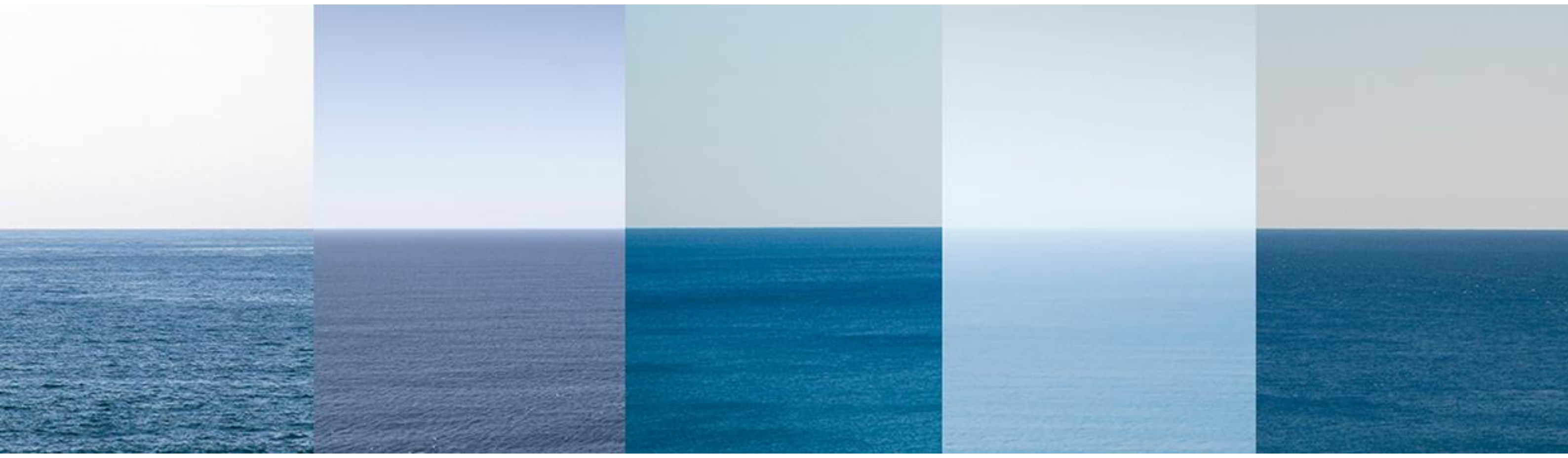

Pipeline Construction Risk Assessment – including North of Bornholm option

For Nord Stream 2

47127-RP-002

2	02/08/2018	Issued for Comment	DAR	FS	DAR
Rev	**Date**	**Document Status**	**Prepared by**	**Reviewed by**	**Approved by**

Nord Stream2 report No: W-OF-OFP-POF-REP-833-RABCNBEN-03

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DOCUMENT ISSUE RECORD

Rev	Date	Status	Prepared by	Reviewed by	Approved by
0	09/07/18	Issued for Comment	D Rankin	F Schlesinger	D Rankin
1	30/07/18	Issued for Comment	D Rankin	F Schlesinger	D Rankin
2	02/08/18	Issued for Comment	D Rankin	F Schlesinger	D Rankin

DOCUMENT CHANGE RECORD

Rev	Section(s)	Page(s)	Brief Description of Change
0			Original Issue to Client -
1			Revisions in accordance with track changes
2			Revisions in accordance with track changes

DOCUMENT HOLD RECORD

Section(s)	Page(s)	Brief Description of HOLD
		Rev 0 – No HOLDs
		Rev 1 – No HOLDs
		Rev 2 – No HOLDs

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1. SUMMARY

Overview

Nord Stream (NSP1) between 2010 and 2012 installed two 48 inch gas pipelines from Portovaya Bay in Russia to Greifswald in Germany and are now planning to install a further two pipelines. This new project is known as Nord Stream2 (NSP2) and the proposed pipeline route is approximately 1250 km long, with a maximum water depth of around 210m. The planned route crosses the territorial waters and Exclusive Economic Zones (EEZ) of Germany, Denmark, Sweden and Finland and the territorial waters in Russia.

Global Maritime has been requested to carry out a quantified risk assessment of the construction phase of the project, i.e. covering:

- Preparation of the landfall facilities including dredging.
- Pre-lay intervention works/rock placement including vessel loading operations.
- Pipe-lay including the pipe load out and transportation.
- Post-lay intervention works/ rock placement including vessel loading operations.
- Pre-commissioning operations.

It should be noted that this document represents GM's current understanding of the project based on available Company-provided information and does not in any way represent any firm commitments from NSP2.

The assessment considers risks as follows:

- Risk to humans: vessel crews, onshore crews, third party personnel i.e. on passing ships and onshore.
- Risk to the environment.

The tolerability criteria and risk assessment methodology are based on standard industry practice and guidelines developed by Det Norske Veritas (DNV-GL) and the UK Health & Safety Executive (HSE).

Project information and some risk related material have been obtained through reference to reports issued by NSP1 and NSP2, Saipem and Ramboll. In particular, the ship traffic risk assessment has been provided by Ramboll. Where possible up-to-date information has been obtained from NSP2 documentation and recent research publications, otherwise reference has been made to documents used for the risk assessment of the NSP1 pipelines.

This report includes a identified pipeline construction hazards and the corresponding quantitative risk assessment considered the following:

- Passing vessel collision with construction vessels.
- Vessel fire.
- Vessel grounding.
- Vessel sinking or capsize.
- Oil spills during bunkering operations.

- Helicopter accidents.
- Vessel position loss – moored and DP vessels.
- Dropped objects – (pipe joints).
- Dropped objects – (anchors)
- Tensioner failure
- A&R winch/wire failure.
- Diving operations.
- Munitions.

Risks to Third Party Personnel

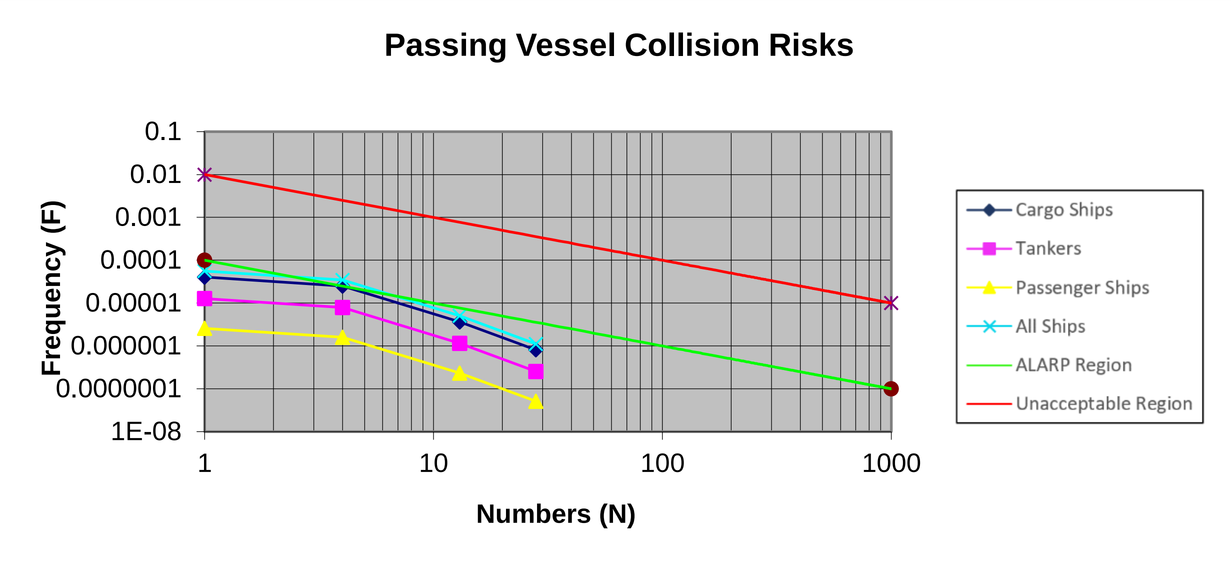
The quantitative assessment concluded that the individual risks to third party personnel are limited to passing vessel collisions and these are summarised in the table below. The individual risks per person per year are provided for the full extent of the pipeline route and for each country segment.

Ship Type	Russia	Finland	Sweden	Denmark	Germany	**Total**
Cargo	5.5×10^{-8}	3.5×10^{-7}	1.8×10^{-6}	1.0×10^{-6}	8.1×10^{-7}	4.0×10^{-6}
Tanker	1.4×10^{-8}	8.7×10^{-8}	4.6×10^{-7}	2.6×10^{-7}	2.0×10^{-7}	1.0×10^{-6}
Passenger	1.5×10^{-10}	9.7×10^{-10}	5.1×10^{-9}	4.4×10^{-9}	2.3×10^{-9}	1.3×10^{-8}
All vessels	6.9×10^{-8}	4.3×10^{-7}	2.3×10^{-6}	1.3×10^{-6}	1.0×10^{-6}	5.1×10^{-6}

The risks to third party personnel were found to be lower than the project tolerability criteria, where the relevant tolerability criteria are indicated below and further described in in section 5 (reference 4.3):

- Maximum risk of fatality for workers 10^{-3} per person per year.
- Maximum risk of fatality for the public 10^{-4} per person per year.
- Broadly acceptable risk 10^{-6} per person per year.

The group risks for third party personnel for the totality of the route are provided on the F-N curve below and it is noted that the risks to cargo ship crews are just inside the ALARP (As Low As Reasonably Practicable) region, which is defined by the red and green lines in the figure below.



Further details including group risks for each country are presented on separate F-N curves in the corresponding section 7.

Risks to Construction Personnel

The individual risks of personnel on the construction vessel are estimated for all potential emergencies and provided below, where all risks are lower than the tolerability criteria of 10^{-3} per person per year:

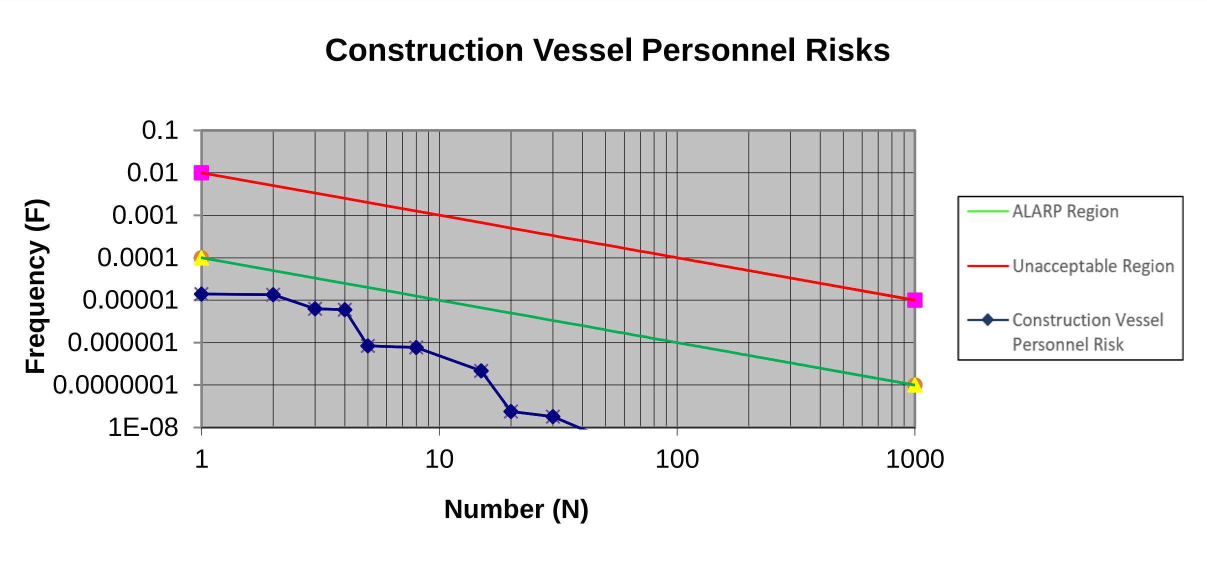
Pipe lay vessel (anchored)	1.9×10^{-5} per person per year.
DP Pipe lay vessel	6.9×10^{-5} per person per year.
Shallow water pipe lay	2.9×10^{-5} per person per year.
Pipe carrier	1.7×10^{-5} per person per year.
Anchor handler	6.2×10^{-6} per person per year.
Supply vessel	1.6×10^{-5} per person per year.
Rock placement	8.8×10^{-6} per person per year.
DSV	7.2×10^{-5} per person per year.
Trench support	1.0×10^{-6} per person per year.
Survey vessel	1.9×10^{-5} per person per year.
AWTI support vessel	5.3×10^{-5} per person per year.
Dredgers (landfall operation)	1.6×10^{-5} per person per year.
Diving operations	6.0×10^{-6} per person per year.

The individual risks for personnel on construction vessels are listed for each vessel type and per relevant country below, where the risk evaluation is based on the number of days vessels operate in the corresponding country sectors.

Vessel	**Russia**	**Finland**	**Sweden**	**Denmark**	**Germany**
Anchored Pipelay					1.9E-05
Anchor handler					5.8E-06
Pipe carrier					5.0E-06
Supply vessel					4.9E-06
DP1 Pipelay	6.6E-06	1.4E-05	3.5E-05	1.2E-05	9.4E-07
Pipe carrier	1.6E-06	3.5E-06	8.3E-06	2.9E-06	2.3E-07
Supply vessel	1.5E-06	3.4E-06	8.1E-06	2.9E-06	2.2E-07
DP2 pipelay		1.3E-05	3.2E-05	1.2E-05	1.2E-06
Pipe carrier		3.2E-06	7.7E-06	2.8E-06	2.8E-07
Supply vessel		3.1E-06	7.5E-06	2.7E-06	2.8E-07
Shallow water Pipelay	8.0E-06				2.9E-05
Anchor handler	1.7E-06				6.2E-06
Pipe carrier	1.5E-06				5.4E-06
Supply vessel	1.4E-06				5.3E-06
Rock placement	8.2E-07	5.5E-06	1.2E-06	1.2E-06	
Mattress installation	1.6E-05	1.6E-05	1.6E-05	9.1E-06	1.6E-05
Trencher			5.8E-07	4.2E-07	
Total IR	**3.9E-05**	**6.2E-05**	**1.2E-04**	**4.6E-05**	**9.9E-05**

Note: Each pipelay vessel is supported by pipe carriers, supply vessels and anchor handlers (where applicable) and these support vessels are assessed in groups defined by the bold borders.

The group risks for construction personnel are provided in the F-N curve below, where the risks are in the broadly acceptable region:



During the construction of line B, line A may be operating and the risk assessment considered potential damage to the line A from dropped pipe joints during loading operations. The risk of dropped object damage was found to be low but this depends on vessel size and with a pipe separation distance of 55 meters it may be necessary to consider loading to the side furthest away from the existing pipeline.

It should be noted that helicopter incidents also fall within the ALARP region. However, this is recognised as an oil industry issue and helicopter operations are carried out in accordance with specific standards and industry guidelines. It is understood that crew changes will be carried out by crew boat and/or helicopter and flights will be considerably fewer than for NSP1. However, provided industry standards are followed it is considered that the risks will be reduced to ALARP levels.

The risks associated with dumped munitions and chemicals are obviously of some concern, where it has not been possible to carry out a quantitative assessment due to the lack of statistical data. However, NSP2 carried out extensive surveys and the intention is to route the pipeline clear of any identified munitions. It is assumed that a munitions procedure will be developed and issued to vessel crews explaining the potential hazards and procedures in the event that munitions are encountered. Provided relevant precautions are taken, it is considered that munitions risks will be reduced as low as possible.

Environmental Risks

The findings of the environmental quantitative risk assessment for the whole route are indicated on the DNV-GL matrix below. No high risk events and only three medium risk were identified. Environmental risks per relevant country are provided in section 7.

Consequences		**Probability** (increasing probability from left to right)			
Descriptive	**Environment**	**Remote** **(< 1.0 x 10^{-5}/y)**	**Unlikely** **(1.0 x 10^{-5} – 1.0 x 10^{-3} /y)**	**Likely** **(1.0 x 10^{-3} – 1.0 x 10^{-2} /y)**	**Frequent** **(1.0 x 10^{-2} – 1.0 x 10^{-1} /y)**
1 **Extensive**	Global or national effect. Restoration time > 10 yr				
2 **Severe**	Restoration time > 1 yr. Restoration cost > USD 1 mil.	**t, v,**	**d, e, f**		
3 **Moderate**	Restoration time > 1 month. Restoration cost > USD 1 K	**g, u, w, x**	**c, h, i, j, k, m, n, o, q, r, s**		
4 **Minor**	Restoration time < 1 month. Restoration cost < USD 1 K		**a, b, l, p,**	**y, z, aa**	
HIGH	The risk is considered intolerable so that safeguards (to reduce the expected occurrence frequency and/or the consequences severity) must be implemented to achieve an acceptable level of risk; the project should not be considered feasible without successful implementation of safeguards				
MEDIUM	The risk should be reduced if possible, unless the cost of implementation is disproportionate to the effect of the possible safeguards				
LOW	The risk is considered tolerable and no further actions are required				

The three medium risks that were identified are: d = 3rd party vessel collision 100 – 1,000 t oil spill; e =3rd party vessel collision > 10,000 t oil spill and f = DP Pipelay collision 750 – 1,250 t oil spill.

These risks are all related to passing vessel collision and collision risk reduction is required to minimise the potential for environmental damage.

Helcom data from 1988 – 2009 indicates that the largest recorded spill in the Baltic Sea was 2,700 t and the estimates above are considered to be conservative.

The Ramboll report on accidental oil spill (reference 6.9) estimated that for any spills occurring in the mid Baltic Sea it would take approximately 48 hours for the oil to reach the coastline, while in coastal areas such as Bornholm this time would obviously be less. It will therefore be necessary to quickly respond to any oil spills. The construction vessels are all required to have SOPEP emergency oil spill procedures and equipment on board.

However, SOPEP kits rarely include provisions for volumes beyond a minor spill (tier 1) and therefore NSP2 has requested that all marine contractors have plans to deal with Tier 2 and Tier 3 spills, through agreements with suppliers of oil spill response equipment.

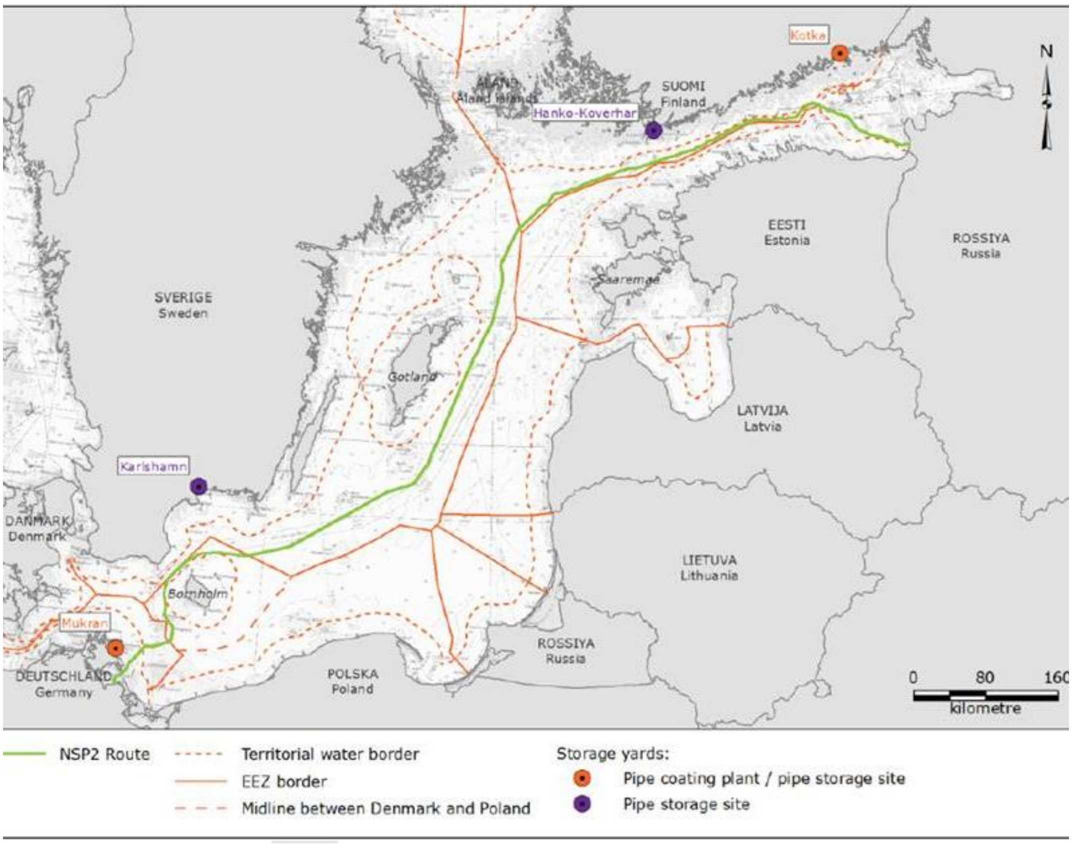
2. INTRODUCTION

2.1 Introduction

2.1.1 The NSP1 pipelines have been operating since 2011 and consist of two 48” diameter lines with a throughput capacity of 55 billion cubic metres/year. Its route runs under the Baltic Sea from Narva Bay in Russia to the German coast in Greifswalder Bodden. The pipeline route is approximately 1250 km long with a maximum water depth of around 250 m. The route crosses territorial waters and Exclusive Economic Zones (EEZ) of Germany, Denmark, Sweden and Finland and the territorial waters of Russia. The risks associated with the reference route South of Bornholm are assessed in Report W-OF-OFP-POF-REP-833-CONRISEN-04 Construction Risk Assessment, this report includes the route North of Bornholm.

2.1.2 NSP2 AG has now been established to construct further two pipelines with the same capacity as NSP1.

2.1.3 The pipeline route is shown below:



2.1.4 The project schedule is currently planned as follows:

- Start of offshore construction lines A and B — 3rd quarter 2018
- Completion of line A — 3rd quarter 2019
- Completion of line B — 4th quarter 2019

- Pre-commissioning line A	3rd quarter 2019
- Pre-commissioning line B	4th quarter 2019

2.1.5 The scope of the present work is to carry out a quantified risk assessment of the construction phase of the NSP2 pipelines project. The assessment covers the whole construction phase of lines A and B including:

- Preparation of the landfall facilities.
- Pre-lay intervention works/ rock placement including vessel loading operations.
- Pipe-lay including the pipe load out and transportation.
- Post-lay intervention works/ rock placement including vessel loading operations.
- Pre-commissioning operations.
- Post lay ploughing operations.

2.1.6 The assessment considers risks as follows:

- Risk to humans: vessel crews, onshore crews, third party personnel i.e. on bypassing ships and onshore.
- Risk to the environment.

2.1.7 The assessment has also considered damage to line A while line B is being installed as line A may be under pressure at this time.

2.1.8 It should be noted that this document represents GM's current understanding of the project based on available Company-provided information and does not in any way represent any firm commitments from NSP2.

2.1.9 Abbreviations

AIS	Automatic Identification System
A&R	Abandonment and recovery
AHT	Anchor handling tug
ALARP	As low as reasonably practicable
ARPA	Automatic Radar Plotting Aid
AUT	Automated Ultrasonic Testing
AWTI	Above water tie-in
BHD	Backhoe Dredger
CB	Cargo Barge
DGPS	Differential global positioning system
DP	Dynamic positioning
DSV	Dive Support Vessel
EIA	Environmental impact assessment
EPC	Engineering, Procurement and Construction
FEED	Front End Engineering and Design
FMEA	Failure modes and effects analysis

GM	Global Maritime
GPS	Global positioning system
HDPE	High density polyethylene
HELCOM	Helsinki Commission (Governing body of the Convention on the Protection of the Marine Environment of the Baltic Sea Area)
HPD	Hopper Barges
ICES	International Council on Exploration of the Seas
ISPS	International Ship and Port Facility Security Code
MBES	Multibeam Echo Sounder
NDE	Non-destructive examination
NEXT	Nord Stream Extension
NSP1	Nord Stream Project 1
NSP2	Nord Stream Project 2
PHV	Pipe Haul Vessel
PLB	Pipelay Barge
PSV	Platform Supply Vessel
PT	Pull Tug
PR	Piling Rig
PRS	Pipeline Repair System
RDV	Rock Placement Vessel
ROV	Remotely operated vehicle
SB	Supply Boat
SBV	Standby Vessel
SHD	Suction Hopper Dredger
SOPEP	Shipboard Oil Pollution Plan
SSS	Side Scan Sonar
SSV	Subsea Support Vessel
SV	Survey Vessel
TAC	Total allowable catch
TEN – E	Trans European Energy Network
TMS	Tug management system
T & I	Transportation and installation
UXO	Unexploded ordnance
VTS	Vessel traffic system.

2.2 Assumptions

2.2.1 The main vessels involved in the pipe lay operations are assumed to be:

- Anchored pipe lay vessel
- Dynamic positioning (DP) pipe lay vessel
- Shallow water anchored pipe lay vessel
- Pipe carriers and supply vessels
- Anchor handling tugs (AHT)
- Rock placement vessels
- Dive support vessel (DSV)
- Dredging vessels
- Survey vessel

2.2.2 Vessel personnel numbers are assumed as follows:

- Pipe lay vessel 300
- Shallow water pipe lay 200
- Anchor handling tug, supply vessel and pipe carrier 15
- DSV and trench support vessel 100
- Rock placement vessel 20
- Cargo ships 20
- Tankers 25
- Passenger ships/Ferries 450
- Dredging personnel 10
- Survey Vessel 40

2.2.3 Vessel durations on site are based on the current project construction schedule and are summarised below

Country	Vessel/Line	Days in 2018	Days in 2019
Russia			
KP 0 to KP 13	Shallow water P/L (A & B)		26
KP 13 to KP 114	DP1 (A)	29	
KP 13 to KP 114	DP1 (B)		28
Finland			
KP 114 to KP 474	DP1 (A)	108	
KP 114 to KP 300	DP1 (B)		61
KP 300 to KP 499	DP2 (B)		56

Country	Vessel/Line	Days in 2018	Days in 2019
Sweden			
KP 499 to KP 1000	DP1 (A)		147
KP 499 to KP 1000	DP2 (B)		136
Denmark			
KP 1000 to KP 1177	DP1 (A)		52
KP 1000 to KP 1177	DP2 (B)		49
Germany			
KP 1177 to KP 1192	DP1 (A)		43
KP 1177 to KP 1192	DP2 (B)		5
KP 1192 to KP 1237	Anchored	88	1
KP 1237 to KP 1264	Shallow water P/L (A&B)	95	00
Total vessel days			
Shallow water P/L		**95**	**26**
DP1 (A)		**137**	**292**
DP2 (B)			**246**
Anchored Pipelay		**88**	**1**

2.2.4 Durations for other construction vessels are as follows:

- Trench support vessel 48 days
- Rock placement 213 days
- DSV 110 days (mattress installation cable crossings)
- AWTI support vessel 168 days

2.2.5 Bunkering frequencies are assumed to be:

- Pipe lay vessel twice a week
- AHT once every six weeks

2.2.6 It is understood that crew change will be by boat and helicopter. For this assessment it is assumed that helicopter crew change will take place once a week with a flight duration of one hour. Helicopter capacity is taken as 15 persons. It is noted that no helicopter changes will be carried out in Russian waters.

3. PROJECT OVERVIEW

3.1 General

3.1.1 This section has been included to provide an overview of the project and some of the construction vessels and equipment that may be used for the various activities. As project procedures have yet to be developed most of the information and figures are based on procedures used for the installation of NSP1 pipelines. Other references have been noted in the text.

3.2 Pipeline Route

3.2.1 During the feasibility study (reference 3.1) for the NEXT project three main reference routes were evaluated from Russia to Germany.

3.2.2 The outcome of the feasibility study led to the development of a reference route which served as the basis for the development of the NSP2 budget and timeline estimate. The Reference Route was defined considering the following:

- Follows existing NSP1 pipelines as far as possible;
- Is deemed a feasible route technically and environmentally;
- Reflects the lowest risk at the current stage.

3.2.3 A re-routing in Danish waters may become necessary, which leads to the routing North of Bornholm considered in this report.

3.2.4 The Reference Route corridor is approximately 1250 km long and is a combination of mainly the FS (Originate in Russia, routing through Finland in the Gulf of Finland, then through Sweden and Denmark to Germany), and the ES (Originate in Russia, routing through Estonia in the Gulf of Finland, then through Sweden and Denmark to Germany) route corridors as evaluated during the Feasibility Study.

3.2.5 The route starts at a landfall in the Narva Bay area and crosses both the existing NSP1 pipelines and the deep water shipping lane in the Russian sector. It then moves into Finnish waters and passes through the Gulf of Finland before entering the Swedish EEZ in the northern part of the Baltic Proper to the north and west of the existing NSP1 pipelines.

3.2.6 The route then crosses the NSP1 pipelines and proceeds through the Swedish EEZ to the east and south of the existing pipelines. At this point, the route is east of the existing NSP1 pipelines and west of the shipping lane as it heads south through the Baltic Proper. Once it has passed the Hoburgs Bank nature reserve, it remains to the east of the NSP1 pipelines, and turns south west heading towards Bornholm.

3.2.7 As it runs towards the southern part of the Baltic Proper, it again crosses the NSP1 pipelines, and passes north and west of Bornholm. It leads through the deep-water route, passes along the one-directional lanes inside the separation zone in the middle of the TSS, and exits the TSS through the precautionary area. The route then heads south east to cross Ronne Bank before turning towards Germany and the landfall at Lubmin.

3.2.8 The proposed lay zones are currently designated as follows but may change as detailed engineering is carried out:

- Lay Zone 1 (KP 13 – 300)

- Lay Zone 2 (KP 300 – 675)
- Lay Zone 3 (KP 675 – 1250)

3.2.9 The gas export pipeline system, has separate anchor corridors for each pipeline route centred on the respective optimised route centrelines, defined as Line A and Line B. Survey data provided by NSP2 indicates that the horizontal separation between lines is as follows:

Separation between NSP1 and NSP2 lines:

- 500m where routes run in parallel (apart from crossings)

Separation between the NSP2 lines:

- Varies from approximately 25m to 105m

3.2.10 On NSP1 it was found that in some locations in the Finnish sector it was not possible to lower the DP system taut wire clump weights. This was due to concerns that the pre-lay survey did not cover these locations and there was a risk of UXO contact. It is recommended that taut wire clump weight requirements are taken into consideration during the route survey planning.

3.3 Technical Design

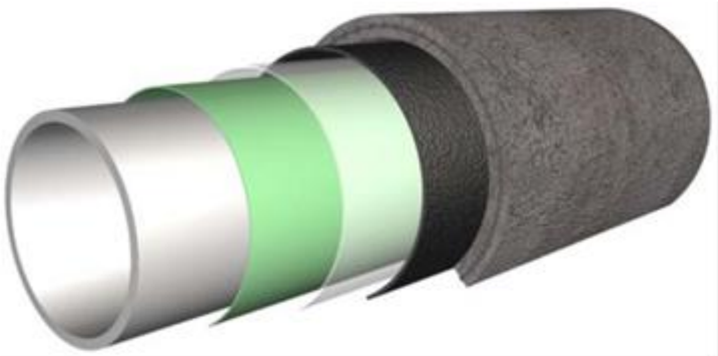
3.3.1 The technical details of NSP2 pipelines are similar to NSP1 pipelines and are indicated in (reference 3.3). The pipelines are divided into three pressure segments according to the pressure drop along the pipelines. The kilometre point (KP) refers the location on the pipeline starting from the Russian landfall at KP 0. Each pipeline will consist of welded steel pipes that are protected with anti-corrosion coating and concrete weight coating.

3.3.2 The pipelines will have a constant inner diameter throughout their length in order to facilitate maintenance operations. The outside diameter will vary due to a combination of varying wall thickness of the steel pipe and varying thickness of the concrete weight-coating, which has been determined based on requirements for pressure containment and stability over the length of the pipelines. The maximum outer diameter of the pipelines will be approximately 1.5 m. To reduce the risk of pipe collapse during construction, buckle arrestors (pipe reinforcement) will be installed in susceptible areas at specific intervals. The buckle arrestors will be welded onto the pipelines through those areas that are susceptible to propagation buckling, i.e. deeper sea areas. The buckle arrestors will be manufactured in the same steel alloy as the pipelines and will be equal in length to the pipe joints but will have a greater wall thickness and machined thinner wall ends.

Property	**Value**
Capacity	55 bcm/y (27.5 bcm/y per pipeline)
Gas	Dry, sweet natural gas
Design pressure	KP 0 – KP 300: 220 barg KP 300 – KP 675: 200 barg KP 675 – KP 1250: 177.5 barg
Design temperature	-10 to +40 °C

Property	Value
Operating temperature	-10 to +40 °C
Design life	50 years
Inner diameter of steel pipe	1,153 mm
Wall thickness of steel pipe	26.8, 30.9, 34.6 or 41.0 mm
Thickness of concrete coating	60 – 110 mm

3.3.3 The bare steel pipe will be coated internally with epoxy flow coating to reduce friction and hence the pressure loss. It will be coated externally with FBE, 3LPE (polyethylene) and with concrete which provides additional weight so the pipe remains stable on the seabed. Both ends of the pipe are kept free of concrete coating so that the joints can be welded offshore. These field joints are corrosion protected after welding by the application of a field joint coating and HDPE foam which is injected into the field joint void. An example of the various layers of pipe coating is shown below.



3.4 Environmental Conditions

3.4.1 A considerable amount of metocean data was obtained for NSP1 and it has been proposed that this will be updated with hindcast models and direct measurement as described in reference 3.4. However, it is noted that the checks carried out during the NEXT feasibility phase showed that the updates were found to be in broad agreement with those from NSP 1 and measured data.

3.4.2 Long term weather data for NSP2 is reported in the project Metocean Design Basis (reference 3.5) which was issued in May 2016. This report provides extensive data on wind, waves and currents. Wave basic data has been entirely derived from the new DHI's Metocean hindcast (covering the period 1979 to 2014). The new DHI's hindcast has been derived from NCEP Climate Forecast System (CFS) and it entirely substitutes the older BALSEA database (used for NSP1 project) which was no longer maintained since 2007. Current basic data have been extracted from the original dataset used for NSP1 and only partially from the DHI operative model. Some of this data is included in this general overview of Baltic Sea weather conditions.

3.4.3 The general climate varies between a relatively mild maritime climate associated with a westerly air flow and the continental extremes of Russia with very cold winters and very hot summers. Fog is most common in winter and early spring and least common in summer.

3.4.4 The frequency of winds of force 7 and above (30 kts, Hs 4.0m) is between 12% and 14% of the time in winter and between 1% and 3% in the summer. Winds prevail predominantly from the SW but also prevail from the NE during high pressure over N. Scandinavia. Sea waves are generated by the wind and the frequency is therefore almost the same as for gales. Some of the roughest seas are experienced in the E of the area with persistent W to SW winds and in the SW with E to NE winds.

3.4.5 Currents in the area are generally weak except when affected by strong winds. In light conditions there is a weak anti-clockwise circulation with rates less than 0.25 knot setting SW near the Swedish coast and NE near the Polish coasts. In the Gulf of Finland the current sets E near the Estonian coast and W near the Finish coast. In general, persistent strong to gale force winds blowing along the length of the Baltic can increase surface currents to 1 to 2 knots.

3.4.6 NSP2 environmental data collection and analysis along a number of points on the route indicates that extreme weather conditions are as follows:

Wind	100 year return	30.65 m/s
	10 year return	27.90 m/s
Wave	100 year return	9.42m Hs
	10 year return	8.23m Hs
Currents	100 year return	2,1 knots
	10 year return	1.3 knots

Note: 10 year and 100 year current data is taken from NSP1 environmental report.

3.4.7 Tidal range is general very low; however, considerable differences in sea level can be caused by strong winds, variation in atmospheric pressure and the seasonal changes in the amount of water brought down by the rivers. A combination of these effects raises or lowers the level of about 0.6 m from the mean although at times this can be greater.

3.4.8 In the winter fog and poor visibility are more frequent in coastal waters than over the open sea due to the lower coastal temperatures and the ice edge. In early winter and late spring sea fog tends to form near the ice edge with mild S to SW winds. Fog frequency in the open sea reaches a maximum between late April and early June. In March and April the percentage frequency of visibilities less than 1 mile is around 25% in the NE of the area, the S tip of Gotland and near the coast of SE Sweden and around 10% elsewhere. In July and August the figures are around 10% and 2% respectively.

3.4.9 In the summer air temperatures over the sea range from around 17° C and in coastal areas up to 30° C. In the winter the air temperature falls to around 2° C in the SW and -2° C in the NE of the area with extremes as low as -15° to -22° C in the NE.

3.4.10 Severe ice conditions are characteristic of the Gulf of Finland and generally appear in the eastern part of the Gulf at the beginning of December and in the central and western parts in January. Ice starts melting around the third week in March or first week in April. In a severe season, ice cover is around 24% of the Gulf during December, reaching 100% in February, March and April and dropping to 13% at the beginning of May. In a milder season, ice cover is around 10% of the Gulf during December reaching 80% in February and dropping to 4% at the beginning of May.

3.5 Munitions and Chemicals

3.5.1 A considerable amount of chemical and explosive munitions has been dumped in the Baltic since the end of the Second World War. Information on locations of chemical dumps has been obtained by the Helsinki Commission in 1993 (reference 3.6). Some dump sites have been formally identified at Bornholm and to the South East of Gotland and some information is available on the location of mine fields. There are also indications that munitions were dumped outside the official dump sites. However, information on other 'formal' sites in the Baltic Marine Area has never been verified.

3.5.2 Fishermen in the Baltic have reported occasionally catching munitions in their gear, the number of which peaked in 1991. This implies that the number of munitions caught in nets is decreasing, even so 25 'catches' were reported in 2003.

3.5.3 A considerable amount of survey and analysis was carried out for NSP1 and this included:

- Pipeline route surveys in 2005, 2006, 2007 and 2008;
- Anchor corridor survey in 2008 and 2009;
- Mine clearance activities carried out by Bactec and the Russian authorities;
- Evaluation of survey results by a number of UXO experts.

3.5.4 The conclusions of the evaluation were:

- None of the inspected objects had been moved by underwater currents nor affected by bottom trawling.
- No buried UXOs were found.
- Disposal was recommended for a number of targets.
- Re-routing as a means to avoid munitions in the Gulf of Finland is not a realistic solution.
- Munitions clearance is required for up to 20 objects within the construction corridor.
- Up to 300 munitions could be expected within the anchor corridor.
- There is a risk that the sweep of the anchor wires could encounter munitions.

3.5.5 During NSP1 the following munitions were located and removed from the German landfall section:

- 4 x 500kg glider bombs (German) / 1 not recovered
- 1 x 7.5 cm grenade (French)

- 1 x 8.8 cm grenade (German)
- 1 x 15 cm grenade (German)
- 1 x 10.5 cm grenade (German)

3.5.6 Further clearance operations have been carried out by the combined navies of the area and these have been mainly concentrated in Estonian waters. The most recent clearance operation took place in September 2006 and the fleet comprised 26 mine clearance measures (MCM) vessels, 4 support ships, 4 drones and mines clearance teams from 14 nations.

Country	Number of Identified Munitions	Types of Munitions
Finland	31	26 mines, 1 possible mine, 2 possible air dropped depth charges, and 2 obstructer mines
Sweden	1 (2)	1 mine, 1 corroded bomb (non-explosive)
Denmark	3	3 chemical munitions
Germany	0	No munitions finds

3.5.7 In consultation with the responsible authorities NSP2 is now establishing procedures for the safe handling of all objects that have to be disposed of before construction work can start.

3.5.8 It is noted in the Helcom report that no munitions found in the Baltic have ever been unintentionally detonated nor has there been any accident during the handling of munitions found in the area (reference 3.8).

3.5.9 Saipem have carried out an assessment of the safety distance between the NSP2 pipelines and any UXO which could be detected on the seabed (reference 3.6). The assessment identifies SLS and ULS which are defined as follows:

The Service Limit State (SLS) is the distance at which the pipeline wall is not damaged as a result of the explosion.

The Ultimate Limit State (ULS) is the distance at which the pipeline wall faces significant plastic strain but wall tearing, or gas release does not occur as a result of the explosion.

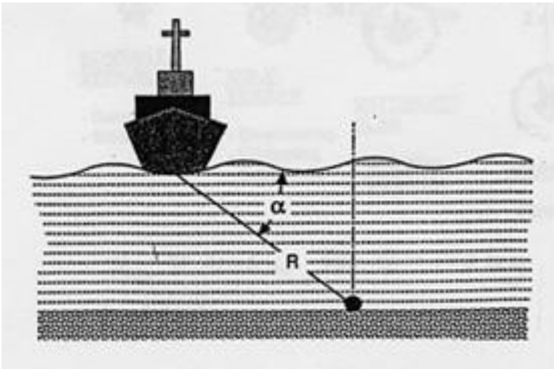
3.5.10 The results are presented for various wall thicknesses and concrete weight coating to provide the NSP2 engineering team with relevant guidance. Typical examples include:

UXO Mass (free water)	ULS Safe Distance	SLS Safe Distance
20 kg	2.0 m	9.0 m
600 kg	7.0 m	30.0 m

3.5.11 Although the probability of accidental disturbance of munitions is considered to be low, a NSP1 survey report (reference 3.10) states that:

- There is no measurement method available that guarantees a clear seabed to a depth of 2 m below the seabed.
- There is no 100% certainty that all munitions will be located.

3.5.12 It will therefore be necessary to implement mitigation measures during construction activities. The main precaution will be to ensure vessels are located a safe distance (R in figure below) from a potential UXO and typical offset ranges are shown in the table below. It is noted that the maximum size munitions object encountered during these surveys so far is estimated to be 320 kg of TNT.



3.5.13 The relationship between charge size, range and damage potential is listed in the following table:

200 kg TNT	800 kg TNT	
Range (**R**)	Range (**R**)	Damage potential
>47m	>94m	None or very limited risk for damage to damaged components
35 – 47m	71 – 94m	Minor displacements of plate steel. Damage to lightweight components.
24 – 35m	47 – 71m	Increasing displacement of steel plates. Impact damage of heavier components.
<=24m	<=47m	Risk for collapse of hull and water intake. Steel thickness = 6 mm
11 – 24m	22 – 47m	High risk for total damage of vessel. Vital components, hull collapse, water intake.
<=11m	<=22m	Risk for collapse of hull and water intake. Steel thickness = 15 mm

3.5.14 Ramboll investigated issues related to chemical warfare agents that were dumped in the Baltic (reference 3.11) and reports that the risk to personnel is almost exclusively related to the possible contact with lumps of viscous mustard gas. Crews of fishing vessels could be in danger from mustard gas or chemical warfare agents if these items were caught in trawls and brought to the surface. It is also noted that pipe lay operations in the Irish Sea, disturbed phosphorous devices which subsequently floated to the surface and posed a risk to seafarers and the general public. The general policy advocated by relevant authorities is to leave dumped munitions on the seabed where they pose no risk.

3.5.15 To evaluate the potential for contamination related to the remains of Chemical Warfare Agents (CWA) a number of seabed surveys and soil samples were carried out and soil samples were taken in Danish waters.

3.5.16 These results concluded that there was an indication of a diffuse low level of background contamination as expected given the history of the area.

3.5.17 The implications of these results were that:

- As the area is extensively trawled it is likely that accumulations of chemicals (e.g. mustard gas residue) will have been spread around the seabed.
- There is a risk that anchor wires may become contaminated with chemicals when they sweep across the seabed.
- There is a risk that in the event of a temporary pipe laydown the laydown head may be contaminated and precautions will be required for recovery.
- There is a risk that laydown on a curved section of the route may be outside the detailed survey corridor.
- The installation contractor must address this risk and have the necessary precautions in place.

3.5.18 The precautions taken in NSP1 included:

- Availability of relevant PPE on the pipelay, trenching and AHT vessels;
- Preparation of chemical control procedures on these vessels;
- The use of specialist contractor to monitor and clean plough during trenching operations;
- Monitoring of anchors before recovery to AHT decks.

3.5.19 As a result of these precautions no UXO or chemical incidents were experienced during NSP1. However, in the Finnish sector there were a number of locations where the DP taut wire clump weights could not be deployed as they had not been covered in the UXO survey. As a result there was a potential for a reduction in DP reference system redundancy; it is understood that the NSP2 survey scope will be adjusted to mitigate this issue.

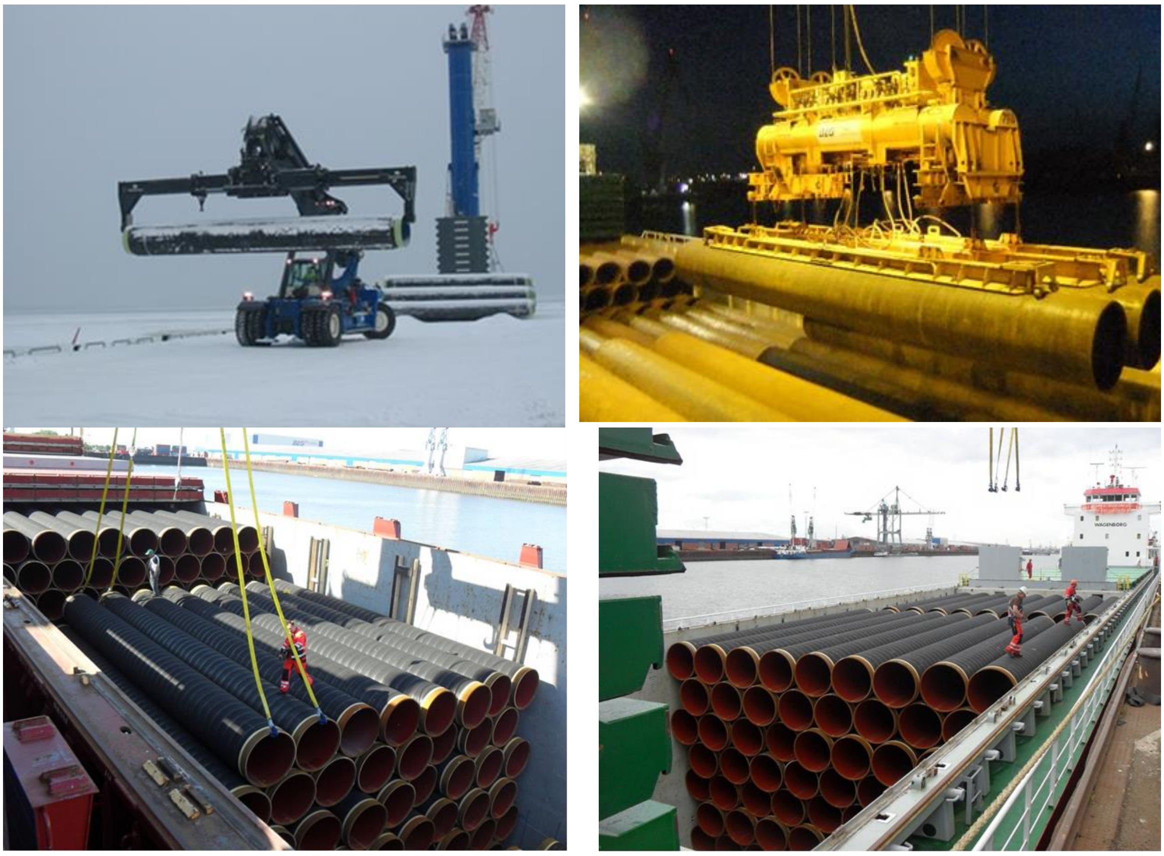
3.5.20 Contact with UXO is still a possibility and the potential hazards to construction vessels are discussed in section 6.11.

3.6 Pipe Logistics

3.6.1 Pipe logistics will be broadly similar to those developed for NSP1.

3.6.2 Pipe transport to the pipe lay vessels will be carried out by pipe carriers and general cargo vessels. Pipes will be stocked in four ports, Mukran, Karlshamn, Hanko-Koverhar and Kotka. These are shown in the figure above, see section 2.1.3.

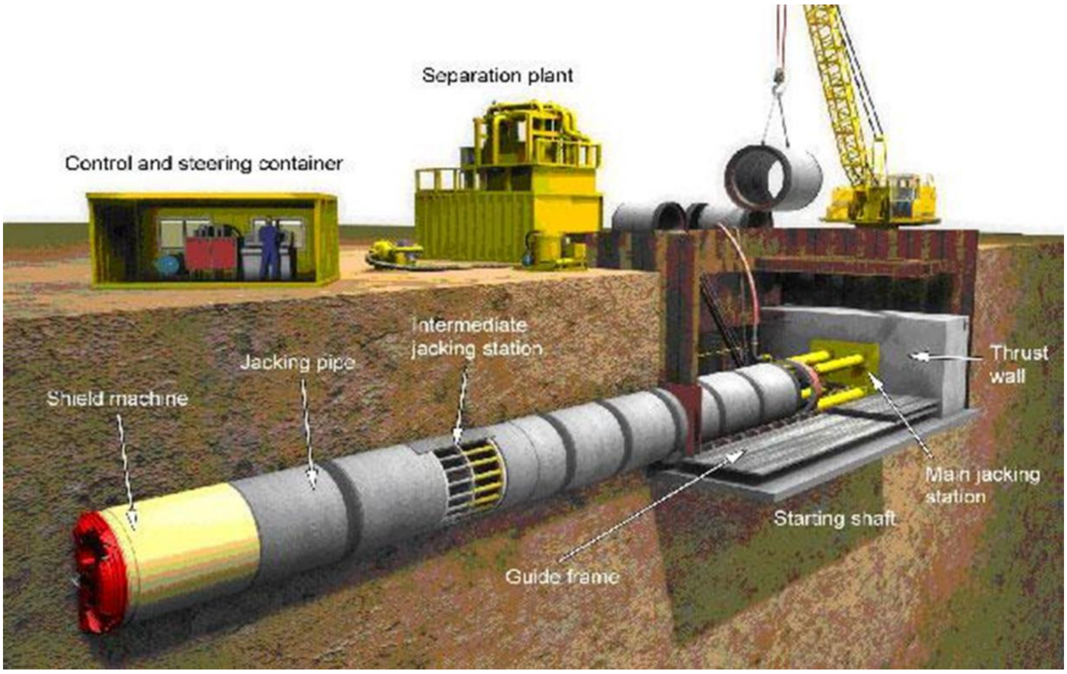
3.6.3 Pipes will be loaded onto the vessels at the stock yards and the vessels will take approximately 10 hours to reach the pipe lay vessel where the pipe joints will be unloaded. Pipe handling and loading operations from NSP1 are shown below.



3.7 Landfall Preparation

3.7.1 A micro tunnel installation method is used for the German landfall and the open trench method is used for the Russian landfall.

3.7.2 The micro tunnel method uses specialised equipment to drill and push the pipe tunnel from the shore out to the landfall approach area. The method has been used to successfully install a 48” pipeline, out to a distance of 1,400m from the shore. A general arrangement of the system is shown in the following figure:



3.7.3 The onshore work includes the preparation of a jacking shaft to allow the installation of the tunnel boring machine, pipe jacking equipment and concrete pipe sections. As the tunnel is bored sections of concrete pipe are inserted into the pipe string until the tunnel section is complete. The tunnel boring machine is recovered by a support vessel at the micro tunnel entrance in a pre-dredged area. The pipe pull-in wire is installed through the tunnel which is then flooded prior to the pull in operation.

3.7.4 The shallow water pipe lay vessel connects the pull-in wire to the initiation head offshore and starts the lay operation using normal start up pipelay procedures until the initiation head is pulled through to the tunnel. The vessel then lays away along the pre-cut trench.

3.7.5 On NSP1 each pipeline was laid in a single pre-cut trench running from the end of a cofferdam in KP 1220 out to KP 1194. The trenches were excavated by backhoe and trailing hopper dredgers using the box-cut method to minimise the volume of material to be dredged. The excavated soil was transported on barges to a dumping ground for temporary storage or permanent disposal depending on soil type. After pipeline installation the trenches were filled up with soil from the dumping ground, this was carried out by trailing suction hopper dredgers or barges. On NSP2 it is understood that a cofferdam will not be used and the trenches will be backfilled first with engineered backfill until 'top of pipe' on the entire trenched route.

3.7.6 On NSP2 the shallow water section will be approximately 30 km in length with a maximum water depth of 18m. The Pomeranian Bay section will be approximately 55 km in length with water depths varying from 15m to 30m.

3.7.7 The preparation of the German landfall site was subject to a number of restrictions as it is located in an environmentally sensitive area (Natura 2000 Flora-Fauna Habitat FFH). These restrictions included a limit on the amount of seabed material that can be excavated at any one time as well as limits on light and noise.

3.7.8 The Russian landfall site will be located in Narva Bay as shown below and will extend out to KP 13. It will be based on the open cut method with a coffer dam extending to KP 0.30 and a trench extending to KP 3.3.

3.7.9 From KP 0.2 to KP 3.3 the pipelines will be installed in the nearshore and onshore section by conventional open cut method and laid in a single trench supported by sheet pile walls on either side in the shallowest area from KP -0.1 to KP 0.3 , corresponding to approximately 2.0m WD. The open cut trench will extend to KP -0.2 where the pulling winch will be located. The centre line spacing of the pipelines will be 6m and the water depth increases gradually to 11.5m

3.7.10 From KP 3.3 to KP 13 the pipelines will lie on the seabed, un-trenched and the centreline spacing of the two pipelines shall be 75m. The water depth gradually increases to 25m through this section.

3.7.11 It is understood that the Russian landfall site will be prepared using conventional equipment and methods and will require the following activities:

- The excavation of a trench from the beach out towards the pull-in location.
- Construction of a cofferdam.
- Installation of pull-in winches and foundations onshore.
- Backfilling of the trenches.
- Removal of cofferdam and site clearance.

3.7.12 The trenches will be deep enough to allow the float out of the pipe and constructed by earth moving equipment onshore and back-hoe dredgers in the near shore area.

3.7.13 Typically a high capacity (600 tonne) linear winch and associated equipment will be set up on the shore and the pull-in cable run out to the lay barge moored offshore. Buoyancy tanks are also prepared for attachment to the pipe to enable it to float out over the shallow section.

3.7.14 The NSP1 scope of works included a survey vessel, two backhoe dredgers and two suction hopper dredgers. A team of divers was required to assist trench excavation and pull-in activities.

3.7.15 The Russian landfall for NSP1 is shown in the figure below. This shows the earth dams either side of the trench.

3.7.16 In NSP2 the Russian landfall in Narva Bay is in a nationally protected Nature Reserve, and a registered Ramsar wetlands site, so the same restrictions discussed here for the German landfall will be applied in Russia. It is noted that the end of nature reserve is at 10m water depth, about 2.5 km offshore.

3.7.17 The scope of work for NSP2 pipelay at landfall Russia is provided in report reference 3.12. Site preparation includes:

- Preparation of access ways for transportation of equipment and materials.
- Installation of pull-in winches and foundations onshore.
- Construction of drainage systems.
- Installation of cofferdam.
- Removal of cofferdam and site clearance.

3.7.18 Following the removal of the cofferdam sheet piles and associated temporary equipment, backfilling was carried out to restore the seabed to its original condition prior to the construction works.

3.7.19 Additional rock placement may be required at the coastline transition zone of the pipelines to prevent degradation of pipeline cover due to coastal erosion.

3.8 Shore Pull and Shallow Water Pipe lay

3.8.1 In Germany a micro tunnel will be used while in Russia a 300m-500m long by 10m wide cofferdam will be used. However, the shallow water lay in Germany is considerably longer than in Russia and subject to strict environmental constraints. In both locations lines A and B will be installed during the same period, to minimise the environmental disturbance.

3.8.2 The shore pulls in Germany and Russia will be carried out from anchored pipe lay vessels. In Germany there will be a 1.1 km pull into a micro tunnel for each line followed by approximately 26.5 km lay and laydown in 18m water depth. The pipe lay vessels will be moored approximately 1 to 1.5 km from the shoreline depending on vessel under keel clearance and pulling cables will be run from the shore along the trench and connected to the pipeline pulling head. The shore end of the cable is connected to linear winches, which are tensioned up to pull the line ashore. This operation will be repeated for both pipelines.

3.8.3 For NSP1 construction the loads were limited to 500 tonnes at the German and Russian ends through the use of buoyancy modules attached to the pipe. These forces were provided by linear winches secured at the shore side of the landfall. The pull-in force is likely to be less in Germany due to the pull into the micro tunnels.

3.8.4 Following the shore pull, the pipe lay will be initiated by the inshore pipe lay vessel out to a water depth of approximately 18m in Germany and 25m at KP 13 in Russia. Tensioner loads for this section, have been analysed and found to vary from 40 to 100 tonnes.

3.8.5 In the Russian landfall, the pipe lay vessel will then lay the pipe out to KP 10, and lay it down and buoy it off for recovery at a later date. This will then be repeated for the second pipeline.

3.8.6 The pipe lay at the German landfall, was complicated by the environmental restrictions associated with its FFH status which extends out to KP 1194. It is not known if these restrictions have changed materially for NSP2 and this information is based on the restrictions applied to NSP1.

3.8.7 Due to the environmental restrictions the maximum amount of material that can be excavated at any one time is approximately 1.0 million m^3 and as a result the shallow water lay will be carried out in ten separate phases. There is also a requirement to remove the topsoil before excavation and then backfill it after the section of pipe has been laid. The sequence for each section is:

- Excavate seabed.
- Lay line A and B sequentially.
- Backfill and even out seabed material.
- Backfill and even out seabed topsoil.

3.8.8 Following completion of the shallow water lay a laydown head will be welded to the pipe which is then laid down ready for an above water tie-in or recovery by the main pipe lay vessel.

3.8.9 There will possibly be up to 8 above water tie-ins (AWTI): However, at this stage the details of the AWTIs have not been defined. It is assumed that above water tie-ins will be carried out by a shallow water pipe lay vessel.

3.8.10 The shore pull arrangement is indicated in the figure below which shows the shore mounted linear winch and control cabin.

3.8.11 Anchor handling operations in the German landfall and shallow water pipe lay sections is complicated, due to the numerous wrecks that need to be accounted for, and will involve:

- The addition of polypropylene ropes to the mooring line segments.
- The movement of mooring wires over water including the use of mid line buoys.
- The use of live anchors;
- The use of very shallow draft AHT or Multicats.

3.8.12 The lay rate for shallow water lay is likely to be in the order of 1 km/day depending on the vessel capabilities and the limitations described above.

3.9 Offshore Pipe lay

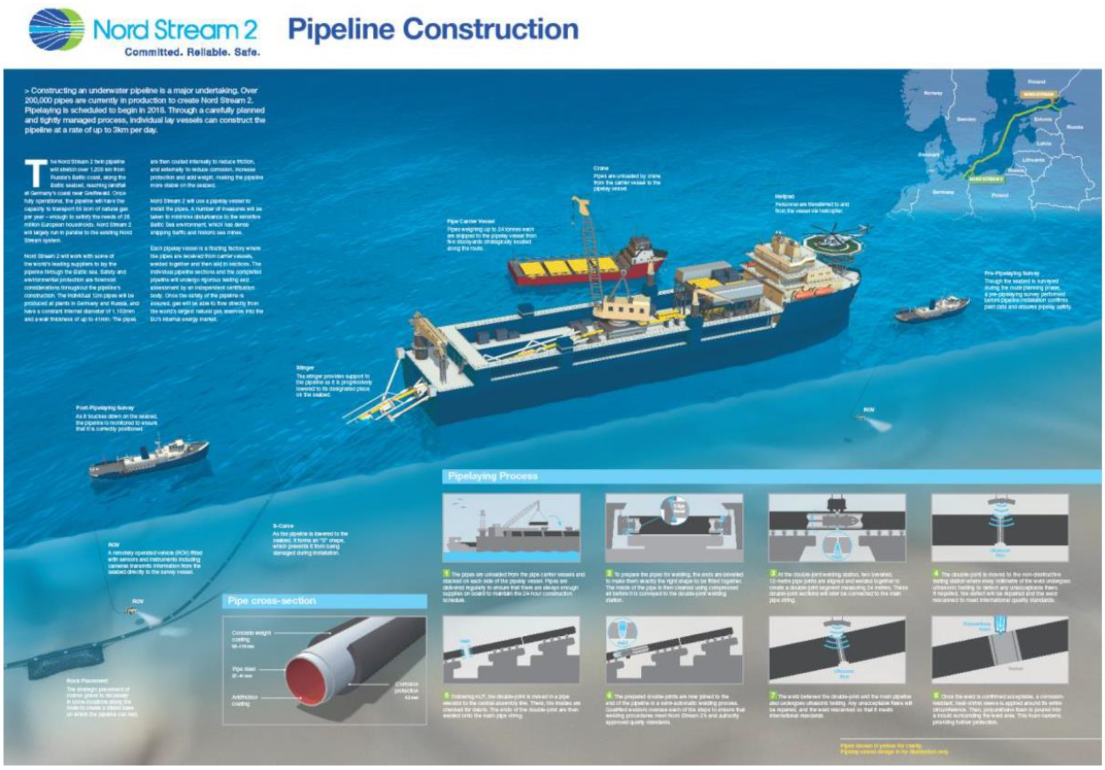
3.9.1 Pipe-laying will be performed using a conventional S-lay process where the individual line pipes are assembled into a continuous pipe string and lowered to the seabed. The pipeline is exposed to different loads during the installation that must be controlled by the installation vessel. An installation analysis is conducted to simulate the conditions during pipe lay to ensure that the load effects are within the design strength criteria of the specific pipe, and the capabilities of the lay vessel.

3.9.2 A typical S-lay system has four main components:

- The stinger which extends the pipe ramp to reduce the length of the over bend. The over bend usually starts behind the tensioners and describes the curve under which the pipe string enters the water.
- The tensioners, which reduce the stresses in the over bend and the sag bend. The sag bend describes the bending under which the pipe string is laid on the seabed.
- The positioning system (anchors or DP), which controls the vessels position. The vessel position must be kept under the specified tension needed to keep the sag bend within the bending limitations of the pipe. The positioning system also ensures the pipeline is laid within its approved corridor on the seabed.

- Abandonment and Recovery (A&R) winch which is used to lay down and recover the pipe line at the end of the pipe lay or in the event of adverse weather. To lay down the pipe the A&R wire is connected to the abandonment or laydown head and the wire lowered as the vessel moves ahead in a series of controlled steps. This is continued until the laydown head lands on the seabed. Pipe recovery is achieved by lifting the A&R wire in a reverse of the laydown sequence.

3.9.3 The process on board the pipe lay vessel comprises the following general steps, which take place in a continuous cycle and are illustrated in the diagram below:



- Beveling of pipe
- Welding of pipe.
- Non-destructive examination (NDE) of welds.
- Weld repairs if necessary.
- Field joint coating.
- Laying on seabed.

3.9.4 The welding of new pipe joints onto the continuous pipe string is performed using either a semi- or fully automated welding process in several stations along a compartment known as the firing line.

3.9.5 Field-joint welds are checked using NDE by automatic ultrasonic testing (AUT) which is used to locate, measure and record defects. Welding-defect acceptance criteria will be established prior to the start of construction and are subject to approval by designated certifying agencies.

3.9.6 After welding and NDE, the field joints are protected against corrosion through the application of heat shrink sleeves which are made of high density polyethylene. The void between adjacent joints is filled with high density polyurethane foam which is injected into a steel former strapped around the joint. The foam cures very quickly and the pipe is moved down the stinger and onto the seabed. The steel former is not removed from the field joint.

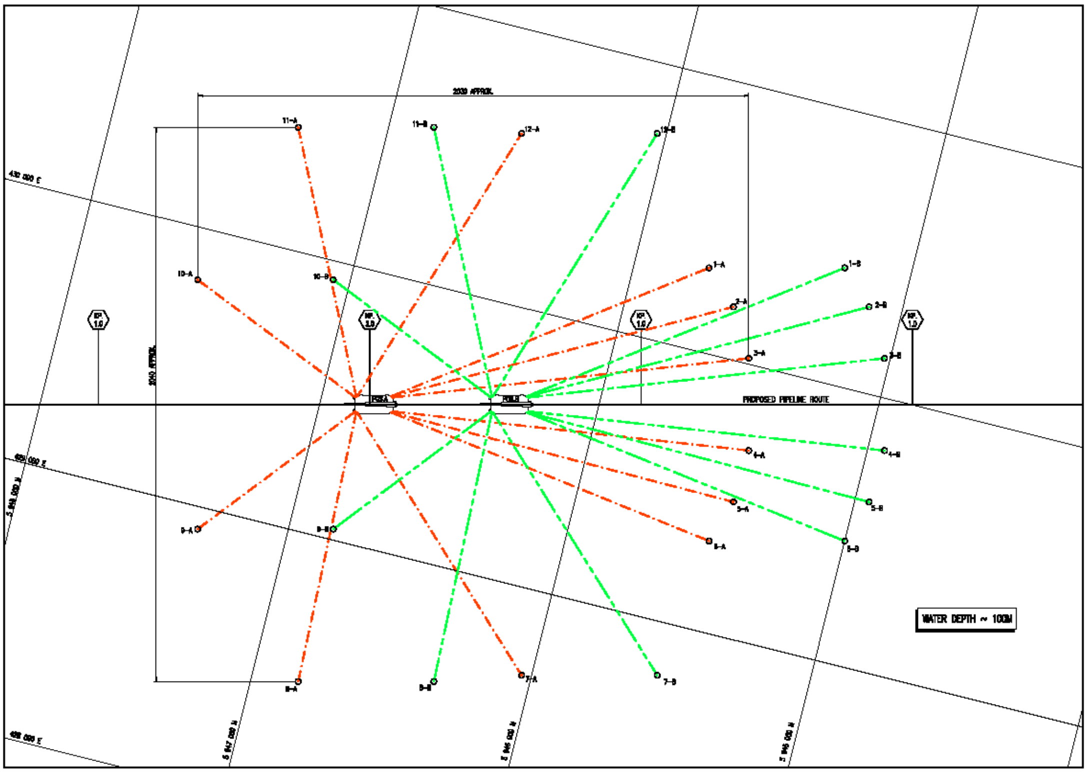
3.9.7 All critical processes on board the lay vessel will be inspected by the contractor's QA/QC crew and thereafter inspected by representatives of the Certification Company and NSP2.

3.9.8 When the jointing process is complete, the vessel is moved forward a distance corresponding to the length of pipe that is being laid, typically one or two pipe joints (12.2 or 24.4 m). Following this move, a new pipe joint(s) is added to the pipe string. Deepwater lay vessels are normally capable of welding double joints, prior to sending them to the firing line, whereas shallow-water lay vessels are only able to weld a single joint at a time.

3.9.9 As the lay vessel moves forward the pipe string exits the stinger of the vessel into the water. The stinger extends some 40 – 100 m behind and below the vessel and has the function of controlling and supporting the pipe configuration. The pipe string running from the stinger to the touchdown location on the seabed is kept under tension at all times, thereby avoiding the risk of buckling and damage to the pipe. A lay rate of between 1 and 4 km per day is expected, depending on type of lay barge and weather conditions experienced.

3.10 Anchor Handling Procedure

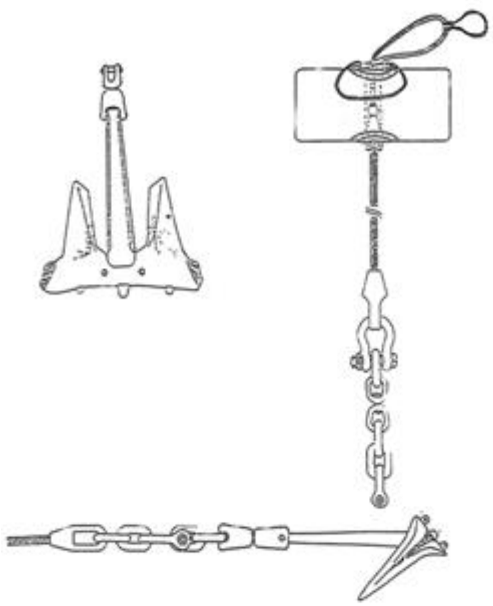
3.10.1 The anchored pipe lay vessels are positioned by a number of anchors and lines which are installed in a typical anchor pattern shown in the figure below.



3.10.2 The anchors are placed on the seabed by anchor handling tugs (AHT) which are equipped with winches and specialised equipment for this operation. The AHTs are also fitted with a DGPS based navigation system, known as a tug management system (TMS) which enables the anchors to be accurately installed in accordance with the pre-defined anchor pattern.

3.10.3 To install an anchor the AHT moves alongside the pipe lay vessel and loads the anchor with its pennant wire and buoy onto its deck. The anchor wire is then passed across to the AHT and secured to the anchor or to a deck fitting. The AHT proceeds to the drop location and lowers the anchor to the seabed by its pennant wire, once in position the pennant buoy is released.

3.10.4 As the pipe lay vessel advances along the route the anchors are recovered to the surface and relocated to a new position. This is carried out using the reverse of the procedure described above; the AHT picks up the pennant buoy, connects the pennant wire to its winch and lifts the anchor to the surface. The AHT then moves to the next location and repeats the operation. Typical anchor, pennant buoy and wire are shown in the figure below.



3.11 Pipe and Cable Crossings

3.11.1 NSP2 lines will cross the NSP1 pipelines in three locations and up to 68 cables depending on the final route selection.

3.11.2 The Sealion cable linking Finland to Russia is approximately 1100 km long and was installed in the spring of 2016. This runs parallel to the NSP2 pipelines but the minimum horizontal distance was not available at the time of writing this report.

3.11.3 The Baltic Connector pipeline will be installed between Finland and Estonia either in September/November 2018, or in June/July 2019 with the crossings located around global KP 256 in Finland. Depending on the schedule there is a possibility that there will be SIMOPS during the installation of NSP2.

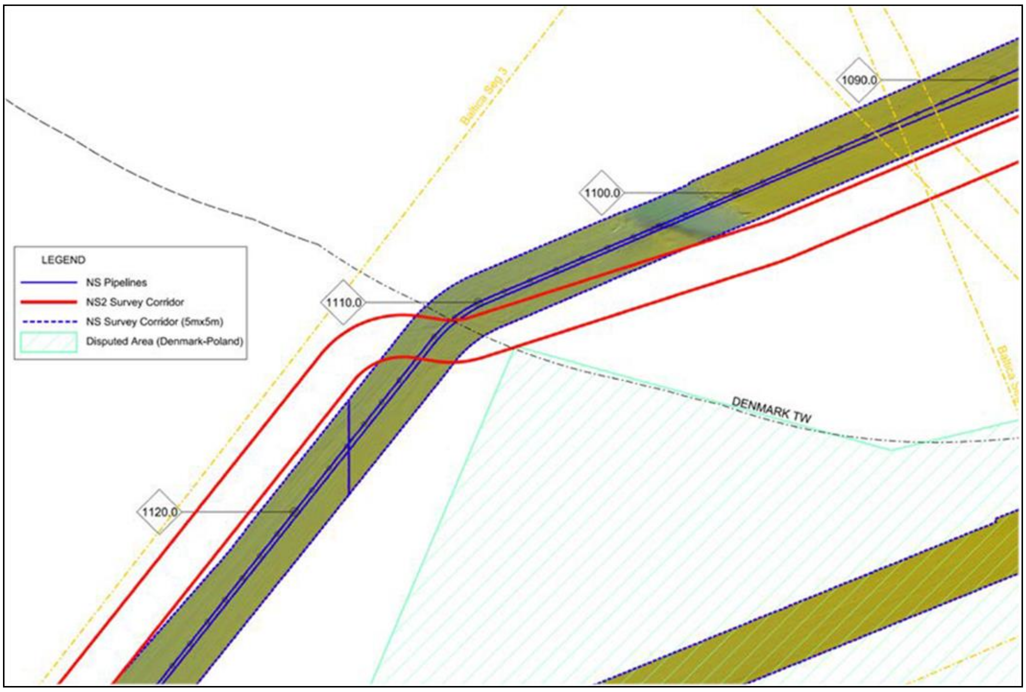
3.11.4 The methods used for cable crossings encountered during NSP1 are summarised below:

Cable Type	Crossing Method
Telecom cables	Protected by sleepers and mattresses as required. Installed by ROV.
Abandoned cables	Cut and removed if required.
Power cables	Protected by sleepers, rock placements and mattresses as required. Installed by ROV.
50 Hz cables	Protected by their burial depth

3.11.5 A concrete mattress is shown in the figure below

3.11.6 The pipe crossings will be in the Finnish, Swedish, and Danish sectors and an example is shown overleaf.

3.11.7 The pipe crossing designs have not been completed yet but typically they comprise a rock placement bridge over the existing pipeline to support the new pipeline and ensure a minimum separation of 0.3 m as defined by DNV-GL Submarine Pipelines Offshore Standard FS 101. The rock placement would typically be installed by a DP fall pipe vessel and it is evident that a considerable amount of material would be required for these crossings.



3.11.8 NSP2 intend to contact all cable owners prior to the pipe lay to agree on the crossing method, as well as discuss commercial and liability aspects of the crossing. This is standard industry practice, and the design and installation method of the crossings will not impose any restrictions to the normal operation of NSP1 Lines 1 and 2.

3.12 Pipe Laydown and Recovery

3.12.1 Lay down of the pipeline, also known as abandonment, may be necessary if the weather makes positioning difficult or causes too much pipe movement within the system. Abandonment of the string can also be a planned operation within the installation sequence, e.g. to change the pipe-laying vessel. Laydown is also possible if vessel breakdown occurs.

3.12.2 An abandonment and recovery head (A&R) is welded on the pipe string and lowered to the seabed by a wire connected to the A&R winch. A typical abandonment and recovery head is shown in the figure below.

3.12.3 Recovery is essentially the reverse operation of abandonment. The abandoned pipe is picked up by the lay vessel and retrieved back into the firing line by means of a wire connected to the A&R head and the A&R winch on the vessel.

3.12.4 The final lay-down of the pipeline in its defined target box is similar to abandonment; however, instead of a simple A&R head, a pipeline lay-down head is used. The laydown head could be either a pig launcher or receiver and final design will depend on the pre-commissioning strategy and selected pipelay sequence.

3.13 Above Water Tie-In

3.13.1 The above water tie-in (AWTI) technique is used to connect two pipe sections that have previously been laid down during various phases of the operation. There will possibly be 8 AWTIs: 2 at KP 13.0, 2 at the micro tunnel exit in Germany, 2 at KP 1197 and 2 at KP 1159. However, at this stage the details of the AWTIs have not been defined. It is assumed that above water tie-ins will be carried out by a shallow water pipe lay vessel. Due to the size of the pipe this method is only applicable for shallow water operations, in this case 10 to 30m water depth.

3.13.2 Above water tie-ins will be carried out by a construction vessel positioned over the tie-in location. The pipes to be connected will have been previously laid down (with an overlap of approximately 24 m) in the tie-in location target box. Buoyancy modules and lift rigging are attached to the pipe sections which are then raised by a number of davits in a controlled manner designed to keep pipe stress within allowable limits.

3.13.3 Once each pipe section is lifted above the water and suspended alongside the barge the work platform is raised and secured below the pipes. Pipe metrology is then carried out and the pipe ends cut back and prepared for the welding process. The pipe ends are then secured in a clamp so that a single butt weld can be carried out. On completion of the welding, inspection and coating operations the work platform is lowered clear of the pipe. The pipe is then lowered by the davits to the seabed by a series of controlled movements combined with movements of the barge to ensure pipe stress levels are kept within allowable limits.

3.13.4 On NSP2 due to the lay corridor width and associated tolerances, permitting etc the laydown of the pipe will not be in a lazy curve (omega profile), laterally offset from the route centreline for a distance slightly in excess of the water depth at the location of the above water tie-in. Post laydown stability/protection measures will include rock placement, concrete mattresses or similar.

3.13.5 Due to a change in schedule an AWTI was not carried out on NSP1. An above water tie-in is shown below:

3.14 Buckled Pipe Repair

3.14.1 A pipeline buckle can occur in the event of pipe lay system failure and the buckle repair procedure depends on whether the buckle is wet or dry. With a dry buckle the pipe is distorted but there is no ingress of water, whereas in a wet buckle the pipe is filled up with water.

3.14.2 With a dry buckle the general repair procedure is to attempt recovery of the pipe through the tensioners so that the damaged pipe can be cut back and normal lay resumed. In some cases it is not possible to pull the buckle through the tensioners and the pipe is then laid down on the seabed and treated as a wet buckle.

3.14.3 In the event of a wet buckle it is likely that the pipe tension would be too high to recover the pipe through the tensioners and it would then be laid down on the seabed. Due to the time required to prepare a repair operation the general approach is to continue the lay operation by initiating a new section of line next to the damaged section. At a later stage a midline hyperbaric tie-in would be carried out and this could be carried out by diver-assisted mechanised welding process. The subsea procedures have not been developed yet and will depend on whether the project complies with Norwegian or UK diving regulations. Norwegian regulations limit diving operations to 180 m while UK regulations would allow diving at 210 m. NSP2 will also include the requirements of the affected country regulations in their diving philosophy. In June 2016 PRS indicated that consultation is ongoing with the Norwegian Regulatory Authorities to extend the current limit for diver assisted operations in Norwegian Waters from 180m to 225m.

3.14.4 The raw seawater in the damaged line would need to be displaced by chemically treated seawater to provide internal corrosion protection. The duration that the pipe can remain filled with untreated water has not yet been determined but will obviously need to be considered when planning the repair operation. It is likely that a dewatering spread will be mobilised and remain on standby throughout pipe lay operations, however it is not possible to nominate its location at this point in time.

3.14.5 NSP1 is a member of the Statoil Administered Pipeline Repair and Subsea Intervention Pool, with the main base in Haugesund, Norway. The PRSI Pool is organised as a non-profit membership club that provides access for its members to a large pool of emergency preparedness equipment that allows fast response and repair of offshore pipelines. PRSI Pool has a number of frame agreements in place to serve urgent need by the members, including vessels, divers, engineering, fabrication and multi-disciplined specialist personnel. Mobilisation duration, based on equipment loaded / embarked on board Member's nominated (diving) support vessel or other transport means from PRSI Pool main Base (deep water quay), is in the order of 3 weeks.

3.14.6 The PRSI equipment was modified to handle the 48” diameter pipelines on NSP1. The successful hyperbaric tie-ins on NSP1 demonstrated the capability of the equipment designed for this purpose.

3.14.7 This repair method would possibly minimise any delay on the pipe lay operation as a lot of subsea preparation work could be carried out while the de-watering spread was prepared.

3.14.8 A further alternative is to complete laydown, cut the line subsea into manageable sections and move the damaged section aside from the lay corridor. Displace the seawater in the flooded the pipe section with treated seawater, using batch of pigs sent from the opposite end of the pipe section (e.g. temporary launcher head pre-loaded with suitably designed pigs) to ensure any debris that may have entered the pipe is removed and the line is inhibited sufficiently to restrict corrosion effects. Install a suitably designed Pipeline Recovery Tool (PRT) and then dewater the line though the PRT. The line can then be recovered by the pipe lay barge to restart pipe lay.

3.15 Pipe Trenching Operations

3.15.1 Details of NSP2 trenching operations are not yet available but will be similar to those used on NSP1.

3.15.2 The NSP1 pipelines were trenched in the near shore areas and a number of sections in the Danish and Swedish sectors. Dredging was used for pre-lay trenching in the near shore areas and a plough was used for post-lay trenching in a number of sections totalling approximately 100 km per line.

3.15.3 Trenching was carried out using the PL3 multipass plough which has a bollard pull capacity of 350 t. The PL3 was deployed from the Far Samson which is a purpose built support vessel with a maximum bollard pull of 432 t.

3.15.4 The PL3 plough incorporates a number of safety features such as load cells, cameras, sonar systems and depth control that allow the plough operator to monitor its progress. The equipment is also fitted with proximity sensors to detect potential contact with the pipe.

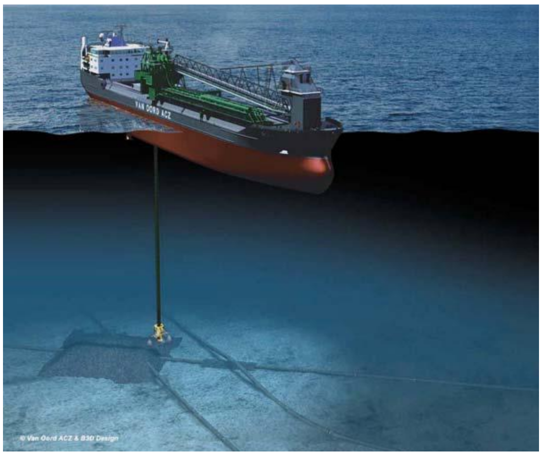
3.15.5 The support vessel is fitted with handling equipment in the form of an A-frame or dedicated crane for the launch and recovery of the trencher. The trencher is normally launched well clear of the pipeline and lowered to 5 – 10 m off the seabed before the support vessel moves towards the pipeline. The trencher is then lowered to the start-up position with the aid of an ROV and sonar to guide it into place. Once in place the lift slings are released and trenching operations are commenced. When the trencher is recovered the lifting slings are connected by ROV and the trencher lifted off the pipe until it is approximately 5-10 m clear, the support vessel then moves well clear of the pipe before the trencher is recovered to the surface.

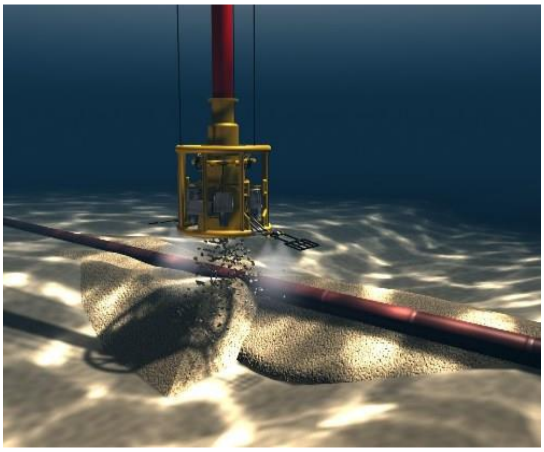
3.15.6 The deployment of the PL3 from the Far Samson is shown below.

3.16 Rock Placement Operations

3.16.1 The term rock-placement is an operation where coarse gravel and small stones are placed to locally reshape the seabed to ensure the long term integrity of the pipeline. Rock placement may also be complimented by the installation of concrete mattresses at selected locations.

3.16.2 Gravel and stones are transported by ship to each location where rock placement is required. The rock material is loaded into the fall pipe by conveyors on the ship and then falls through the water column in the fall pipe. The geometry of each gravel support is designed by the engineers according to seabed conditions, bathymetry in the surroundings, currents, etc. The lowest part of the fall pipe is equipped with nozzles to allow a very precise shaping of each gravel support and the process is monitored subsea by an ROV and the final geometry is controlled by surveying.





Rock Placement Vessel (left) and fall-pipe distributing rocks on pipeline

3.16.3 Rock placement is primarily required for the following purposes:

- Supports for free-span correction (pre-lay and post-lay).
- Gravel cover (post-lay) for additional stabilisation of the pipeline after pipe-lay (for certain sections).
- Gravel basement at locations where major pipe sections will be welded together (tie-in).
- Supports for cable crossings.
- Supports and post-lay at the pipeline crossings.
- Possible rock dumpings at the AWTI locations.

3.16.4 In addition rock placement of the pipelines above the seabed may also be considered as a means to provide local protection from dropped or dragged anchors and to some extent ship grounding.

3.16.5 The bulk of rock- placement activities are performed to restrict stress due to free-span development and to ensure local dynamic stability. Rock- placing for free-span correction will be carried out both pre and post pipe lay.

3.17 Pre-Commissioning

3.17.1 The offshore pipeline pre-commissioning concept for NSP2 will be completed using a “dry” pre-commissioning method without pressure testing or hyperbaric tie-ins.

3.17.2 The offshore pipeline will not be pressure-tested with water, only cleaning and gauging will be considered using dry air as pigging medium. The pipelines will not be water filled and, consequently, no dewatering and drying are required. Lines will be pressured to 30 bar with compressed air for stable pig running conditions in a compressible medium. Leak detection shall be carried out by use of an inspection pig or alternatively by an external ROV survey in conjunction with the cleaning and gauging pigging operation. The dry cleaning and gauging pig train will be launched from Germany towards Russia. Medium used to propel the pig train will be dried compressed air with water dew point below -60°C and maximum oil content of 0.01 ppm. As no water is used, there will be no additives and no such discharges. According to this philosophy, hyperbaric tie-in operations will not be needed since laying activities from Russia to Germany could be performed by means of shallow and deep-water barges, which will operate through multiple pipeline abandonments and recoveries. There will possibly be 8 AWTIs: 2 at KP 13.0, 2 at the micro tunnel exit in Germany, 2 at KP 1197 and 2 at KP 1159.

3.17.3 Additional tie-ins (e.g. above water tie-ins) will be performed depending on selected installation scenario / schedule.

3.18 Construction Vessels

3.18.1 The following offshore installation vessels will be involved in the project:

- Pipe lay Vessels – DP
- Shallow water pipe lay vessel
- Trench support vessel
- Anchor Handling Tug
- Survey Vessel
- Dive Support Vessel
- Pipe Carrier/Supply Vessel
- Rock Placement Vessel
- Backhoe Dredger
- Trailer Suction Hopper Dredger
- Split hopper Barges
- Cargo Barge
- Multicat.

4. RISK ASSESSMENT METHODOLOGY

4.1 Introduction

4.1.1 This assessment has been carried out in accordance with DNV-GL (reference 4.1) and IMO (reference 4.2) guidelines for risk management and formal safety assessment in marine and subsea operations. Reference has also been made to NSP1 risk management procedure (reference 4.3) and Saipem risk assessment reports (references 4.4) to ensure compatibility in methodology and tolerability criteria between the construction and operating phases.

4.2 Methodology

4.2.1 In accordance with the DNV-GL guidelines the risk assessment has been carried out in the following steps:

- An overall hazard assessment to define medium, low or high potential risk categories.
- A detailed, quantitative assessment based on the medium and high risk categories identified in the overall assessment.
- Identification of measures required to reduce potential risks to acceptable levels.

4.2.2 Previous work on NSP1 included a qualitative risk assessment of construction activities (reference 4.5) and a quantitative risk assessment (reference 4.5) and this has been used as the basis for the overall assessment of hazards and risks.

4.2.3 The hazard assessment has identified a number of hazards that lie in the ALARP zone and these have been subjected to a quantitative risk assessment (QRA) which is described in the following paragraphs:

4.2.4 The quantitative assessment has been carried out in the following phases:

- Estimation of event frequencies/probabilities.
- Development of risk evaluation logic.
- Identification of hazard consequences.
- Evaluation of risks

4.2.5 The scope of this risk assessment has considered two categories, namely:

- Humans – fatal or major injuries.
- Environment – impact from construction activities.

4.2.6 The quantitative risk assessment has been carried out through reference to historical data, the use of event trees and DNV-GL formulae where relevant. Worksheets are attached in the appendices and include:

Input data

- Event frequencies.
- Conditional probabilities.
- Persons at risk.

Output data

- Individual and group risks for project personnel based offshore.
- Individual and group risks for third party personnel based onshore and by passing vessels.
- Frequencies of environmental damage.

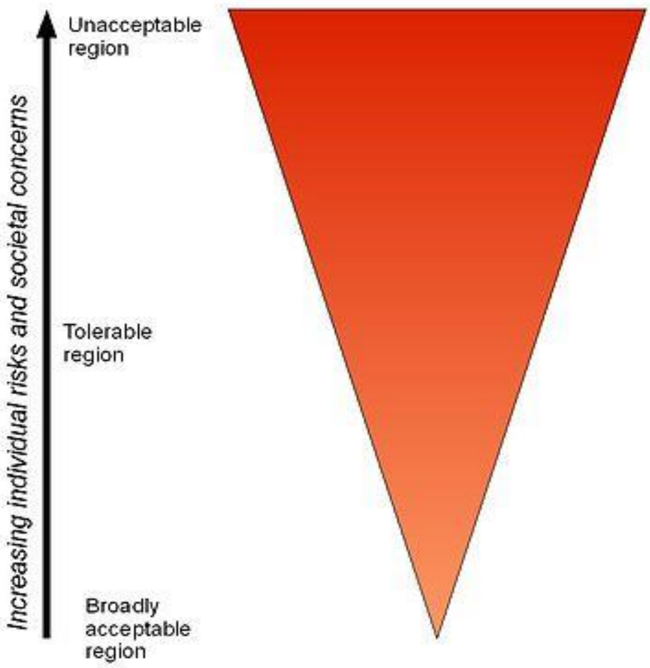
4.2.7 As well as presenting group risks on an F-N curve they have been calculated as the 'potential loss of life' (PLL) which is a product of the event frequency multiplied by the conditional probability of fatality and the number of potential fatalities.

4.2.8 The individual risk value has been calculated by dividing the potential loss of life by the number of persons exposed to that risk. As mentioned earlier it is assumed that personnel work equal time on and off the vessels. Individual risks for passengers have conservatively been based on the same exposure times as vessel crew.

5. RISK TOLERABILITY CRITERIA

5.1 ALARP Principle

5.1.1 The UK Health and Safety Executive have provided risk assessment guidance (reference 5.1) to the major hazard industries including nuclear, rail and offshore. The HSE's approach is based on a tolerability of risk (TOR) framework shown below which aims to reduce the risks to "as low as reasonably practicable" (ALARP). In the oil and gas industries it has become standard practice to assess risk levels on the ALARP principle which is shown below.



Risk Level	Risk Reduction Requirement
Unacceptable Region	Risk cannot be justified save in extraordinary circumstances
Tolerable Region (ALARP)	Upper level - Control measures must be introduced to drive residual risk towards broadly acceptable region Lower level - Risk is only tolerable if further risk reduction would exceed the improvement gained
Broadly Acceptable Region	Level of residual risk regarded as insignificant and further effort to reduce risk not likely to be required

5.1.2 This approach is based on risk tolerability which is divided into three regions. The upper region is considered unacceptable except in extraordinary circumstances. Generally risks in this region cannot be justified and should be reduced irrespective of costs.

5.1.3 The lower region is considered to be "broadly acceptable" where risk is negligible and no risk reduction is required.

5.1.4 In the ALARP region risks are considered tolerable but should be reduced to a level that is as low as is reasonably practicable. This is generally interpreted to mean cost-effective and risk reduction should be technically practicable and the costs should not be disproportionate to the improvements gained.

5.2 Risk Evaluation Criteria

5.2.1 Individual risks – the risk experienced by individuals on the installation. This usually refers to the risk of death, and may be expressed as an individual risk per annum (IRPA) or a fatal accident rate (FAR) per 100 million exposed hours. IRPA can be factored to take into account the individual's work/leave schedule, and in this case it has been assumed that workers have equal time at home and work. This work routine is normal practice for offshore workers in Northern Europe. This means that the total exposed population is taken as twice the total crew.

5.2.2 IR criteria for hazardous activities are generally set using risk levels that have already been accepted from other industrial activities and depend on two aspects:

- if the risk is taken voluntarily (i.e. crew member on a vessel).
- if the individual has no control over the risk (i.e. a passenger on a vessel).

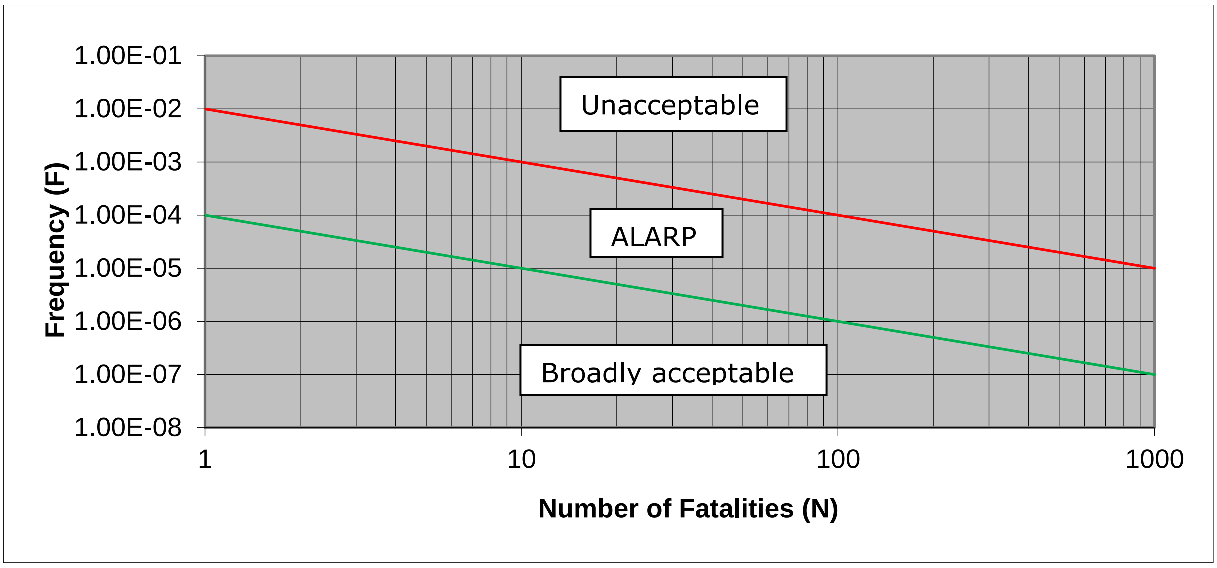
5.2.3 The tolerability criteria for Individual Risk in the offshore industry are generally set as follows:

- Maximum tolerable risk for workers 10^{-3} per person per year.
- Maximum tolerable risk for the public 10^{-4} per person per year.
- Broadly acceptable risk 10^{-6} per person per year.

5.2.4 For reference these rates are compared with fatalities rates experienced by the general public in UK (reference 5.1):

Death by accidents (all)	1 in 4064 per year or	2.4×10^{-4} per person per year
Death from cancer	1 in 387 per year or	2.6×10^{-3} per person per year.
Death by road accidents	1 in 16800 per year or	5.9×10^{-5} per person per year

5.2.5 Group risks – the risk experienced by the whole group of personnel working on the installation or otherwise affected by it. This usually refers to the risk of death, and is usually expressed as an average number of fatalities per installation-year, known variously as annual fatality rate, potential loss of life (PLL), expectation value, rate of death, etc. Alternatively, it may be expressed as an F-N curve, showing the cumulative frequency (F) of events involving N or more fatalities. A typical F-N diagram is shown below. The red and green lines define the ALARP region.



5.2.6 In this assessment group risk will be estimated as potential loss of life and shown on an F-N curve where sufficient data is available.

5.2.7 The DNV-GL risk matrix (reference 5.2), shown overleaf, has been used for the qualitative risk assessment of all hazards and for the quantitative assessment of environmental hazards.

Consequences			Probability (increasing probability →)			
Descriptive	**People**	**Environment**	**1 Remote** (< 1.0 x10^{-5}/y)	**2 Unlikely** (1.0 x 10^{-5} – 1.0 x 10^{-3} /y)	**3 Likely** (1.0 x 10^{-3} – 1.0 x 10^{-2} /y)	**4 Frequent** (1.0 x 10^{-2} – 1.0 x 10^{-1} /y)
Extensive A	Fatalities	Global or national effect. Restoration time > 10 yr	**A1**	**A2**	**A3**	**A4**
Severe B	Major Injury	Restoration time > 1 yr. Restoration cost > USD 1 mil.	**B1**	**B2**	**B3**	**B4**
Moderate C	Minor Injury	Restoration time > 1 month. Restoration cost > USD 1 K	**C1**	**C2**	**C3**	**C4**
Minor D	Illness or Slight Injury	Restoration time < 1 month. Restoration cost < USD 1 K	**D1**	**D2**	**D3**	**D4**
HIGH	The risk is considered intolerable so that safeguards (to reduce the expected occurrence frequency and/or the consequences severity) must be implemented to achieve an acceptable level of risk; the project should not be considered feasible without successful implementation of safeguards					
MEDIUM	The risk should be reduced if possible, unless the cost of implementation is disproportionate to the effect of the possible safeguards					
LOW	The risk is considered tolerable and no further actions are required					

6. PIPELINE CONSTRUCTION HAZARDS

6.1 Introduction

6.1.1 An initial assessment of construction phase activities has been carried out to identify hazards that require more detailed assessment. This assessment has been based on the DNV-GL risk acceptance criteria matrix described in section 5.

6.2 Hazard Categories

6.2.1 The risk assessment has considered the following activities/hazards:

- General marine activities including fishing activities, collision, grounding, sinking, fire, military exercises, munitions & chemicals, helicopter transport, site security and adverse weather
- Environmental hazards.
- Landfall preparation including dredging (general and site specific)
- Shore pull and shallow water pipe lay
- Pipeline initiation
- Normal pipe lay operations
- Anchor handling operations
- Cable crossings
- Pipe crossings (if relevant)
- Pipe lay down and recovery operations
- Pipe transport and offshore handling operations
- Above water tie-in
- Buckled pipe repair (contingency)
- Pipe trenching operations
- Rock placement operations
- Pipeline testing and pre-commissioning
- UXO disposal operations

These are described in the following paragraphs

6.3 Fishing Activities

6.3.1 The main hazard related to fishing activities during the construction phase is the potential of collision with construction vessels. Construction vessels which are free to manoeuvre, such as pipe carriers and supply vessels, present no more risk than other cargo vessels in the area. These vessels operate under the International Regulations for the Prevention of Collision at Sea and are required to take avoiding action when encountering vessels engaged in fishing.

6.3.2 Construction vessels which are moored or dynamically positioned are unable to manoeuvre freely and the fishing vessels are required to take avoiding action. It is standard procedure to issue Notice to Mariners warnings well in advance of construction activities and these are backed up by regular Navtex warnings and verbal warnings broadcast on VHF. In NSP1 Nord Stream held meetings with relevant Baltic Sea fishery organisations to discuss and agree action required to co-ordinate fishing and construction activities. It is assumed this consultation will be repeated for NSP2.

6.3.3 In addition a visual and radar look out is kept at all time and this is applicable to all construction vessels. These vessels are fitted with ARPA radar systems which can automatically plot passing vessel trajectories and raise an alarm if a potential collision situation exists. The AIS system also assists the identification of passing vessels and provides information on position, course and speed. These aids are particularly effective in poor visibility.

6.3.4 It is also noted that fishing is carried out at speeds of around 3 to 4 knots which generally allows time to take evasive action and in the worst case results in a low impact collision.

6.3.5 There is the possibility of trawl board impact with the pipeline after installation. A Saipem study on NSP1 (reference 6.1) analysed trawl board impact and concluded that the pipeline can withstand estimated trawl board impact loads, pull-over loads and hooking loads provided free-spans are kept within project parameters. The risks related to this hazard are covered in risk assessments of the pipeline in operational mode.

6.3.6 Ramboll also assessed the risks that the pipeline present to fishing boats (reference 6.2) and concluded that the risk of damage to fishing gear is 3.2×10^{-2} per year. The risk of loss of a fishing vessel due to hooking (capsize as a result of fishing gear being hooked on the pipeline) is estimated to be 8.1×10^{-8} per year which is very low.

6.3.7 It is therefore concluded that the risks to fishing or construction vessel personnel or to the environment are low and no further assessment is required.

6.4 Passing Vessel Collision

6.4.1 A detailed ship traffic analysis and collision risk studies have been carried out by Ramboll (references 6.3 and 6.4) issued in April 2018. The studies analysed ship traffic on a reference reporting line at the entrance to the Baltic Sea.

6.4.2 This report line has the highest density of shipping along the selected route and is between the West Gotland Basin and the Bornholm Basin. This report line can be used as a proxy approximation for the total volume of shipping that is in the Baltic Sea as it covers the main transit route into the Baltic Sea.

6.4.3 Ship traffic data has been based on the following sources:

- Automatic Identification System (AIS) data.
- Charts.

6.4.4 AIS data from 2007 to 2014 was analysed and the data comprised 14 items of information on each vessel including vessel size, type, position, course and speed.

6.4.5 For reference the annual shipping movements along the main sailing routes through the Baltic Sea in 2014 were reported as follows:

- North of Bornholm 47,433
- South of Bornholm 5,351
- South of Gotland 21,199
- Gulf of Finland (W end) 27,087

6.4.6 It is noted that NSP1 lines were laid with no reported vessel traffic incidents and a number of risk reduction measures were put in place. These included the implementation of a traffic warning procedure, the establishment of an exclusion zone around the pipe lay vessel and issue advance warnings via Navtex and in the Notice to Mariners in the affected areas. In addition prior consultation with the coastguards and maritime authorities in the affected areas was carried out in advance so that all shipping was aware of the situation.

6.4.7 Where relevant installation contractors prepare specific procedures for crossing shipping lanes and areas of high traffic density, these include the use of pilots, guard boats and the regular issue of navigation warnings. NSP2 also intend to provide native speakers on the lay vessel in order to allow communication with local vessels such as fishing vessels and coasters.

6.4.8 Collision with military vessels has not been specifically addressed as Ramboll do not have data on these vessels as they are not required to carry AIS. However, military vessel traffic is relatively small compared to the amount of commercial traffic and would not change the statistics greatly. In addition, military vessels generally have a higher level of manning and, in some cases, competence than commercial vessels and are less likely to be involved in collisions. Any large scale movement of military vessels is likely to be associated with a military exercise which NSP2 will be aware of in advance. However, with regard to communications with the various military forces special attention will need to be paid to submarine exercises.

6.4.9 In NSP1 pipe lay operations were carried out with involvement of the Baltic Sea maritime authorities and precautions included:

- VTS Reporting – German Bight Traffic (German Sector)
- SHIPPOS Reporting System (Danish Sector)
- FartygsRapporteringsSystemet, FRS (Swedish Sector)
- Gulf of Finland Reporting System, GOFREP (Finnish Sector)

6.4.10 It is noted that there was only one reported vessel traffic incident on NSP1 when a passing vessel broke down and was in danger of drifting onto the Skandi Artic which was engaged in diving operations. The standby vessel towed the vessel clear.

6.4.11 Considering the amount of ship traffic along the route there is a medium possibility of collision with the construction vessels and the risks have therefore been considered in the quantitative assessment.

6.5 Attendant Vessel Collision

6.5.1 There is also a potential for collision between any of the attendant installation vessels and the main construction vessel. Attendant vessels include anchor handling vessels, pipe carriers, supply vessels and survey vessels which are required to operate in close proximity to the construction vessel.

6.5.2 Attendant vessel movements within the construction zone are generally controlled by the main construction vessel (e.g. pipe lay vessel) and vessel speeds are low. The pipe carriers are the most frequent attendant vessels and as they are fitted with DP do not moor alongside the pipe lay vessel but stand-off at a distance of 5 to 10 metres. Supply vessels visit less frequently but approach the main construction vessel in the same way as the pipe carriers and it is therefore considered that the risk of attendant vessel collision is low and no further assessment has been carried out.

6.6 Grounding

6.6.1 It is evident that grounding can only occur in coastal waters and is therefore unlikely to affect the major construction vessels but could affect the pipe carriers, supply vessels or rock placement vessels as they approach or leave port. Grounding incidents near a port are likely to be relatively low impact which could nevertheless result in an oil spill but are unlikely to result in crew injury or fatality.

6.6.2 The pipe carrier vessels will carry out most port calls and although the loading ports are very close to the open sea a grounding incident is always possible and this risk has been considered in the quantitative assessment in section 7.

6.7 Vessel Sinking

6.7.1 Vessel sinking or capsize is generally caused by severe weather, un-seaworthy vessels or a combination of the two. In addition to normal classification surveys and ISM requirements offshore construction vessels are also subject to regular inspections by charterer and operator company surveyors. As a result these vessels tend to be in better condition than general cargo vessels and are unlikely to be un-seaworthy.

6.7.2 In the event of severe weather the pipe carriers, rock placement and supply vessels will be able to take shelter in an appropriate location within a relatively short space of time. The pipe lay vessels are much larger and can generally ride out a storm without running for shelter, although it may be necessary to lay the pipe down before the onset of the severe weather. In extreme conditions the pipe lay vessels could also move to a sheltered location for the duration of the storm.

6.7.3 It is therefore considered that the probability of a vessel sinking is low, and this is supported by UK HSE Accident Statistics for Mobile Units (reference 6.5) which reports one sinking incident between 1990 and 2005. However, as the consequences could include fatality/injury to personnel or environmental damage this has been quantitatively assessed in section 7.

6.8 Vessel Fire

6.8.1 World-wide shipping casualty statistics indicate that the frequency of vessel fires is similar to collision frequency and accounts for approximately 14% of casualties. However, data on incidents in the Baltic Sea indicate that fires account for 9% of vessel casualties (reference 6.6 Annual Report on Shipping Accidents in the Baltic Sea in 2013 - Helcom 2014). Although offshore construction vessels generally have a better safety record than other merchant vessels there is always a possibility of fire, and this has been considered in the quantitative assessment.

6.9 Vessel Bunkering Operations

6.9.1 During the pipe lay operation a number of vessels will need to load bunkers offshore and there is a potential for oil spills. The majority of vessels will be able to load bunkers in port but the pipe lay and anchor handling tugs will most likely require refuelling offshore. Although the number of bunkering incidents offshore is generally reported to be low it is considered that a quantitative risk assessment should be carried out bearing in mind the environmental concerns in the Baltic area.

6.10 Military Exercises

6.10.1 Military exercises are carried out by NATO and a number of the Baltic States and it is understood that NSP2 will investigate military exercise areas as part of the EIA. The impact of military exercises on NSP1 was assessed in a Ramboll report (reference 6.7) which identifies the areas along the route that would be subject to military exercises. The locations where the pipeline route crosses exercise areas mainly occur in the EEZ but in Russia, Denmark and Germany military practice areas are crossed in territorial waters.

6.10.2 These exercises may include submarine, gunnery, mine laying and air force practice and it is evident that these could either delay operations or result in damage or injury if carried out in the vicinity of pipeline construction operations.

6.10.3 On NSP1 Nord Stream approached all relevant authorities and developed procedures and agreements on how this issue will be addressed.

6.10.4 Provided these permits are obtained the risk to personnel and the environment from military exercises is considered to be low and no further assessment has been carried out.

6.11 Munitions and Chemicals

6.11.1 The hazards associated with the presence of munitions and chemicals include:

- Construction vessel contact with munitions (Anchors or DP clump weights);
- Pipeline contact with munitions;
- General public contact with munitions washed ashore;
- Trencher contact with munitions;
- Munitions recovered to the surface with anchors or trenching equipment e.g. ploughs;
- Construction personnel contact with chemicals on anchor wires or subsea equipment (ploughs, ROVs, etc.);
- UXO disposal operations.

6.11.2 A construction vessel anchor could make contact with dumped munitions and this is particularly relevant to pipe lay operations which require continual movement of anchors and wires. To minimise this risk an anchor corridor survey will be carried out 1 km either side of the pipeline route and instrumentation will include side scan sonar, magnetometer and Multibeam Echo Sounder. The anchor patterns will be planned so that anchors remain within the surveyed corridor but avoid targets identified as possible munitions from MBES and SSS

6.11.3 The pipeline could come into contact with munitions during pipelay but the probability of this is considered to be low considering the amount of survey that will be carried out prior to pipe touch down. On NSP1 the pipeline route visual survey covered 25 metres either side of the route and the detailed munitions survey covered 7.5 metres either side of the route. The pipe installation tolerance is +/- 7.5 metres along the main route and +/- 2.5 metres on restricted areas such as crossings so the pipe should be positioned within the survey boundaries. During pipelay operations the pipe layback is likely to be in excess of the safe distance and the probability of vessel damage in the event of an explosion is considered to be low. Touchdown monitoring is carried out by an ROV deployed from a survey vessel which would normally be positioned near the touchdown position. However, the vessel offset can be extended by increasing ROV tether length and the probability of vessel damage in the event of an explosion is considered low.

6.11.4 There is a possibility that munitions could be disturbed during installation operations and drift onto the pipe after installation. However, near-bottom currents in the dumping areas are reported to be too weak to move heavy munitions (reference 6.8) and this risk is considered to be low. Additionally any released chemicals would most likely disperse in the water and the toxicity would be reduced to non-harmful levels.

6.11.5 There is also a possibility that any munitions released through seabed disturbance could eventually drift ashore and pose a risk to the general public. In the Helcom report it was stated that there were only 7 confirmed finds on the coast and none of them could be attributed to being washed ashore. It was concluded that the seabed currents were too weak to move munitions ashore and that in addition they would need to be moved upwards from a water depth of 100 metres in order to be washed ashore. The risk of general public contact with munitions is therefore considered to be low.

6.11.6 Although sub-bottom profile and pipe tracker surveys have been carried out along the pipeline route there is still a remote possibility that dumped ordnance could be unearthed during trenching operations. In the event that live munitions were encountered during trenching then it is likely that the pipeline and plough would be damaged and require repair. It is unlikely that the trenching support vessel would be damaged as the vessel would be positioned well ahead of the plough position.

6.11.7 Personnel would obviously be at risk if an item of munitions was brought to the surface when an anchor or subsea equipment was recovered on board a support vessel. However, all anchor and equipment recoveries are supervised from the surface and any munitions would be sighted before the equipment was lifted on deck and relevant steps would be taken to deal with the situation.

6.11.8 The minimum separation between lines A and B will be 55 m plus for the anchored pipelay section of the route and this is greater than the minimum SLS/ULS distances estimated by Saipem. However, the separation distance is less than the SLS/ULS distance at the landfalls and in a relatively small number of locations along the route and NSP2 will need to check carefully for the presence of munitions in these areas. This is only relevant when line A is operating and lines B is being installed. However, the combined probability of munitions contact with the pipe and the separation being less than the SLS/ULS distance is considered to be very low.

6.11.9 During subsea operations there is a possibility that the equipment will come into contact with chemicals that could harm personnel involved in the recovery operations. This equipment could include anchors, anchor wires, ploughs, diving bells, welding habitats, ROV, etc. and the installation contractors will need to develop procedures to ensure personnel are protected. This may also be relevant to above water tie-ins when the pipe is recovered to the surface where workers could come into direct contact with chemicals. In locations where there is a possibility of contact with chemicals relevant PPE will need to be provided to exposed personnel. On NSP1 installation contractors were required to follow requirements described in document G-CE-MUN-SOW-000-CMCONTAM-A "Scope of work for the identification, detection and subsequent management of contamination arising from chemical munitions", a similar document will be prepared for NSP2.

6.11.10 Lines and equipment used in subsea operations could be coated with chemicals which could harm construction personnel when handling the equipment on the surface. However, provided relevant personal protective equipment (PPE) is used in chemical hazard locations, the risk of injury should be low. It is noted that Helcom recommend procedures and equipment to be used where the risk of contact with chemicals exists.

6.11.11 UXO disposal is carried out using ROVs to install a detonation charge in close proximity to the UXO and then firing the charge when the ROV has been recovered to the surface and the support vessel moved to a safe distance. Hazards include:

- Premature firing of detonation charge;
- UXO detonation while charge is being set;
- Damage to vessels and equipment following UXO detonation;
- Injury/fatality to personnel;
- Injury/fatality of marine life.

6.12 Helicopter Transport

6.12.1 Some crew changes will be made by helicopter and it is estimated that there will be a maximum of one flight a week.

6.12.2 Helicopter crew change is considered to be one of the higher risks that an offshore worker encounters. However, recent statistics indicate that helicopter safety is improving although there has been a recent accident in Norway that resulted in the fatality of all on board.

6.12.3 In the event of an accident the main risk is obviously to the helicopter crew and passengers although there is a possibility of fire if the accident occurs on the construction vessel helideck. However, helidecks are fitted with specific firefighting and rescue equipment and a helideck fire team is standing by in close attendance for each take-off and landing. Consequently the potential for escalation of a helideck fire to the rest of the vessel is very low.

6.12.4 It is planned to use AW139 (or equivalent) helicopters for these flights with a capacity of between 15 and 18 passengers. Helicopter incident statistics have been recorded for a number of years and it has therefore been possible to carry out a quantitative assessment of this risk.

6.13 Site Security

6.13.1 There is some concern that non-project personnel may enter construction sites or vessels and either commit terrorist offences or injure themselves through contact with construction activities.

6.13.2 Following the 9/11 attacks in the USA the potential for security threats to ports and ships has been recognised and IMO have introduced the International Ship and Port Facility Security Code (ISPS). The code requires the implementation of a number of security measures on ships and in ports and in particular this only allows access to personnel who have prior approval from the port or vessel operator. The code also requires the implementation of certain protective security measures depending on the situation prevailing at the time.

6.13.3 All vessels above 300 gross registered tonnes are required to comply with ISPS and this is applicable to all main construction vessels working on the project. It is therefore considered that security risks to the construction fleet and personnel will be no higher than those experienced on other vessels navigating in the Baltic Sea at the time.

6.13.4 During construction activities onshore and offshore there is a possibility that members of the public may visit the sites and be vulnerable to injury. However, this is considered unlikely as the onshore sites will be fenced off to restrict access only to construction workers and a nominal safety zone will be established to restrict access to the offshore sites. For each offshore operation the main construction vessel acts as the central marine controller and incoming construction vessels request permission before they enter the safety zone, usually taken as a 500 metre radius. Therefore any leisure craft would be kept away from construction activities and the potential for third party injury is considered to be very low.

6.14 Adverse Weather

6.14.1 Offshore construction is scheduled to take place all year round, subject to the ice limitations between December and April, and the vessels will be subjected to all weather conditions. Provided the weather limitations of the pipe lay barge and support vessels are not exceeded adverse weather is unlikely to pose a significant risk. If necessary the pipeline can be abandoned in a controlled and timely fashion prior to the onset of adverse weather.

6.14.2 During anchor handling operations in rough weather there is a possibility that deck crews could fall overboard or be injured by moving buoys, anchors or rigging equipment. Deck crew are equipped with relevant PPE including buoyancy aids and safety harnesses when necessary. It is also standard practice for deck crew to move behind safety barriers when wires are under tension and anchors and buoys are being moved on deck. In the event of severe weather anchor handling operations are halted until the wind and wave drops to acceptable safe limits.

6.14.3 Fog conditions increase the potential for collision between the main construction vessel and passing and attendant vessels. Attendant vessels operating in close proximity to the main construction vessel will be working at reduced speed or stationary. Any collisions should therefore be at low impact with limited damage potential. The potential for collision with passing vessels should be reduced provided effective traffic management systems are in place, regular navigation warnings are issued and enhanced watch keeping procedures are followed. The additional risks due to poor visibility are considered to be relatively low.

6.14.4 The main construction vessels are not classed to operate in ice conditions so the installation schedule has been planned to prevent any delays due to sea icing. There may be occasions when very low temperatures are encountered and these could have adverse effects on the welding processes and prolong the welding times. Low temperatures may also limit deck operations such as rigging, pipe joint and anchor handling operations and also result in prolonged operating times. Deck surfaces may also be coated in ice and will need to be kept clear to prevent slips, trips and falls. It is recommended that cold weather operations be specifically addressed in project procedures and safety documentation.

6.14.5 Provided relevant precautions are taken with respect to adverse weather, low temperatures and ice management the risk of injury/fatality or environmental damage is considered to be low and no further assessment has been carried out.

6.15 Environmental Hazards

6.15.1 Apart from oil pollution discussed earlier and the restrictions imposed in the Natura 2000 areas the main concerns regarding damage to the environment are:

- Sediment spreading;
- Operations in spawning grounds;
- Noise;
- Seabed disturbance;
- Project delay;
- Waste disposal from construction vessels;
- Use of large land areas for pre-commissioning equipment;
- Air borne discharges.

6.15.2 During dredging, trenching and pipe lay some sediment transport will occur but in sensitive areas, such as the German landfall, measures will be taken to minimise sediment spreading. These measures will include the use of cofferdams to contain excavated soil and silt screen to prevent the movement of sediment outside the construction area.

6.15.3 Pipeline construction operations in spawning grounds would have a serious environmental impact and the only way to prevent this is to restrict access during the spawning season. On NSP1 there were a number of restrictions in Russia, Sweden and Denmark but it is not known if these have changed for NSP2.

6.15.4 Noise levels are of particular concern in the German landfall area and an assessment has been carried out to ensure that noise level requirements will not be exceeded. Measures include limiting the size of vessels operating near the coast and the use of silenced construction machinery where relevant.

6.15.5 During offshore operations the seabed will be locally disturbed by anchor operations, dredging, trenching and pipe lay but this is considered to have low environmental impact.

6.15.6 Any project delay would extend the environment exposure to construction activities, but it is obviously in the interests of NSP2 and the contractors to complete the work within the schedule. It is inevitable that some delay may occur but in most cases this will result in the stoppage of operations and consequently any potential negative environmental impact would be minimised as subsea operations and associated seabed disturbance would be halted. Some surface operations may continue but are unlikely to cause any environmental damage that has not been addressed elsewhere (e.g. potential oil spillage during bunkering operations).

6.15.7 Waste disposal by construction vessels would obviously lead to increased pollution offshore and eventually around the coastal areas. However, all vessels are required to comply with IMO MARPOL requirements related to discharge of oil and waste products. The Baltic Sea is defined as a 'Particularly Sensitive Sea Area' and virtually no disposal is allowed offshore. All vessels are required to maintain an oil and waste record book where the disposal of all waste is recorded. This entails the use of specialist shore contractors who issue official receipts for any waste disposed onshore, these records are regularly inspected by port and flag state inspectors. It is considered that the risk of pollution through the disposal of oil or waste is low.

6.15.8 Ramboll have carried out a study to assess the oil spreading and oil concentrations from an accidental oil spill in the Baltic Sea during construction of NSP2 (reference 6.9). The study investigated oil spill scenarios in four locations; Denmark, Sweden and Finland (2 locations). The drift studies showed that the shortest travel time for exceedance of 15mg/l (from the spill location in Denmark) is approximately 20 hours for Bornholm (Denmark), approximately 30 hours for the southern coastline of Sweden and approximately 30 hours for the northern coastline of Germany. In the Sweden scenario the shortest travel time for the oil slick to reach the eastern coastline of Sweden (>15mg/l) is approximately 30 hours. The consequences of the two oil spill locations in the Gulf of Finland were found to be relatively similar. After two days the oil from the spill locations would reach the coastlines of Finland and Estonia, however, with a relatively low probability

6.15.9 It is noted that 48 hours is taken as the maximum time expected to launch an oil spill response procedure, including oil containment and dispersion/disposal.

6.15.10 Ramboll studies on of decay on NSP1 show that the majority (85%-93%) of diesel disperses and floating diesel would not be present 48 hours after the release. After 48 hours, 60%-63% of crude oil would remain in the water; approximately 26%-32% of crude oil would evaporate and only a minor fraction of approximately 10% would disperse. The decay of bunker oil is much slower; after 48 hours 78%-90% of bunker oil remains in the water and 4%-14% disperses. In the event of an oil spill along the pipeline route impacts on the coasts would occur, especially in the Arkona Basin and Bornholm Channel.

6.15.11 Depending on the final option selected for pre-commissioning of the NSP2 offshore pipeline sections, there could be a requirement to temporarily use a large land allotment area for laydown of involved equipment. The area may require the construction of temporary roads, earth works, pipelines and the installation of equipment and associated temporary buildings. Construction hazards such as noise, air pollution, oil pollution, etc. will be controlled through site HSE procedures and the risks are considered to be low.

6.15.12 Environmental issues related to construction operations in environmental protection areas such as Natura 2000 are addressed in the EIA documentation prepared for each EEZ.

6.15.13 Environmental risks are considered in much more detail in the EIA submissions prepared by Ramboll and have not been subject to quantified assessment in this report.

6.16 Landfall Preparation - Russia

6.16.1 The hazards associated with this landfall preparation include:

- Moving vehicles, excavators and loads
- Lifting operations – dropped or swinging loads
- Oil leaks
- Noise
- Working at height or over/near water
- Vessel (dredgers, barges etc) emergencies such as collision, capsize and grounding
- General construction site hazards – e.g. welding, powered tools and manual handling
- Diving operations
- The possible presence of buried unexploded munitions
- Adverse weather
- Work in deep excavations.

6.16.2 It should be noted that the project safety management system will require the preparation of procedures, HAZIDs and toolbox talks before any operations start.

6.16.3 Moving vehicles, excavators and lifting operations are all standard construction site activities and all rigging equipment is inspected and certified before use. Heavy lifts are engineered to ensure lifting equipment is adequate and all lifting operations are supervised by experienced personnel. Provided site safety procedures are in force the probability of injury/fatality to personnel is considered to be low.

6.16.4 Oil spill prevention includes the use of bunds and double wall tanks for onshore fuel storage and oil spill clean-up kit is on site in the event of a local spill. Backhoe dredger equipment is hydraulically operated and hose failure could result in spillage to the sea. However NSP2 require all contactors to develop Spill Prevention and Response Plans and provided these are in force the probability of a major spill is considered to be low.

6.16.5 Workers are provided with safety harnesses and buoyancy vests when working at height and/or over water and the risk of falls or drowning is considered to be low.

6.16.6 A survey vessel continually monitors the trench depth and location of soil dump areas so the dredgers and barges working in the near shore zone will be aware of shallow water areas and grounding is considered unlikely.

6.16.7 A large number of vessels could be working in the area and therefore there is a potential for collision. However all vessel movements are controlled by the construction manager and the probability of collision is considered to be low. In the worst case any impact would be at low speed and major injury or damage is considered unlikely.

6.16.8 Diving operations in the near shore and pull-in areas will be carried out in relatively shallow water and provided normal diving procedures are followed the risk to divers is considered to be low.

6.16.9 There is a risk of unearthing unexploded ordnance (UXO) during dredging and preparation activities and the following risk reduction measures (reference 6.10) will be established:

- Documents relating to mine clearance of the right of way and landfall sites shall be obtained from the local authorities.
- A comprehensive soil survey will be carried out in areas where the presence of mines of other explosive devices is known to have existed previously. It is understood that the survey will include the use of metal detectors
- The risks associated with the possible presence of UXO during construction activities will be determined by staff from the Russian Civil Defence Force. This will be based on the results of the soil survey and authorities understanding of the mine situation in the area.
- Construction personnel will have a safety briefing on the areas where explosives objects may be located and the relevant safety measures required when working in these areas.
- These safety briefings will include UXO familiarisation by the Russian Civil Defence Forces.
- During excavation operations at night extensive lighting will be provided to illuminate the earthworks. When dump trucks are used for loading excavated soil a separation zone of 50 m shall be established between the trucks being loaded and those waiting to be loaded.
- In the event that UXO are found during construction all work shall be stopped, construction personnel evacuated and the situation reported to the relevant local authorities. The area will then be fenced off to prevent the entry of unauthorised personnel.
- Lifting, disarmament, transportation and disposal of detected explosives shall only be carried out by specialists of the Russian Civil Defence Force.

6.16.10 If an explosive object cannot be removed it will be destroyed in position by the relevant specialists. In this event a safe area will be established and fenced off and security guards will warn the general public through the use of flags, alarms, lanterns, whistles and megaphones.

6.16.11 If the potential blast area extended beyond the construction site then it would be necessary to issue warnings to the public and evacuate any areas considered to be at risk.

6.16.12 Once the munitions survey has been completed the probability of unearthing a UXO is considered to be very low; however, if one was encountered it could result in a serious injury or fatality. In accordance with the DNV-GL risk matrix this falls into the medium risk category. Due to the very limited data on contact with munitions a quantitative assessment is not appropriate; however NSP2 are making considerable efforts to minimise the effects of this hazard and it is considered that the risk is reduced to ALARP levels. The risks to the public are considered to be low.

6.16.13 Adverse weather such as low temperatures, snow, ice, high winds, heavy rain, etc. could affect the work site conditions and increase risks to the construction teams. However, these risks should be minimised by the implementation of contractor HSE procedures which will be monitored by Nord Stream. Adverse weather risks are therefore considered to be low.

6.16.14 Some of the construction activities may require deep excavations and there is a risk of trench/wall collapse which could injure construction personnel. Deep excavations would be engineered and earth support equipment used where relevant and the associated risks are considered to be low.

6.16.15 Apart from the UXO risk this type of site preparation is a standard operation required for most export lines and is not considered a high risk activity. However, in the event that unidentified munitions were encountered during dredging operations the crews would be at risk and a quantitative assessment has been carried out in section 7.17.

6.17 Landfall Preparation – Germany

6.17.1 The hazards are similar to those identified in the Russian landfall with additional hazards related to the micro-tunnel construction and environmental concerns related to noise, pollution, silt transportation and seabed contamination.

6.17.2 Hazards related to micro tunnel construction are summarised in the following table

Activity/Hazard	**Control Measures**
Tunnel Excavation	
Face stability Ground water inundation Ingress of hazardous materials Unexpected obstructions, both naturally occurring and man made Over/under excavation	Face stabilisation Tunnel Boring Machine choice Monitor and control rate of advance / excavation / ground movement and surface settlement Manage/control water ingress Ventilation Non-intrusive surveys
Confined Space/Tunnel Environment	
Environmental conditions Restricted access Fire Slippery surfaces Underground plant	Atmospheric monitoring Ventilation Restrict access Use permits systems Training Competence Planning Emergency response Housekeeping Fire suppression
Man/Machine Interface	
Movement of plant above and below ground Contact with exposed moving parts Uncontrolled movement of hydraulic jacks	Safe systems of work Planning and set-up Segregation Guarding Competent operatives and operators Effective communications systems Failsafe systems Behaviour based safety

Activity/Hazard	Control Measures
Stored Energy	
Electrical equipment Pneumatic systems Hydraulic systems High pressure water systems Slurry and slurry separation systems	Safe systems of work Competent personnel Inspection/maintenance regime Isolation protocols Pressurised systems training
Material Usage	
Manual handling Pipe handling and storage Slurry Spoil Additives and chemicals	Training and competence Mechanical handling, where practical COSHH assessment and awareness Adequate ventilation Appropriate PPE
Working at Height/Depth	
Operatives falling down shaft Tools or materials falling down shaft Access/egress	Safe systems of work Training and competence Security Adequate barriers Scaffolding 2 means of access/egress from shafts
Lifting Operations	
Working over shafts. Working within compounds. Lifting over personnel. Interaction with the public/traffic	Training and competence Lift planning and supervision Communication Certified plant and equipment Periodic inspection regime Properly planned site set up Design of foundations / ground support for craneage operations Avoidance of lifting over personnel Safe areas in pit bottom
Occupational Health	
Noise Air quality Vibration Heat Eye injury/damage Weils disease Working hours (shift patterns) Stress	Provision of advice, guidance, information and education on occupational health good practice. Behavioural based safety, focussing on changing operatives behaviour Regular health surveillance Monitoring conditions including the atmosphere, water additives and naturally occurring substances such as radon Minimise exposure Appropriate PPE for the task

6.17.3 Noise, light, and exhaust pollution are limited in certain areas of the landfall site and detailed procedures are being developed to ensure these requirements are met. This includes restricting access to construction vessels that meet the noise level requirements. Silt transportation is also of some concern and silt screens will be used to minimise this.

6.17.4 There is a remote possibility that UXO will be unearthed during construction activities as the area has already been surveyed by magnetometer and metal detectors and no objects have been found. Although risk reduction measures will be implemented to reduce the risk to ALARP levels a quantitative assessment of dredging operations has been carried out in section 7.17.

6.17.5 A large number of vessels could be working in the area and therefore there is a potential for collision. However all vessel movements are controlled by the construction manager and the probability of collision is considered to be low. In the worst case any impact would be at low speed and major injury or damage is considered unlikely. It is noted that no collision incidents involving recreational vessels were reported on NSP1.

6.17.6 The risks associated with the preparation of the German landfall are therefore considered to be relatively low. The main concern being to ensure the environmental impact is minimised and that all relevant requirements are met. The environmental impact has been addressed elsewhere by Ramboll and it is considered that construction risks are relatively low and therefore have not been included in the quantified risk assessment.

6.18 Shore Pull and Shallow Water Pipe lay

6.18.1 In Germany the pull-in will be to microtunnels and in Russia to a cofferdam.

6.18.2 The main hazards related to shore pull and shallow water pipe lay operations are:

- Pipe lay or attendant vessel grounding;
- Failure of pull-in wire or rigging;
- Failure of buoyancy elements;
- Tensioner failure;
- Failure of pull-in winch;
- Adverse weather.
- Vessel collision.

6.18.3 As these operations are carried out in relatively shallow water grounding of any of the vessels involved is a potential hazard which could result in hull damage and pollution. Dredging operations will be carried out to prepare the site for pull-in operations and ensure the water depth is adequate. It is also noted that the pipe lay vessel and supporting vessels used on these operations are generally shallow draft. Water depths are also checked by shallow water survey vessels that carry out bathymetry surveys during dredging operations so the water depths in the area are known. However, the pipe pull-in and lay away is a standard operation and providing it is properly planned and under keel clearance is monitored the associated risks are considered to be low.

6.18.4 At the German Landfall there is a shallow sand bar which will have to be dredged to provide a flotation channel. The maximum allowable dredged depth requires a very shallow draft and a minimum under keel clearance. As the water depth is weather/wind driven, it will also include a weather window requirement to be assessed in more detail when the contractor and barge is known.

6.18.5 Failure of the pull-in wire or rigging would interrupt the operation while catastrophic failure could result in serious injury to the winch operators onshore and damage to equipment but would have no environmental impact. This is a standard operation and providing it is correctly engineered using normal factors of safety and the equipment is correctly set up and tested this is considered to be a relatively low risk operation.

6.18.6 In the event that one or more buoyancy elements became detached from the pipeline the pull-in load would increase and eventually it would not be possible to continue pulling the pipe ashore. However, the pull-in speed is relatively low and the loads are monitored during the pull so it is unlikely that the pipe or rigging would be overstressed. The main effect would be to delay the operation while the buoyancy modules are re-connected. This is considered to be a low risk.

6.18.7 In the event of a tensioner failure the pipe lay operation would cease while the failed unit is repaired. Tensioners are designed to fail to the brakes-on position and the pipe should not move as a result of this failure. If it was necessary to open a tensioner for repair then the load may be supported by the other tensioners if the load is within their capacity. If not the load would need to be transferred to the A&R winch and the pipe eventually laid down if required.

6.18.8 Failure of the pull-in winch would result in a delay while the equipment is repaired but is unlikely to result in personnel injury unless the failure caused a rapid release of pull-in tension. Winch failure is unlikely to cause environmental damage.

6.18.9 Adverse weather would delay the operation if it exceeded the pre-determined criteria. Depending on the severity of the conditions it should be possible to maintain tension but in the worst case it would be necessary to lay the pipe down and remove buoyancy elements if pipe movement was excessive. Provided operations are carried out in accordance with the weather criteria it is considered that the probability of injury or environmental damage as a result of adverse weather is low.

6.18.10 A number of anchor handlers, survey vessels, line pull vessels etc. are involved in shore pull and shallow water pipe lay operations and there is a potential for collision. However all vessel movements are controlled by the construction manager and the probability of collision is considered to be low. In the worst case any impact would be at low speed and major injury or damage is considered unlikely.

6.18.11 It is noted that the German Landfall is in a very popular leisure sailing area with lots of marinas in the surrounding area. Most private sailing boats are not equipped with AIS and are therefore not accounted for in any traffic statistics. As in NSP1, NSP2 will employ Guard Vessels (probably local fishermen like on NSP1) to watch out and inform sailors during the dredging/pipe lay/backfilling campaign.

6.18.12 It is therefore considered that risks related to shore pull and shallow water lay are low and will not be included in the quantified assessment.

6.19 Pipe lay Initiation

6.19.1 At this stage specific pipe lay initiation procedures have not been developed but it is generally carried out using a standard method which is summarised below:

- The initiation system comprises a deadman anchor (DMA) and a start-up wire which is connected to a start-up head welded to the first pipe joint.
- The DMA is installed on the seabed at a certain distance behind the required position of the start-up head. The DMA can take the form of an anchor or pile depending on initiating loads and seabed conditions.
- The start- up wire is connected to the DMA and a load test carried out to ensure system integrity.
- A series of measurements are carried out to define the length of wire required to ensure the start-up head lands in the target box.
- A pennant buoy is connected to the free end of the start-up wire and the wire laid on the seabed.
- In parallel the firing line on the pipe lay vessel is filled with pipe and the start-up head welded onto the pipe joint at the aft end of the firing line.
- The pipe lay vessel takes up position ahead of the DMA and is moved back until it can recover the pennant buoy and pull the wire along the stinger.
- The start-up wire is connected to the start-up head.
- The pipe lay vessel moves ahead as pipe joints are added to the pipe string which is monitored as it moves over the stinger.
- Once the start-up head is clear of the stinger the vessel continues to move ahead while adjusting pipe tension, stinger angle and vessel position in accordance with pre-engineered steps that ensure the pipe can be laid onto the seabed without overstressing it.

6.19.2 The hazards associated with pipeline initiation are:

- Rigging operations at height and over water.
- Initiation wire or rigging failure.
- DMA movement.
- Tensioner failure.
- Initiation head weld failure.
- Incorrect stinger setting when starting up in shallow water.

6.19.3 The preparation work for pipe lay initiation includes a considerable amount of rigging work with large diameter wires. Some of these rigging operations are carried out at height and over water and there is a potential for rigger injury or fatality unless safe procedures are carried out. Although this is a standard operation it is normal practice to hold tool box talks before the operation and it is considered that the risk of injury is low.

6.19.4 Failure of the initiation wire or rigging under tension could cause injury or fatality to firing line personnel and damage to the vessel and the pipeline. All rigging is specifically designed for the operation and only certified equipment is used and failure is considered unlikely. Once the wire has been attached to the start-up head and all checks are complete, access to the aft end of the firing line and stinger is restricted and the operation managed remotely from the control room via CCTV and remote instrumentation. In the event of wire failure it is unlikely that any personnel would be in close proximity and the risks to personnel are considered to be low.

6.19.5 Movement of the DMA would result in a reduction in the start-up tension which may result in damage to the pipe but is unlikely to cause any injury to personnel in the firing line.

6.19.6 Tensioner failure during pipeline initiation would be similar to those experienced during pipe lay and could result in injury/fatality to firing line workers or loss of the pipe. However, tensions are generally low at pipeline start up and, as mentioned previously, tensioner failure is considered unlikely.

6.19.7 Failure of load bearing welds on the initiation head when under tension could result in injury to personnel and damage to the vessel and pipeline. However, the initiation heads are fabricated in accordance with a quality test and inspection plan which includes NDE inspection and the probability of weld failure is therefore considered to be low.

6.19.8 Incorrect setting of the stinger angle in shallow water could result in stinger contact with the seabed and possible damage to the pipeline. It is normal industry practice for the contractor, client and marine warranty surveyor to check stinger settings prior to starting pipe lay operations. In addition some stingers are fitted with sonar to measure seabed clearance. Although a stinger contact incident occurred some time ago it is considered to be a relatively rare incident and the risk is considered to be relatively low.

6.19.9 The risks of injury/fatality or environmental damage during pipe lay initiation are therefore considered to be low.

6.20 Normal Pipe lay Operations

6.20.1 On NSP1 maximum lay tensions were estimated to be 270 tonnes and the lay vessel tensioner capacity will need to be in excess of this. The maximum tensioner capacity of most large pipe lay vessels can easily handle the anticipated lay tensions but will need to be verified when vessels are nominated.

6.20.2 The main hazards related to normal pipe lay are:

- Tensioner failure (slippage or loss of pipe);
- Loss of position;
- Munitions (considered earlier);
- Collision (considered earlier);
- Adverse weather (low temperatures, high winds and seas).

6.20.3 Tensioner failure could result in pipe slippage or loss of the pipe.

6.20.4 Pipe slippage is caused by insufficient friction between the pipe and tensioner tracks due to the composition of the pipe coating. This is generally checked during the engineering phase and is also the subject of tests during mobilisation and is unlikely to occur.

6.20.5 In the event of a tensioner failure there should be sufficient tensioner redundancy to allow the load to be maintained by the other tensioners and this should be considered during vessel selection.

6.20.6 Loss of lay vessel position would deflect the pipeline and possibly overstress and/or buckle the pipe. It is noted that there were a number of DP incidents on NSP1, some relating to difficulties experienced using the taut wire reference system in the vicinity of UXOs. Buckle arrestors will be installed in high risk locations to limit the length of buckled pipe. With a moored vessel a buckle could be caused by the failure of a mooring line or a dragged anchor. It is standard procedure to carry out a pull test on anchors after they have been installed and this minimises the possibility of a dragged anchor. Prior to a pipe lay operation a mooring analysis is normally carried out to identify limiting weather conditions and calculate vessel offsets in the event of a line failure. Mooring wires are also fitted with tension meters, so line tensions can be monitored and relevant action taken if tensions approach a safe working limit.

6.20.7 Loss of position on a DP pipe lay vessel can be caused by failure of the DP control system, the DP references, the propulsion system or the power generation system. It is industry practice to carry out a failure modes effect analysis (FMEA) of a DP vessel to identify any potential single point failure and then carry out annual trials to demonstrate the system redundancy.

6.20.8 Loss of vessel position may result in unplanned movement of the pipe in the firing line and this could result in injury/fatality to the workers in the vicinity. However, alarms are located at each station in the firing line and the workers would be warned in the event of potential pipe movement. Provided normal industry practice is followed the risk of personnel injury/fatality resulting from vessel position loss is considered to be low.

6.20.9 The main impact of adverse weather is the potential for position loss and pipeline overstress through excessive vessel motion. Pipeline parameters and limits are calculated during the detail design phase and operations halted as these limitations are reached. Dependent on the weather forecast the decision is taken to either continue laying at a slower speed or to lay the pipe down until the weather improves. With moored vessels adverse weather tends to affect anchor handling operations before pipe lay limitations are reached and the relevant action taken well in advance of the onset of bad weather. The main result of bad weather is delay, the risk of injury or environmental damage is considered to be low.

6.20.10 The risks related to tensioner failure, collision and position loss have been considered in the quantified risk assessment.

6.21 Anchor Handling Operations

6.21.1 The main concerns related to anchor handling are injury/fatality to the anchor handling crew and damage to any adjacent pipelines, cables or other subsea infrastructure. Deck operations during anchor handling are supervised by the vessel Master who has a clear view over the work area and the crew are trained and experienced in this work. Procedures and deck arrangements minimise crew exposure to wire and rigging equipment under tension and operations are halted when weather conditions approach safe working limits. The risks to personnel are therefore considered to be low.

6.21.2 When anchor handling operations are carried out near pipelines there is always a possibility of pipeline damage by dragged or dropped anchors. However, the offshore industry has developed procedures over the years that have considerably reduced the frequency of anchor damage to subsea assets. Precautions include the use of certified rigging equipment for mooring wires and shackles and the requirement to lift the anchor onto the AHT deck and double secure it on deck when crossing subsea pipelines or other assets.

6.21.3 On this project anchors will only be used by the shallow water pipe lay vessel and one of the main pipe lay vessels, all other vessels will either be equipped with DP or use joystick control to avoid using anchors near the pipelines.

6.21.4 Anchor handling operations for the construction vessels are normally controlled by surveyors on the construction vessels through the use of a tug management system (TMS). The TMS comprises a survey system that displays the position of all field installations (platforms, pipelines and subsea structures) and overlays the position of all vessels in the field in real time. This system is used to direct the anchor handling tugs (AHT) where to lay and recover the anchors; the AHTs also have a slave display which enables them to identify field equipment and the target anchor location.

6.21.5 On NSP2 the main areas of concern would be at pipe and cable crossings and when the second line is laid when the first line is operating. Installation contractors have well developed procedures for laying pipe over other pipelines or cables and these includes the installation of protective mattresses over the crossing and the careful movement of anchors over the crossing. The anchor handling procedure ensures that in general anchors are never placed closer than 200 meters from a pipeline or cable.

6.21.6 In some cases there is a possibility that the catenary of an anchor wire could come into contact with a pipeline or cable. To prevent this, catenary calculations are carried out and if necessary a buoyancy unit (or damage prevention buoy) is attached to the mooring wire to increase the vertical clearance and avoid contact.

6.21.7 Line B will be laid parallel to line A with a horizontal separation distance of approximately 55 metres. If there is a potential for wire contact with the pipeline the wire will be fitted with additional buoyancy as described above. As the first pipe may be operating during the installation of the second line anchor handling operations will need to be carefully controlled and monitored to ensure that there is no risk of anchor damage to the first line. All personnel involved in anchor handling operations should be well briefed on the potential hazards associated with this activity.

6.21.8 Provided these procedures are followed the risk to personnel or damage to the environment is considered to be low and no further analysis has been carried out.

6.22 Pipe Crossings

6.22.1 The main hazards related to a pipe crossing are:

- Dropped object on crossed pipeline (pipe joints, taut wire clump weights)
- Anchor dragged over crossed pipeline;
- Anchor dropped on crossed pipeline.

6.22.2 It is standard practice to stop loading/discharging pipe joints and cargoes at a specified distance either side of the crossing and provided this is enforced the dropped object hazard would be negligible.

6.22.3 Provided the anchor handling procedures described in section 6.21 are complied with these anchoring hazards would also be negligible.

6.23 Cable Crossings

6.23.1 The main hazard related to cable crossings is the potential for damaging the cable being crossed. During the preparation phase this could be caused by dropped objects and during pipe lay this could be caused by anchor damage. Dropped object management is a standard industry practice and the risk of damage to the crossed cables is considered to be low. Damage by pipe lay anchors has been discussed previously.

6.23.2 It is noted that some 50 Hz cables will cross the pipelines in the German nearshore section.

6.23.3 In uneven seabed areas cable spans could be under tension and need to be handled with care during preparation for cable crossings. However, it is understood that this would be carried out by ROVs and there would be no risk of injury to divers.

6.23.4 Cable crossing procedures present low risks of injury or environmental damage and this subject has not been considered further.

6.24 Pipe Laydown and Recovery Operations

6.24.1 Pipe laydown is a standard procedure where the Abandonment and Recovery (A&R) winch is connected to a laydown head which is welded to the end of the pipeline. The pipe lay vessel moves ahead while the lay tension is transferred from the tensioners to the A&R winch which is then slacked off in accordance with the laydown analysis. The vessel continues to move ahead until the laydown head touches down on the seabed. This operation is generally monitored by an ROV deployed from a survey vessel. The recovery operation is the reverse of the laydown procedure.

6.24.2 No analysis has been carried out to date but A&R loads in some parts of the route are likely to be similar to the lay tensions i.e. up to 300 tonnes. The hazards associated with pipeline laydown and recovery are:

- Tensioner failure;
- A&R winch or wire/rigging failure;
- Failure of laydown head welds;
- Sudden onset of adverse weather.
- Stinger failure

6.24.3 The consequences of tensioner failure during pipeline laydown or recovery would be similar to those experienced during pipe lay except that the A&R winch would most likely be connected to the pipe at the same time. The risks are therefore considered to be the same, if not slightly lower, as those for normal pipe lay.

6.24.4 Failure of the A&R winch would delay the laydown/recovery operation while it was repaired but is unlikely to result in injury or environmental damage unless there was a catastrophic structural failure. In the event of a drive system failure the brakes are automatically applied and the load held on the brake. If the failure occurred while the pipe was suspended part way between the vessel and seabed it should be possible to lower it as the drive system has several motors to provide redundancy.

6.24.5 Failure of the A&R wire or rigging under tension could cause extensive injury or fatality to firing line personnel and damage to the vessel and the pipeline. The A&R wire and associated rigging is engineered for the anticipated loads and is certified so the probability of failure is low. Once the A&R wire has been attached to the laydown head and all checks are complete, access to the firing line is closed off and the operation managed remotely from the control room via CCTV and remote instrumentation. In the event of wire failure it is unlikely that any personnel would be in close proximity and the risks to personnel are considered to be low. The probability of injury/fatality as a result of tensioner or A&R wire failure has not been considered further.

6.24.6 Failure of load bearing welds on the laydown head when under tension could result in injury to personnel and damage to the vessel and pipeline. However, the laydown heads are fabricated in accordance with a quality test and inspection plan which includes NDE inspection and the probability of weld failure is therefore considered to be low.

6.24.7 The sudden onset of adverse weather during pipe laydown or recovery could result in a pipe buckle due to additional loads on the pipe or excessive vessel movement. However, consistent weather forecasting should provide sufficient warning of the onset of unstable weather conditions and minimise the potential for this type of incident. As mentioned above access to the firing line is restricted during pipe laydown and recovery operations and the risk of injury to personnel is considered to be low.

6.25 Pipe Transport and Offshore Handling Operations

6.25.1 Pipe supply is a critical part of the operation and can be considered in several phases:

- Transport from the pipe mills to the coating yards.
- Transport from the coating yards to the storage/marshalling yards.
- Transport from the storage/marshalling yards to the pipe lay vessels.
- Transport of quarantined pipe from the pipe lay vessels to the storage/marshalling yards.

6.25.2 Transport from the pipe mills will be carried out by train or by standard cargo vessels where the bare pipe is stowed in the holds secured in place. This is generally treated as a standard cargo although on some projects shipments are subject to marine warranty approval.

6.25.3 Transport from the coating yards to the storage/marshalling yards can be carried out by cargo vessel or a purpose built pipe carrier.

6.25.4 The hazards related to marine transportation include collision, grounding, fire and sinking. These risks are common to all shipping operations and provided international regulations and good shipping practices are complied with the risk of loss of the transport vessel and cargo is considered to be low. However, considering the high number of port call that pipe carriers will carry out these risks have been included in the quantified risk assessment.

6.25.5 The transport of pipe to the pipe lay vessel is carried out by dedicated pipe carriers which hold position alongside the pipe lay vessel while pipes are offloaded. This is more or less a continual process required to maintain pipe stock on the pipe lay vessel. Modern pipe carriers are fitted with DP which ensures reliable position keeping while the pipe lay vessel moves ahead.

6.25.6 The 48" pipe joints weigh approximately 24 tonnes and lifts will be carried out in accordance with the crane capacity but are likely to be single lifts. There is no specified weather limit for pipe handling operations but they are generally stopped when the relative vessel motions affect the safety of the riggers on the pipe carrier.

6.25.7 The main hazards are pipe carrier collision with the pipe lay vessel and dropped pipe. As indicated above pipe carrier operation close to a lay barge is a standard operation and provided normal industry standards and limits are followed the associated collision risks are considered to be low.

6.25.8 The probability of a section of pipe being dropped is considered to be low; however, the underwater excursion of dropped tubulars can be relatively high. A preliminary calculation based on DNV-GL recommended practice (reference 6.11) indicates a possible excursion of around 60 metres. This is particularly relevant to pipe handling operations for the second line when the first line is in operation.

6.25.9 The horizontal separation between lines when on DP is 105m in water depths greater than 100m and 75m for depths less than 100m. On an anchored lay barge the separation is 55m where the depth is greater than 30m and 75m for depths less than 30m.

6.25.10 When in close proximity to subsea structures it is standard practice to stop pipe handling operations or only load pipe on the side of the vessel that is furthest from the pipe. Provided this practice is followed the probability of pipeline damage from a dropped pipe is considered to be low.

6.25.11 Saipem indicate that they have transhipped some 1,086,803 pipes and only dropped two pipes, one was dropped onto the lay vessel deck and one dropped into the sea. Bearing in mind the potential consequences of a dropped pipe on an operating line this has been considered in the quantified risk assessment.

6.25.12 It is noted that no pipe joints were dropped into the sea during the installation of NSP1 pipelines 1 and 2.

6.26 Above Water Tie-In

6.26.1 It is understood that up to 8 AWTIs will be carried out on NSP2 and the main hazards have been considered in this section:

- Failure of the pipe lifting equipment and rigging;
- Loss of buoyancy modules;
- Barge loss of position;
- Clamp/work platform failure;
- Adverse weather;
- Diving incidents.

6.26.2 Failure of the lift davits, winches, rigging or buoyancy modules could result in the pipe being overstressed or, in the worst case, dropped overboard. The support vessel davit and winch capacity will have to be designed to ensure they exceed the anticipated installation loads. The buoyancy modules will be securely clamped to the pipe and inspected by divers to check the integrity of the clamps. The work is generally carried out within a clearly defined weather window so these loads should not be exceeded. The risk of lifting or buoyancy equipment failure is therefore considered to be low.

6.26.3 Loss of barge position during the lifting operations could overstress the davits and result in injury or fatality to the workers on the over side platform. Since this work is carried out in relatively calm seas, generally less than Hs 1.5m, position loss is considered to be a low risk. However, AWTI position loss has been included in the quantified assessment of pipe lay vessel position loss.

6.26.4 Structural failure of the clamp or work platform could result in failure to complete the weld or in the event of catastrophic failure result in the pipe dropping to the seabed. However, these items are carefully engineered and dynamic analyses are carried out to define actual weather limits, the risk of this failure happening is therefore considered to be very low. It should be noted that AWTI is a relatively standard operation and GM have been involved in a number of projects, including a 48” pipeline, where AWTI was completed without any particular problems.

6.26.5 As mentioned above, an AWTI will need to be carried out in calm conditions and the onset of adverse weather could result in overloading the davits and associated rigging equipment and potentially injure personnel. The risk of adverse weather can be minimised through the use of more than one weather forecast and the presence of a meteorologist on the vessel.

6.26.6 Diving operations will be required to install buoyancy elements and connect davit lift wires to the pipe. This will be carried out in relatively shallow water depths and most likely use surface demand diving methods. Hazards include physiological and industrial type incidents such as decompression sickness, dropped objects, poor visibility, etc. and will be subject to specific risk assessments carried out prior to the operation. Provided these operations are carried out in accordance with relevant regulations and IMCA guidelines the risk of injury/fatality are considered to be no higher than on any other pipe lay project.

6.26.7 The probability of injury/fatality or environmental damage is considered to be low and, apart from position loss, no further analysis has been carried out.

6.27 Buckled Pipe Repair

6.27.1 A buckled pipe could be repaired subsea or above water depending on the type of buckle, wet or dry, and the water depth in the buckle location. Depending on the extent of damage it may be possible to recover a dry buckle through the tensioners, cut out the damaged sections and recommence pipelay operations. In the case of a wet buckle the pipeline would have to be dewatered before recovery. The buckled section would be cut out subsea, a recovery tool installed and the pipeline dewatered. The pipe could then be recovered to the pipelay vessel and pipelay operations recommenced.

6.27.2 Buckles on heavy wall pipe are considered to be rare and it is noted that there were no incidents on NSP1. The risks related to buckle repair are almost the same as those encountered in pipeline laydown and recovery described earlier; risks associated with subsea intervention would also need to be considered during the preparation phase. These include crane/rigging failure, DSV loss of position, malfunction of subsea handling equipment and diving incidents.

6.27.3 The only difference being the unpredictability of pipe condition after a dry buckle has occurred and great care is taken when recovering a buckled pipe to the surface. It may also be possible to repair the pipe subsea without recovery to the surface in which case this risk would be eliminated. However, it is noted that this is a rare occurrence and as such has not been analysed further.

6.28 Pipe Trenching Operations

6.28.1 The principal hazards related to trenching are:

- Launch/recovery equipment failure;
- Variations in soil conditions;

- Support vessel loss of position;
- Loss of telemetry;
- Contact with munitions (see section 6.11).

6.28.2 Failure of the launch/recovery equipment and rigging could result in injury/fatality to the deck crew or damage to subsea assets. However, all lifting equipment is specifically designed for the operation and regularly inspected. Lifts are over-boarded well clear of subsea assets and the deck crew stand well clear once the lift is clear of the deck. Provided all normal launch and recovery procedures are followed the risk of injury/fatality and damage to subsea assets is considered to be low.

6.28.3 Variations in seabed conditions can cause problems during trenching operations. If harder than expected soil conditions are encountered the tow loads can increase and eventually overstress the tow rigging. However, it is normal practice to fit a 'fuse' in the tow rigging and this is a short length of wire with a breaking load lower than the rest of the rigging. In the event of an increase in tension the fuse parts ensuring the remaining equipment is not overstressed, the fuse is then replaced and operations continued. On the support vessel or tugs access to the main deck is restricted when the tow line is under tension and the risk of injury/fatality is considered to be low.

6.28.4 Support vessel loss of position could pull the trencher off course and impose a lateral load on the pipe. In most cases the loss of position would be detected early enough to cease operations and pay out the trencher tow line and/or umbilical to reduce tow wire tensions and prevent damage to the pipe. The exception to this would be a DP drive off which can result in a relatively rapid deviation from the desired course and position. However, this is a relatively rare occurrence and DP trenching operations have been carried out for a considerable number of years without major incident. It is therefore considered that this risk is low; however, the probability of position loss has been considered in a quantitative assessment.

6.28.5 Loss of telemetry from the plough could result in damage to the pipeline if trenching continued with a failed system as it may not be possible to ascertain plough loads on the pipe. There is generally some redundancy in the telemetry system and it may be possible to continue trenching without recovering the plough to the surface for repair. However, this type of incident is unlikely to result in injury to personnel or damage to the environment and the risk is considered to be very low.

6.29 Rock Placement

6.29.1 Rock placement will be carried out on crossings and parts of the route where span rectification, pipeline stabilisation or protection is required. Rock placement may be carried out before and after the pipe has been laid and is generally carried out from DP fall pipe vessels or side dump vessels. The hazards related to this operation are:

- Vessel instability
- Vessel grounding
- Vessel collision in port
- Loss of position
- Passing vessel collision with rock placement vessel.

6.29.2 Vessel instability could result in excessive list and potential capsize leading to injury/fatality of the crew. Loading operations are planned in advance and are normally monitored using the vessel ballast management systems. Crew competence and experience would also reduce the risk of vessel instability.

6.29.3 Vessel grounding could occur during entry and departure from the loading port and this could result in injury/fatality to the vessel crews and a possible oil spill. However, this is a hazard faced by all vessels and the risk is minimised through the use of vessel navigation procedures, officer competence, pilotage during port movements and the preparation of passage plans.

6.29.4 Vessel collision in port could result in injury/fatality and an oil spill but the risk is minimised by vessel navigation procedures, officer competence, pilotage, the Master's familiarity with the port and low manoeuvring speeds.

6.29.5 DP failure would result in loss of vessel position but this would have no impact to subsea equipment and no potential for injury or pollution. The potential for this event is minimised by the DP system redundancy, approved DP procedures, operator training and experience and annual DP trials.

6.29.6 Passing vessel collision with rock placer would result in injury/fatalities to the rock placer crew, possible oil spill and injury/fatalities to passing vessel crews and passengers. The risk of collision is reduced through standard collision avoidance procedures, the use of navigation warnings, Notice to Mariners, ARPA radar, AIS, prohibition areas established around stationary rock placement vessels, and emergency procedures. Rock placer vessels also have a certain freedom of movement as they are not connected to equipment on the seabed; however, this movement is restricted when the fall pipe is in position.

6.29.7 Provided normal industry marine and survey procedures are followed the probability of all these events is considered to be low. However, the risks of vessel instability, grounding and passing vessel collision have been considered in the quantified assessment.

6.30 Pipeline Testing and Pre-Commissioning

6.30.1 As the hydrotest waiver has been implemented the testing and commissioning operation will be carried out at the German and Russian landfalls and marine operations will be limited to leak detection from a survey vessel.

6.30.2 The main hazard associated with pre-commissioning and testing is:

- Equipment failure under pressure

6.30.3 Failure of pumps, hoses and fittings could result in injury/fatality to the test personnel; however, procedures are engineered, and all equipment is certified, tested and inspected before use. It is standard practice to use specialist contractors for this scope of work and all relevant safety management practices such as HAZIDs, tool box talks, etc. are carried out prior to the operation. It is therefore considered that the risk of injury or fatality is low. However, a detailed risk assessment will be carried out when the testing sub-contractor is nominated.

6.30.4 Site safety issues such as high noise levels will be managed by the NSP2 Safety Management System and the relevant contractor HSE procedures.

6.30.5 The risks to personnel or the environment are considered to be low and have not been quantitatively assessed.

7. QUANTITATIVE RISK ASSESSMENT

7.1 General

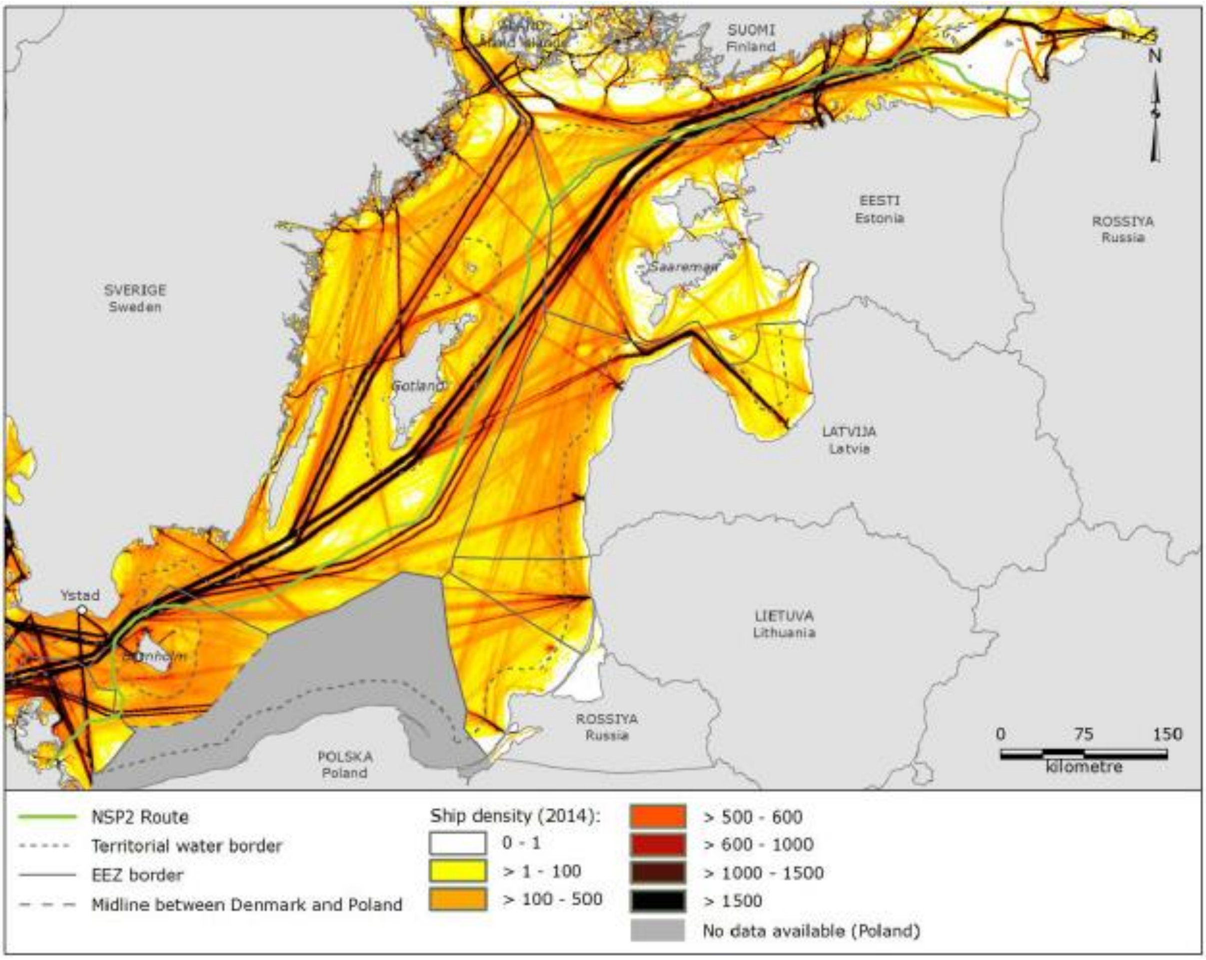
7.1.1 The pipeline construction hazard section identified a number of hazards that would need to be assessed quantitatively, these include:

- Passing vessel collision with construction vessels.
- Vessel fire.
- Vessel grounding.
- Vessel sinking or capsize.
- Oil spills during bunkering operations.
- Helicopter accidents.
- Vessel position loss – moored and DP vessels.
- Dropped objects – (pipe joints).
- Dropped objects – (anchors)
- Tensioner failure
- A&R winch/wire failure.
- Diving operations.
- Munitions.

7.1.2 Unless noted otherwise the methodology for these hazards is provided in Appendix I.

7.2 Passing Vessel Collision Methodology

7.2.1 The pipeline will cross many existing traffic routes and these are illustrated in the figure below which also includes the coating yards and trans-shipment sites. Ramboll have carried out a ship traffic collision analysis (reference 6.4) and this data has been used as the basis for the GM scope of work.



7.2.2 As part of the traffic collision study Ramboll analysed the ship traffic pattern of the Normand Aurora pipe carrier vessel during the laying of NSP1 and used this data as part of the basis for the pipe carrier collision risk assessment.

7.2.3 Before and during the construction of the pipeline there will be an increase in ship traffic in the Baltic Sea due to the movement of the pipe carriers and the pipe lay vessel. When either a pipe carrier or the pipe lay vessel crosses an existing shipping route there is a risk of a ship-to-ship collision. In order to assess the risk Ramboll have developed a model according to the methodology described in Appendix I.

7.2.4 As indicated above for the pipe carriers Ramboll have used Normand Aurora data to calculate the steaming distance from the relevant port to the pipe lay vessel. They also identified the shipping routes the vessels would cross together with the crossing angles to estimate the probability of collision on each shipping route.

7.2.5 For the lay barge risk assessment the lay vessel was treated as a slow moving vessel along the pipeline route at a speed equivalent to 3 km a day. As with the pipe carriers the probability of collision was estimated for each shipping lane encountered by the lay barge. Some collisions with offshore installations have occurred as a result of vessels drifting into a platform following mechanical failure; however, this type of incident represents a small percentage of collision situations and has not been considered in this assessment.

7.2.6 The following paragraphs consider the consequences of these collisions in two categories, namely third party passing vessels and construction vessels. In the event of a collision a stationary construction vessel will be hit by the third party passing vessel. While the stationary construction vessel could be damaged at any location on the vessel the passing vessel is likely to be damaged only in the bow area. However a construction vessel underway (e.g. pipe carrier) could strike a passing vessel and damage any part of that vessel. The consequences of collision have been mainly based on statistical data and vessel traffic data provided by Ramboll.

7.3 Passing Vessel Collision

7.3.1 The consequences of a collision will vary for each vessel type and the distribution of vessel types has been taken from the Ramboll study on ship traffic (reference 6.4) moving along the reference route through the Baltic. The derivation of risk factors is shown in Appendix I.

7.3.2 The individual risks have been assessed for each passing vessel type as follows:

	Cargo Ship	Tanker	Passenger Ship
Frequency of collision per year	1.4×10^{-3}	4.6×10^{-4}	9.2×10^{-5}
Conditional probability of fatality	0.028	0.028	0.028
Frequency of fatality	4.1×10^{-5}	1.3×10^{-5}	2.6×10^{-6}
Persons on board	20	25	450
Number of fatalities	4	4	4
Potential loss of life	1.6×10^{-4}	5.1×10^{-5}	1.0×10^{-5}
Individual risk	4.1×10^{-6}	1.0×10^{-6}	1.1×10^{-8}

7.3.3 The individual and group risks have also been estimated for the section of pipe in each country along the route. This has been carried out using the same methodology and the results are summarised in the following tables.

Individual Risks:

Russia

	Cargo Ship	Tanker	Passenger Ship
Frequency of collision per year	2.0×10^{-5}	6.1×10^{-6}	1.2×10^{-6}
Frequency of fatality	5.5×10^{-7}	1.7×10^{-7}	3.5×10^{-8}
Number of fatalities	4	4	4
Potential loss of life	2.2×10^{-6}	6.9×10^{-7}	1.4×10^{-7}
Individual risk	5.5×10^{-8}	1.4×10^{-8}	1.5×10^{-10}

Finland

	Cargo Ship	Tanker	Passenger Ship
Frequency of collision per year	1.2×10^{-4}	3.9×10^{-5}	7.8×10^{-5}
Frequency of fatality	3.4×10^{-6}	1.0×10^{-6}	2.2×10^{-7}
Number of fatalities	4	4	4

	Cargo Ship	Tanker	Passenger Ship
Potential loss of life	1.4×10^{-5}	4.3×10^{-6}	8.8×10^{-7}
Individual risk	3.5×10^{-7}	8.7×10^{-8}	9.7×10^{-10}

Sweden

	Cargo Ship	Tanker	Passenger Ship
Frequency of collision per year	6.5×10^{-4}	2.0×10^{-4}	4.1×10^{-5}
Frequency of fatality	1.8×10^{-5}	5.7×10^{-6}	1.1×10^{-6}
Number of fatalities	4	4	4
Potential loss of life	7.2×10^{-5}	2.3×10^{-5}	4.6×10^{-6}
Individual risk	1.8×10^{-6}	4.6×10^{-7}	5.1×10^{-9}

Denmark

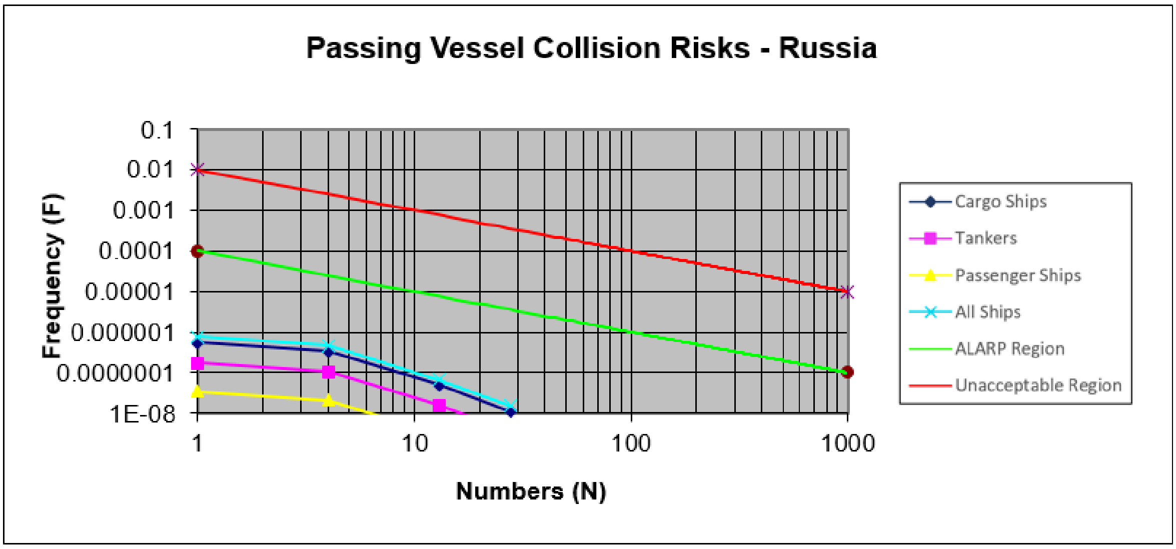
	Cargo Ship	Tanker	Passenger Ship
Frequency of collision per year	3.7×10^{-4}	1.2×10^{-4}	3.6×10^{-5}
Frequency of fatality	1.0×10^{-5}	3.2×10^{-6}	9.9×10^{-7}
Number of fatalities	4	4	4
Potential loss of life	4.1×10^{-5}	1.3×10^{-5}	4.0×10^{-6}
Individual risk	1.0×10^{-6}	2.6×10^{-7}	4.4×10^{-9}

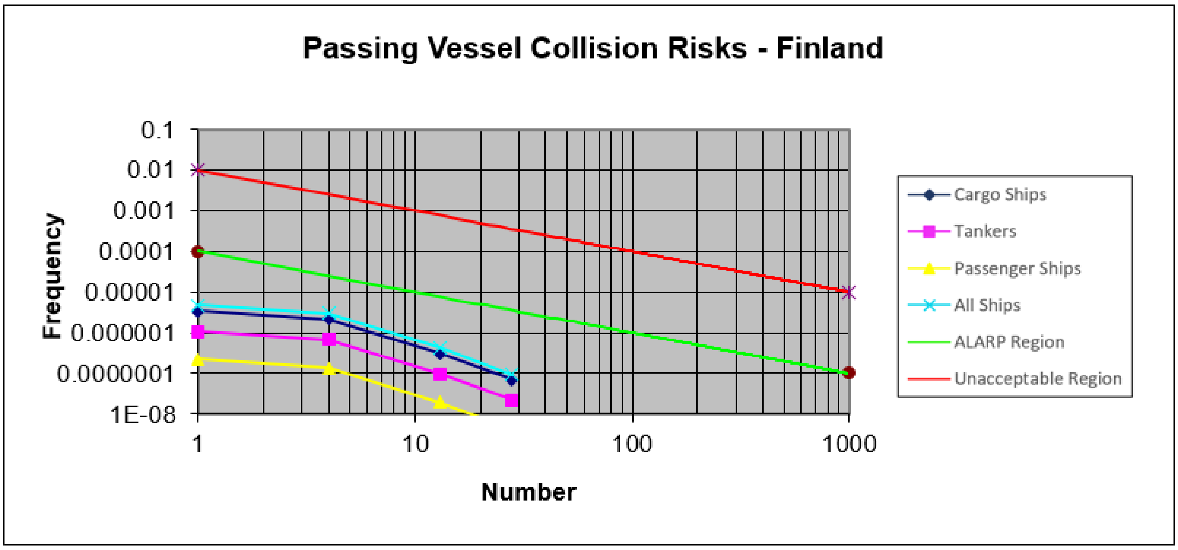
Germany

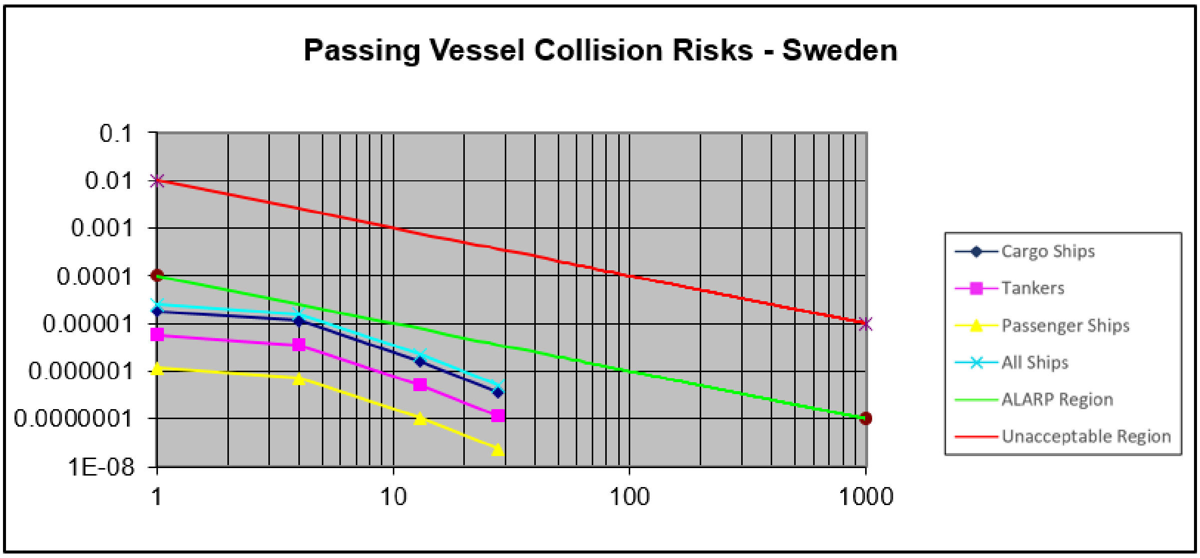
	Cargo Ship	Tanker	Passenger Ship
Frequency of collision per year	2.9×10^{-4}	9.1×10^{-5}	1.8×10^{-5}
Frequency of fatality	8.1×10^{-6}	2.6×10^{-6}	5.1×10^{-7}
Number of fatalities	4	4	4
Potential loss of life	3.2×10^{-5}	1.0×10^{-5}	2.0×10^{-6}
Individual risk	8.1×10^{-7}	2.0×10^{-7}	2.3×10^{-9}

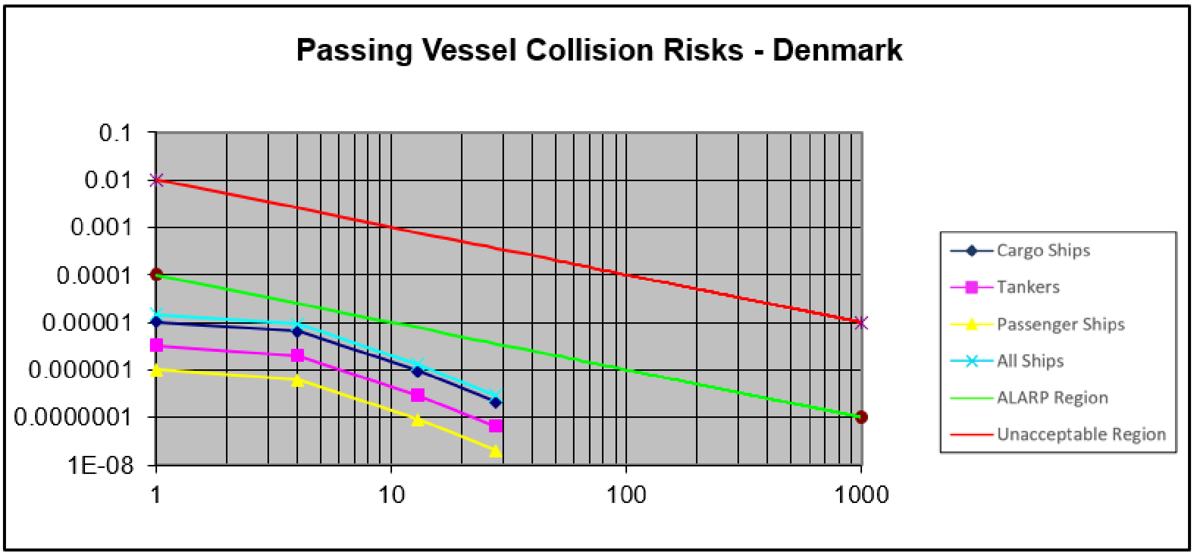
7.3.4 It can be seen that the individual risks are below the tolerability criteria outlined in section 5. The group risks for individual countries are shown in the following F-N graphs. The red and green lines indicate the ALARP region.

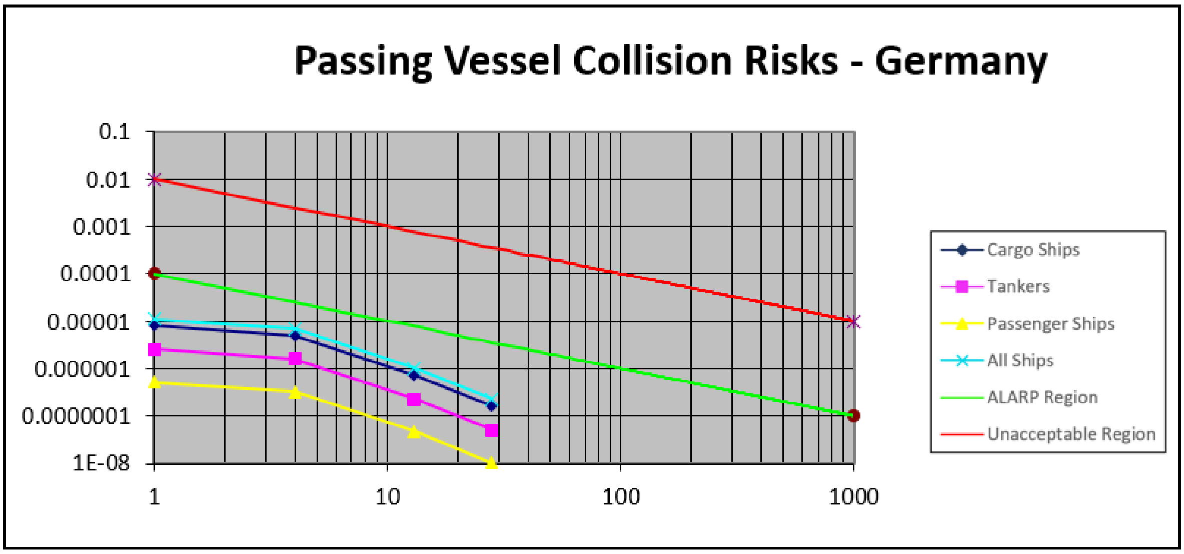
Group Risks:


Passing Vessel Collision Risks - Russia
Frequency (F)
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
1E-08
1
10
100
1000
Numbers (N)
Cargo Ships
Tankers
Passenger Ships
All Ships
ALARP Region
Unacceptable Region


Passing Vessel Collision Risks - Finland
Frequency
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
1E-08
1
10
100
1000
Number
Cargo Ships
Tankers
Passenger Ships
All Ships
ALARP Region
Unacceptable Region


Passing Vessel Collision Risks - Sweden
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
1E-08
1
10
100
1000
Cargo Ships
Tankers
Passenger Ships
All Ships
ALARP Region
Unacceptable Region


Passing Vessel Collision Risks - Denmark
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
1E-08
1
10
100
1000
Cargo Ships
Tankers
Passenger Ships
All Ships
ALARP Region
Unacceptable Region



7.3.5 Similarly group risks are in the broadly acceptable zone.

7.3.6 Pollution – The data used in the following tables has been derived from a DNV-GL oil spill risk report for the Australian Maritime Safety Authority (reference 7.1) and in the Baltic Sea by Ramboll for NSP1 (reference 7.2) and more details are provided in Appendix I.

	Spill Size				
	1-10 t	**10-100 t**	**100-1000 t**	**1000-10000 t**	**>10000 t**
Spill distribution	0.13	0.26	0.38	0.18	0.05
Pr pollution	0.11	0.11	0.11	0.11	0.11
Conditional	0.01	0.03	0.04	0.02	0.01
Collision	2.0×10^{-3}	2.0×10^{-3}	2.0×10^{-3}	2.0×10^{-3}	2.0×10^{-3}
Pollution	2.9×10^{-5}	5.9×10^{-5}	8.6×10^{-5}	4.0×10^{-5}	1.1×10^{-5}

7.3.7 The spill probabilities (pollution frequency / year) for individual countries are summarised in the following table:

Country	**Spill Size**				
	1-10 t	**10-100 t**	**100-1000 t**	**1000-10000 t**	**>10000 t**
Russia	4.0×10^{-7}	8.0×10^{-7}	1.2×10^{-6}	5.5×10^{-7}	1.5×10^{-7}
Finland	2.5×10^{-6}	5.0×10^{-6}	7.4×10^{-6}	3.5×10^{-6}	9.7×10^{-7}
Sweden	1.3×10^{-5}	2.6×10^{-5}	3.8×10^{-5}	1.8×10^{-5}	5.0×10^{-6}
Denmark	7.5×10^{-6}	1.5×10^{-5}	2.2×10^{-5}	1.0×10^{-5}	2.9×10^{-6}
Germany	5.9×10^{-6}	1.2×10^{-5}	1.7×10^{-5}	8.2×10^{-6}	2.3×10^{-6}

7.4 Construction Vessel Collision Risks

7.4.1 In the event of a collision situation arising some of the construction vessels will have limited manoeuvring capabilities and will have to rely on assistance from the other project vessels that may be in the area (e.g. anchor handlers or supply vessels) to act as guard vessels.

7.4.2 Trench support and rock placement vessels have some degree of manoeuvrability and should be able to take some avoiding action albeit at reduced speed. Dive support vessels need 20 to 30 minutes to recover divers to the bell and the bell to the surface before they can take avoiding action which may require releasing or cutting any down lines connected to the subsea worksite.

7.4.3 The main pipe lay vessels are unlikely to be able to take avoiding action and would have to rely on the anchor handling tugs to act as guard vessels and attempt to warn off the incoming vessel. It is therefore considered that the LMIU data is not directly applicable to this scenario and an event tree has been developed to reflect this. In the event of a passing vessel collision the consequences include:

- Vessel instability or capsize.
- Vessel fire.
- Oil spill.

These have been considered in the event tree shown in Appendix I.

7.4.4 The number of fatalities has been based on the data used for the passing vessel collision risks but some engineering judgement has been made considering vessel type and size. The risks are summarised on the table below:

Vessel	**DP Pipe lay**	**Anchored Pipelay**	**Shallow water p/l**	**Rock Placement**
Days on location	292	88	95	213
Event Fr	3.3×10^{-4}	1.0×10^{-4}	1.0×10^{-4}	2.6×10^{-4}
Prob. Fatality	0.045	0.045	0.045	0.045
POB	300	300	200	20
Fr. Fatality	1.5×10^{-5}	4.5×10^{-6}	4.6×10^{-6}	1.1×10^{-5}
No. Fatalities	8	8	8	4
PLL	1.2×10^{-4}	3.6×10^{-5}	3.8×10^{-5}	4.6×10^{-5}
IR	2.0×10^{-7}	5.9×10^{-8}	9.6×10^{-8}	1.1×10^{-6}
Vessel	**AHT**	**Pipe Carrier & Supply v/l**	**Trench Support**	**Survey**
Days on location	95	292	48	292
Event Fr	1.1×10^{-4}	9.1×10^{-4}	5.8×10^{-5}	3.5×10^{-4}
Prob. Fatality	0.045	0.045	0.045	0.045
POB	15	15	100	40
Fr. Fatality	5.1×10^{-5}	4.1×10^{-5}	2.6×10^{-6}	1.6×10^{-5}
No. Fatalities	4	4	5	8
PLL	2.6×10^{-5}	1.5×10^{-4}	1.3×10^{-5}	1.3×10^{-4}
IR	6.8×10^{-6}	5.1×10^{-6}	6.5×10^{-8}	1.6×10^{-6}

7.4.5 Pollution probability

Major oil spills in the existing ship traffic in the Baltic Sea are very rare according to the Helsinki Commission.

The DNV-GL study mentioned previously (reference 7.1) estimated that the conditional probability of a non-tanker bunker spill as a result of a collision was 0.10. This is comparable with the Helcom data and has been used for this assessment. The spill size has been estimated in accordance with vessel bunker capacity and, in accordance with reference 7.1, it has been assumed that 30% to 50% of bunker oil could be spilled after a collision incident. The probability of environmental damage is estimated as follows:

Vessel	**DP Pipe lay**	**Anchored Pipelay**	**Shallow water p/l**	**Rock Placement**
Days on location	292	88	95	213
Event Fr	3.5×10^{-4}	1.0×10^{-4}	1.0×10^{-4}	2.6×10^{-4}
Prob. Spill	0.10	0.10	0.10	0.10
Fr. Spill	3.5×10^{-5}	1.0×10^{-5}	1.0×10^{-5}	2.6×10^{-5}
Bunker Capacity (t)	2,500	2,500	1,000	1,700
Spill size (t)	750 – 1,250	750 – 1,250	300-500	500 – 850
Vessel	**AHT**	**Pipe Carrier & Supply v/l**	**Trench Support**	**Survey**
Days on location	95	292	48	292
Event Fr	1.1×10^{-4}	9.1×10^{-4}	5.8×10^{-5}	3.5×10^{-4}
Prob. Spill	0.10	0.10	0.10	0.10
Fr. Spill	1.1×10^{-5}	9.1×10^{-5}	5.8×10^{-6}	3.5×10^{-5}
Bunker Capacity (t)	1,000	1,000	1,700	1,700
Spill size (t)	300 – 500	300-500	500-850	500-850

7.5 Vessel Fire

7.5.1 As pipe lay operations will be carried out throughout the year the quantitative assessment for fire risk is based on the probability of fire/per vessel/per year and the historical data has been reviewed with this in mind. The assessment has considered service vessels (pipe carriers, anchor handlers, etc.) and pipe lay vessels separately due to the difference in crew sizes. It has been assumed that service vessels have an average crew size of 15-20 and the pipe lay vessels a crew of 300. The background to this assessment is explained in Appendix I.

7.5.2 The consequences of an engine room or machinery space fire are estimated as follows:

Vessel	**DP Pipe lay**	**Anchored Pipelay**	**Shallow Water P/L**	**Rock Placement**
Days on location	292	88	95	213
Event Fr	2.0×10^{-3}	6.0×10^{-4}	6.0×10^{-4}	1.5×10^{-3}
Prob. Fatality	0.073	0.073	0.073	0.073
POB	300	300	200	20
Fr. Fatality	1.5×10^{-4}	4.4×10^{-5}	4.7×10^{-5}	1.1×10^{-4}
No. Fatalities	8	8	6	2
PLL	1.1×10^{-3}	3.3×10^{-4}	2.8×10^{-4}	2.1×10^{-4}
IR	1.8×10^{-6}	9.5×10^{-7}	7.1×10^{-7}	5.3×10^{-6}

Vessel	AHT	Pipe Carrier & PSV	Trench Support	Survey
Days on location	95	292	48	292
Event Fr	6.5×10^{-4}	2.0×10^{-3}	3.3×10^{-4}	2.0×10^{-3}
Prob. Fatality	0.073	0.073	0.073	0.073
POB	15	15	100	40
Fr. Fatality	4.7×10^{-5}	1.5×10^{-4}	2.4×10^{-5}	1.5×10^{-4}
No. Fatalities	2	2	6	8
PLL	7.1×10^{-5}	2.2×10^{-4}	7.2×10^{-5}	1.2×10^{-3}
IR	2.4×10^{-6}	7.3×10^{-6}	3.6×10^{-7}	1.5×10^{-5}

7.5.3 The consequences of an accommodation fire are estimated as follows:

Vessel	DP Pipe lay	Anchored Pipelay	Shallow Water P/L	Rock Placement
Days on location	292	88	95	213
Event Fr	3.5×10^{-4}	1.0×10^{-4}	1.1×10^{-4}	2.6×10^{-4}
Prob. Fatality	0.073	0.073	0.073	0.073
POB	300	300	200	20
Fr. Fatality	2.6×10^{-5}	7.7×10^{-6}	8.4×10^{-6}	1.9×10^{-5}
No. Fatalities	15	15	15	4
PLL	3.9×10^{-4}	1.2×10^{-4}	1.2×10^{-4}	7.5×10^{-5}
IR	6.4×10^{-7}	1.9×10^{-7}	3.0×10^{-7}	1.9×10^{-6}
Vessel	**AHT**	**Pipe Carrier & PSV**	**Trench Support**	**Survey**
Days on location	95	292	48	292
Event Fr	1.1×10^{-4}	3.5×10^{-4}	5.8×10^{-5}	3.5×10^{-4}
Prob. Fatality	0.073	0.073	0.073	0.073
POB	15	15	100	40
Fr. Fatality	8.4×10^{-6}	2.6×10^{-5}	4.2×10^{-6}	2.6×10^{-5}
No. Fatalities	3	3	8	8
PLL	2.5×10^{-5}	7.7×10^{-5}	3.4×10^{-5}	2.1×10^{-4}
IR	8.4×10^{-7}	2.6×10^{-6}	1.7×10^{-7}	2.6×10^{-6}

7.5.4 The probability of damage to the environment is estimated as follows:

Vessel	DP Pipe lay	Anchored Pipelay	Shallow water p/l	Rock Placement
Days on location	292	88	95	213
Event Fr	2.0×10^{-3}	6.0×10^{-4}	6.0×10^{-4}	1.5×10^{-3}
Prob. Spill	0.045	0.045	0.045	0.045
Fr. Spill	9.0×10^{-5}	2.7×10^{-5}	2.7×10^{-5}	6.6×10^{-5}
Bunker Capacity (t)	2,500	2,500	1,000	1,700
Spill size (t)	250	250	100	170

Vessel	AHT	Pipe Carrier & Supply v/l	Trench Support	Survey
Days on location	95	292	30	292

Vessel	AHT	Pipe Carrier & Supply v/l	Trench Support	Survey
Event Fr	6.0×10^{-4}	2.0×10^{-3}	3.3×10^{-4}	2.0×10^{-3}
Prob. Spill	0.045	0.045	0.045	0.045
Fr. Spill	2.7×10^{-5}	9.0×10^{-5}	1.5×10^{-5}	9.0×10^{-5}
Bunker Capacity (t)	1,000	1,000	1,700	1,700
Spill size (t)	100	100	170	170

7.6 Vessel Grounding

7.6.1 Vessel grounding is obviously of concern due to the potential environmental damage. The main pipe lay vessels are not considered to be at risk due to the fact that they will be operating in open water for most of the time. However, the pipe carriers, supply vessels and the rock placement vessels will be continually entering and leaving port and could ground during port visits although the low tidal range in the Baltic Sea reduces the probability of this. The rock placement vessel will load material in a port in Finland which has yet to be determined while the pipe carriers will load pipe at Mukran (Germany), Karlshamn and Slite (Sweden), Hanko-Koverhar, and Kotka (Finland). The survey vessels will be occupied in a number of activities but are expected to make one port call every 3 weeks.

7.6.2 Grounding probabilities have been estimated on the number of movements per vessel type per year. The pipe carriers are scheduled to make one port visit every 2 days, supply vessels one visit every 5 days and the rock placement vessels one visit every 10 days.

7.6.3 The probability of pipe carrier grounding is estimated as follows:

Duration of pipe lay	292 days per year
Days per visit	2 days
Number of visits	146 per year
Probability per move	1.05×10^{-5}
Frequency of grounding	1.5×10^{-3} per year

7.6.4 The probability of rock placement vessel grounding is estimated as follows:

Duration of rock placement	213 days per year
Days per visit	10 days
Number of visits	21 per year
Probability per move	1.05×10^{-5}
Frequency of grounding	2.2×10^{-4} per year

7.6.5 The probability of supply vessel grounding is estimated as follows:

Duration of pipe lay	292 days per year
Days per visit	5 days
Number of visits	58 per year
Probability per move	1.05×10^{-5}
Frequency of grounding	6.1×10^{-4} per year

7.6.6 The probability of survey vessel grounding is estimated as follows:

Duration	292 days per year
Number of visits	14 per year

Probability per move	1.05×10^{-5}
Frequency of grounding	1.5×10^{-4} per year

7.6.7 The frequency of fatality following grounding is estimated as follows:

7.6.8 Frequency of fatality Pipe Carrier

Frequency of grounding	1.5×10^{-3} per year
Conditional probability of fatality	0.009
Frequency of fatality	1.4×10^{-5} per year
Persons on board	15
Number of fatalities	2
Potential loss of life	2.9×10^{-5} per year
Individual risk	6.9×10^{-7} per year

7.6.9 Frequency of fatality Rock Placement Vessel

Frequency of grounding	2.2×10^{-4} per year
Conditional probability of fatality	0.012
Frequency of fatality	2.7×10^{-6} per year
Persons on board	20
Number of fatalities	2
Potential loss of life	5.4×10^{-6} per year
Individual risk	1.3×10^{-7} per year

7.6.10 Frequency of fatality Supply Vessel

Frequency of grounding	6.1×10^{-4} per year
Conditional probability of fatality	0.009
Frequency of fatality	5.5×10^{-6} per year
Persons on board	15
Number of fatalities	2
Potential loss of life	8.3×10^{-6} per year
Individual risk	2.8×10^{-7} per year

7.6.11 Frequency of Fatality Survey Vessel

Frequency of grounding	1.5×10^{-4} per year
Conditional probability of fatality	0.024 ($6.0 \times 10^{-4} \times 40$)
Frequency of fatality	3.5×10^{-6} per year
Persons on board	40
Number of fatalities	4
Potential loss of life	1.4×10^{-5} per year
Individual risk	1.8×10^{-7} per year

7.6.12 Spill probability

The DNV-GL report (reference 7.1) reports that out of 90 groundings 7 were serious or resulted in a total loss and the corresponding conditional probability of a spill incident is therefore estimated to be 0.08. The spill size has been estimated in accordance with vessel bunker capacity and it has been assumed that 30% to 50% of bunker oil could be spilled after a grounding incident. The probability of environmental damage is estimated as follows.

7.6.13 Pipe Carrier

Frequency of grounding	1.5×10^{-3} per year
Conditional probability of spill	0.08

Frequency of spill	1.2×10^{-4} per year
Vessel bunker capacity	1000 tonnes
Estimated spill size	300 to 500 tonnes

7.6.14 Rock Placement Vessel

Frequency of grounding	2.2×10^{-4} per year
Conditional probability of spill	0.08
Frequency of spill	1.8×10^{-5} per year
Vessel bunker capacity	1700 tonnes
Estimated spill size	500 to 850 tonnes

7.6.15 Supply Vessel

Frequency of grounding	6.1×10^{-4} per year
Conditional probability of spill	0.08
Frequency of spill	4.9×10^{-5} per year
Vessel bunker capacity	1000 tonnes
Estimated spill size	300 to 500 tonnes

7.6.16 Survey Vessel

Frequency of grounding	1.5×10^{-4} per year
Conditional probability of spill	0.08
Frequency of spill	1.2×10^{-5} per year
Vessel bunker capacity	1000 tonnes
Estimated spill size	300 to 500 tonnes

7.7 Vessel Sinking

7.7.1 The probability of vessels sinking or capsizing is generally low, for example Helcom reported that 16 vessels sunk in the Baltic Sea between 1989 and 2006.

7.7.2 The risks of sinking for the various construction vessels have been estimated as follows:

Vessel	DP Pipe lay	Anchored Pipelay	Shallow Water P/L	Rock Placement
Days on location	292	88	95	213
Event Fr	3.4×10^{-6}	1.0×10^{-6}	1.1×10^{-6}	2.5×10^{-6}
Prob. Fatality	0.043	0.043	0.043	0.043
POB	300	300	200	20
Fr. Fatality	1.5×10^{-7}	4.4×10^{-8}	4.8×10^{-8}	1.1×10^{-7}
No. Fatalities	50	60	50	4
PLL	8.8×10^{-6}	2.7×10^{-6}	2.4×10^{-6}	4.3×10^{-7}
IR	1.5×10^{-8}	4.4×10^{-9}	6.0×10^{-9}	1.1×10^{-8}

Vessel	AHT	Pipe Carrier & PSV	Trench Support	Survey
Days on location	95	292	48	292
Event Fr	1.1×10^{-6}	3.4×10^{-6}	5.6×10^{-7}	3.4×10^{-6}
Prob. Fatality	0.043	0.043	0.043	0.043
POB	15	15	100	40
Fr. Fatality	4.8×10^{-8}	1.5×10^{-7}	2.4×10^{-8}	1.5×10^{-7}
No. Fatalities	3	3	20	8

Vessel	AHT	Pipe Carrier & PSV	Trench Support	Survey
PLL	1.4×10^{-7}	4.4×10^{-7}	4.8×10^{-7}	1.2×10^{-6}
IR	4.8×10^{-9}	1.5×10^{-8}	2.4×10^{-9}	1.5×10^{-8}

7.7.3 The probability of a spill and associated spill quantities for the various vessels have been estimated in the following paragraphs:

Vessel	DP Pipe lay	Anchored Pipelay	Shallow water p/l	Rock Placement
Days on location	292	88	95	213
Event Fr	3.4×10^{-6}	1.0×10^{-6}	1.1×10^{-6}	2.5×10^{-6}
Prob. Spill	0.75	0.75	0.75	0.75
Fr. Spill	2.6×10^{-6}	7.7×10^{-6}	8.3×10^{-7}	1.9×10^{-6}
Bunker Capacity (t)	2,500	2,500	1,000	1,700
Spill size (t)	750 – 1250	750 - 250	300 - 500	500 - 850
Vessel	**AHT**	**Pipe Carrier & PSV**	**Trench Support**	**Survey**
Days on location	95	292	48	292
Event Fr	1.1×10^{-6}	3.4×10^{-6}	5.6×10^{-7}	3.4×10^{-6}
Prob. Spill	0.75	0.75	0.75	0.75
Fr. Spill	8.3×10^{-7}	2.6×10^{-6}	4.2×10^{-7}	2.6×10^{-6}
Bunker Capacity (t)	1,000	1,000	1,700	1,700
Spill size (t)	300-500	300-500	500-850	500-850

7.8 Oil Spills – (Bunkering Operations)

7.8.1 Most of the construction vessels will be able to load fuel oil in port; however, the pipe lay vessels and the anchor handlers will need to be refuelled offshore. It is assumed that the pipe lay vessels will be refuelled from a supply vessel and will load approximately 500 tonnes twice a week and the anchor handlers will be refuelled from the pipe lay vessels.

7.8.2 Typical AHT fuel capacity is 1000 tonnes with a consumption of approximately 15 tonnes per day. AHTs generally need to maintain a minimum amount of fuel on board for stability; assuming that 400 tonnes are needed for stability, it is estimated that an AHT will refuel once every 6 weeks. Corresponding refuelling frequencies for these vessels are therefore:

DP Pipe lay vessel	83 times per year
AHTs	3 times a year
Shallow water pipe lay	27 times a year

7.8.3 DNV-GL data for ship to ship transfer (reference 7.1) reports 1 spill in 2000, resulting in a spill frequency of 5.0×10^{-4} per transfer.

7.8.4 Based on the average rate the estimated spill probability for project vessels is estimated as follows:

Pipe lay vessels	$83 \times 5.0 \times 10^{-4}$	$= 4.2 \times 10^{-2}$ per year.
AHTs	$3 \times 5.0 \times 10^{-4}$	$= 1.5 \times 10^{-3}$ per year.
Shallow water pipe lay	$27 \times 5.0 \times 10^{-4}$	$= 1.3 \times 10^{-2}$ per year.

7.8.5 An oil spill study carried out by the International Tanker Owners Pollution Federation (ITOPF) analysed spills from 1995 to 2004 and noted that in bunkering incidents no spills greater than 7 tonnes had been recorded.

7.8.6 The Russian and German landfalls will be in nature reserves and the Russian landfall is very close to the Estonian border (a transnational oil spill would have severe consequences). Both conditions warrant specific measures such as the availability of Tier 2 spill response equipment in the proximity of the spread or the deployment of booms during bunkering operations or a ban on bunkering at less than a specified distance from the shore or a combination of the above measures. The risk of spillage in these areas is therefore considered to be higher than in normal landfall situations.

7.8.7 Pipe lay vessels and AHTs have a detailed set of bunker procedures that ensure oil transfer operations are carried out so that the possibility is minimised. It is standard procedure to ensure that hoses are checked, spill trays are in place, oil spill kit is in place, scuppers are blocked, communications are in place and that operations are closely monitored on both vessels. In compliance with the MARPOL regulations all vessels are required to carry a shipboard oil pollution emergency plan (SOPEP) which must be approved by a ship classification society. This includes procedures to control discharge and the reporting requirements in the event of an accidental spill. It is understood that NSP2 propose to have dedicated on site recovery equipment (OSR) and a certified OSR team (1 on-scene manager + 1 rescuer) on AHT vessels as a mitigation measure.

7.8.8 Some of the more modern AHTs are fitted with overflow tanks that act as a buffer tank in the event that a main fuel tank is overfilled. In some offshore operations one or more of the support vessels is fitted with spill response equipment that can be used in the event of a spill and this will be specified in the NSP2 vessel equipment requirements.

7.8.9 Oil transfer hoses are generally fitted with self-sealing couplings which close off the hose ends when they have been disconnected from the bunker points. Hose internal diameter is generally 4" and therefore only contains a relatively small volume of oil (approx. 1 m^3 per 100 m hose length).

7.8.10 The historical oil spill frequencies are therefore considered to be high bearing in mind the bunkering procedures referred to above and the actual spill rate is likely to be considerably lower and, with low spill quantities, fall into the low risk category. However it is noted that low spill quantities can cover large water areas and long shorelines.

7.9 Helicopter Accidents

7.9.1 During the pipeline installation crew changes of NSP2 personnel will be carried out by helicopter; crew change frequency is planned every two weeks but it is conservatively assumed there will be one flight a week. Precise details of these crew changes are not known at this stage but an estimate of flight numbers and times has been carried out to provide an indication of risks to personnel.

7.9.2 It is noted that contractor personnel crew changes will be carried out by a vessel and at this stage it is assumed that this will be by pipe carriers.

7.9.3 As a result of the number of accidents in the early phases of the development of the North Sea a considerable amount of analysis has been carried out by the UK

HSE over the years. An earlier report (reference 7.4) was issued in 2004 and covered the period from 1976 to 2002. During the period 1994 to mid-2002 there were no fatalities on the UKCS. As a result, year on year improvement in overall safety performance is evident from 1993 up to July 2002 when a Sikorsky S76 fatal accident occurred in the Leman Field as a result of catastrophic main rotor blade failure. A more recent incident occurred in Morecambe Bay in December 2006 and resulted in the fatality of all 7 passengers and 2 crew.

7.9.4 Incident data from 1976 to 2002 is presented in the table below.

	Per 100,000 Flying Hours		**Per 100,000 Sectors (Flight Stages)**	
	Occupant fatal accident rate	Non-fatal accident rate	Occupant fatal accident rate	Non-fatal accident rate
1976 – 1984	1.68	2.24	0.81	1.08
1985 – 1993	6.18	2.19	2.52	0.89
1994 – 2002	1.34	0.98	0.61	0.44
1976 – 2002	3.24	1.84	1.44	0.82

Note: A stage refers to landing and take-off accidents and is independent of the number of flight hours.

7.9.5 A more recent report (reference 7.5) lists 8 fatal accidents during this period, the most recent being an accident off Peterhead which resulted in 16 fatalities. The report provides accident statistics adjusted to take into account current helicopter types to give the following rates:

Per 100,000 Flying Hours		**Per 100,000 Sectors (Flight Stages)**	
Occupant fatal accident rate	Non-fatal accident rate	Occupant fatal accident rate	Non-fatal accident rate
1.98	1.40	0.99	0.70

7.9.6 The equivalent accidents rates are:

Fatal accident rate per hour - 1.98×10^{-5} per hour
Fatal accident rate per stage- 9.90×10^{-6} per stage

7.9.7 Assuming one flight a week the probability of a fatal accident is estimated as follows:

Return trips per week	1
Trips per year	52
Hours per flight	1 hr
Stages per flight	2
Number of flights	104

Total hours	104
Total stages	208
Frequency fatality – hours	2.06×10^{-3} per year
Frequency fatality – stages	2.06×10^{-3} per year
Total Frequency	4.12×10^{-3} per year

7.9.8 The Oil & Gas report identified 7 relevant events that resulted in the fatality of 65 passengers out of a total of 91 indicating a fatality rate of 71%. This may appear high but it is noted that in the last 4 accidents in the North Sea everyone on board died.

Note: This data does not include the 1986 incident in Sumburgh, Scotland where 44 out 45 passengers died when a Chinook helicopter crashed. After this incident Chinook helicopters were removed from offshore service and the accident is not representative of current operations.

7.9.9 This has been used to estimate helicopter risks for the DP pipe lay vessel below:

Frequency of fatality	3.2×10^{-3} per year
Number of passengers	15
Number of fatalities	11
Potential loss of life	3.5×10^{-2} per year
Individual risk	5.8×10^{-5} per year

7.9.10 The risks associated with DSV crew changes will be lower as the vessel will only be on location for a relatively short period of time. These are estimated below:

Frequency of fatality	1.2×10^{-3} per year
Number of passengers	15
Number of fatalities	11
Potential loss of life	1.3×10^{-2} per year
Individual risk	6.3×10^{-5} per year

7.9.11 The risks associated with crew changes on the shallow water pipe lay vessel are estimated below:

Frequency of fatality	1.07×10^{-3} per year
Number of passengers	15
Number of fatalities	11
Potential loss of life	1.1×10^{-2} per year
Individual risk	2.7×10^{-5} per year

7.9.12 Little material or environmental damage has been associated with helicopter accidents other than damage to, or loss of, the helicopters themselves. It is therefore considered that there would be no environmental damage following a helicopter accident.

7.10 Vessel Position Loss – Anchored Vessels

7.10.1 Loss of position is more likely to result in a buckled pipe than injury to personnel; however, there is a possibility that the pipe movement may result in injury/fatality.

7.10.2 The frequency of fatality on the anchored pipelay vessel is estimated as follows:

Frequency of 2 lines or more failing	1.3×10^{-3} year
Frequency of 2 lines failure	2.1×10^{-4} year

Weather factor	0.2
Frequency of position loss	6.4×10^{-5} year
Conditional probability of fatality	0.05
Frequency of fatality	3.1×10^{-6} per year
Persons on board	300
Number of fatalities	3
Potential loss of life	9.4×10^{-6} per year
Individual risk	1.6×10^{-8} per year

7.10.3 The frequency of fatality resulting from mooring system failure on the shallow water pipe lay vessel is estimated below:

Frequency of 2 lines or more failing	1.3×10^{-4} year
Frequency of 2 lines or more failing	3.2×10^{-4} year
Weather factor	0.2
Frequency of position loss	6.7×10^{-5} year
Conditional probability of fatality	0.05
Frequency of fatality	3.4×10^{-6} per year
Persons on board	200
Number of fatalities	2
Potential loss of life	6.8×10^{-6} per year
Individual risk	1.7×10^{-8} per year

7.10.4 Position loss during the above water tie-in has also been considered. It is assumed that this work will be carried out by a shallow water pipe lay vessel which generally carries fewer personnel than the larger pipe lay vessels, in this case it is assumed that the total personnel on board will be 200. The potential number of fatalities has been based on the conservative assumption that 10 welders will be located on the work platform and the fatality rate is 50%. The equivalent risks are estimated to be:

Frequency of position loss	1.2×10^{-4} year
Conditional probability of fatality	0.05
Frequency of fatality	6.0×10^{-6} per year
Persons on board	200
Number of fatalities	5
Potential loss of life	3.0×10^{-5} per year
Individual risk	7.5×10^{-8} per year

7.10.5 Vessel position loss would have no effect on the environment.

7.11 Vessel Position Loss – DP Vessels

7.11.1 Dynamic Positioning (DP) system failure during pipe lay or trenching operations could result in fatality either through the uncontrolled movement of pipe through the firing line or the overloading of a plough tow wire. However, it should be noted that to date no fatalities of this type have been reported.

7.11.2 The probability of fatality following DP position loss is estimated as follows:

DP failure per hour	3.5×10^{-5} per hour
Days on DP	261 days
Frequency of position loss	2.1×10^{-1} per year
Conditional probability of fatality	0.005
Frequency of fatality	1.2×10^{-3} per year

Persons on board	300
Number of fatalities	3
Potential loss of life	3.7 x 10^{-3} per year
Individual risk	6.1 x 10^{-6} per year

7.11.3 DP Trenching Operations may be carried out after the pipelines have been laid and it is currently estimated that up to 95 km (for both lines) will be trenched in 2018. It is estimated that this will take approximately 30 days. In the event of a DP position loss the plough tow wire would be slacked down so there is a low probability of personnel injury/fatality following position keeping failure and this is indicated as follows:

Duration	48 days
DP failure rate	3.5 x 10^{-5} per hour
Frequency of position loss	4.0 x 10^{-2} per year
Conditional probability fatality	0.002
Frequency of fatality	8.0 x 10^{-5} per year
Persons on board	100
Number of fatalities	1
Potential loss of life	8.1 x 10^{-5} per year
Individual risk	4.0 x 10^{-7} per year

7.11.4 Vessel loss of position would have no impact on the environment.

7.12 Dropped Objects (Pipes)

7.12.1 During pipe lay in close proximity to existing lines there is a possibility that a dropped pipe joint could damage the existing lines. The horizontal separation between pipelines is defined in the design basis are as follows:

7.12.2 Separation between NSP1 and NSP2 lines

- Anchored lay vessel - 1000 m (WD<30 m), 1200 m (30 m<WD<100 m) and 1400 m (WD>100 m)
- DP lay vessel – 500 m

With a minimum separation of 500 m it is considered that the probability of a dropped pipe joint contacting the NSP1 lines is extremely low.

Operational procedures will define that no pipe transfer operations at pipeline crossings will be permitted until the minimum separation of 500m is achieved.

7.12.3 Separation between the two NSP2 lines

- Anchored lay vessel – 55 m (assumed to be a monohull vessel)
- DP lay vessel – 75 m (WD<100 m), 105 m (WD>100 m)

With these separations there is a possibility of a dropped pipe joint contacting the adjacent line and these risks have been considered further.

7.12.4 The probability of a pipe falling overboard and hitting the operating pipeline has been estimated using the methodology described in DNV-GL Recommended Practice DNV-GL-RP-F-107, Risk Assessment of Pipeline Protection (reference 6.11). The calculations have been carried out on an Excel spreadsheet and were first checked against the DNV-GL example given in the RP to confirm correct use of the various formulae. The methodology is described Appendix I.

7.12.5 The calculations are based on pipeline separations indicated above and an angular deviation angle of 5° (reference 6.11 table 10). An example of the inputs and results are attached in Appendix I and the results summarised in the following tables.

7.12.6 The following table summarises the total annual frequency of hitting the pipe and the energy distribution for anchored operations. These results are based on loading from the side nearest the pipe.

	Energy Band (kJ) – Anchored (separation 55 m)				
Water Depth	**100-200**	**200-400**	**400-800**	**>800**	**Total Fr Hit**
50 m	1.3E-16	1.9E-16	3.8E-16	5.7E-16	2.4E-13
100 m	1.7E-08	2.6E-08	5.2E-08	7.7E-08	3.4E-05
150 m	2.2E-07	3.3E-07	6.5E-07	9.8E-07	4.3E-04
200 m	9.6E-07	1.4E-06	2.9E-06	4.3E-06	1.9E-03

7.12.7 The following table summarises the total annual frequency of hitting the pipe and the energy distribution for anchored operations. These results are based on loading from the side on the opposite side of the pipe.

	Energy Band (kJ) – Anchored (separation 55 m – 'far' side)				
Water Depth	**100-200**	**200-400**	**400-800**	**>800**	**Total Fr Hit**
50 m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
100 m	6.6E-20	9.9E-20	2.0E-19	3.0E-19	6.6E-19
150 m	2.2E-12	3.3E-12	6.6E-12	1.0E-11	2.2E-11
200 m	4.5E-10	6.7E-10	1.3E-09	2.0E-09	4.5E-09

7.12.8 The following table summarises the total annual frequency of hitting the pipe and the energy distribution for DP pipe lay operations with a 75m separation.

	Energy Band (kJ) DP (separation 75 m, wd < 100 m)				
Water Depth	**100-200**	**200-400**	**400-800**	**>800**	**Total Fr Hit**
50 m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
100 m	6.0E-11	9.0E-11	1.8E-10	2.7E-10	6.0E-10

7.12.9 The following table summarises the total annual frequency of hitting the pipe and the energy distribution for DP pipe lay operations with a 105m separation.

	Energy Band (kJ) DP (separation 105 m, wd >100m)				
Water Depth	**100-200**	**200-400**	**400-800**	**>800**	**Total Fr Hit**
100 m	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
150 m	2.3E-12	3.4E-12	6.8E-12	1.0E-11	2.3E-11
200 m	3.1E-09	4.6E-09	9.2E-09	1.4E-08	3.1E-08

7.12.10 The following table shows the energy for different damage classes for pipe with wall thickness of 34.6 mm and 30.9 mm. These values have been taken from Saipem Pipeline Damage Assessment (reference 7.6).

Damage Class	**Energy (kJ)**	**Energy (kJ)**	**Damage Description**
Wall thickness	34.6 mm	30.9 mm	
D0	77.5	65.4	No damage
D1	219.2	185	Minor damage
D2	402.7	339.8	Major damage – no release of hydrocarbons
D3-R0	620	523.2	Major damage – minor release of hydrocarbons
D3-R1	866.4	731.2	Major damage – major release of hydrocarbons

7.12.11 The Saipem calculation indicates that hydrocarbon release is likely for the energy bands of 400 kJ and above and this corresponding frequency is as follows:

Pipe lay Mode and Separation	**Annual Pr > 400 kJ**
Anchored – 55 m ‘near’ side	9.0×10^{-6}
Anchored 55 m ‘far’ side	3.4×10^{-9}
DP 75 m	4.5×10^{-10}
DP 105 m	2.3×10^{-8}

7.12.12 If the first line is not operational when the second line is installed the consequence would be major damage and would require extensive repair. If the first line is operating the consequence would be the release of hydrocarbons and this is discussed in the following paragraphs.

7.12.13 It can be seen that the frequency of hydrocarbon release as a result of a dropped pipe joint is very low for all cases except the anchored vessel loading pipe on the side nearest the existing pipeline.

7.12.14 It is evident that the probability of hitting the pipe increases as the horizontal separation decreases. The anchored case is based on a vessel with a beam of 32.2m. However, the loading operations of the anchored pipe lay vessel will need to be managed to ensure risks are maintained at ALARP levels.

7.12.15 Saipem (references 7.7 – 7.11) have considered the consequence of gas leakage following pipe damage and this has been referred to in this assessment. In the event of a subsea gas release the vapours will form a gas cloud when they reach the surface and if no immediate ignition occurs will dilute in the air. If the cloud encounters an ignition source before it is diluted below its flammable limit a flash fire will occur. If the release at the surface has sufficient velocity a jet fire will occur.

7.12.16 The Saipem report concludes that the surface velocity will be such that a gas cloud will form and that ignition probability will be 1.0 for any vessel located within the cloud. Calculations following a full bore rupture of the pipeline indicate the following limits:

Distance of Flammable Limits at 10 m height		
Upper Flammable Limit (UFL) in metres	Lower Flammable Limit (LFL) in metres	LFL/2 – metres
79	136	193

7.12.17 It therefore evident, that in the event that a dropped pipe joint strikes the pipe and there is a full bore release, the pipe carrier and the pipe lay vessel will be within the flammable limits. It is also possible that an AHT and survey vessel could also been in close proximity depending on the phase of the operation. Saipem indicate that flash fires generally have a short duration and do less damage to equipment and structures than personnel. It is assumed that anyone caught in a flash fire would probably be killed, and the fatality rates are based on the number of crew on the open deck at the time of the flash fire.

7.12.18 It has been conservatively estimated that 20% of vessel crew would be on deck and exposed to the flash fire. This corresponds to 50 on the pipe lay vessel, 10 on the survey vessel and 3 on the pipe carrier and anchor handler tug.

7.12.19 The individual risks for various pipeline separations are estimated in the following table:

	Pipe lay Vessel	Pipe Carrier	AHT	Survey Vessel
Anchored Vessel				
55 metre Separation (near existing pipe)				
Frequency of gas release per year	9.0E-06	9.0E-06	9.0E-06	9.0E-06
Potential loss of life per year	4.9E-04	2.7E-05	2.7E-05	9.0E-05
Individual risk per year	9.0E-07	9.0E-07	9.0E-07	9.0E-07
55 metre Separation (far side of pipe)	3.4E-09	3.4E-09	3.4E-09	3.4E-09
Frequency of gas release per year	1.84E-07	1.02E-08	1.02E-08	3.4E-08
Potential loss of life per year	3.40E-10	3.4E-10	3.4E-10	3.4E-10
Individual risk per year				
	Pipe lay Vessel	**Pipe Carrier**		**Survey Vessel**
DP Vessel				
75 metre Separation				
Frequency of gas release per year	4.5E-10	4.5E-10		4.5E-10
Potential loss of life per year	2.7E-08	1.4E-09		4.5E-09
Individual risk per year	4.5E-11	4.5E-11		4.5E-11
105 metre Separation				
Frequency of gas release per year	2.3E-08	2.3E-08		2.3E-08
Potential loss of life per year	1.4E-06	6.9E-08		2.3E-07
Individual risk per year	2.3E-09	2.3E-09		2.3E-09

7.12.20 It is noted that in areas where the separation distance is 55 m pipe loading may need to be carried out on the 'far' side of the existing line. This restriction only applies to the installation of the second NSP2 line.

7.12.21 There is also a possibility that vessels located near to the gas plume could experience loss of buoyancy and start sinking. This was considered in a recent HSE research report (reference 7.12) into the stability of semi-submersible drilling rigs and only two loss of buoyancy incidents were reported over a period 1974 to 1998. These related to shallow water blowouts where one rig caught fire and the other developed a major list but did not catch fire. It concluded that the risk of fire or explosion was higher than the risk of loss of buoyancy.

7.12.22 Laboratory experiments (reference 7.13) on a small scale indicate that in a rising plume of small bubbles (smaller than the vessel), the vessel is more likely to be pushed aside rather than sink provided the fluid is unconfined (i.e. the fluid can move away from the bubble source area) and this effect was observed by GM in a drill ship incident some years ago.

7.12.23 In the dropped pipe situation both the pipe carrier and the pipe lay vessel would be some way from the centre of the gas plume and it is more likely that the vessels would be pushed aside rather than sink. Based on the above comments it has been assumed that the probability of sinking is 0.2. Vessel abandonment in this situation would be more difficult and the conditional probability of unsuccessful rescue derived in the section on sinking has been increased from 0.04 to 0.1, this corresponds to a combined probability of 0.02.

7.12.24 The risks associated with gas release and loss of buoyancy are indicated on the following table:

	Pipe lay Vessel	**Pipe Carrier**	**AHT**	**Survey Vessel**
Anchored Vessel				
55 metre Separation (near existing pipe)				
Frequency of gas release per year	9.0E-06	9.0E-06	9.0E-06	9.0E-06
Potential loss of life per year	5.4E-06	2.7E-07	2.7E-07	9.0E-07
Individual risk per year	9.0E-09	9.0E-09	9.0E-09	9.0E-09
55 metre Separation (far side of pipe)				
Frequency of gas release per year	3.4E-09	3.4E-09	3.4E-09	3.4E-09
Potential loss of life per year	1.84E-09	1.02E-10	1.02E-10	3.40E-10
Individual risk per year	3.40E-12	3.4E-12	3.40E-12	3.40E-12
DP Vessel				
75 metre Separation				
Frequency of gas release per year	4.5E-10	4.5E-10		4.5E-10
Potential loss of life per year	2.7E-10	1.4E-11		4.5E-11
Individual risk per year	4.5E-13	4.5E-13		4.5E-13
105 metre Separation				
Frequency of gas release per year	2.3E-08	2.3E-08		2.3E-08
Potential loss of life per year	1.4E-08	6.9E-10		2.3E-09
Individual risk per year	2.3E-11	2.3E-11		2.3E-11

7.12.25 As would be expected the anchored pipe lay case presents the highest risk as has been discussed previously.

7.12.26 In the event that a vessel did sink there is likely to be some oil spillage and the risks associated with sinking have been addressed previously in section 6.7 of this report.

7.12.27 Ramboll have concluded that the toxicity of released gas to the environment is negligible as only a limited amount of gas will dissolve in the water and the major part will escape to the atmosphere. The impact on marine life will be local and due to:

1) The depletion of dissolved oxygen, and
2) The possible super-saturation of the sea with dissolved gas.

The Saipem risk assessment reports (reference 7.7 – 7.11) conclude that consequences of gas release to the environment are moderate.

7.13 Anchor Damage

7.13.1 The separation between the NSP1 and NSP2 lines will be a minimum of 500m and it is considered unlikely that pipe lay vessel anchors will be handled across the NSP1 lines. However, the separation between the two SP2 lines will be a minimum of 55 m and anchors will be handled across the first line while the second line is installed. The possibility of pipeline damage during anchor handling operations is considered in this section.

7.13.2 During the installation of lines A or B the NSP1 lines will be operating and there is a potential for anchor damage while the pipe lay vessel progresses along the pipeline route. Damage to the pipe can be caused either by anchors that are dropped on the pipeline or dragged against it during anchor wire tensioning operations.

7.13.3 No historical data has been identified to cover this particular situation so this assessment has been based on engineering judgement and company experience of pipe lay operations. The damage estimate has therefore been based on the number of anchor movements per year combined with the probability of anchor contact with the pipeline.

7.13.4 It is assumed that the anchored pipe lay vessel is equipped with 10 anchors and it is evident that only anchors from one side of the vessel could contact the pipeline. The number of anchor movements is estimated as follows:

Kilometres per year	76 km
Anchors per side	5
Kilometres per anchor pattern	2 km
Number of anchor patterns	36
Anchor movements per year	180

7.13.5 An anchor could be dropped on a pipeline either if it had been lowered in the wrong potion or if it was accidentally dropped from an AHT during anchor relocation. It is considered very unlikely that an anchor could be lowered in the wrong position for the following reasons:

- The anchor position is plotted prior to installation and in accordance with DNV-GL guidelines the drop position would be at least 250 m from the pipeline.
- The pipe lay vessel and AHT positions are fixed through the use of differential GPS with an accuracy which is typically in the order of +/- 1 metre.
- Anchors are positioned through the use of a tug management system which includes a display of all vessel and subsea pipeline positions.
- Anchor positioning is overseen by the anchor foreman and surveyor on the pipe lay vessel and the Master on the AHT.

7.13.6 It is therefore considered that an accidental drop would be a more realistic scenario. It is standard industry practice to lift the anchor on deck and double secure it while the AHT crosses the pipeline. In order for an anchor to be dropped on an existing pipeline the following system failures would need to take place:

- The anchor would have to be carried on the stern roller instead of the deck (contrary to standard procedures).
- The anchor pennant wire or rigging would need to fail.
- The AHT would need to be positioned above the pipe when it dropped the anchor.

7.13.7 The conditional probability of these failures is estimated as follows:

- Probability anchor is not secured on deck 0.02
- Probability of pennant rigging failure 0.02
- Probability that AHT is located over the pipe 0.05

Total conditional probability (0.02 x 0.02 x 0.05)	2.0×10^{-5} per anchor movement.
Total number of moves	180
Probability of anchor dropped on pipe	3.6×10^{-3} per year.

It is noted that no accidental drop of an anchor was reported on NSP1 and this estimate is considered to be very conservative.

7.13.8 Pipe lay anchors typically weigh around 26 tonnes which correspond to the Class 6 vessels defined in the Saipem Pipeline Damage Assessment (reference 7.6). This assessment concluded that impact energies from a dropped anchor of this size would be in the order of 70 kJ and would fall into the D1 damage class and only cause minor damage to the pipeline. It is noted that the impact energy would need to be greater than 500 kJ before any gas release occurred; it is therefore considered that the risk of gas release following a dropped anchor incident is very low and the potential loss of life would be correspondingly much lower.

7.13.9 As mentioned above the anchor patterns are designed to ensure anchors are located at a safe distance from a crossed pipeline. Once the anchor is installed the anchor wire is slowly tensioned and the wire line-out and tension read outs are monitored to verify if the anchor is dragging. If the anchor is found to drag it is reset in a different location and the procedure is repeated. In order for an anchor to be dragged against a pipeline the following failures would need to occur:

- The anchor would have to drag under tension.
- The anchor drag would have to remain un-detected by the anchor winch operator and anchor foreman on the pipe lay vessel.
- The anchor would have to drag at least 250 metres.

7.13.10 The conditional probability of an anchor being dragged against a pipe is estimated as follows:

- Probability that anchor drags — 0.2
- Probability that anchor drag is not detected — 0.05
- Probability that anchor drags greater than 250 m — 0.005

Total conditional probability (0.2 x 0.05 x 0.005)	5.0×10^{-5} per anchor movement.
Total number of moves	180
Probability of anchor dragged against pipe	9.0×10^{-3} per year.

This is considered to be a conservative value as it is extremely unlikely that an anchor could drag for 250 m without being detected by the anchor winch operator.

7.13.11 The Saipem report referred to above concluded that major damage and gas release would occur to the pipe if point forces imposed by a dragged anchor were in excess of 800 kN. If an anchor was eventually dragged against a pipeline the anchor wire loads would increase and this would be shown on the anchor wire load gauges. It is considered unlikely that the winch operator would not notice this increase and the probability of imposing a load greater than 800 kN is therefore estimated to be 0.01.

7.13.12 During this operation the AHT may still be in close proximity to the anchor pennant buoy and could be exposed to any released gas. However, at the first sign of gas release the vessel should be able to clear the area and the probability ignition and fatality is estimated to be 0.1. The consequences of a dragged anchor are estimated as follows:

Pr anchor dragged against the pipe	8.1×10^{-3} per year
Pr anchor wire pull > 80 tonnes	0.01
Pr gas release	8.1×10^{-5} per year
Conditional pr gas ignition and fatalities	0.1
Frequency of fatality	8.1×10^{-6} per year
Persons on board	15
Number of fatalities	3
Potential loss of life	2.4×10^{-5} per year
Individual risk	8.1×10^{-7} per year

7.13.13 The risk of damage to the first line during the installation of the second line is therefore considered to be low. However, the duration of the pipe lay programme is such that human error could occur as a result of complacency and it will be necessary to ensure that anchor handling procedures are followed at all times.

7.14 Tensioner Failure

7.14.1 There is very little public domain data on the failure of tensioners and this assessment has therefore been based on data provided by Saipem and Allseas. Allseas data for NSP1 are taken from reference 7.14. These data cover the period 2005 to 2008 and indicate that there have been two incidents on the Solitaire where the pipeline slipped through the tensioners due to lack of friction between the tensioner pads and the weight coating of the pipe. In both instances the slippage was limited to between 6 and 9 metres and there was no damage to the pipe or injury to personnel in the firing line. The DP running hours during this period was 31,200 hours and the corresponding incident frequency is 6.4 x 10^{-5} per hour.

7.14.2 Saipem data (reference 7.15) indicates that since the Castoro 6 started operations one pipeline has been dropped as a result of a tensioner problem. Although the pipe was damaged no injuries were sustained by the vessel personnel. The hourly incident frequency has been estimated as follows:

Operating period	28 years (1979 to 2007)
Number of days worked per year	200 (average over last 5 years)
Number of incidents	1
Failure rate	7.4 x 10^{-6} per hour

7.14.3 The frequency of fatalities has been based on the Castoro 6 data for a period of one year. Historical data indicates that there is a very low probability of fatality and a probability of 0.005 has been assumed; it is also assumed that the potential number of fatalities is 3. The frequency of fatality on the pipe lay vessels (DP and anchored) and the shallow water pipe lay vessels is estimated as follows:

	Anchored Pipelay Vessel	**DP Pipelay**	**Shallow Water Pipelay**
Days per year	88	292	95
No of operating hours	2112	7008	2280
Failure rate per hour	7.4 x 10^{-6}	7.4 x 10^{-6}	7.4 x 10^{-6}
Failure rate per year	1.4 x 10^{-2}	5.2 x 10^{-2}	1.5 x 10^{-2}
People on board	300	300	200
Conditional prob of fatality	0.005	0.005	0.005
Frequency of fatality per year	7.9 x 10^{-5}	2.6 x 10^{-4}	8.5 x 10^{-5}
Number of fatalities	3	3	3
Potential loss of life per year	2.4 x 10^{-4}	7.8 x 10^{-4}	2.5 x 10^{-4}
Individual Risk per year	3.9 x 10^{-7}	1.3 x 10^{-6}	6.4 x 10^{-7}

7.14.4 Tensioner failure would have no environmental impact.

7.15 A&R Winch/Wire Failure

7.15.1 To date no incidents of A&R winch or wire have been reported in the public domain. It is considered that the probability of wire failure is higher than winch failure and the assessment is therefore based on wire failure. In the absence of A&R wire failure data it has been necessary to use lifting incident data published by the OGP (reference 7.16). The data is based on offshore drilling rig lifting incidents and is considered conservative as A&R winches are operated far less frequently than drilling rig cranes and derricks and A&R operations are very closely monitored and controlled.

7.15.2 The pipe will be recovered and laid down at least 2 times along the route and it has also been assumed that the pipe may be laid down in the event of heavy weather. The total number of A&R operations on the pipe lay vessels has been assumed to be 20 per year and 6 per year on the shallow water pipe lay vessel as it will be on locations for shorter periods. The conditional probability of fatality is assumed to be 0.05 and the potential number of fatalities has been assumed to be 2 as the firing line is generally clear of personnel during A&R operations. The frequency of fatality is estimated as follows:

Vessel	Anchored Pipelay	DP Pipelay	Shallow Water Pipe lay
Accidents per lift	1.4×10^{-6}	1.4×10^{-6}	1.4×10^{-6}
No of A&R operations per year	6	20	6
Frequency of failure per year	8.4×10^{-6}	2.8×10^{-6}	8.4×10^{-6}
People on board	300	300	200
Conditional probability of fatality	0.05	0.05	0.05
Frequency of fatality per year	4.2×10^{-7}	1.4×10^{-6}	4.2×10^{-7}
Number of fatalities	2	2	2
Potential loss of life per year	8.4×10^{-7}	2.8×10^{-6}	1.3×10^{-6}
Individual risk per year	1.4×10^{-9}	4.7×10^{-9}	2.1×10^{-9}

7.15.3 A&R winch or wire failure would have no environmental impact.

7.16 Diving Operations

7.16.1 Diving operations will be carried out in deep and shallow water. The deep water operations will mainly be related to repair work if required while shallow water diving operations will be required for above water tie-ins and shore pull activities. Deep water work will be carried out using saturation diving methods and shallow water diving will be carried out using surface demand methods. Risks associated with diving can be categorised into physiological incidents and work site incidents. Shallow and deep diving operations are carried out in accordance with defined decompression tables and provided these are complied with physiological risks should be reduced to ALARP levels. Similarly, provided diving activities are carried out in accordance with industry standards such as IMCA, work related risks should also be reduced to ALARP levels.

7.16.2 IMCA Safety and Environmental Statistics for diving operations in 2013 indicated that there had been 9 fatalities recorded worldwide. The diving time over this period was reported to be 1,008 million man hours.

The corresponding fatality rate = $9/ (1{,}008.0 \times 10^{6}) = 8.9 \times 10^{-9}$ per hour.

7.16.3 Diving support for the AWTIs is estimated to last approximately 7 days for each tie-in. The corresponding frequency of fatality is estimated as follows:

Number of working hours	1344 hours (8 tie-ins x 7 days)
Fatality rate	8.9×10^{-9} per hour
Frequency of fatality	1.2×10^{-5} per year
Number of divers in saturation	9
Potential loss of life	1.1×10^{-4} per year

Individual risk	6.0×10^{-6} per year

7.16.4 The individual risk is based on the exposure over the tie–in period as it is likely that the work will only be carried out by one diving team during the 28 day period.

7.16.5 The individual risk is based on the exposure over the tie–in period as it is likely that the work will only be carried out by one diving team.

7.16.6 Diver fatality would have no environmental impact.

7.17 Munitions Risks

7.17.1 The results of the route surveys were not available when this report was prepared so the munitions assessment is based on the NSP1 route data. It is noted that no munitions incidents were reported during the construction of NSP1 and the assessment is considered to be conservative.

7.17.2 The munitions density is based on the results of the NSP1 pipe route survey and is estimated as follows:

Pipe corridor length	642 km
Corridor width	15 m
Area corridor	9,630,000 m^2
Total ordnance found on route	4
Munitions density	4.2×10^{-7} per m^2

7.17.3 This distribution has been used to estimate the probability of fatality on vessels following the explosion of munitions and is based on a fault tree which is attached in Appendix I although the input values differ for each case.

Anchor Handling

7.17.4 This assessment estimates the probability of a pipe lay vessel anchor being dropped on or near munitions. It is noted that the anchored and shallow water pipelay vessels are scheduled to lay 89 km of pipe in 2018.

7.17.5 The probability that munitions are located in the anchor drop locations is estimated as follows:

Route length	89 km
Route length per anchor pattern	0.4 km
Number of moves	222.5
Number of anchors moved per pattern	10
Total number of moves	2225
Number of anchor handling tugs	2 (at least)
AHT anchor drops	112.5 per AHT
Anchor drop area	25 m^2 (5 m x 5 m)
Munitions density in touch down area	1.0×10^{-5} m^2 ($4.2 \times 10^{-7} \times 25$)
Munitions density in area for all drops	1.2×10^{-2} per m^2

7.17.6 The fault tree analysis indicates that the risks to AHT crew are as follows:

Probability of fatality	5.2×10^{-6}
POB	15
Number of fatalities	3
Potential loss of life	1.6×10^{-5} per year
Individual Risk	5.2×10^{-7} per year

7.17.7 This represents the worst case probability as it has been assumed that the conditional probability of explosion following anchor contact with munitions is 1.0. Reduction in this probability could result in a reduction in Individual Risk by an order of magnitude.

Rock Placement

7.17.8 Details of the NSP2 rock placement scope were not available at the time of writing this report so the assessment is based on the NSP1 line.

7.17.9 The risk assessment only considered pre-lay rock placement as any munitions identified during the pipe lay would be removed. In NSP1 pre-lay rock placement was carried out over 876 km in the Finish and Swedish sectors. The munitions distribution is based on the results of the pipe route survey and is estimated as follows:

Pipe corridor length	876 km
Corridor width	15 m
Area corridor	13,140,000 m^2
Total ordnance found on route	32
Munitions density	2.4×10^{-6} per m^2

7.17.10 The rock placement supports comprise gravel sleepers with the following geometry:

Top length	5.0 m
Top width	12.0 m
Sleeper height	variable
Side slope	1:2
Base length	17 m (assuming 3 m height)
Base width	24 m
Base area	408 m^2
Number of supports	177
Total rock placement area	72,216 m^2

7.17.11 The probability that munitions are located in the rock placement locations is estimated as follows:

Munitions density in the rock placement area 1.7×10^{-1} per m^2 ($2.4 \times 10^{-6} \times$ 72,216)

7.17.12 The fault tree analysis indicates that the risks to rock placement vessel crew are as follows:

Probability of fatality	3.9×10^{-6}
POB	20
Number of fatalities	3
Potential loss of life	1.2×10^{-5} per year
Individual Risk	2.9×10^{-7} per year

7.17.13 This represents the worst case probability as it has been assumed that the conditional probability of explosion following rock placement vessel contact with munitions is 0.9. Reduction in this probability could result in a reduction in Individual Risk by an order of magnitude.

Landfall Operations

The trenched area in the German landfall is indicated below:

KP 31.488 – KP 54.400 738,514 m^2

KP 54.400 – KP 68.722	333,192 m^2
KP 68.722 – KP 71.083	141,465 m^2
KP 71.083 – KP 83.800	321,419 m^2
Total	1,534,290 m^2.

7.17.14 In NSP1 the route survey and landfall survey in Germany identified no munitions so the distribution of munitions is considered to be very low. However, for the purposes of this study it has been assumed that if 1 munition was found in the German sector of the pipe line route the munitions density would be as follows:

Area corridor	1,534,290 m^2
Total munitions	1
Munitions density	6.5×10^{-7} per m^2
Number of dredgers	4
Munitions density in trenched area	2.50×10^{-1} per dredger

7.17.15 The fault tree analysis indicates that the risks to dredger crew are as follows:

Probability of fatality	1.08×10^{-4}
POB	10
Number of fatalities	3
Potential loss of life	3.2×10^{-4} per year
Individual Risk	1.6×10^{-5} per year

7.17.16 This represents the worst case probability as it has been assumed that the conditional probability of explosion following dredge contact with munitions is 1.0. Reduction in this probability could result in a reduction in Individual Risk by an order of magnitude.

7.17.17 On NSP1 there was no information available on munitions in the Russian landfall area and it was not included in the risk assessment.

8. RISK ASSESSMENT RESULTS

8.1.1 The results of this risk assessment are summarised in the following tables and graphs and are presented separately for third party vessels and construction vessels.

8.2 Third Party Vessels

8.2.1 The individual risks have been assessed for each passing vessel type as follows:

	Cargo Ship	**Tanker**	**Passenger Ship**
Frequency of collision per year	1.4×10^{-3}	4.6×10^{-4}	9.2×10^{-5}
Potential loss of life	1.6×10^{-4}	5.1×10^{-5}	1.0×10^{-5}
Individual risk	4.1×10^{-6}	1.0×10^{-6}	1.1×10^{-8}

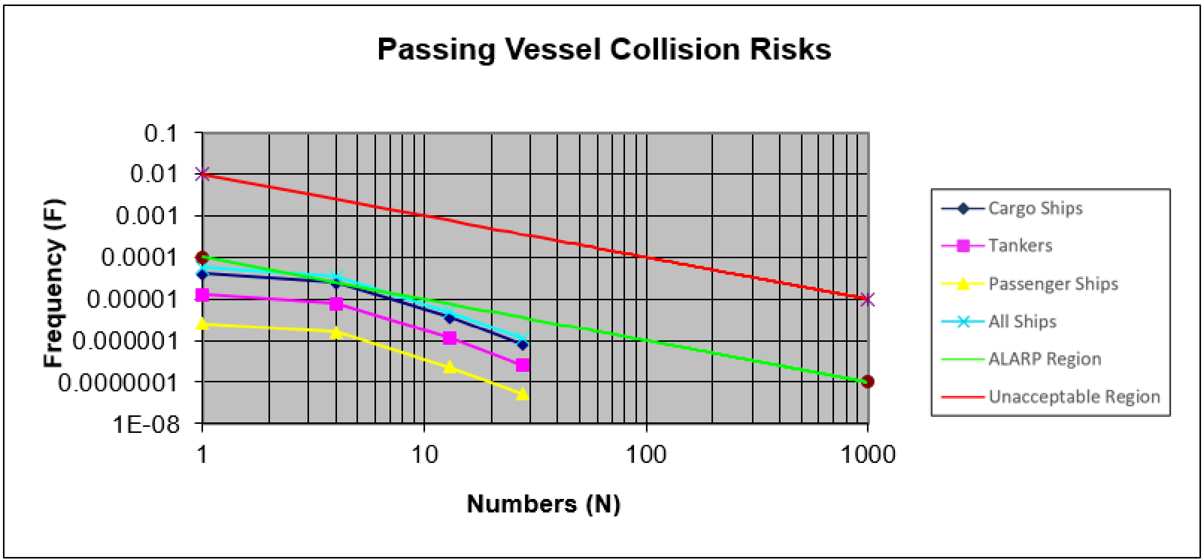
8.2.2 The individual and group risks have also been estimated for the section of pipe in each country along the route. This has been carried out using the same methodology and the results are summarised in the following tables.

<u>**Individual Risks:**</u>

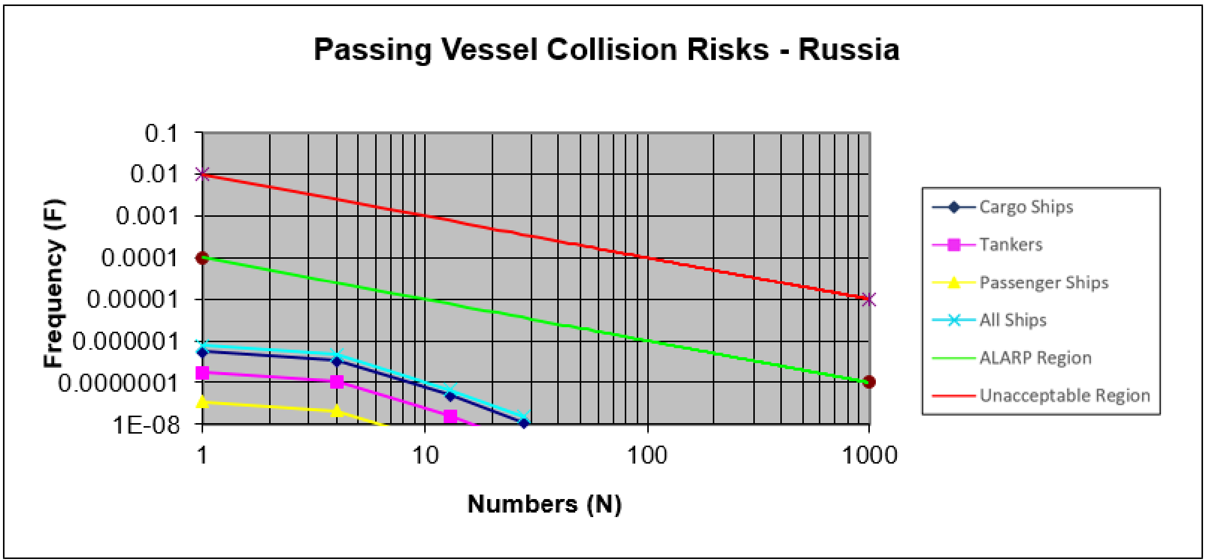
	Cargo Ship	**Tanker**	**Passenger Ship**
Russia			
Frequency of collision per year	2.0×10^{-5}	6.1×10^{-6}	1.2×10^{-6}
Frequency of fatality	5.5×10^{-7}	1.7×10^{-7}	3.5×10^{-8}
Number of fatalities	4	4	4
Potential loss of life	2.2×10^{-6}	6.9×10^{-8}	1.4×10^{-7}
Individual risk	5.5×10^{-8}	1.4×10^{-8}	1.5×10^{-10}
Finland			
Frequency of collision per year	1.2×10^{-4}	3.9×10^{-5}	7.8×10^{-6}
Frequency of fatality	3.3×10^{-6}	1.0×10^{-6}	2.2×10^{-7}
Number of fatalities	4	4	4
Potential loss of life	1.4×10^{-5}	4.3×10^{-6}	2.1×10^{-6}
Individual risk	3.5×10^{-7}	8.7×10^{-8}	9.7×10^{-10}
Sweden			
Frequency of collision per year	6.5×10^{-4}	2.0×10^{-4}	4.1×10^{-5}
Frequency of fatality	1.8×10^{-5}	5.7×10^{-6}	1.1×10^{-6}
Number of fatalities	4	4	4
Potential loss of life	7.2×10^{-5}	2.3×10^{-5}	4.6×10^{-6}
Individual risk	1.8×10^{-6}	4.6×10^{-7}	5.1×10^{-9}
Denmark			
Frequency of collision per year	3.7×10^{-4}	1.2×10^{-4}	3.6×10^{-5}
Frequency of fatality	1.0×10^{-5}	3.2×10^{-6}	9.9×10^{-7}
Number of fatalities	4	4	4
Potential loss of life	4.1×10^{-5}	1.3×10^{-5}	4.0×10^{-6}
Individual risk	1.0×10^{-6}	2.6×10^{-7}	4.4×10^{-9}

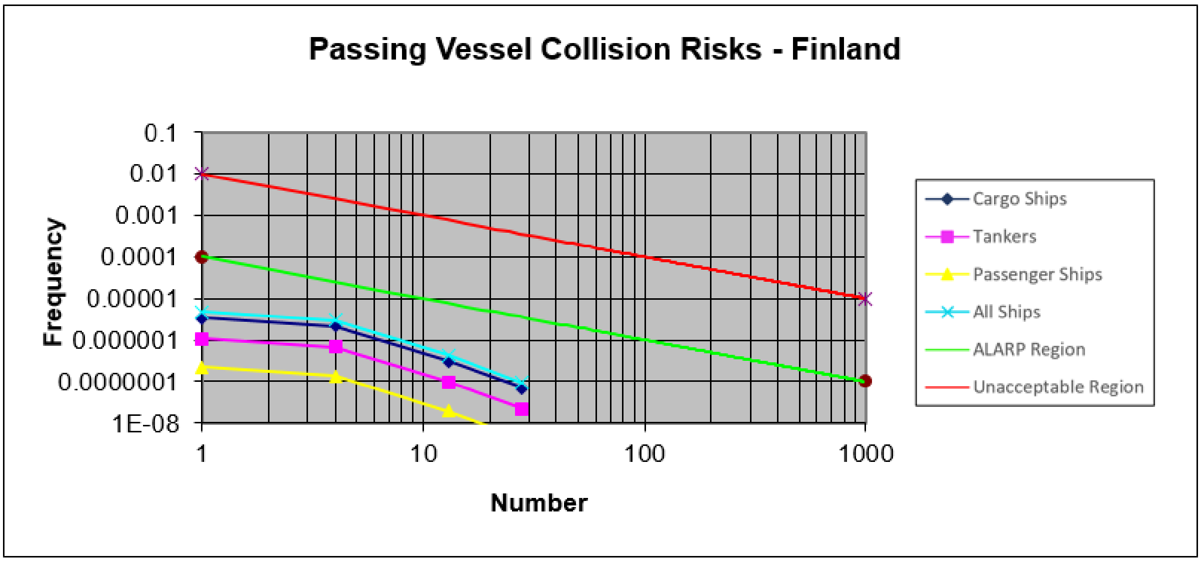
	Cargo Ship	Tanker	Passenger Ship
Germany			
Frequency of collision per year	2.9×10^{-4}	9.1×10^{-5}	1.8×10^{-5}
Frequency of fatality	8.1×10^{-6}	2.6×10^{-6}	5.1×10^{-7}
Number of fatalities	4	4	4
Potential loss of life	3.2×10^{-5}	1.0×10^{-5}	2.0×10^{-6}
Individual risk	8.1×10^{-7}	2.0×10^{-7}	2.3×10^{-9}

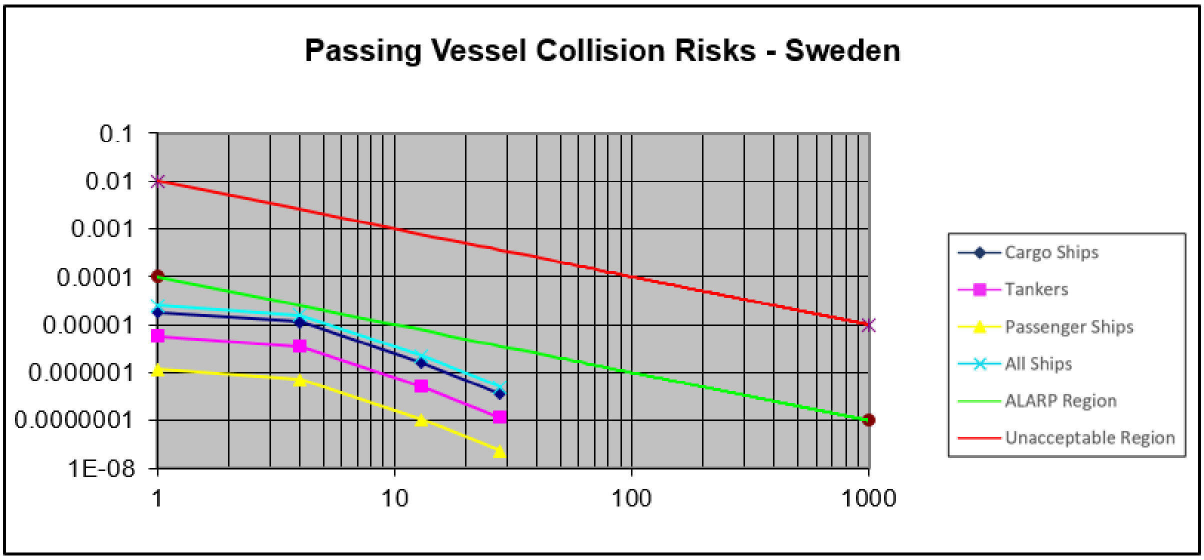
8.2.3 It can be seen that the individual risks are below the tolerability criteria outlined in section 3. The group risks for all passing vessels are shown in the following F-N graph. The upper and lower limits of the ALARP region are shown by red and green lines.

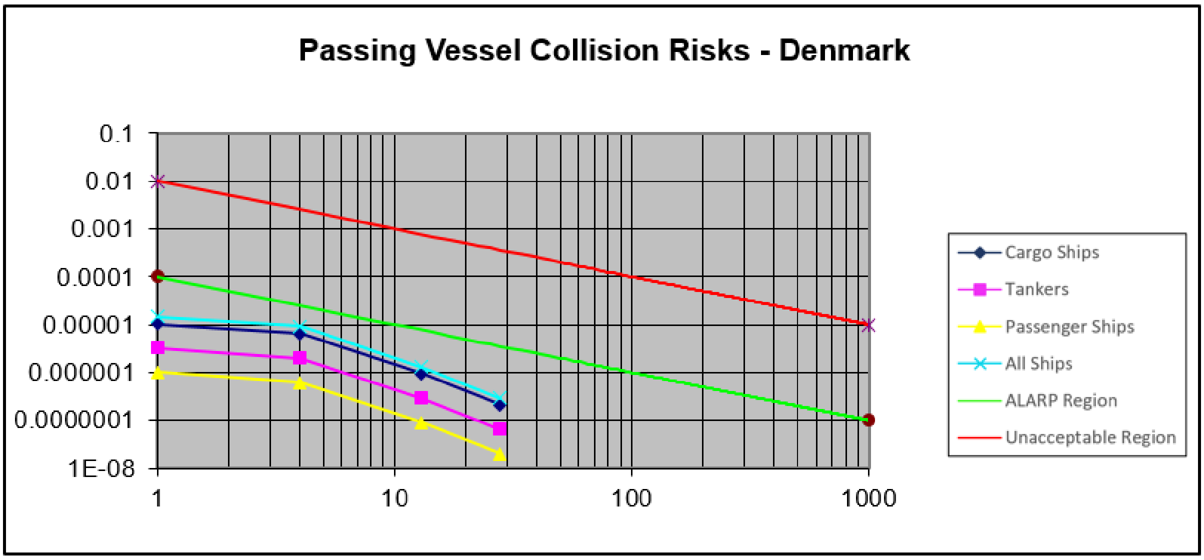


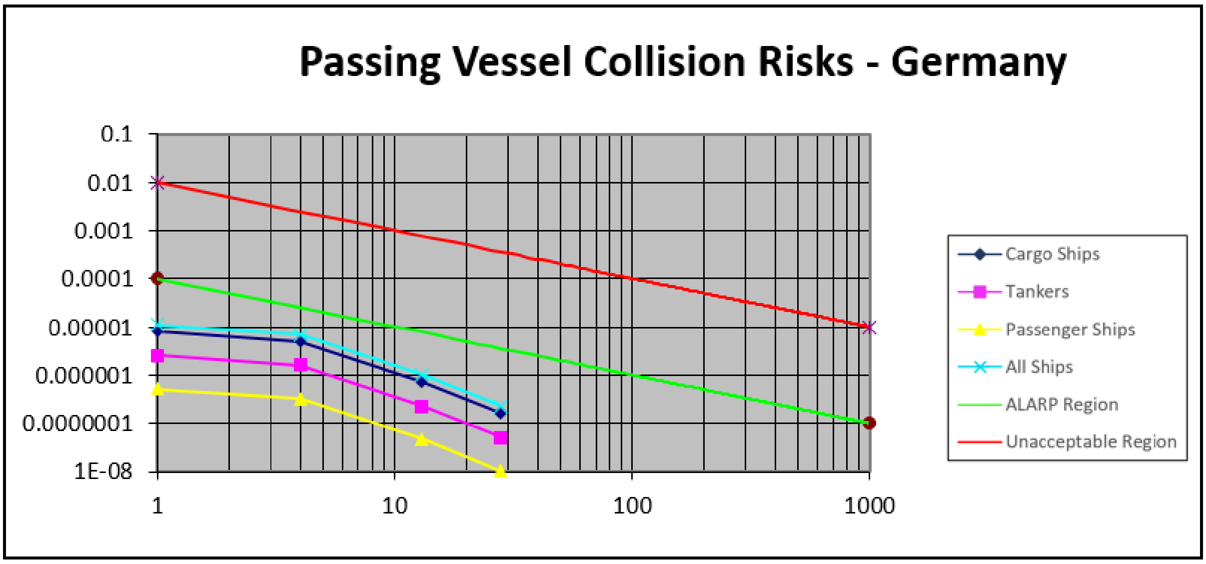
8.2.4 Group risks for individual countries are presented below:




Passing Vessel Collision Risks - Finland
Frequency
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
1E-08
1
10
100
1000
Number
Cargo Ships
Tankers
Passenger Ships
All Ships
ALARP Region
Unacceptable Region


Passing Vessel Collision Risks - Sweden
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
1E-08
1
10
100
1000
Cargo Ships
Tankers
Passenger Ships
All Ships
ALARP Region
Unacceptable Region





8.2.5 The group risks for all countries are all within the broadly accepted zone.

8.3 Construction Vessels

8.3.1 The construction vessel Individual Risks are shown in the table below:

VESSEL TYPE	ANCHORED PIPELAY					DP PIPELAY					PIPE CARRIER		
Days per year	88				292				292				
	Fr Fatality	PLL	IR	N Fatalities	Fr Fatality	PLL	IR	N Fatalities	Fr Fatality	PLL	IR	N Fatalities	
EVENT													
Collision	4.46E-06	3.57E-05	5.94E-08	8	1.48E-05	1.18E-04	1.97E-07	8	4.06E-05	1.52E-04	5.08E-06	4	
Engine Room Fire	4.40E-05	3.30E-04	5.50E-07	8	1.46E-04	1.10E-03	1.83E-06	8	1.46E-04	2.19E-04	7.30E-06	2	
Accommodation Fire	7.74E-06	1.16E-04	1.94E-07	15	2.57E-05	3.85E-04	6.42E-07	15	2.57E-05	7.71E-05	2.57E-06	3	
Vessel Grounding	0	0	0	0	0	0	0	0	1.15E-05	1.73E-05	5.76E-07	2	
Vessel Sinking	4.44E-08	2.66E-06	4.44E-09	60	1.47E-07	8.83E-06	1.47E-08	60	1.47E-07	4.42E-07	1.47E-08	3	
Vessel Position loss	3.13E-06	9.40E-06	1.57E-08	3	1.23E-03	3.68E-03	6.13E-06	3	0	0	0	0	
Tensioner Failure	7.86E-05	2.36E-04	3.93E-07	3	2.61E-04	7.82E-04	1.30E-06	3	0	0	0	0	
A&R winch/wire failu	4.20E-07	8.40E-07	1.40E-09	2	1.40E-06	2.80E-06	4.67E-09	2	0	0	0	0	
Helicopter Accident	9.50E-04	1.01E-02	1.69E-05	11	3.25E-03	3.46E-02	5.76E-05	11	0	0	0	0	
Dropped pipe													
Ignition	9.00E-06	5.40E-04	9.00E-07	60	9.00E-06	5.40E-04	9.00E-07	60	9.00.E-06	2.70.E-05	9.00.E-07	3	
Buoyancy loss	1.80E-07	5.40E-06	9.00E-09	30	1.80E-07	5.40E-06	9.00E-09	30	1.80.E-07	2.70.E-07	9.00.E-09	2	
Totals			1.9E-05				6.9E-05				1.7E-05		

VESSEL TYPE		ROCK PLACEMENT				ANCHOR HANDLER				DSV		
Days per year	213				95				110			
	Fr Fatality	PLL	IR	N Fatalities	Fr Fatality	PLL	IR	N Fatalities	Fr Fatality	PLL	IR	N Fatalities
EVENT												
Collision	1.15E-05	4.59E-05	1.15E-06	4	5.11E-06	2.05E-05	6.83E-07	4	5.92E-06	2.96E-05	1.48E-07	5
Engine Room Fire	1.07E-04	2.13E-04	5.33E-06	2	4.75E-05	7.13E-05	2.38E-06	2	5.50E-05	1.65E-04	8.25E-07	3
Accommodation Fire	1.87E-05	7.50E-05	1.87E-06	4	8.36E-06	2.51E-05	8.36E-07	3	9.68E-06	7.74E-05	3.87E-07	8
Vessel Grounding	2.68E-06	5.37E-06	1.34E-07	2	0	0	0	0	0	0	0	0
Vessel Sinking	1.07E-07	4.30E-07	1.07E-08	4	4.79E-08	1.44E-07	4.79E-09	3	5.55E-08	1.11E-06	5.55E-09	20
Vessel Position loss	0	0	0	0	0	0	0	0	4.62E-04	1.39E-03	6.93E-06	3
Munitions	3.90E-06	1.17E-05	2.93E-07	3	5.20E-06	1.56E-05	5.20E-07	3	0	0	0	0
Anchor drag- ignitio	0	0	0	0	0	0	0	3	0	0	0	0
Helicopter Accident	0	0	0	0	0	0	0	0	1.19E-03	1.27E-02	6.33E-05	11
Dropped pipe												
Ignition					9.00E-06	2.70E-05	9.00E-07	3				
Buoyancy loss					1.80E-07	2.70E-07	9.00E-09	2				
Totals			8.8E-06				6.2E-06				7.2E-05	

VESSEL TYPE		TRENCH SUPPORT				SHALLOW WATER PIPELAY				SUPPLY VESSEL		
Days per year	48				95	excl AWTI			292			
	Fr Fatality	PLL	IR	N Fatalities	Fr Fatality	PLL	IR	N Fatalities	Fr Fatality	PLL	IR	N Fatalities
EVENT												
Collision	2.58E-06	1.29E-05	6.46E-08	5	4.81E-06	3.85E-05	9.63E-08	8	4.06E-05	1.52E-04	5.08E-06	4
Engine Room Fire	2.40E-05	7.20E-05	3.60E-07	3	4.75E-05	2.85E-04	7.13E-07	6	1.46E-04	2.19E-04	7.30E-06	2
Accommodation Fire	4.22E-06	3.38E-05	1.69E-07	8	8.36E-06	1.25E-04	3.14E-07	15	2.57E-05	7.71E-05	2.57E-06	3
Vessel Grounding	0	0	0	0	0	0	0	0	5.52E-06	8.28E-06	2.76E-07	2
Vessel Sinking	2.42E-08	4.84E-07	2.42E-09	20	4.79E-08	1.92E-06	4.79E-09	40	1.47E-07	4.42E-07	1.47E-08	3
Vessel Position loss	8.06E-05	8.06E-05	4.03E-07	1	3.38E-06	6.77E-06	1.69E-08	2	0	0	0	0
Tensioner Failure	0	0	0	0	8.48E-05	2.54E-04	6.36E-07	3	0	0	0	0
A&R winch/wire failu	0	0	0	0	4.20E-07	8.40E-07	2.10E-09	2	0	0	0	0
Helicopter Accident	0	0	0	0	1.03E-03	1.10E-02	2.74E-05	9	0	0	0	0
Totals			1.0E-06				2.9E-05				1.6E-05	

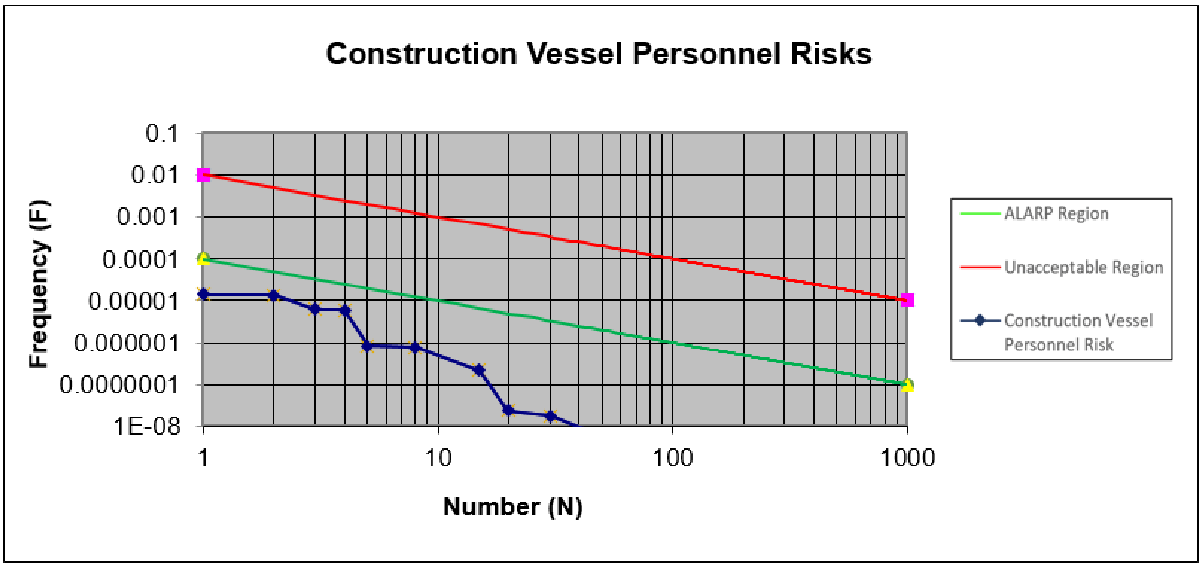
VESSEL TYPE		SURVEY VESSEL				AWTI VESSEL		
Days per year	292				168			
	Fr Fatality	PLL	IR	N Fatalities	Fr Fatality	PLL	IR	N Fatalities
EVENT								
Collision	1.57E-05	1.26E-04	1.57E-06	8	8.51E-06	6.81E-05	1.70E-07	8
Engine Room Fire	1.46E-04	1.17E-03	1.46E-05	8	8.40E-05	5.04E-04	1.26E-06	6
Accommodation Fire	2.57E-05	2.06E-04	2.57E-06	8	1.48E-05	2.22E-04	5.54E-07	8
Vessel Grounding	3.50E-06	1.40E-05	1.75E-07	4	0	0	0	0
Vessel Sinking	1.47E-07	1.18E-06	1.47E-08	8	8.47E-08	4.24E-06	1.06E-08	3
AWTI Pos loss	0	0	0	0	5.98E-06	2.99E-05	7.48E-08	5
Helicopter Accident	0	0	0	0	1.90E-03	2.02E-02	5.06E-05	11
Totals			1.9E-05				5.3E-05	

8.3.2 Construction vessel Individual Risks per country are listed below. These are based on the number of days vessels operate in the various country sectors.

Vessel	**Russia**	**Finland**	**Sweden**	**Denmark**	**Germany**
Anchored PL					1.9E-05
AHT					5.8E-06
Pipe carrier					5.0E-06
PSV					4.9E-06
DP1 PL	6.6E-06	1.4E-05	3.5E-05	1.2E-05	9.4E-07
Pipe carrier	1.6E-06	3.5E-06	8.3E-06	2.9E-06	2.3E-07
PSV	1.5E-06	3.4E-06	8.1E-06	2.9E-06	2.2E-07
DP2 PL		1.3E-05	3.2E-05	1.2E-05	1.2E-06
Pipe carrier		3.2E-06	7.7E-06	2.8E-06	2.8E-07
PSV		3.1E-06	7.5E-06	2.7E-06	2.8E-07
Shallow water PL	8.0E-06				2.9E-05
AHT	1.7E-06				6.2E-06
Pipe carrier	1.5E-06				5.4E-06
PSV	1.4E-06				5.3E-06
Rock dump	8.2E-07	5.5E-06	1.2E-06	1.2E-06	
DSV	1.6E-05	1.6E-05	1.6E-05	9.1E-06	1.6E-05
Trencher			5.8E-07	4.2E-07	
Total IR	**3.9E-05**	**6.2E-05**	**1.2E-04**	**4.6E-05**	**9.9E-05**

Note: Each pipelay vessel is supported by pipe carriers, supply vessels and anchor handlers (where applicable) and these support vessels are assessed in groups defined by the bold borders.

8.3.3 The assessment of group risks for construction vessels has been based on the highest frequency per number of fatalities on the F-N curve below.



8.3.4 The group risks are below the ALARP criteria.

8.4 Environmental Risks

8.4.1 The estimated oil spill frequencies and quantities are summarised below:

Item	Hazards	Probability Oil Spill (per year)	Potential Spill Quantities (t)
	Passing Vessel Collision		
a		2.9 x 10^{-5}	1 – 10
b		5.9 x 10^{-5}	10 – 100
c		8.6 x 10^{-5}	100 – 1.000
d		4.0 x 10^{-5}	1,000 – 10,000
e		1.1 x 10^{-5}	> 10,000
	Construction Vessel Collision		
f	DP Pipe lay Vessel	3.5 x 10^{-5}	750 – 1,250
g	Trench Support Vessel	5.8 x 10^{-6}	500 – 850
h	Rock Dump Vessel	2.6 x 10^{-5}	500 – 850
i	Pipe Carrier & Supply vessel	9.1 x 10^{-5}	300 – 500
j	AHT	1.1 x 10^{-5}	300 – 500
k	Shallow water lay	1.0 x 10^{-5}	300 – 500
	Vessel Fire		
l	Pipe Carrier/Supply vessel	9.0 x 10^{-5}	100
m	Rock placement vessel	6.6 x 10^{-5}	170
n	DP Pipe lay vessel	9.0 x 10^{-5}	250
o	Trench Support	1.5 x 10^{-5}	250

Item	Hazards	Probability Oil Spill (per year)	Potential Spill Quantities (t)
p	Shallow water lay	2.7×10^{-5}	100
	Vessel Grounding		
q	Pipe Carrier	1.2×10^{-4}	300 - 500
r	Rock Dump Vessel	1.8×10^{-5}	500 - 850
s	Supply vessel	4.9×10^{-5}	300 - 500
	Vessel Sinking		
t	Trench Support Vessel	4.2×10^{-7}	750 - 1,250
u	Pipe Carrier/Supply	2.6×10^{-6}	300 - 500
v	DP Pipe lay Vessel	2.6×10^{-6}	750 - 1,250
w	Rock Dump vessel	1.9×10^{-6}	500 - 850
x	Shallow water lay	8.3×10^{-7}	300 – 500
	Oil Spill – Bunkering		
y	Anchor Handler Tug	1.5×10^{-3}	0 - 10
z	DP Pipe lay	4.2×10^{-2}	0 - 10
aa	Shallow water lay	1.3×10^{-2}	0 - 10

Consequences		Probability (increasing probability →)			
Descriptive	**Environment**	**Remote** (< 1.0 x 10^{-5}/y)	**Unlikely** (1.0 x 10^{-5} – 1.0 x 10^{-3} /y)	**Likely** (1.0 x 10^{-3} – 1.0 x 10^{-2} /y)	**Frequent** (1.0 x 10^{-2} – 1.0 x 10^{-1} /y)
1 Extensive	Global or national effect. Restoration time > 10 yr				
2 Severe	Restoration time > 1 yr. Restoration cost > USD 1 mil.	**t, v,**	**d, e, f**		
3 Moderate	Restoration time > 1 month. Restoration cost > USD 1 K	**g, u, w, x**	**c, h, i, j, k, m, n, o, q, r, s**		
4 Minor	Restoration time < 1 month. Restoration cost < USD 1 K		**a, b, l, p,**	**y, z, aa**	

HIGH	The risk is considered intolerable so that safeguards (to reduce the expected occurrence frequency and/or the consequences severity) must be implemented to achieve an acceptable level of risk; the project should not be considered feasible without successful implementation of safeguards
MEDIUM	The risk should be reduced if possible, unless the cost of implementation is disproportionate to the effect of the possible safeguards
LOW	The risk is considered tolerable and no further actions are required

Risk Categories

a	3rd party vessel collision 1 – 10 t spill	**o**	Trench support vessel fire
b	3rd party vessel collision 10 – 100 t spill	**p**	Shallow water pipe lay vessel fire
c	3rd party vessel collision 100 – 1000 t spill	**q**	Pipe carrier grounding
d	3rd party vessel collision 1000 – 10,000 t spill	**r**	Rock placement vessel grounding
e	3rd party vessel collision > 10,000 t spill	**s**	Supply vessel grounding
f	DP Pipe lay vessel collision	**t**	Trench support vessel sinking
g	Trench support vessel collision	**u**	Pipe carrier/supply sinking
h	Rock placement vessel collision	**v**	DP Pipe lay vessel sinking
i	Pipe carrier/Supply vessel collision	**w**	Rock placement vessel sinking
j	Anchor handler collision	**x**	Shallow water pipe lay vessel sinking
k	Shallow water pipe lay vessel collision	**y**	Bunkering – AHT
l	Pipe carrier/Supply vessel fire	**z**	Bunkering – DP Pipe lay vessel
m	Rock placement vessel fire	**aa**	Bunkering – shallow water pipelay
n	DP Pipe lay vessel fire		

8.5 Environmental Risks (By Country)

8.5.1 The passing vessel collision spill frequencies (pollution frequency/year) for individual countries are summarised in the following table:

Country	Spill Size				
	1-10 t	10-100 t	100-1000 t	1000-10000 t	>10000 t
Russia	4.0×10^{-7}	8.0×10^{-7}	1.2×10^{-6}	5.5×10^{-7}	1.5×10^{-7}
Finland	2.5×10^{-6}	5.0×10^{-6}	7.4×10^{-6}	3.5×10^{-6}	9.7×10^{-7}
Sweden	1.3×10^{-5}	2.6×10^{-5}	3.8×10^{-5}	1.8×10^{-5}	5.0×10^{-6}
Denmark	7.5×10^{-6}	1.5×10^{-5}	2.2×10^{-5}	1.0×10^{-5}	2.9×10^{-6}
Germany	5.9×10^{-6}	1.2×10^{-5}	1.7×10^{-5}	8.2×10^{-6}	2.3×10^{-6}

9. CONCLUSIONS

9.1 People

Third Party Personnel

9.1.1 The only third party exposure to risk, during the construction phase of the project, is during the landfall and shallow water pipe lay inshore, and in passing vessel situations offshore.

9.1.2 Onshore exposure, would only occur if non-construction personnel entered the landfall sites, or approached inshore construction vessels. However, the general public will be prevented from accessing these sites and vessels through the use of normal site security arrangements onshore, and safety zones around the inshore vessels. In the event that unexploded munitions were found during landfall preparations, and the potential blast area extended beyond the construction site, then it would be necessary to move the public to a safe area, and the risk of injury or fatality to the general public is therefore considered to be low.

9.1.3 Offshore exposure, is limited to the crews and passengers of passing vessels that could collide with construction vessels. The individual risks for crews and passengers per person per year, are estimated as follows:

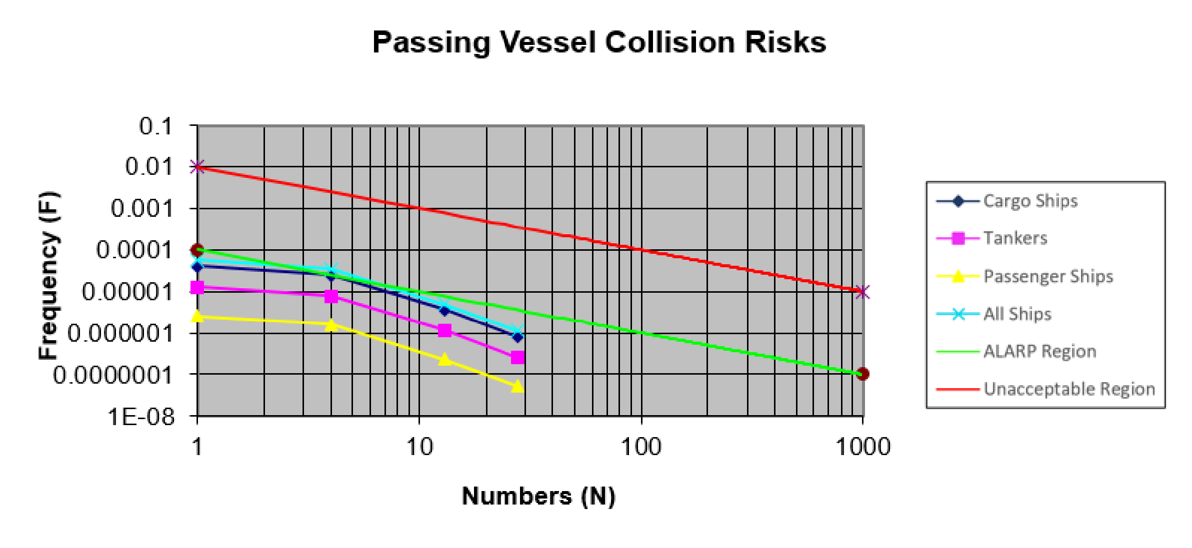
Ship Type	Russia	Finland	Sweden	Denmark	Germany	**Total**
Cargo	5.5×10^{-8}	3.5×10^{-7}	1.8×10^{-6}	1.0×10^{-6}	8.1×10^{-7}	4.0×10^{-6}
Tanker	1.4×10^{-8}	8.7×10^{-8}	4.6×10^{-7}	2.6×10^{-7}	2.0×10^{-7}	1.0×10^{-6}
Passenger	1.5×10^{-10}	9.7×10^{-10}	5.1×10^{-9}	4.4×10^{-9}	2.3×10^{-9}	1.3×10^{-8}
All vessels	6.9×10^{-8}	4.3×10^{-7}	2.3×10^{-6}	1.3×10^{-6}	1.0×10^{-6}	5.1×10^{-6}

9.1.4 This determined, that the individual risks to crew and passengers were below the tolerability criteria established for this project. However it is noted that individual risks for Denmark and Germany are higher for than the route South of Bornholm.

9.1.5 For ease of reference the tolerability criteria are:

Maximum risk for workers	10^{-3} per person per year.
Maximum risk for the public	10^{-4} per person per year.
Broadly acceptable risk	10^{-6} per person per year.

9.1.6 The group risks are shown on the F-N curve overleaf, and it is noted that the risks to cargo ship crews are just inside the ALARP region. Collision avoidance measures carried out by the main construction vessels, are likely to reduce this risk, and this is discussed later in this section. F-N curves for each country are included in section 7.3.4 and risks are well within the broadly acceptable zone.



Construction Personnel Risks

9.1.7 The risks associated with the onshore construction of the landfall sites are generally considered to be low and similar to the risks encountered in any other landfall operation. However, the potential presence of unexploded ordnance in Russia, and to a lesser extent in Germany, introduces an element of risk not normally encountered in landfall sites. Nord Stream will implement a number of risk reduction measures, including a munitions survey prior to the operation, and it is considered that there is low probability that construction personnel will encounter any unexploded ordnance. However, in the event that munitions were unearthed and accidentally detonated it is likely that construction personnel in the vicinity could be injured or killed. However, it is noted that no incidents were reported in NSP1 and it is considered that this risk will fall into the ALARP region.

9.1.8 The individual risks of personnel on the construction vessels, were estimated for all potential emergencies and found to be lower than the tolerability criteria. The individual risks for the vessels are summarised below:

Pipe lay vessel (anchored)	1.9×10^{-5} per person per year.
DP Pipe lay vessel	6.9×10^{-5} per person per year.
Shallow water pipe lay	2.9×10^{-5} per person per year.
Pipe carrier	1.7×10^{-5} per person per year.
Anchor handler	6.2×10^{-6} per person per year.
Supply vessel	1.6×10^{-5} per person per year.
Rock placement	8.8×10^{-6} per person per year.
DSV	7.2×10^{-5} per person per year.
Trench support	1.0×10^{-6} per person per year.
Survey vessel	1.9×10^{-5} per person per year.
AWTI support vessel	5.3×10^{-5} per person per year.
Dredgers (landfall operation)	1.6×10^{-5} per person per year.
Diving operations	6.0×10^{-6} per person per year.

9.1.9 It can be seen that the individual risks on the main construction vessels are slightly higher than on the other vessels. This is mainly due to the fact that they are the only vessel that will use helicopters for crew changes all year round and the risks are correspondingly higher.

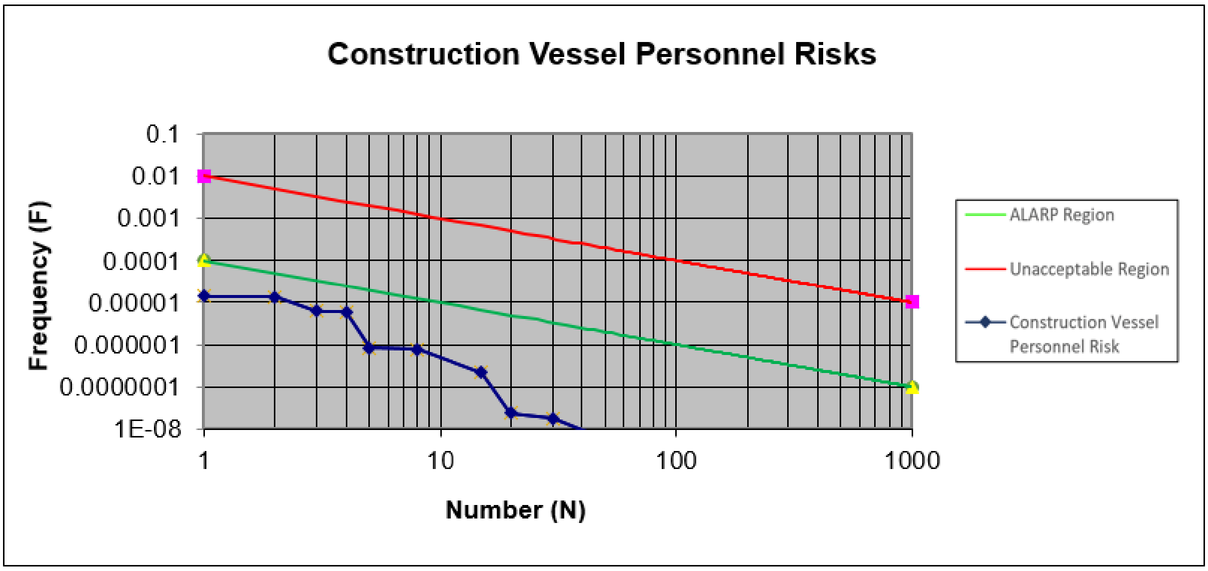
9.1.10 Construction vessel Individual Risks per country are listed below. These are based on the number of days vessels operate in the various country sectors.

Vessel	Russia	Finland	Sweden	Denmark	Germany
Anchored Pipelay					1.9E-05
Anchor handler					5.8E-06
Pipe carrier					5.0E-06
Supply vessel					4.9E-06
DP1 Pipelay	6.6E-06	1.4E-05	3.5E-05	1.2E-05	9.4E-07
Pipe carrier	1.6E-06	3.5E-06	8.3E-06	2.9E-06	2.3E-07
Supply vessel	1.5E-06	3.4E-06	8.1E-06	2.9E-06	2.2E-07
DP2 pipelay		1.3E-05	3.2E-05	1.2E-05	1.2E-06
Pipe carrier		3.2E-06	7.7E-06	2.8E-06	2.8E-07
Supply vessel		3.1E-06	7.5E-06	2.7E-06	2.8E-07
Shallow water Pipelay	8.0E-06				2.9E-05
Anchor handler	1.7E-06				6.2E-06
Pipe carrier	1.5E-06				5.4E-06
Supply vessel	1.4E-06				5.3E-06
Rock placement	8.2E-07	5.5E-06	1.2E-06	1.2E-06	
Mattress installation	1.6E-05	1.6E-05	1.6E-05	9.1E-06	1.6E-05
Trencher			5.8E-07	4.2E-07	
Total IR	3.9E-05	6.2E-05	1.2E-04	4.6E-05	9.9E-05

Note: Each pipelay vessel is supported by pipe carriers, supply vessels and anchor handlers (where applicable) and these support vessels are assessed in groups defined by the bold borders.

9.1.11 These risks are below the risk criteria described in section 5.

9.1.12 The group risks are shown in the following F-N curve (ALARP region shown by red and green lines) and are within the broadly acceptable zone.



9.1.13 During the construction of line B, line A may be operating and the risk assessment considered potential damage to the line from dropped pipe joints during loading operations. The risk of dropped object damage was found to be low but this depends on vessel size and with a pipe separation distance of 55 meters it may be necessary to consider loading to the side furthest away from the existing pipeline.

9.1.14 It should be noted that helicopter incidents also fall within the ALARP region but this is recognised as an oil industry issue and helicopter operations are carried out in accordance with specific standards and industry guidelines. Construction crews will change by crew boat, and helicopter crew changes will be restricted to NSP2 personnel only and flights will be considerably fewer than for NSP1. However, provided industry standards are followed it is considered that the risks will be reduced to as low as is practicable.

9.1.15 The risks associated with dumped munitions and chemicals are obviously of some concern but it has not been possible to carry out a quantitative assessment due to the lack of statistical data. However, NSP1 and NSP2 have carried out extensive surveys and the intention is to route the pipeline clear of any identified munitions. It is assumed that a munitions procedure will be developed and issued to vessel crews explaining the potential hazards and procedures in the event that munitions are encountered. Provided relevant precautions are taken it is considered that munitions risks will be reduced as low as is practicable.

9.2 Environment

9.2.1 The environmental risks are indicated on the DNV-GL matrix below and it can be seen that there are no high risk events and only one medium risk which is listed below.

Consequences		Probability (increasing probability →)			
Descriptive	**Environment**	**Remote** (< 1.0 x 10^{-5}/y)	**Unlikely** (1.0 x 10^{-5} – 1.0 x 10^{-3} /y)	**Likely** (1.0 x 10^{-3} – 1.0 x 10^{-2} /y)	**Frequent** (1.0 x 10^{-2} – 1.0 x 10^{-1} /y)
1 Extensive	Global or national effect. Restoration time > 10 yr				
2 Severe	Restoration time > 1 yr. Restoration cost > USD 1 mil.	**t, v,**	**d, e, f**		
3 Moderate	Restoration time > 1 month. Restoration cost > USD 1 K	**g, u, w, x**	**c, h, i, j, k, m, n, o, q, r, s**		
4 Minor	Restoration time < 1 month. Restoration cost < USD 1 K		**a, b, l, p,**	**y, z, aa**	
HIGH	The risk is considered intolerable so that safeguards (to reduce the expected occurrence frequency and/or the consequences severity) must be implemented to achieve an acceptable level of risk; the project should not be considered feasible without successful implementation of safeguards				
MEDIUM	The risk should be reduced if possible, unless the cost of implementation is disproportionate to the effect of the possible safeguards				
LOW	The risk is considered tolerable and no further actions are required				

9.2.2 **Note: d = 3rd party vessel collision 100 – 1,000 t spill; e =3rd party vessel collision > 10,000 t spill and f = DP Pipelay collision 750 – 1,250t**.

9.2.3 It can be seen that these risks are all related to passing vessel collision and collision risk reduction is required to minimise the potential for environmental damage. It is noted that the increase in category **e** probability is due to the re-route North of Bornholm.

9.2.4 Helcom data from 1988 – 2009 indicates that the largest recorded spill in the Baltic Sea was 2,700 te and the estimates above are considered to be conservative.

9.2.5 The Ramboll report (reference 6.9) on accidental oil spill estimated that for any spills occurring in mid Baltic Sea it would take approximately 48 hours for the oil to reach the coastline while in coastal areas such as Bornholm this time would obviously be less. It will therefore be necessary to be able to respond quickly to any oil spills. The construction vessels are all required to have SOPEP emergency oil spill procedures and equipment on board, however SOPEP kits rarely include provisions for anything beyond a minor spill (tier 1) and therefore NSP2 has requested that all marine contractors have plans to deal with Tier 2 and Tier 3 spills, most likely through agreements with suppliers of oil spill response equipment.

9.3 Risk Reduction Measures

9.3.1 A number of risk reduction measures have been identified in this assessment and are summarised below in order to enable follow up during the construction phase.

9.3.2 Vessel collision is the highest risk that third party and construction vessels may encounter. Potential consequences include fatalities and oil pollution. It is evident that the collision risk reduction measures will need to be implemented in areas of high traffic.

9.3.3 The presence of UXO and chemicals munitions onshore and offshore present an obvious risk to personnel, vessels and equipment. Risk reduction measures should include the following as a minimum:

- Development of relevant procedures in the event that munitions are encountered during operations. These should include the results of risk assessments and HAZIDs.
- Investigation of potential effects of explosions on construction vessels and risk reduction measures if required.
- Development of procedures for munitions clearance/disposal if required.
- Safety training/briefing to all personnel likely to be exposed to munitions.
- Provision of suitable PPE, procedures and equipment for construction workers likely to be exposed to chemical munitions.
- Provision of suitable PPE, procedures and equipment for workers and divers involved in above water tie-ins and subsea operations in areas where chemicals could be located.

9.3.4 The width of the anchor corridor survey should be compatible with the anchor patterns planned for the installation of both pipelines.

9.3.5 Anchor handling operations will need to be carefully managed during the installation of line B when line A is already installed and in operation to ensure that all relevant precautions are taken to prevent pipeline damage. Due to the duration of the pipe lay operations it will be necessary to ensure that human errors do not arise as a result of complacency.

9.3.6 Pipe loading/handling operations will also need to be carefully managed during the installation of line B. It is recommended that in areas where the separation distance is 55 m a more detailed assessment is carried out, taking into account the actual water depth in that area. If necessary pipe handling operations will need to be modified and this may include the requirement to load pipe on one side of the vessel in critical areas.

9.3.7 Bunker and oil spill response procedures should be prepared/verified to ensure the risk of oil pollution is minimised.

9.3.8 Relevant procedures should be prepared for operations in adverse weather conditions such as low temperatures, ice, snow, high winds. This should include consideration for precautions required during pipe joint loading and anchor handling operations.

9.3.9 Contingency procedures should be developed to manage problems that could arise during pre-commissioning operations. These problems could include stuck pigs, excessive aeration of test water and inadequate cleaning.

9.3.10 Procedures should ensure compliance with requirements related to operations in environmentally sensitive areas (e.g. Natura 2000) as well as actions identified in the EIA documentation.

10. REFERENCES

3.1 NEXT Route Crossings Summary N-GE-SUR-REP-000-R0000002 Rev A – Nord Stream AG September 2012

3.2 Design Basis W-EN-ENG-GEN-REP-804-009202EN-03 – Saipem April 2014

3.3 NEXT Specification for Line Pipe N-GE-PLM-SPE-000-LINEPISP Rev A 29 January 2009

3.4 Saipem S.p.A. Technical Note - Metocean data overview 5th November 2015

3.5 Nord Stream2 Metocean Design Basis – Saipem W-EN-OFP-POF-REP-804-071508EN-02 May 2016

3.6 Report on Chemical Munitions Dumped in the Baltic Sea – Danish Environmental Protection Agency – January 1994

3.7 Munitions Identification Expert Review G-EN-SUR-RPT-108-UXOC1400-A 2008 – MMT September 2008

3.8 3rd Periodic Assessment of the State of the Marine Environment of the Baltic Sea. Helcom 1996

3.9 Effects of Underwater Explosions – Snamprogetti - G-EN-PIE-REP-102-00072528

3.10 Key Issues Paper "Munitions: Chemical and Conventional" Nord Stream January 2009

3.11 Chemical warfare agents dumped in the Baltic Sea Ramboll G-PE-PER-EIA-100-49300000-01 version 0

3.12 W-RU-SWP-LFR-SOW-800-SWPSOWEN-04 Scope of Work for Russian Nearshore Pipelay and AWTI's

3.13 NEXT Route Crossings Summary N-GE-SUR-REP-000-R0000002 Rev A – Nord Stream August 2012

4.1 Risk Management in Subsea and Marine Operations - DNV-GL Recommended Practice-H101 January 2003

4.2. Formal Safety Assessment – IMO Marine Safety Committee Circular MSC/78/19/2 February 2004

4.3 Risk Management - Nord Stream G-GE-RSK-PRO-000-RSKMNG-01

4.4 Pipeline Protection Design against Ship Traffic Related Threats – Snamprogetti G-EN-PIE-REP-102-00072523

4.5 Nord Stream Pipeline Project – Marine and Engineering Risk Review – Global Maritime G-GE-RSK-REP-126-GM-48869-02

4.6 Nord Stream Pipeline Project Risk Assessment Construction Phase - Global Maritime G-GE-RSK-REP-126-00049203-D 3rd April 2009

5.1 Reducing Risks, Protecting Persons UK HSE 2001 ISBN 0 7176 2151 0

5.2 DNV-GL RP H101 Risk Management in Marine and Subsea Operations

6.1 Pipe Trawl Gear Interaction – Snamprogetti Presentation in Malmo Sweden November 2007

6.2 Trawling Frequencies And Risk To Fishing Vessels Ramboll G-GE-RSK-REP-100-426J0000 (01)

6.3 Nord Stream Project 2 Ship Traffic Background Report Ramboll - W-PE-EIA-POF-REP-805-060100EN-01 May 2016

6.4 Nord Stream Project 2 Ship-Ship Collision Report Ramboll W-PE-EIA-POF-REP-805-RN0600EN-05 - June 2018

6.5 Accident Statistics for Floating Offshore Units – UK Continental Shelf 1980 – 2005 HSE Research Report 567. DNV-GL 2007

6.6 Marine Transport in the Baltic Sea - Helcom Report 2006

6.7 Military Practice Areas - Ramboll G-PE-PER-EIA-100-49200000-01

6.8 Report on Chemical Munitions Dumped in the Baltic Sea - Helcom March 1994

6.9 NSP2 Modelling Of Oil Spill- Ramboll - W-PE-EIA-POF-REP-805-070200EN-05- July 2016

6.10 Construction Organisation of Dry Pipeline Section – Volume 7 Book 2 – Petergaz – G-PE-LFR-REP-101-07020000-03

6.11 Risk Assessment of Pipeline Protection - Recommended Practice DNV-GL-RP-F107 October 2010

7.1 Ship Oil Spill Risk Models Appendix IV DNV-GL Report for Australian Maritime Safety Authority December 2011

7.2 Accidental Oil Spill During Construction – Ramboll - G-PE-PER-EIA-100-43a70000-01

7.3 Identification of Marine Environment High Risk Areas in the UK – Safetec UK December 1999

7.4 UK Offshore Public Transport Helicopter Safety Record (1976 – 2002). HSE Report by John Burt Associates Limited / BOMEL Limited

7.5 UK Offshore Commercial Transport Helicopter safety Record 1981-2010 – Oil & Gas UK 2011

7.6 Pipeline Damage Assessment against Commercial Ship Traffic Threats in the Finnish EEZ Snamprogetti G-GE-PIE-REP-102-00072513

7.7 Risk Assessment Report for Finnish Area Operational Phase (Kalbadagrund) - Snamprogetti - G-GE-PIE-REP-102-00085217

7.8 Risk Assessment Report For German EEZ Area Operational Phase – Snamprogetti G-GE-PIE-REP-102-00085207

7.9 Risk Assessment Report For Denmark Area (South Of Bornholm) - Operational Phase - Snamprogetti G-GE-PIE-REP-102-00085219

7.10 Risk Assessment Report For Sweden Area Operational Phase - Snamprogetti G-GE-PIE-REP-102-00085213

7.11 Risk Assessment Report For Russian Area Operational Phase - Snamprogetti G-GE-PIE-REP-102-00085215

7.12 Review Of Issues Associated With The Stability Of Semi-Submersibles HSE Research Report 473 – BMT Fluid Mechanics 2006

7.13 Combining Modelling With Response In Potential Deep Well Blowout: Lessons Learned From Thunder Horse. CJ Beegle-Krause, NOAA and W Lynch, BP - 2005 International Oil Spill Conference

7.14 Bulletin 51 – Pipe lay of Nord Stream Line 1 – Construction Risk Assessment – Allseas document 309871-ITT-NOS-001-051

7.15 Saipem E-Mail 24th June 2008

7.16 OGP report 434-8 Mechanical Lifting Failures March 2010

A1 Collision Incidents Database 2000 to 2006 - Lloyds Marine Intelligence Unit

A2 IMO Nav510 Passenger Ship Safety: Effective Voyage Planning for Passenger Ships. DNV-GL, NMD, NSA, Kongsberg Maritime.

A3 Update of the UKCS Risk Overview – HSE Report OTH 94 458 – DNV-GL Technica

A4 Risk Assessment of Buoyancy Loss (RABL), Summary of Programme Results, Vinnem, J.E., Intl. Conf. Mobile Offshore Structures, City University, London, September 1987.

A5 Safety Assessment Considerations for Offshore Floating Production and Storage Units. I Thompson and D Prentice

A6 Helcom data on Ship Accidents in the Baltic Sea Area 1989 – 2006. Download from website

A7 ECDIS for Navigational Safety in Marine Transportation – E Vanem, M Eide, R Skang DNV-GL Research and Innovation E-Navigation Conference Oslo December 2007

A8 Evacuation, Escape and Rescue Research Report – Bercha Engineering June 2001

A9 Experience And Risk Assessment Of FPSOs In Use On The Norwegian Continental Shelf Descriptions Of Events. RL Leonhardsen, G Ersdal and A Kvitrud Norwegian Petroleum Directorate

A10 Anchor line failures- Norwegian Continental Shelf - 2010-2014 Report 992081 Petroleumstilsynet 21.08.14

A11 Risk Analysis of Collision of Dynamically Positioned Support Vessels with Offshore Installations. IMCA 115 1994

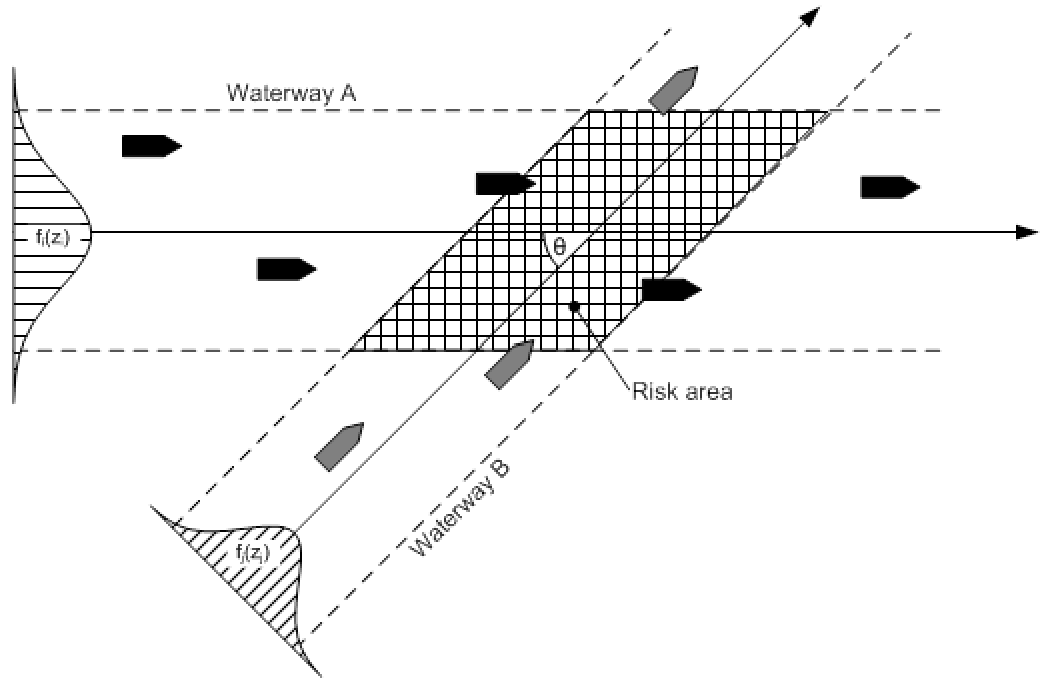
A12 Risk Analysis of DSV – Confidential Report GM-45269-0108-49022 January 2008

APPENDICES

APPENDIX A QRA METHODOLOGY AND CALCULATIONS

A1 - PASSING VESSEL COLLISION

The methodology for assessing the risk of ship-to-ship collision is summarised in the following paragraphs. The frequency of collision between two waterways can be described by the following formulae. The following figure illustrates the crossing area between the two waterways and the intersection angle, θ.



The geometrical collision diameter is given by the formula

$$D_{i,j} = \frac{L_i^A \cdot V_j^B + L_j^B \cdot V_i^A}{V_{i,j}} \sin(\theta) + B_j^B \left(1 - \left(\sin(\theta) \cdot \frac{V_i^A}{V_{i,j}}\right)\right)^{1/2} + B_i^A \left(1 - \left(\sin(\theta) \cdot \frac{V_j^B}{V_{i,j}}\right)\right)^{1/2}$$

Where:

A, B = Waterway name

Li = Length of investigated vessel (e.g. pipe carrier)

Lj = Length of traffic route vessel

Vi = Speed of investigated vessel (e.g. pipe carrier)

VJ = Speed of traffic route vessel

Bi = Breadth of investigated vessel (e.g. pipe carrier)

BJ = Breadth of traffic route vessel

The collision diameter describes the diameter where collision between two vessels is possible. The diameter is taken from the mid-points of the two vessels that are treated as rectangular boxes.

The relative velocity between the two vessels is given by:

$$V_{i,j} = \sqrt{\left(V_i^A\right)^2 + \left(V_j^B\right)^2 - 2 \cdot V_i^A \cdot V_j^B \cdot \cos(\theta)}$$

The number of possible collisions is then found by integrating over the risk area, *Da*, and summarizing all involved vessels. In the cases treated in the present study *I* = 1 (only one vessel crossing a traffic route at the time). The lateral distributions, *f*, are for simplicity taken to be uniformly distributed over the route width. The route width of waterway 2 is taken to be 1m (i.e. no spreading). The number of possible collisions is also dependent on the speed of the crossing vessel. This is included by the term Δt describing the crossing time.

$$N_{ss} = \sum_{i=1}^{N_A} \sum_{j=1}^{N_B} \iint \frac{N_i^A \cdot N_j^B}{V_i^A \cdot V_j^B} \cdot f_i^A \cdot f_j^B \cdot V_{ij} \cdot D_{i,j} \cdot dA \cdot \Delta t$$

To obtain the collision frequency the number of possible collisions must be multiplied by the causation probability. This probability takes into account the possibility of the crew interacting to avoid collision with another vessel. In previous work submitted to IMO the causation probability, Pc has been estimated to be 9·10-5.

$$F_{ss} = P_c \cdot N_{ss}$$

The annual frequencies of passing vessel collision with construction vessels have been assessed by Ramboll (reference 6.1) and are as follows:

Vessels	Russia	Finland	Sweden	Denmark	Germany	Total
Pipe lay vessel	5.20E-06	5.32E-05	1.27E-04	1.73E-04	5.67E-05	4.15E-04
Pipe lay carriers	1.66E-05	4.40E-05	6.32E-04	1.93E-04	2.54E-04	1.14E-03
Intervention vessels (DSV etc)	5.16E-06	7.32E-05	1.31E-04	1.43E-04	8.82E-05	4.41E-04
Total (i.e. passing vessels)	2.70E-05	1.70E-04	8.90E-04	5.09E-04	3.99E-04	2.00E-03

The frequency of collision for all these vessels incorporates a factor for the following risk reduction measures:

- Raised awareness of construction operations through the publication of warning in the notices to mariners prior to the operation. Additionally Navtex warnings will be issued prior to and during the operations. (Factor 0.75)
- Traffic control via the Vessel Traffic System in the Gulf of Finland (GoF). This is only applicable to the GoF and the factor been applied to GOF collision frequencies alone. (Factor 0.2)
- Establishment of safety zone around pipe lay vessel plus Saipem collision avoidance measures such as the use of guard boats, pilots, native language speakers and ARPA radar on the pipe lay vessels. (Factor 0.1)
- The use of AIS to identify, locate and communicate with nearby vessels. (Factor 0.55)

PASSING VESSEL COLLISION RISK

The consequences of a collision will vary for each vessel type and the distribution of vessel types has been taken from the Ramboll study on ship traffic (reference 6.4) moving along the main route reference through the Baltic. The total number of vessel movements was reported to be 47,500 and after adjustment for unknown vessel categories the distribution is shown in the following table.

Vessel Type	Distribution
Cargo	0.73
Tanker	0.23
Passenger	0.05

The annual frequency of collision for each vessel type is therefore estimated as follows:

	Russia	Finland	Sweden	Denmark	Germany	Total
Passing vessels	2.70E-05	1.70E-04	8.90E-04	5.09E-04	3.99E-04	2.00E-03
Cargo	1.96E-05	1.24E-04	6.46E-04	3.70E-04	2.90E-04	1.45E-03
Tanker	6.15E-06	3.89E-05	2.03E-04	1.16E-04	9.09E-05	4.55E-04
Passenger	1.24E-06	7.84E-06	4.09E-05	2.34E-05	1.83E-05	9.18E-05

The number of people on board these vessels has been based on the Saipem analyses as follows:

Vessel Type	Individuals per
Cargo	20
Tanker	25
Passenger	450 including crew

The fatality rate has been assessed by reference to Lloyds Maritime Intelligence Unit (LMIU) data on ship-ship collisions and the associated statistics relating to the number of deaths and missing persons (reference A1). This database reported a total of 2,376 vessels that were involved in a collision. Incident data was screened to remove incidents concerning vessel types deemed not relevant to this particular analysis (e.g. fishing vessels and inland ferries).

Evaluation of this data provided the following statistics:

- Vessels involved in collision incident: 2,376
- Vessels involved in collision incidents following screening: 2,118
- Vessels involved in collision incidents with fatalities: 60
- Fatalities: (includes confirmed deaths and missing persons) 251

From this the conditional probability of a fatality(ies) occurring as a result of collision has been calculated as 60/2,118 = 0.028 per collision. The corresponding probability of fatality following a collision with construction vessels is indicated below:

Conditional probability of fatality	0.028.
Frequency of fatality – cargo ship	4.0×10^{-5} per year.
Frequency of fatality – tanker	1.3×10^{-5} per year.
Frequency of fatality – passenger ship	2.6×10^{-6} per year.

The LMIU statistics were further broken down as shown in the table below:

No. of deaths or missing persons	No. of occurrences	Death / missing persons	Probability
0	2058	0	0.97213
1	23	23	0.01086
2	7	14	0.00331
3	8	24	0.00378
4	5	20	0.00236
5	1	5	0.00047
6	2	12	0.00094
7	4	28	0.00189
8	2	16	0.00094
9	1	9	0.00047
11	0	0	0.00000
10	2	20	0.00094
11	0	0	0.00000
12	1	12	0.00047
13	2	26	0.00094
14	1	14	0.00047
28	1	28	0.00047
Totals	**2,118**	**251**	**1.00000**

The average fatality rate is 4 fatalities per collision and it is noted that there appears to be no correlation between vessel or crew size and the number of fatalities. By way of comparison a Norwegian joint industry study (reference A2) on passenger ship safety submitted to the IMO estimated that the fatality rate per passenger per collision was 5.4×10^{-3}. For a ship with 450 passengers and crew this equates to 2.4 fatalities per collision; however, for the purposes of this analysis a fatality rate of 4 per collision has been assumed.

In order to assess group risks for passing vessels the Lloyds data was analysed to calculate the number of fatalities in 4 groups as indicated in the following table.

Fatality Range	No. of Fatalities	Percentage	Average No. Fatalities per Fatality Range
1 fatality	23	0.38	1.00
1 – 10 fatalities	148	0.53	4.63
11 to 20 fatalities	52	0.07	13.00
20 plus fatalities	28	0.02	28.00

The corresponding fatality numbers and frequencies have been derived as follows:

	Cargo	Tanker	Passenger
Frequency of fatality	2.9×10^{-5}	9.0×10^{-6}	1.8×10^{-6}
Probability of 1 fatality	0.38	0.38	0.38
Frequency of 1 fatality	1.1×10^{-5}	3.4×10^{-6}	6.9×10^{-7}
Probability of 4 fatalities	0.53	0.53	0.53
Frequency of 4 fatalities	1.5×10^{-5}	8.8×10^{-6}	9.7×10^{-7}
Probability of 13 fatalities	0.07	0.07	0.07
Frequency of 13 fatalities	2.0×10^{-6}	6.3×10^{-7}	1.3×10^{-7}
Probability of 28 fatalities	0.02	0.02	0.02
Frequency of 28 fatalities	5.8×10^{-7}	1.8×10^{-7}	3.7×10^{-8}

Pollution following collision

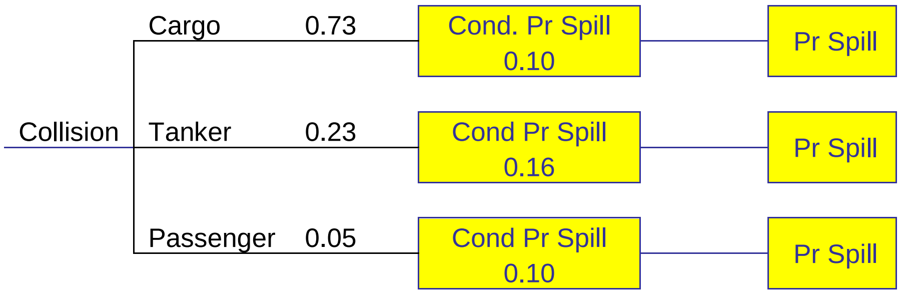
In an oil spill risk study for the Australian Maritime Safety Authority the probability of oil pollution following a collision has been estimated by DNV-GL (reference 7.1) and separated into cargo spills from tankers and bunker spills from all other vessels. The probabilities were obtained through analysis of worldwide data from 2000 to 2010 for tanker cargo spills and 1992 to 1997 for cargo vessel bunker spills and are listed below.

Vessel Type	Total Loss	Serious Casualty	Non Serious Casualty	Total
Tankers	0.43	0.15	0.03	0.12
Vessels other than Tankers	0.20	0.08	0.02	0.02

As the number of total losses is considerably less than serious casualties the probabilities have been combined as follows:

- Probability of cargo spill tankers 0.16 (36 spills in 227 collisions)
- Probability of bunker spill other vessels 0.10 (6 spills in 63 collisions)

These values have been entered into the event tree presented overleaf and the probability of pollution following a collision was estimated to be 0.11.



For NSP1 Ramboll have analysed the consequences of accidental oil spill during construction (reference 7.2) and used data from the Danish Ministry of Defence to estimate the frequency of oil spills characterised by oil type. The distribution given in the table below applies to Danish waters, but it is assumed to be representative of the Baltic region because the traffic in and out of this region passes through the Danish straits. It is noted that GM have been unable to find more recent data on oil spill distribution in the Baltic Sea.

	1-10 t	**10-100 t**	**100-1000 t**	**1000-10000 t**	**>10000**
Crude oil	0%	1%	1%	2%	2%
Bunker oil	10%	20%	30%	11%	1%
Diesel	3%	5%	7%	4%	1%
Petrol	0%	0%	0%	1%	0%
Other	0%	0%	0%	0%	0%
Total	13%	26%	38%	18%	5%

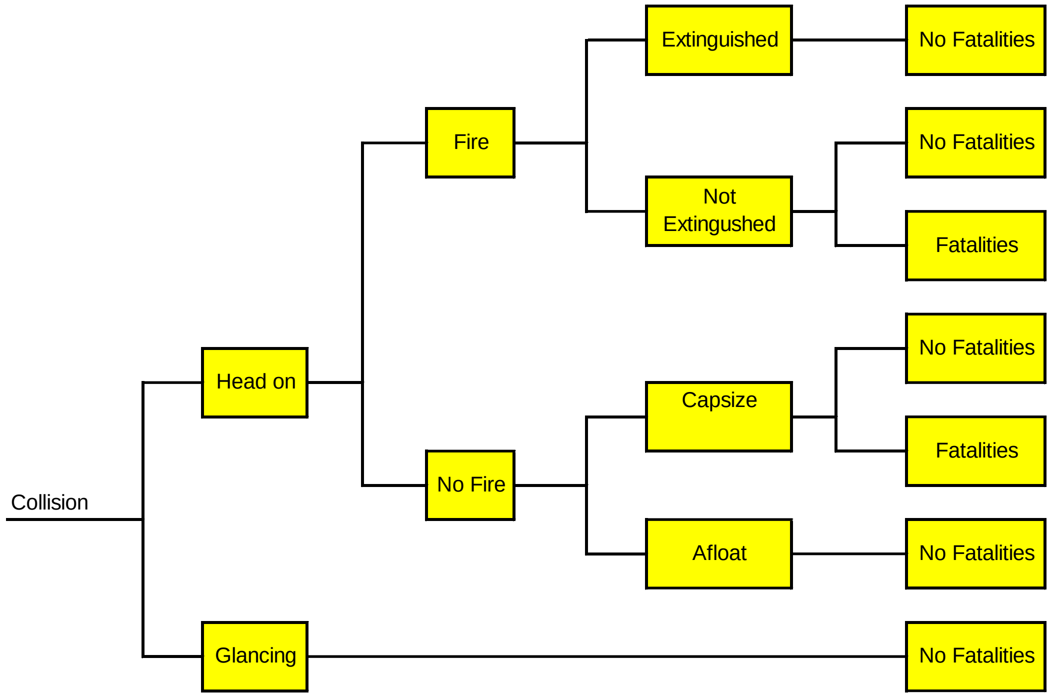
The probability of pollution, 0.11, has been combined with the spill size distribution to estimate the conditional probability of a spill which is then combined with the frequency of collision. These values, which are applicable to the whole route, are shown in the table below.

	Spill Size				
	1-10 t	**10-100 t**	**100-1000 t**	**1000-10000 t**	**>10000 t**
Spill distribution	0.13	0.26	0.38	0.18	0.05
Pr pollution	0.11	0.11	0.11	0.11	0.11
Conditional	0.01	0.03	0.04	0.02	0.01
Collision	1.4×10^{-3}	1.4×10^{-3}	1.4×10^{-3}	1.4×10^{-3}	1.4×10^{-3}
Pollution	2.1×10^{-5}	4.2×10^{-5}	6.1×10^{-5}	2.9×10^{-5}	8.0×10^{-6}

A2 - CONSTRUCTION VESSEL COLLISION RISKS

The main pipe lay vessels are unlikely to be able to take avoiding action and would have to rely on the anchor handling tugs to act as guard vessels and attempt to warn off the incoming vessel. It is therefore considered that the LMIU data is not directly applicable to this scenario and an event tree has been developed to reflect this. In the event of a passing vessel collision the consequences include:

- Vessel instability or capsize.
- Vessel fire.
- Oil spill.



Following a review of 20 passing vessel collisions with semi-submersible vessels in the North Sea DNV-GL Technica (reference A3) divided collisions into two types: head on and glancing.

- Head on – where the passing vessel is stopped by the construction vessel.
- Glancing – where the passing vessel brushed against the platform. Accident experience shows that for most platforms this event caused negligible damage.

This led to the estimate that 60% of collisions were glancing blows and 40% were head on and these probabilities have been assumed for this assessment. It is noted that a glancing blow could still cause severe damage to the outer extremities of both vessels but the probability of fatalities or major environmental damage is considered to be low.

A review of the LMIU data indicates that only 4 vessels caught fire following a collision and this equates to a probability of 1.9×10^{-3} which is very low. However, if the passing vessel involved in the collision was a tanker the probability of a fire would be higher. A review of tanker collision incidents (reference 6.8) indicates that approximately 40% of collisions resulted in fires and since 19% of the passing vessels are tankers the probability is estimated to be: 0.4 x 0.19 = 0.076.

In the event of a fire the vessel fire team would attempt to extinguish the fire while non-essential personnel would be mustered at their emergency stations. Pipe lay vessels have a large number of trained personnel available for emergency situations and it is likely that they could extinguish most fires. However, some fire-fighting equipment, such as fire lines, may be damaged following a collision and it is conservatively estimated that the probability of extinguishing a fire would be 0.5.

The probability of fatality if the fire cannot be extinguished is again likely to be relatively low as all non-essential personnel would have been evacuated if it was considered that the fire was escalating. However, a conservative probability of 0.5 has been assumed here.

In the DNV-GL Technica study referred to above data from the risk of buoyancy loss (RABL) study (reference A4) was analysed and it was concluded that there was a 20% probability that a semi-submersible would capsize following a collision. This is considered applicable as a number of pipe lay vessels are semi-submersibles. The probability of fatality following a capsize has conservatively been assumed to be 0.5.

The resultant conditional probability of fatality is calculated to be 0.045. The collision risks have been assessed in accordance with the pipe lay collision frequency derived previously and Ramboll data for the pipe carriers and intervention vessels with no risk reduction factor.

The pipe lay vessel will be engaged in construction activities on line A for approximately one year and has the highest exposure to collision risks. The other construction vessels, such as the DSV or rock placement vessel, will be exposed for much shorter durations and the Ramboll data has been adjusted accordingly.

A3 - VESSEL FIRE

Historical data on vessel fires has been reported in a number of studies and Helcom include it in their annual reports on shipping incident in the Baltic Sea. These reports indicate typical annual rates of between 3% and 9% per year but do not provide information on the frequencies per vessel year.

A review of Lloyds Register data for engine room and accommodation fires (Reference A5) determined the frequencies as follows:

Engine room 2.5×10^{-3} per vessel per year.

Accommodation 4.4×10^{-4} per vessel per year.

A more recent DNV-GL report (reference 7.1) reviewed incidents from 2000 to 2010 does not differentiate between engine and accommodation fires but identified fire/explosion frequencies as follows:

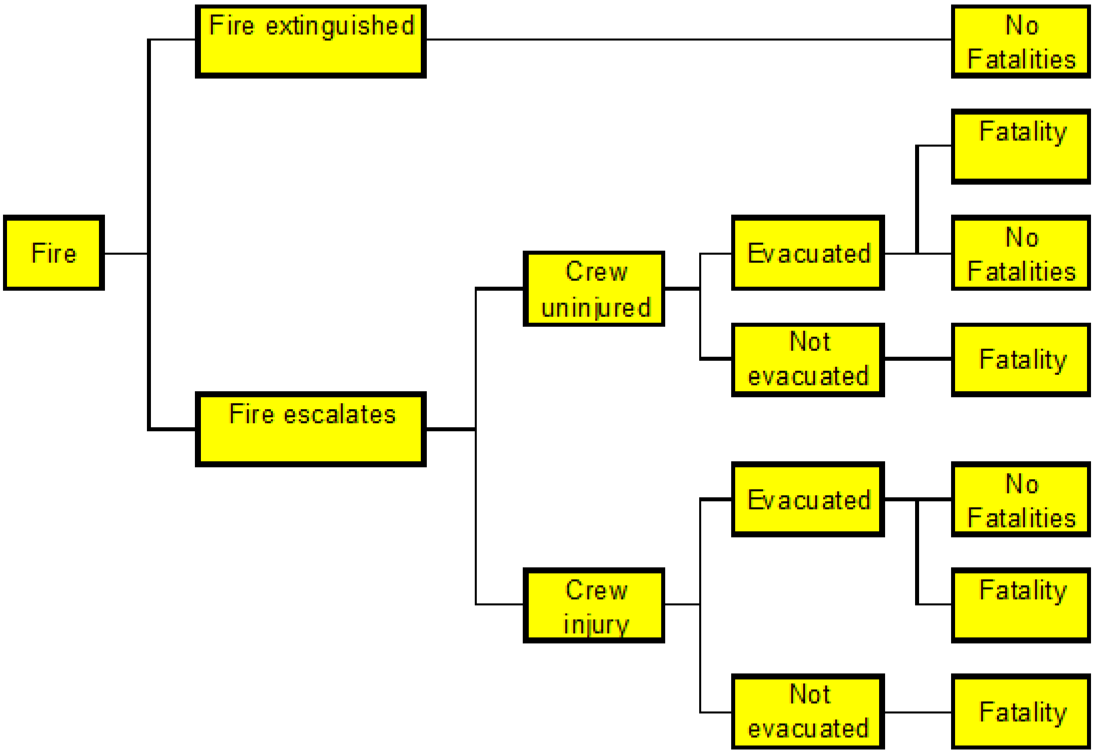
Incident	Non Serious	Serious	Total Loss
Fire/Explosion	1.4×10^{-4}	1.1×10^{-3}	2.6×10^{-4}

The combined frequency of the serious and total loss incidents is 1.36×10^{-3} which is the same order of magnitude as the Lloyds data. It is considered the Lloyds data is still valid for this assessment and this has been used for this assessment.

The DNV-GL report indicates that the probability of an oil spill following fire or explosion is 0.045. In this case it is considered more likely that there would be an oil spill following an engine room fire and this frequency has been used as a basis for the assessment of risk to the environment.

Similarly there is limited data on oil spill size following a fire. However, a review of the Helcom incident data from 1989 to 2006 showed that the maximum spill size was $2.5m^3$ and a conservative estimate has been based on 10% of bunker size.

In the event of a fire the vessel fire team will attempt to extinguish the fire using fixed and portable fire-fighting equipment and non-essential personnel will assemble at their muster stations. If the fire escalates non-essential personnel will be evacuated and the fire team will continue to fight the fire. In the event that the fire cannot be controlled the vessel will be abandoned. This sequence is modelled in the fault tree below which is used to estimate the frequency of personnel fatality.



The following values have been used for this assessment:

Probability that fire is extinguished	0.8
Probability of crew injury	0.4
Probability of uninjured crew evacuated	0.8
Probability of injured crew evacuated	0.5
Pr fatality during uninjured crew evacuation	0.05
Pr fatality during injured crew evacuation	0.1

Bearing in mind the amount of safety training that offshore crews receive these values are considered to be conservative. The results of the event tree calculation indicate that the conditional probability of fatality as a result of a fire is 0.073.

The number of fatalities is based on the numbers of crew considered to be at risk during a fire. In engine room fires the first response will be to close the ventilation and initiate the fixed fire-fighting system and the persons at risk are likely to be limited to engine room staff and the potential number of fatalities has been estimated accordingly. In an accommodation fire more personnel are likely to be at risk, particularly in the event of a cabin fire, and fatalities are considered to be higher for this hazard.

A4 - VESSEL GROUNDING

Helcom (reference A6) data for accidents in the Baltic Sea indicate that there were 63 grounding incidents in the Gulf of Finland between 2000 and 2006 giving an average annual rate of 9 per year. The report indicates that the average traffic in the Gulf of Finland is 40,000 vessels entering and leaving per year. This equates to a grounding incident rate of 2.25 x 10-4 per vessel year but it is difficult to convert this to a value that could be used to estimate port visit risks.

A Safetec study (reference 7.3) on marine accidents around the UK coast estimated the combined frequency for powered and drifting grounding to be:

Probability per movement 1.5×10^{-5}

The Safetec data also includes a breakdown of vessel types and concluded that the grounding frequency of offshore supply vessels was better than average by a factor of 0.7. The frequency of grounding has therefore been estimated as

Probability per move $0.7 \times 1.5 \times 10^{-5} = 1.05 \times 10^{-5}$ per movement.

Grounding probabilities have therefore been estimated on the number of movements per vessel type per year. The pipe carriers are scheduled to make one port visit every 2 days, supply vessels one visit every 5 days and the rock placement vessels one visit every 10 days.

Frequency of Injury/fatality

A review of Helcom data on Baltic Sea accidents appears to indicate that there is a very low probability of fatality following a grounding incident but there is insufficient data available to derive a meaningful probability of fatality. In fact the Finnish Maritime Authority report no injuries resulting from grounding have been reported in the last 20 years (Reference Methods to Quantify Maritime Accidents for Risk-based decision making Baltic Sea Region January 2012)

However, a formal safety assessment (FSA) of cruise ships has been carried out by DNV-GL (reference A7) and this included the development of a grounding model which estimated the following fatality rates in a grounding incident:

Oil, chemical, LNG and container vessels:	2.0×10^{-4} per crew member/per grounding
Bulk carriers and general cargo	6.0×10^{-4} per crew member/per grounding

For the purposes of this study a conservative value of 6.0×10^{-4} per crew member/per grounding has been assumed and with a vessel complement of 20 results in a conditional probability of fatality of 0.012 and for a crew of 15 the probability is 0.009.

The number of fatalities following a grounding is considered to be low and a conservative estimate of 10% of vessel crew has been assumed.

Oil spills resulting from a grounding incident is discussed in section 7.6.10.

A5 - VESSEL SINKING

The probability of vessels sinking or capsizing is generally low, for example Helcom reported that 16 vessels sunk in the Baltic Sea between 1989 and 2006.

At this stage in the project it is difficult to estimate the number of vessel movements or distance steamed and a review of Helcom accident data has been reviewed to estimate the annual frequency as follows:

Number of incidents:	16 from 1989 to 2006
Incident frequency	1 per year
Number of vessels per year	376,671 (ships crossing AIS lines in the Baltic Sea)
Incident frequency	2.65×10^{-6} per vessel, per year

The most recent data from 2013 indicates that capsizing represented 1% of all incidents and this corresponds to an incident frequency of 4.28×10^{-6} per year.

The safety of vessel personnel obviously depends on the ability to evacuate the ship before it sinks. In the smaller support vessels, such as pipe carriers or anchor handlers, the only evacuation options are lifeboats or life rafts. The larger pipe lay and construction vessels also have the option of helicopter evacuation and assistance from the support vessels in the area.

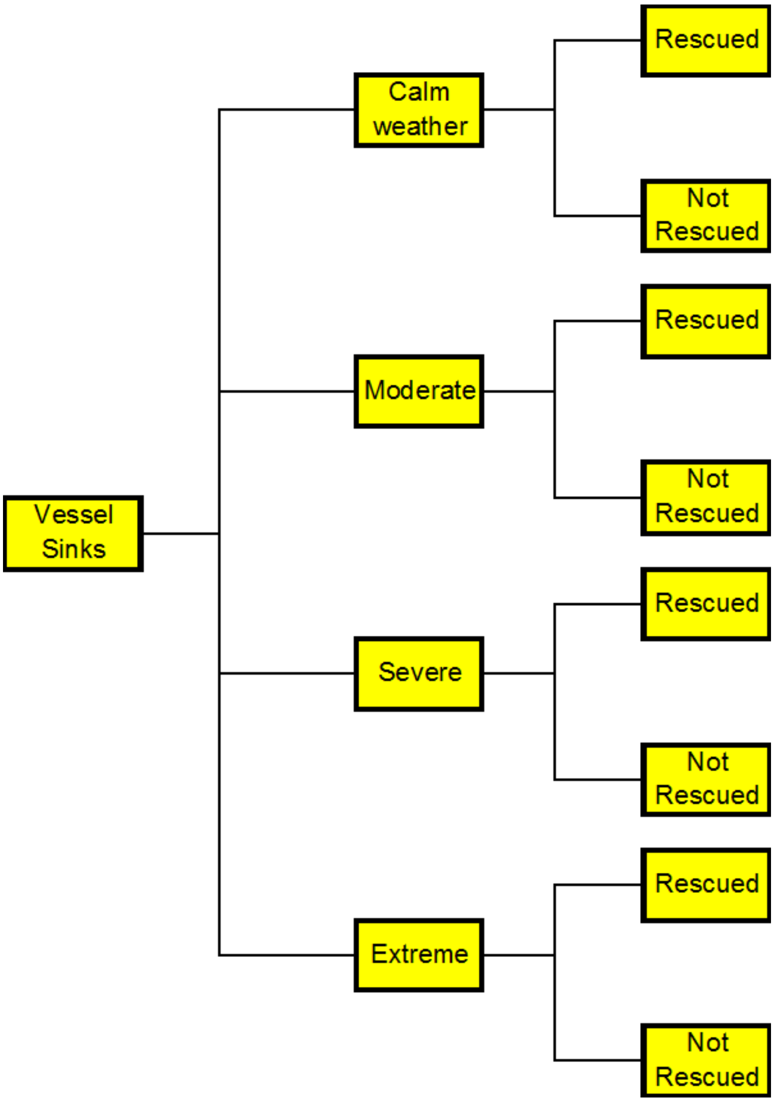
In the offshore industry a considerable amount of research has been carried out on the subject of evacuation, escape and rescue (EER) and it is now possible to carry out real time simulations to determine the probability of successful evacuations. However, a detailed EER analysis is not considered relevant here and an event tree has been developed for this purpose.

The main factor affecting EER success is the weather and previous work (reference A8) carried out on this subject estimated the success rate of various rescue systems based on weather criteria categorised as: Calm, Moderate, Severe and Extreme. This data has been combined with information from the Project Metocean Design Basis (reference 3.4) and presented in the following table:

Weather	**Wind Speed**	**Occurrence in the Baltic Sea (%)**	**Success Rate (Enclosed Lifeboat)**
Calm	0 – 16kts	68.461	0.99
Moderate	16 – 33kts	30.683	0.90
Severe	33 – 55 kts	0.854	0.40
Extreme	> 55 kts	0.002	0.05

Note: Weather data taken for KP 822

This data has been used in the following event tree to derive the probability of fatalities as a result of a vessel sinking.



The resulting probability is 0.043

In the event of a vessel sinking there is a relatively high probability of an oil spill and the Safetec study (reference 7.3) assumed a probability of 1.0. However, a review of the Helcom data on cargo vessel incidents in the Baltic Sea indicated the following occurrence of pollution after a vessel sinking.

Pollution	8 incidents
No pollution	4 incidents
Unknown	4 incidents

This appears to indicate that pollution does not always occur after a vessel sinks and assuming that pollution occurred in the 'unknown' incidents the historical probability of pollution is 0.75.

The spill sizes reported by Helcom range from 0.1m3 for a 15,396 ton vessel to 37.5m3 for a 350 ton vessel. However, there is insufficient data to estimate a correlation between spill size and vessel size. The spill size has therefore been estimated in accordance with the Safetec estimates based on vessel bunker capacity and it has been assumed that 30% to 50% of bunker oil could be spilled after a sinking/capsize incident.

A6 - VESSEL POSITION LOSS – ANCHORED VESSELS

It is evident that failure of the mooring systems on the anchored vessels would result in loss of position and could result in damage to the pipe and possible injury to personnel working in the firing line. If heavy weather is forecast the pipeline is laid down until the weather improves and loss of vessel position would not affect the pipeline. However, in the event that the forecast is incorrect there is a possibility that the weather could increase before the pipe could be laid down. In this situation one or more anchor wires could be overloaded and eventually fail resulting in loss of position.

Historical data on mooring line failure is mainly based on drilling rig operations where the vessel is generally required to ride out a storm and failure rates are higher than those experienced by pipe lay vessels.

Over the years mooring line failures have been investigated by a number of organisations to estimate failure rates and a number of recent papers indicate that mooring system reliability has improved. The most recent data is provided by the UK HSE report (reference 6.5) which has reviewed offshore incident data from 1980 to 2005. This review included most offshore incident databases as follows:

FOCUS	UK HSE (Field Operations Division).
ORION	UK HSE (Offshore Safety Division).
MAIB	UK Marine Accidents Investigation Bureau.
World Offshore Accident Databank	WOAD, DNV-GL Norway.

This report identifies the number and frequency of anchor system failures over the period of 1990 to 2005 and this data is indicated below:

Vessel Type	No of incidents	Frequency per rig year.
Drilling units	146	0.149
Production units	14	0.087

In a more specific paper presented by the Norwegian Petroleum Directorate (reference A9) mooring failures in the Norwegian sector of the North Sea were analysed and identified 8 cases where one line had failed and 2 cases where 2 or 3 lines failed. The paper then concluded that the corresponding mooring line failure rates were:

- Single line failure 4.4×10^{-3} year
- Two or more lines 1.3×10^{-3} year

A recent review of anchor line failures in Norway (reference A10) concludes that failure rates are similar to those list above:

- Single line failure 9.2×10^{-3} year
- Two or more lines 1.2×10^{-3} year

A failure rate of 1.3×10^{-3} year will be used for this study.

It has been assumed that the probability of an incorrect weather forecast coinciding with heavy weather is 0.2 although this is felt to be conservative. Loss of position is more likely to result in a buckled pipe than injury to personnel; however, there is a possibility that the pipe movement may result in injury/fatality. In this event the possibility of fatality is assumed to be 0.05 as there should be time to warn workers to stand clear of the pipe. The number of personnel working in the firing line is assumed to be 18 as there are up to 9 work stations on the pipe lay vessel with 2 workers per station. The potential number of fatalities has conservatively been assumed to be 10% of firing line workers rounded up to 2.

A7 - VESSEL POSITION LOSS - DP

Dynamic Positioning (DP) system failure during pipe lay or trenching operations, could result in fatality either through the uncontrolled movement of pipe through the firing line or the overloading of a plough tow wire. However, it should be noted that to date no fatalities of this type have been reported.

DP position loss is generally categorised as a drive off, drift off or a large excursion, these are summarised as follows:

Drive off- The vessel is driven off position by its own thrusters because the DP control system believes the vessel to be off position.

Drift off – The vessel drifts off position because of insufficient thruster capacity or because the DP control system believes vessel to be keeping position.

Large excursion – The vessel moves outside her normal footprint (usually +/- 3 metres) because of a disturbance to the DP control system.

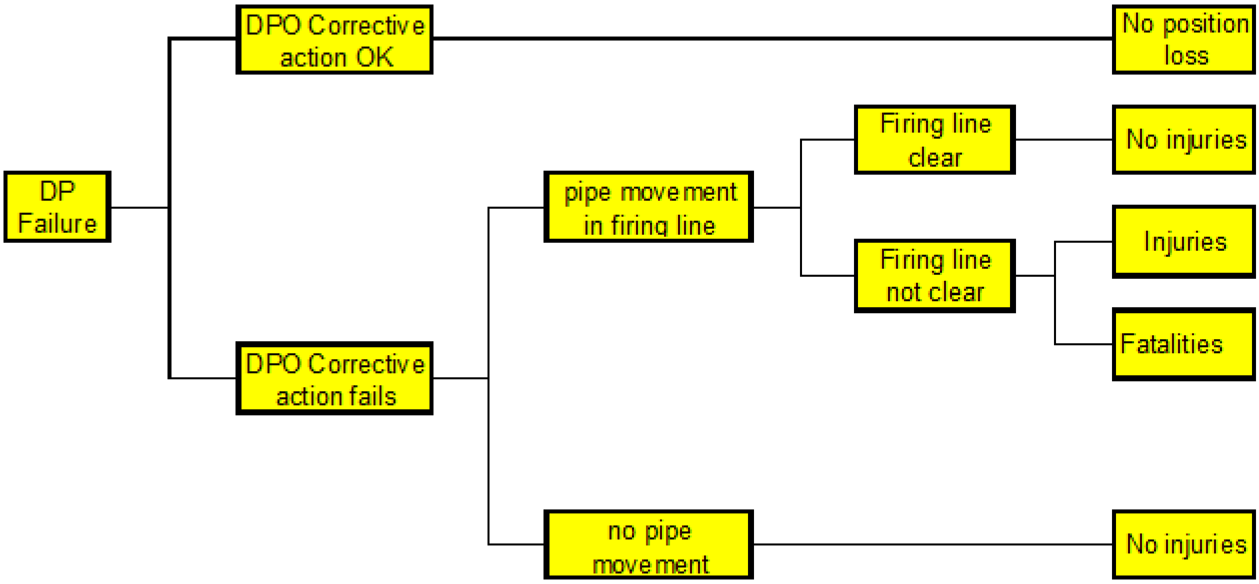
The frequency of DP failure was initially reported in IMCA report M115 (reference A11) in 1999 but has been updated over subsequent years and a recent analysis by GM (reference A12) indicates typical failure rates as follows:

Drive off	1.57×10^{-5} per hour
Drift off	3.25×10^{-5} per hour
Large excursion	1.97×10^{-5} per hour
Total	6.79×10^{-5} per hour

It is noted that these rates are still considered valid at the time of writing this report in 2016.

Since a drift off generally results in a relatively low vessel speed there is more time to warn firing line personnel and is not considered to present an immediate risk to them. The frequencies of drive off and large excursion have therefore been used in this assessment and results in a frequency of 3.54×10^{-5} per hour

Pipe lay Operations. The DP pipe lay vessels are scheduled to lay for a period of up to 244 days a year, and the probability of position loss and fatality is estimated in accordance with the event tree shown below:

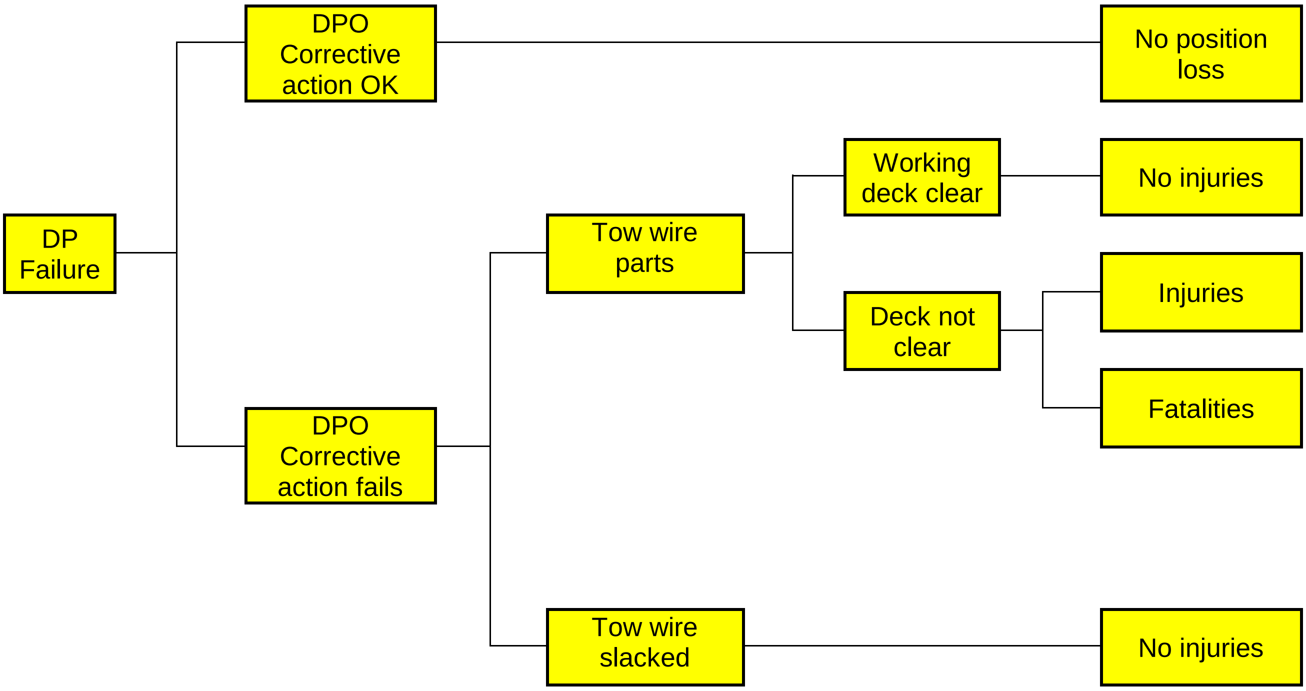


The steps in the event tree are explained as follows:

- In the event of DP failure the DP operator (DPO) may be able to take corrective action to prevent or avoid position loss and the possibility of this is assessed at 50%.
- Depending on the failure mode the pipe may or may not move in the firing line and again a 50% probability has been assumed for this possibility.
- If the pipe moves along the firing line there is the potential that personnel could be injured or worst if they were in close proximity to the pipe when it moved. In the event of DP problems audio-visual alarms along the firing line would be activated and most personnel should have moved clear of the pipe before it started moving. The probability of the line being clear is estimated to be 80%.
- If personnel were not clear of the line when it started moving there is a possibility of entrapment between the moving line and equipment such as rollers, tensioners etc. The probability of fatality as a result of this entrapment is assumed to be 10%.

The conditional probability of fatality is estimated to be 0.005.

The Fault tree for trenching operations is shown overleaf:



The probabilities are estimated as follows:

- DPO corrective action successful - 50%
- Tow wire not slacked in time and parts – 20%
- Working deck not cleared in time – 20%
- Probability of fatality – 10%

The resultant conditional probability is estimated to be 0.002.

A8 - DROPPED OBJECTS (PIPES)

During pipe lay in close proximity of existing lines there is a possibility that a dropped pipe joint could damage the existing lines. The separations defined in the design basis are as follows:

Separation between NSP1 and NSP2 lines

- Anchored lay vessel - 1000m (WD<30m), 1200m (30m<WD<100m) and 1400m (WD>100m)
- DP lay vessel – 500m

With a minimum separation of 500m it is considered that there is no possibility of a dropped pipe joint contacting the NSP1 lines.

Separation between the two NSP2 lines

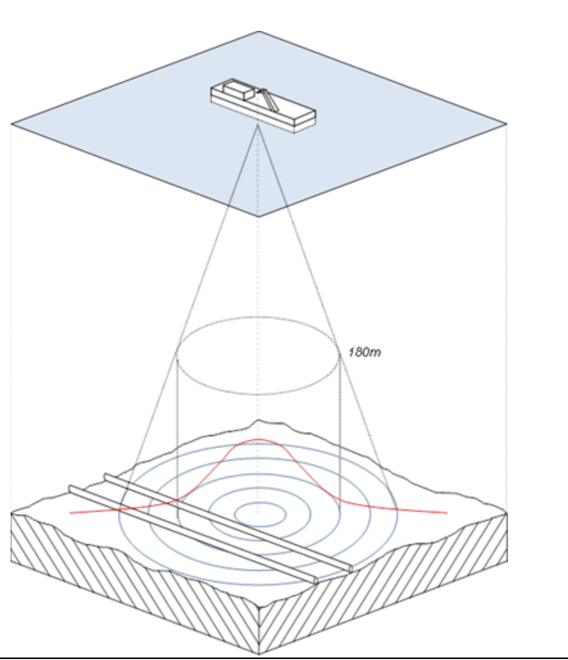
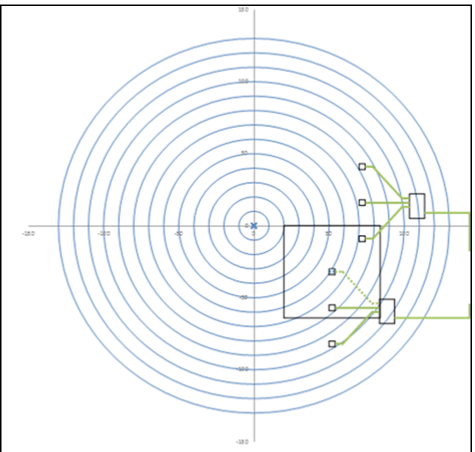
- Anchored lay vessel – 55m
- DP lay vessel – 75m (WD<100m), 105m (WD>100m)

With these separations there is a possibility of a dropped pipe joint contacting the adjacent line and these risks have been considered further.

The probability of a pipe falling overboard and hitting the operating pipeline has been estimated using the methodology described in DNV-GL Recommended Practice DNV-GL-

RP-F-107 Risk Assessment of Pipeline Protection (reference 6.11). The calculations have been carried out on an Excel spreadsheet and were first checked against the DNV-GL example given in the RP to confirm correct use of the various formulae. The methodology is summarised in the following paragraphs.

The probability of hitting a subsea line is based on the drop frequency of the object and the conditional probability that the pipe will hit the subsea line. A sketch of the arrangement is shown below:

	
Drop cone and landing distribution	Example drop radii and subsea layout at a well cluster

The probability of pipeline damage as a result of a dropped object is estimated from energy and pipeline strength calculations. In the absence of detailed information a distribution of impact energies is provided in the DNV-GL report and this has been used for this assessment.

The DNV-GL report includes an analysis of dropped object accident data issued by the UK Department of Energy and covers the period 1980 to 1986. The suggested frequency for the lift of a > 20 tonne object from a supply vessel to a platform is 1.6×10^{-5} per lift. Saipem data (reference 6.24) indicates that they have transferred 1,086,803 pipe joints since 1988 and have dropped two pipe joints in this period; one joint was dropped during transfer from deck storage to the bevelling rack and one joint was dropped into the sea. This indicates a frequency of pipe joints dropped into the sea of: 1/1,086,803 = 9.2×10^{-7} per lift. However, this is considerably lower than the frequency indicated in the DNV-GL report and the conservative value of 1.6×10^{-5} per lift has been used for this analysis. It is noted that there were no cases of dropped pipe joints on NSP1 and this value is considered to be conservative.

The current plan is that the maximum pipe lay vessels lay durations will be as follows:

- DP1 – 234 days (2018)
- DP2 – 261 days (2019)

- Anchored vessel – 88 days (2018)

This analysis is therefore based on 261 days operation per year and the number of pipe joints transferred to the lay vessel has been calculated as follows:

Lay rate	2.5 km per day
Lay duration	261 days per year
Number of joints transferred	55,235 per year
Number of joints transferred per side	27,617 per year (see note 1)

Note 1: The beam of the anchored pipe lay vessel is assumed to be 32.3 metres and the dropped pipe analysis has only considered pipes dropped from the side nearest to the pipe.

The excursion of dropped objects in the sea is dependent on the shape and weight of the object and this is discussed in the DNV-GL report. Long slender objects, e.g. pipes, may experience an oscillating behaviour; massive, box-like objects will tend to fall more or less vertically. The actual fall-pattern for a pipe is dependent on the entry angle into the sea and DNV-GL recommended that for a flat/long shaped object weighing over 8 tonnes an angular deviation of 5° is used for probability calculations.

The object excursions are assumed to be normally distributed and the DNV-GL method suggests dividing the seabed area into several rings. The probability of a 'hit' within two circles around the drop point P hit,r within inner radius ri and outer radius ro can be found by P hit,r = P(ri < x ≤ ro) = P(x ≤ ro) − P(x ≤ ri)

In this case the breadth of each ring has been taken as 10 metres and the hit probability within each of these rings has then been calculated for the deviation angle of 5° and a number of different water depths. The separation between the pipeline centres is 55, 75 and 105 metres.

Within a certain ring, the probability of hitting a pipeline with an object, P,hit,sl,r, can be described as the exposed area of the pipeline within a ring divided by the total area of the ring, multiplied by the probability of hit within the ring

$$P_{hit,sl,r} = \frac{P_{hit,r} \times L_{sl}\,(D + B/2 + B/2)}{A_r}$$

Where:

P,hit ,sl ,r = Probability of hitting subsea line (sl) within a certain ring, r

P,hit, r = Probability of hitting within the ring

Lsl = Length of subsea line within the ring (m)

D = Diameter of subsea line (m)

B = Breadth of falling object (pipe joint length for side impact and diameter for end on impacts)

Ar = Area within the ring (m^2)

DNV-GL indicate that the spreading of long/flat objects will increase down to 180m after which the spreading does not increase significantly. The effects of currents become more pronounced in deep water and may be included if there is a dominant current direction. However, due to the duration and varied locations of the pipe lay operation the effects of current have not been considered here.

The kinetic energy of the dropped object depends on the mass and velocity of the object and the velocity depends on the shape of the object. However, a pipe will constantly change direction when falling and the projected area will also change and an angle of 45° is recommended in the absence of more detailed analysis.

Pipe joint kinetic energy has been calculated in accordance with the following equation

E E =	$ET + EA = m + ma \cdot vT^2 \quad = ½ (m + ma)\ vT^2$
E E =	Effective impact energy
ET =	Terminal energy
EA =	Added mass energy
m =	Mass of the object (kg)
ma =	Added mass
g =	Gravitation acceleration (9.81 m/s2)
V =	Volume of the object (the volume of the displaced water) (m3)
ρwater =	Density of water (i.e. 1025 kg/m3)
CD =	Drag-coefficient of the object
A =	Projected area of the object in the flow direction (m2)
Vt =	Terminal velocity through the water (m/s)
Ca =	Added mass drag coefficient
ma =	$\rho w \cdot Ca \cdot V$.

and

$$vT^2 = \frac{(m - V \cdot \rho\ water) \cdot g \cdot}{½\ \rho\ water \cdot CD \cdot A}$$

The effective impact energy is calculated to be 438.99 k Joules. However, it has not been possible to determine the distribution of the energy bands and the values given in Table 12 of the DNV-GL paper have been used. These are based on a flat/long shaped object weighing more than 8 tonnes and are shown below:

Conditional Probabilities of Impact Energies					
Energy Band (kJ)					
<50	50 – 100	100 – 200	200 – 400	400 – 800	> 800
0%	0%	10%	15%	30%	45%

It is noted that this distribution is based on a pipe joint weight of 9 to 10 tonnes while the average weight of a NSP2 pipe joint is 25 tonnes.

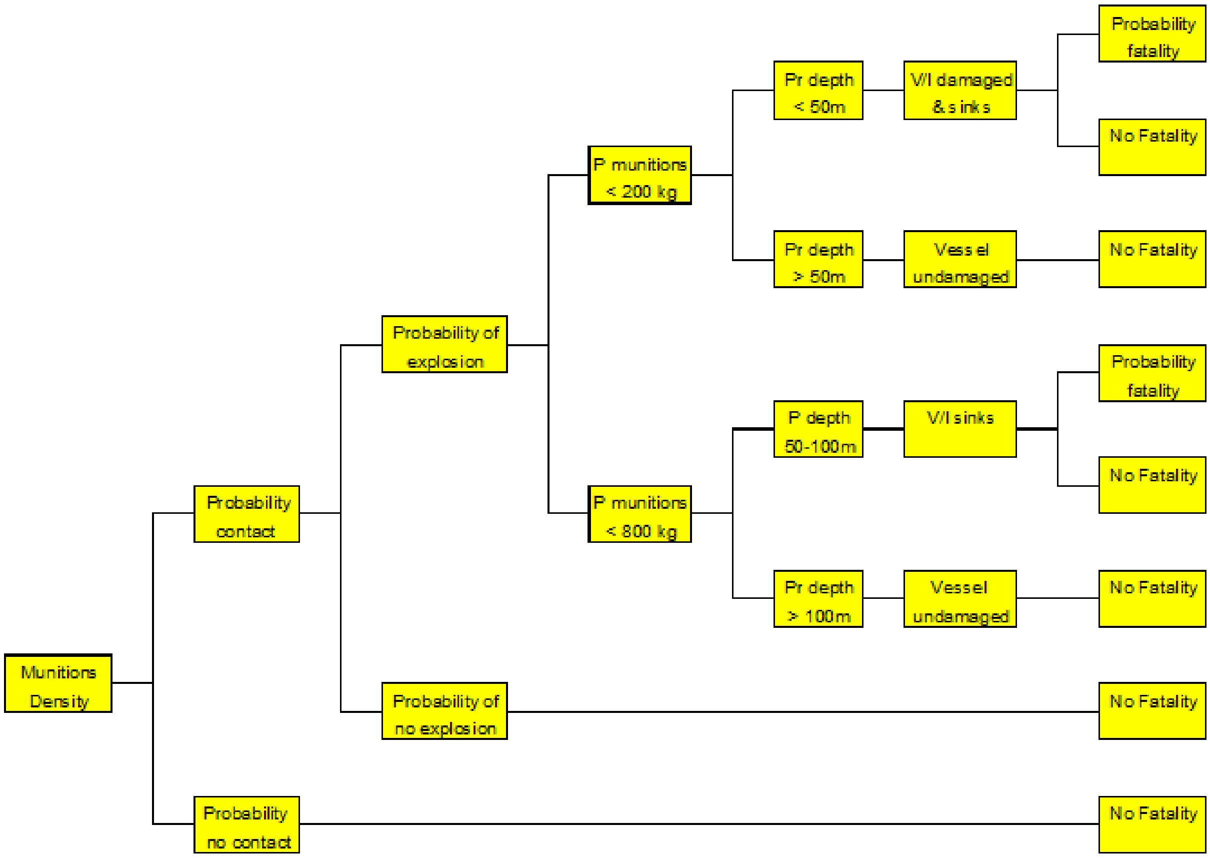
A9 - MUNTIONS RISKS

The results of the current route surveys were not available at the time this report was prepared so this assessment is based on NSP1 data. The munitions density is based on the results of the NSP1 pipe route survey and is estimated as follows:

Pipe corridor length 642,000 m

Corridor width	15 m
Area corridor	9,630,000 m^2
Total ordnance found on route	4
Munitions density	4.2 x 10^{-7} per m^2

This distribution has been used to estimate the probability of fatality on vessels following the explosion of munitions and is based on the following fault tree although the input values differ for each case.



The following values have been used as input values in the fault tree calculation.

Anchor Handling

Probability of anchor contact with munitions:

The results of the anchor corridor survey will be used to develop the anchor patterns and ensure anchors are not landed near known munitions positions. It is therefore considered that the probability of anchor contact is low and the project team estimate the probability as 0.05.

Probability of munitions explosion:

There is some uncertainty regarding the probability that anchor contact with munitions would result in explosion. Munitions volatility depends very much on the condition of the outer coating and the degree of water ingress and it is difficult to assess this with any degree of accuracy. The worst case situation has therefore been assumed with a probability of 1.0.

Probability that munitions size is < 200 kg:

The munitions survey to date has found a whole range of charges from 30 kg, 40kg, 75kg, 100kg, 115 kg and 150 kg with a few larger charges of 250 to 300 kg in weight. Although previous literature indicated that larger charges may have been dumped in the Baltic Sea the survey has not identified any charge larger than 320 kg. For the purposes of this assessment an average weight of 200 kgs has been assumed with a probability that 99% of munitions are 200 kgs or less.

Percentage Water Depth < 50m:

The safe stand-off distance for charges of 200kg or less is 50m and this occurs over 20.7% of the route. With reference to table 2.5.34 it is conservatively assumed that a vessel located within this range would suffer major damage, water ingress and possibly sink.

Percentage Water Depth between 50 and 100m:

The safe stand-off distance for charges of 800kg or less is 100m and this occurs over 50.8% of the route.

Probability of fatality following sinking

In the event that a vessel was severely damaged and sank the probability of fatality is estimated to be 0.043 as derived in section A5 in this report.

<u>Rock Placement</u>

The following values have been used as input values in the fault tree calculation:

Probability of placed rock contact with munitions:

The rock placement locations have been surveyed as part of the route survey and additionally the seabed is surveyed by ROV prior to each rock placement operation. It is therefore considered that the probability of rock placement contact is very low and is estimated to be 0.01.

Probability of munitions explosion:

There is some uncertainty regarding the probability that rock placement contact with munitions would result in explosion. As mentioned above it is difficult to assess munitions volatility with any degree of accuracy. However, the maximum size of gravel used in the rock placement is 50 mm in diameter and it is considered unlikely that this could initiate an explosion and a probability of 0.9 has been assumed.

Probability that munitions size is < 200 kg:

As discussed previously it has been assumed that the probability that munition charges are 200 kgs or less is 99%.

Percentage Water Depth < 50m:

The safe stand-off distance for charges of 200kg or less is 50m and this occurs over 5.1% of the route in Finland and Sweden. It is conservatively assumed that a vessel located within this range would suffer major damage, water ingress and possibly sink.

Percentage Water Depth between 50 and100m:

The safe stand-off distance for charges of 800kg or less is 100m and this occurs over 75.7% of the route.

Probability of fatality following sinking

In the event that a vessel was severely damaged and sank the probability of fatality is assumed to be 0.043 as derived in section A5 in this report.

<u>Landfall Operations</u>

Probability of anchor contact with munitions:

The pipeline route and landfall area survey identified no munitions and it appears that there is a very low probability that munitions will be encountered during dredging operations. The project team estimate the probability as 0.01.

Probability of munitions explosion:

As previously mentioned there is some uncertainty regarding the probability that dredger contact with munitions would result in explosion. The worst case situation has therefore been assumed with a probability of 1.0.

Probability that munitions size is < 200 kg:

As mentioned previously the average weight of 200 kgs has been assumed with a probability of 99% that munitions are 200 kgs or less.

Percentage Water Depth < 50m:

It has been assumed that all operations are carried out in water depths of less than 50m. It is conservatively assumed that a vessel located within this range would suffer major damage, water ingress and possibly sink.

Percentage Water Depth between 50 and 100m:

As above it is assumed that all operations are carried out in water depths of less than 50m.

Probability of fatality following sinking

In the event that a vessel was severely damaged and sank the probability of fatality is assumed to be 0.043 as derived in section A5 in this report.