	3.23E-02
	FEX	3.68E+0	5.78E+00	3.26E+00	2.76E+01	1.72E-01	9.14E-03	2.83E-02
	PGrd	5.83E+0	6.57E-01	2.73E-01	3.76E+00	9.85E-01	6.89E-02	8.17E-02
	DGrd	1.11E+0	1.56E+01	1.17E+01	8.23E+01	9.84E-01	5.88E-02	2.44E-01
	PPlat	0.00E+0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	DPlat	0.00E+0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Total	2.25E+0	3.33E+01	2.09E+01	1.68E+02	2.46E+00	1.54E-01	4.17E-01

Appendix 10: Risk assessment of alternative tanker routing. Report from DNV

Safeguarding life property and the environment safeguarding life property and the environment safeguarding



Det Norske Veritas

Risk Assessment of Alternative Tanker Routing

for

Norwegian Centre for Transport Research

DNV Project No. 24427562
Revision 2 – 22 January 2010

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MANAGING RISK

Executive Summary

The Norwegian Centre of Transport Research (NCTR) is leading a study to assess the risk reduction benefit of deep sea routing for oil tankers off the coast of Norway. NCTR contracted Det Norske Veritas (DNV) to perform the detailed risk analysis calculations because of DNV's considerable experience in marine risk assessment. This document reports the results of DNV's work.

Four distinct situations ("Cases") were evaluated as follows:

- Case A: This used marine traffic patterns from the year 2008 and the present tanker routes.
- Case B: This used marine traffic patterns from the year 2008 and the proposed new tanker routes.
- Case C: This used estimated marine traffic patterns for the year 2025 and the present tanker routes.
- Case D: This used estimated marine traffic patterns for the year 2025 and the proposed new tanker routes.

DNV calculated the following results for these 4 cases:

- The frequency of serious accidents for all ship types and all accident types.
- The frequency of cargo and bunker oil spilling accidents for oil tankers and chemical tankers (cargo spills only) and for bunker spills (all ship types).
- The risk of cargo oil spills (for oil tankers and chemical tankers) and bunker oil spills (all ship types).

Marine accident risks are expressed in terms of the expected (average) quantity of oil (cargo or bunker) lost from containment per year.

All results were obtained in both tabular form and in terms of the geographical positions of higher risk locations.

NCTR was responsible for all data collection tasks associated with this work, and were also responsible for interpreting the results of the risk assessments. DNV was responsible for checking the input data, presenting the input data into the risk model, data and results handling, and for generating the output tables and plots.

Finally, this report provides *examples* of the types of information generated by the risk modelling work. NCTR has been provided by email with many more detailed results (tables of results and plots) than those presented in this report. *The information in this report should not be interpreted without reference to these additional results.*

Contents

1. INTRODUCTION

1.1 Background

Commercial shipping results in a range of impacts to the wider environment, due to the intended routine release of materials such as exhaust gases, and of risks to the environment due to the potential unintended release of materials as a result of accidental events. Unfortunately shipping accidents can result in very severe impacts, particularly to coastal regions, due to the potential release of very large quantities of hazardous or ecotoxic cargo materials, such as crude oil, during accidents to shipping.

Prudent authorities which have the responsibility for pollution response in coastal regions seek to understand the risks to which they may need to respond in order that appropriate contingency plans and response options may be identified prior to an accident occurring. Prompt and effective spill response is considered to be a very important mitigation measure to reduce the environmental impacts if an accident occurs.

The Norwegian Centre of Transport Research (NCTR) is leading a study to assess the risk reduction benefit of alternative (deep sea) routing for oil tankers off the coast of Norway. NCTR contracted Det Norske Veritas (DNV) to perform the detailed risk analysis calculations because of our considerable experience in marine risk assessment. This document reports the results of DNV's work which, in turn, will be an input into the report written by NCTR.

1.2 Scope and Objective

The scope of this work is confined to the release of the following materials from ships due to accidental events:

- Crude oil and refined products carried as cargo by tankers.
- Bunker fuel oil carried by all ships.

Accidents in port approach and port areas are excluded from the scope of this work. The shipping patterns and other input data are characteristic of shipping operations in the year 2008. Shipping patterns (similar to today and new routes) have also been estimated by NCTR for the year 2025. The risks evaluated are restricted to the risks to the marine environment due to the accidental release of cargo oils and bunker fuel into the sea; human fatality and any other types of risk are excluded from the scope of this work. The risks to the marine environment are evaluated in terms of the frequency and quantity of material released into the environment. That is, DNV has not performed dispersion modelling or made estimates of the relative ecotoxicity of different materials within this report. Finally, an assessment of residual risk acceptability is also excluded from the scope of this work.

The objectives of this work are:

- To determine the risk benefit for deep water routing of oil tankers in 2008.
- To estimate the risk benefit for deep water routing of oil tankers in 2025.

DNV understand that this report will be an input into the wider project programme that is being performed and co-ordinated by NCTR. It was agreed that:

- NCTR would be responsible for all data collection activities and would provide all data to DNV.

- DNV would be responsible for entering the data into the marine risk model and calculating the results required.
- NCTR would be responsible for interpreting the results of the risk assessment.

This report describes the work performed by DNV.

2. RISK ASSESSEMNT APPROACH AND METHODOLOGY

2.1 Introduction

The risk assessment process can be summarised by the following points:

- What can happen, or hazard identification;
- How often will it happen, or accident frequency analysis;
- How bad will it be, or accident consequence analysis;
- Where is it likely to happen, which supports accident contingency planning;
- What can be done to stop it, or risk reduction analysis;
- Are risk reduction measures worth it, or cost benefit analysis;
- Are the residual risks, after the application of the selected risk reduction measures (if any) acceptable, or risk acceptance criteria.

DNV's project scope mainly addresses the first 4 points and explicitly excludes consideration of the last 2 points.

2.2 Hazard Identification

Analysis of historical ship accident data indicates that almost all open-water shipping losses (excepting causes such as war or piracy) can be categorised into the following generic accident types:

- Ship-ship collision: abbreviated by "collis";
- Powered grounding (groundings which occur when the ship has the ability to navigate safely yet goes aground, such as the *Exxon Valdez*): abbreviated by "PGrd";
- Drift grounding (groundings which occur when the ship is unable to navigate safely due to mechanical failure, such as the *Braer*): abbreviated by "DGrd";
- Structural failure/ foundering whilst underway: abbreviated by "Struc";
- Fire/ explosion whilst underway: abbreviated by "Fex";
- Powered ship collision with fixed marine structures such as platforms or wind turbines (similar definition to powered grounding): abbreviated by "PPlat";
- Drifting ship collision with fixed marine structures such as platforms or wind turbines (similar definition to drift grounding) : abbreviated by "DPlat".

These generic accident types effectively represent the results of a high level marine transportation hazard identification (HAZID) exercise and are applicable for most marine transportation systems. DNV considers that this high level HAZID is sufficient for these risk calculations.

2.3 Risk Analysis Methodology

DNV has developed the Marine Accident Risk Calculation System (MARCS) to perform this type of calculation. MARCS is described in detail in Appendix I and the input data that is used by MARCS is shown in Appendix II.

This risk analysis methodology has been applied to the following ship types in this study, as described in more detail in Appendix II:

- Type 1: Chemical tankers and refined product tankers;
- Type 2: Gas tankers;
- Type 3: Oil (crude) tankers;
- Type 4: Not used;
- Type 5: Not used;
- Type 6: Cargo > 5000bt;
- Type 7: Other >5000bt;
- Type 8: All other.

Cargo oil spill risk is calculated from chemical tankers (Type 1) and oil tankers (Type 3). Bunker fuel oil risk spilt from bunker tanks (distinct from bunker fuel oil as a cargo) is calculated from all ship types.

2.4 Risk Analysis Results

The following types of results are presented in this report in Section 3 below:

- An analysis of traffic data in terms of:
    - Transits per day for each ship type (as defined within any one calculation location according to the key shown in Table 2.1). See Figure 3.1 as an example.
    - The total number of vessel-miles within the calculation area and within each defined sub-areas (see Figure 2.1). The sub-areas are defined to assist the additional analysis to be performed by NCTR.
- An analysis of total accident frequency (frequency of serious accidents per year but not necessarily involving cargo or bunker spill into the sea) in terms of:
    - The frequency of all accidents per year.
    - The total number of accidents per year as a function of vessel type and accident type within the calculation area and within each defined sub-areas (see Figure 2.1). The sub-areas are defined to assist the additional analysis to be performed by NCTR.
- An analysis of cargo oil or bunker oil spilling accident frequency (frequency of cargo or bunker spilling accidents per year) in terms of:
    - The frequency of all cargo oil or bunker oil spilling accidents per year (as defined within any one calculation location according to the key shown in Table 2.2). See Figure 3.2 as example.
    - The total number of cargo spilling accidents per year as a function of vessel type and accident type within the calculation area and within each defined sub-areas (see Figure 2.1). The sub-areas are defined to assist the additional analysis to be performed by NCTR.
- An analysis of cargo and bunker oil spilling accident risk (weight of cargo or bunker oil spilled into the sea per year) in terms of:

- The oil spilling risk of all accidents per year (as defined within any one calculation location according to the key shown in Table 2.3). See Figure 3.3 as an example.
- The cargo spill risk per year as a function of vessel type and accident type within the calculation area and within each defined sub-areas (see Figure 2.1). The sub-areas are defined to assist the additional analysis to be performed by NCTR.

Note that in this report the terms “cargo spill” or “cargo risk” also cover bunker fuel oil releases, though strictly bunker oil is not cargo.

See Appendix II for the definition of the terms study area and calculation location.

Table 2.1 Key to Ship Transit Plots

Colour	Transit Frequency (movements per day within each calculation location)
Grey	0.05 to 0.1
Cyan	0.1 to 0.5
Green	0.5 to 1
Yellow	1 to 5
Orange	5 to 10
Red	> 10

Table 2.2 Key to Accident Frequency Plots

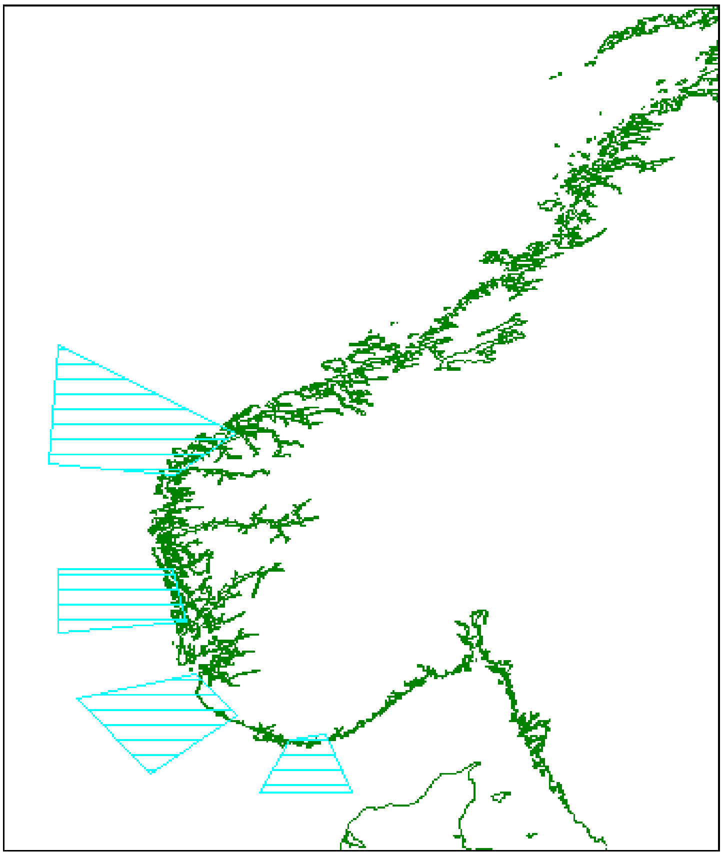
Colour	Accident Frequency (accidents per year within each calculation location)
Grey	1.0 E-08 - 1.0 E-06
Cyan	1.0 E-06 - 1.0 E-05
Green	1.0 E-05 - 1.0 E-04
Yellow	1.0 E-04 - 1.0 E-03
Orange	1.0 E-03 - 1.0 E-02
Red	> 1.0 E-02

Table 2.3 Key to Accident Risk Plots

Colour	Cargo Spill Risk (tonnes cargo spilt per year within each calculation location)
Grey	1.0 E-06 – 1.0 E-05
Cyan	1.0 E-05 – 1.0 E-04
Green	1.0 E-04 – 1.0 E-02
Yellow	1.0 E-02 – 1.0 E-01
Orange	1.0 E-01 – 1.0
Red	> 1.0

Note the terms study area (the total area under study), the study sub-areas (as defined in Figure 2.1) and the calculation location (each “pixel” of the calculation as determined by the calculation resolution) are described further in Appendix I and Appendix II.

Figure 2.1 Definition of Sub-Areas defined to aid the Analysis



It should be noted that 4 additional sub-areas were defined to enable the results to be presented in alternative ways. These additional sub-areas were requested by NCTR.

3. SUMMARY OF RISK RESULTS AND DISCUSSION

This section presents a summary of the results of the risk analysis for shipping in Norwegian waters. The complete risk results have been sent to NCTR by email.

3.1 Analysis of Traffic Data

Table 3.1 shows the analysis of the total traffic data (number of vessel miles per year) that is used as the basis of the risk results in this study.

Table 3.1 Analysis of Total Traffic Data (nautical miles per year) in the Study Area for each Case

	Case A	Case B	Case C	Case D
Chemical Tanker	9.58E+05	1.21E+06	1.42E+06	1.57E+06
Gas Tanker	3.27E+05	3.85E+05	1.45E+06	2.11E+06
Oil Tanker	6.09E+05	8.63E+05	9.03E+05	1.57E+06
Cargo	1.25E+06	2.21E+06	1.50E+06	2.73E+06
Other >5000bt	4.64E+05	6.91E+05	5.54E+05	8.17E+05
Other	4.43E+06	4.52E+06	4.02E+06	4.09E+06
Total	8.04E+06	9.88E+06	9.85E+06	1.29E+07

Table 3.1 indicates that a total of between 8 and 13 million ship-miles are travelled within the defined study area per year. Assuming an average ship speed of 12 knots, this corresponds to an average of about 95 ships in the study area at any one time. More detailed traffic results have been supplied by email.

Figure 3.1 shows the geographical distribution of all traffic types for Case A.

Figure 3.1 Example Ship Transit Plot for Case A excluding Traffic Type 8 (key in Table 2.1)

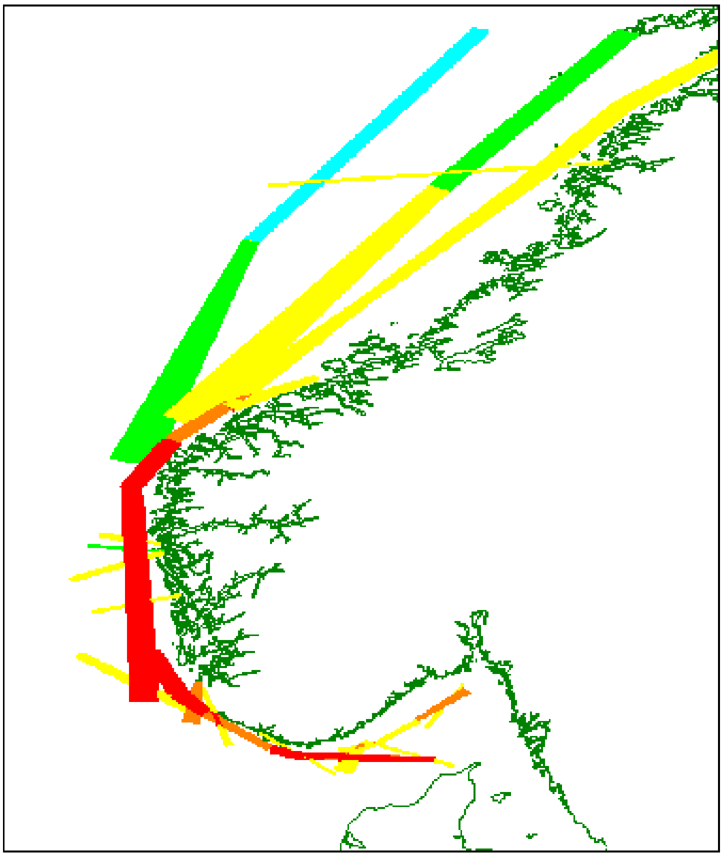


Table 3.2 summarises the traffic plots that were prepared and transmitted to NCTR.

Table 3.2 Definition of Traffic Plots Generated

	Plot File Names			
Plot Description	**Case A**	**Case B**	**Case C**	**Case D**
All traffic except Type 8	A-TraffAll.bmp	B-TraffAll.bmp	C-TraffAll.bmp	D-TraffAll.bmp
Traffic for chemical (Type 1) and oil tankers (Type 3)	A-Traf13.bmp	B-Traf13.bmp	C-Traf13.bmp	D-Traf13.bmp

3.2 Accident Frequency and Spilling Accident Frequency Results

Detailed accident frequency results have been sent to NCTR by email. These results include:

- Accident frequency (accidents per year) by ship type and accident type.
- Cargo and bunker fuel oil spilling frequency (spilling accidents per year) by ship type and accident type.
- Cargo and bunker fuel oil risks (average tonnes of oil lost from containment per year) by ship type and accident type.

Each of the above results are also shown by sub-area and by type of material spilt.

Figure 3.2 shows an example plot of the frequency of all cargo spilling accidents for chemical tankers (Type 1) and oil tankers (Type 3) combined for Case A. Similar plots for other cases were sent to NCTR by email.

Figure 3.2 Example Spilling Accident Frequency Plot for Case A (see Table 2.2 for key)

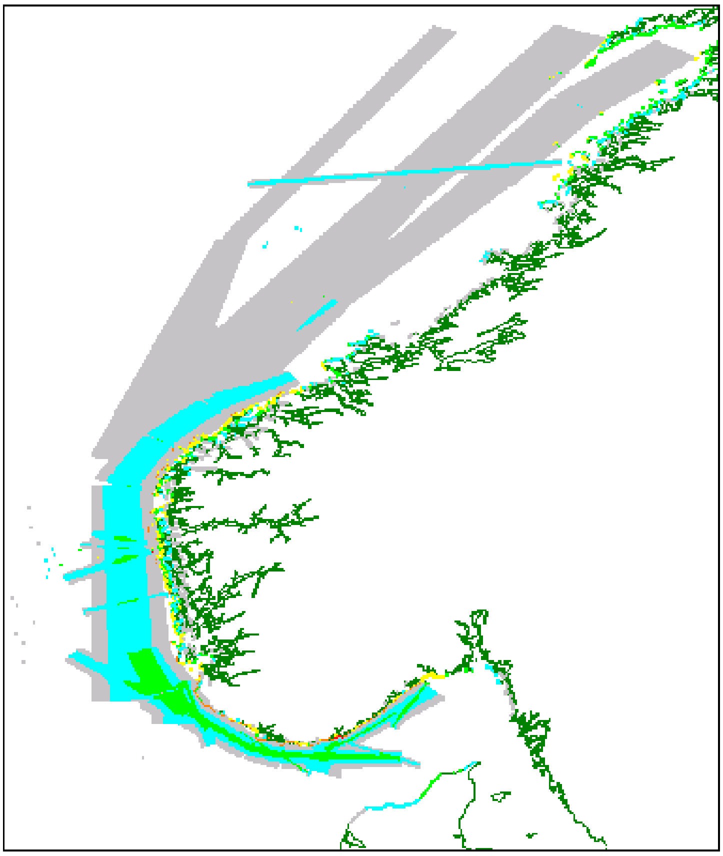


Table 3.3 summarises the spilling accident frequency plots that were prepared and transmitted to NCTR.

Table 3.3 Definition of Spilling Accident Frequency Plots Generated

	Plot File Names			
Plot Description	**Case A**	**Case B**	**Case C**	**Case D**
Bunker spills from all traffic plus cargo oil spill from chemical tankers (Type 1) and oil tankers (Type 3)	A-AllSpillFreq. bmp	B-AllSpillFreq. bmp	C-AllSpillFreq. bmp	D-AllSpillFreq. bmp

3.3 Cargo Spill Risk Results

Detailed accident risk results have been sent to NCTR by email. These results include:

- Cargo and bunker fuel oil risks (average tonnes of oil lost from containment per year) by ship type and accident type. These results are also shown by sub-area and by type of material spilt.

Figure 3.3 shows an example plot of the risk of all cargo spilling accidents for chemical tankers (Type 1) and oil tankers (Type 3) combined for Case A. Similar plots for other cases were sent to NCTR by email.

Figure 3.3 Example Accident Risk Plot of Cargo Oil Spilling Risk for Chemical Tankers and Oil Tankers for Case A (see Table 2.3 for key)

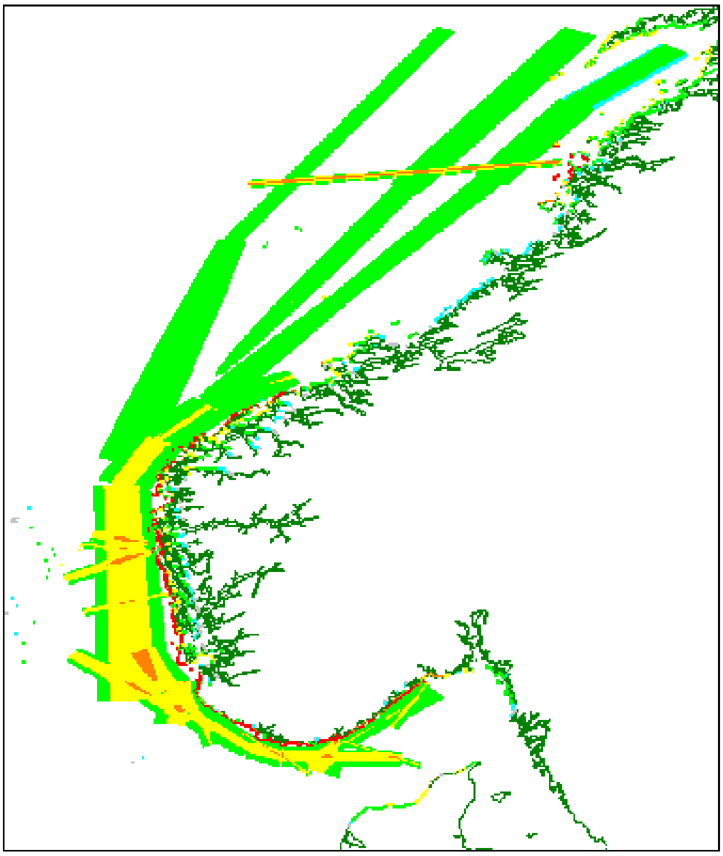


Table 3.4 summarises the oil spill accident risk plots that were prepared and transmitted to NCTR.

Table 3.4 Definition of Oil Spill Accident Risk Plots Generated

	Plot File Names			
Plot Description	**Case A**	**Case B**	**Case C**	**Case D**
Cargo oil spill risk from chemical tankers (Type 1) and from oil tankers (Type 3)	A-13Rsk.bmp	B-13Rsk.bmp	C-13Rsk.bmp	D-13Rsk.bmp
Bunker oil spill risk from all traffic types and cargo oil spill from chemical tankers (Type 1) and oil tankers (Type 3)	A-AllRsk.bmp	B-AllRsk.bmp	C-AllRsk.bmp	D-AllRsk.bmp

4. SUMMARY

A marine risk analysis of the Norwegian sector of the North Sea has been performed. The results show the relative risks for 4 different marine traffic scenarios.

This report provides *examples* of the types of information generated by the risk modelling work. NCTR has been provided by email with much more detailed results (tables of results and plots) than those presented in this report. *The information in this report should not be interpreted without reference to these additional results.*

NCTR was responsible for input data quality and for the interpretation of the results.

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