Nord Stream
The new gas supply route for Europe

Nord Stream Environmental Impact Assessment Documentation for Consultation under the Espoo Convention

Nord Stream Espoo Report: Key Issue Paper Maritime Safety

February 2009

English version | Key Issue Paper Maritime Safety

ENG

Please note:

The “Nord Stream environmental impact assessment documentation for consultation under the Espoo Convention” will, hereinafter and throughout the entire documentation as submitted hereunder, be referred to as the “Nord Stream Espoo Report” or the “Espoo Report”.

The English version of the Nord Stream Espoo Report has been translated into 9 relevant languages (hereinafter referred to as the "Translations") . In the event that any of the Translations and the English version conflict, the English version shall prevail.

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1 Introduction

One of Nord Stream's main objectives is to design, build and operate its pipelines safely.

Nord Stream recognises that the construction and operation of the Nord Stream pipelines give rise to many hazards which present risks to members of the public, Nord Stream Project workers, equipment and the environment. These risks and their impacts will vary over the life cycle of the Project. Some risks remain constant while others arise and diminish; the risks and any changes in the risks will be monitored and acted upon by Nord Stream throughout the life of the pipeline.

Nord Stream has been committed to undertaking thorough assessments of the risks associated with all project activities. The process consists of several steps. Firstly the potential hazards associated with constructing and operating the pipelines are identified; secondly, the level of risk is assessed and compared to the risk acceptability criteria/standards set for the Project. Thirdly, potential risk mitigation measures are identified and adopted where necessary to ensure that risks will be avoided or reduced to levels which are as low as reasonably practicable. In accordance with the Espoo regulations only the risks to third parties are discussed in the following sections. "Third party" is defined as someone other than the principal parties, that are Nord Stream AG and its contractors. Since Nord Stream pipeline is an offshore pipeline, the risk to members of the public is mainly from potential impacts on the crew and passengers on passing ships.

1.1 Hazard identification

Hazard identification is a comprehensive process of compiling an inventory of the project activities that could harm people and/or the environment. Knowledge and understanding of the project's activities, public activities and the natural environment are necessary to ensure a high quality hazard identification process. Therefore Nord Stream works with highly experienced professionals including vessel captains, offshore and engineering specialists for design, construction and operation to ensure that all relevant hazards are identified. These hazards are summarized in the HAZID-report and cover categories such as hydrocarbons release, explosives, third party equipment, objects under induced stress, dynamic situation hazards (e.g. fishing activities and ship traffic), natural and environmental hazards, corrosion, installation, construction and interactions of the installation with the surroundings.

1.2 Risk Assessment

A risk assessment is a careful examination of the identified hazards, consideration of the likelihood of the harm being realised and the severity of the impacts, thereby allowing an estimation of the risks. Risk assessments are conducted for all capital projects in the oil and gas sector and similar industries, for example civil engineering schemes including motorway or dam construction.

All identified hazards are screened using a qualitative risk assessment methodology. Those that pose potentially significant risks are then subjected to detailed risk assessment, and the results are compared with the Project's risk acceptability criteria. The risk assessments have been undertaken in accordance with the relevant Det Norske Veritas (DNV) codes, standards and recommended practices. DNV is a respected, independent Norway-based consultancy which is the independent certifying body of Nord Stream Project.

The results of the risk assessments are used to determine whether adequate precautions have been taken - or whether more should be done to prevent harm. In essence, the risk assessments are used to help identify the measures needed to ensure that risks from the hazards are adequately controlled/managed or completely eliminated.

If the risk arising from a hazard is considered unacceptable, the risk is removed or reduced irrespective of cost. For hazards presenting lower risk levels, the costs and benefits of alternative risk mitigation are evaluated to identify the most cost effective risk reducing measures. Where the levels of risks are broadly acceptable (i.e. hazards that have low impact and/or are very unlikely to occur) no further risk mitigation is considered.

1.3 Risk Management System & Risk Mitigation

Nord Stream has implemented a risk management system to monitor and control risks efficiently, including the implementation of mitigation measures. Internally the "risk owners" for their respective area of responsibility have been identified; the risk owners are responsible for proactively monitoring risks and ensuring their effective management. Mitigation measures are considered during all project phases.

Reporting is undertaken via the Risk Register. Risk reports are run from the database for review by Nord Stream's risk management committee, a cross-functional team, and for reporting to management by the risk manager.

Strategies for risk mitigation are developed and there is an ongoing process (overseen by the risk management committee) of monitoring, appraisal and reassessment by risk assessors. All risks are managed to levels which are "as low as reasonably practicable" (the ALARP principle).

Implementation of an integrated HSE Management System (HSE MS) will ensure that the HSE policy and objectives are achieved. The HSE MS applies to all phases of the Project. The structure of the HSE MS is based on the Plan-Do-Check-Act cycle which enables Nord Stream to identify the HSE risks in the Project and systematically control those risks in order to achieve the requirements of the HSE policy. The overall structure of the HSE MS is aligned to the international standards OHSAS 18001:1999 (Occupational safety and health management system: specification) and ISO 14001:2004 (Environmental management systems: requirements with guidance for use).

Nord Stream operates a quality management plan (QMP) which is aligned to ISO 10005:2005. Internal processes are defined as the organizational activities which support the design, construction and eventual operation of the pipeline. A quality assurance and project certification philosophy has been defined and adopted for the planning, design and construction phases. The purpose is to assure that the Nord Stream pipeline system is designed, fabricated, installed and commissioned in line with the highest quality standards in the offshore pipeline industry. In relation to design and construction services, the QA/QC system works on three levels:

- Nord Stream requires that all contractors, manufacturers and vendors operate a certified and fully functional quality management system

- An independent third-party expert organisation has been assigned by Nord Stream to witness, audit and supervise all aspects of the Project

- All critical vendor and contractor activities will be supervised by Nord Stream’s own experts or by personnel and inspectors who have been appointed by Nord Stream to monitor and verify that the high standards agreed to in the contracts are achieved

These three independent levels of quality assurance will ensure that the Nord Stream pipelines are designed and built to the highest quality and safety standards.

Nord Stream works with highly experienced partners, e.g. marine, offshore and engineering consultants to ensure high safety standards during design, construction and operation. All efforts are made to guarantee that risks are firstly understood and secondly, effectively managed and controlled.

Nord Stream and its partners continually train staff and contractors in health, safety, and environmental protection measures and standards aiming to minimise the influence of human errors on pipeline safety and reliability.

All Nord Stream contractors are qualified providers and have substantial international project experience. Installation and operational methods follow standard industry procedures. For example:

- Saipem has been contracted to lay the pipe. The company laid its first offshore oil and gas pipeline in 1982. The company recently successfully completed the Dolphin Project (48" gas pipeline across the Persian Gulf from Qatar to the United Arab Emirates) and installed the deepest offshore pipeline in the Black Sea (Blue Stream Project)

- Nord Stream runs the same offshore distance (1,200km) as the successful Langeled pipeline (connecting Norway to the UK). Nord Stream technology has been thoroughly proven in numerous offshore pipelines operating successfully

Highest safety standards are a primary design objective for Nord Stream. Therefore, in accordance with the relevant DNV standards, risks to pipeline integrity caused by hazards such as earthquake, storm, coastal erosion, ice, waves and currents, trawling activities, ship traffic and corrosion have been considered in the pipeline design.

For example:

- Nord Stream will use virtually impenetrable steel pipes of up to 41 millimetres thick, with an external concrete coating of up to 110 millimetres

- To prevent corrosion an anticorrosion-coating is applied to the pipeline. Sacrificial anodes are also attached to the pipeline

- During winter time, temperatures in the Gulf of Finland result in ice forming at the Russian shoreline. Therefore Nord Stream pipeline will be buried below the maximum depth of ice gouge in this area

Risks during construction will be mainly mitigated firstly by avoidance and then by safety procedures. Details of the construction phase are discussed further in **Section 2**. Examples of risk mitigation measures include:

- To reduce the risk of collision between the lay barges and passing vessels an exclusion zone will be established around the construction area

- Maximum ice cover occurs in late February/early March. Ice is particularly prevalent in the Gulf of Finland. Therefore no construction is planned in these areas during this time of the year

Potential impacts on third parties and the environment during pipeline operation arise in the event of pipeline failure. These risks have been evaluated and where necessary mitigation measures have been implemented. Risk mitigation examples include:

- Corrosion protection has been considered in the design

- Quality control has been established to minimize the risk of material defects during manufacturing and construction

- Regular internal and external inspection of the pipeline to ensure integrity

- Continuous monitoring of operation parameters

A detailed description of methodology and results of the risk assessment regarding the construction and the operations phase are described in **chapter 5** “Risk Assessment” of the Espoo Report. In the following section some of the main risk issues highlighted in this chapter are summarized.

2 Maritime Safety Hazards

The Nord Stream Project involves the construction of two parallel pipelines that run for 1,220 km on the seabed of the Baltic Sea. The pipeline is created by welding together sections of pipe aboard a special pipe-lay vessel that places the line on the seabed as it is assembled. The activities involved in laying a pipeline are shown in **Figure 2.1**.

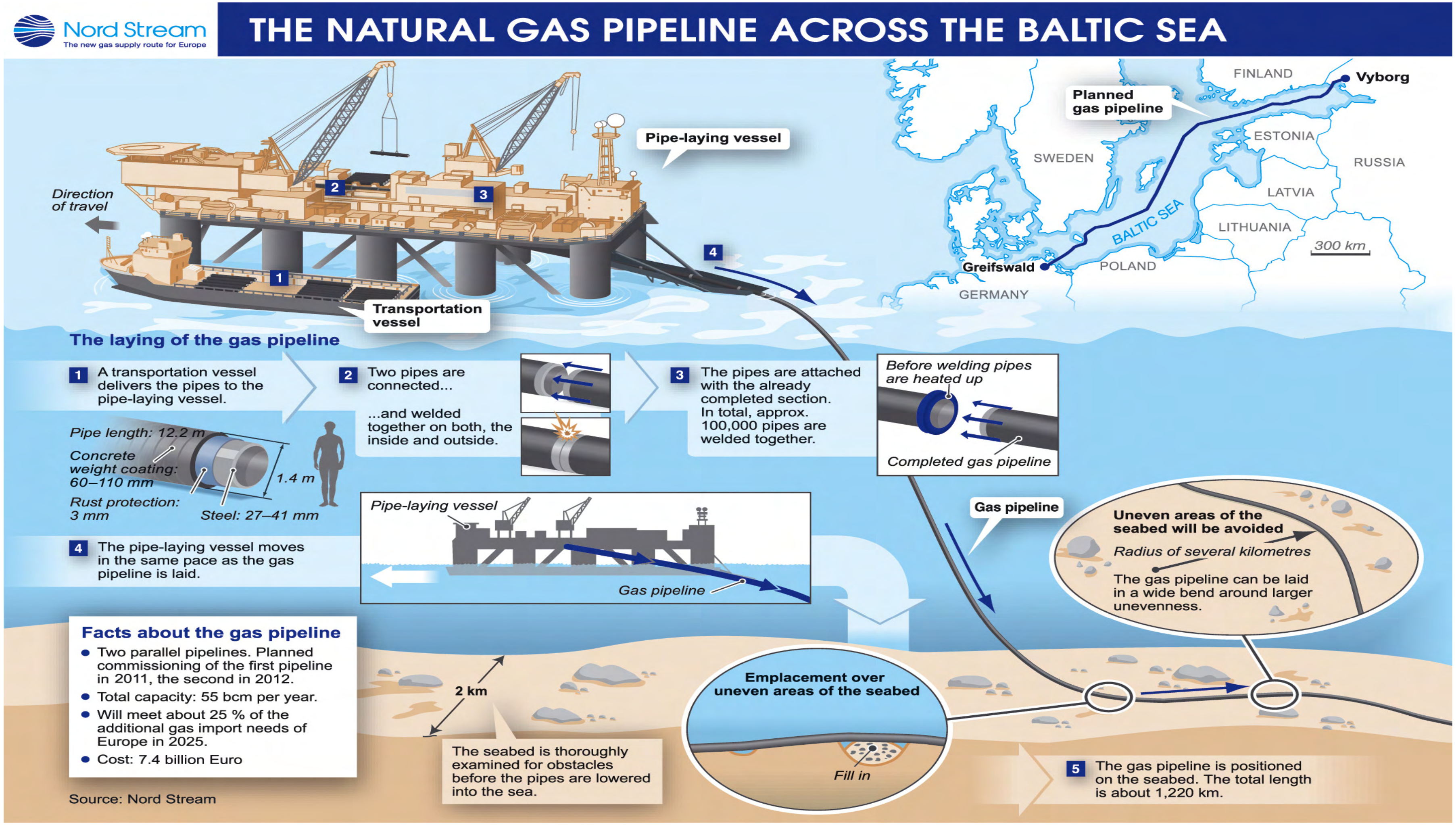


Figure 2.1 Laying the pipeline

An example of a pipe-lay barge is shown in **Figure 2.2**. Typical examples of the support vessels are shown below in **Figure 2.3** and **Figure 2.4**.

Figure 2.2 Castoro 6 pipe-lay barge

Figure 2.3 Anchor handling tug

Figure 2.4 A typical pipe carrier

As a result of the construction activities, and operation of the pipelines, there are a number of maritime related hazards for which the associated risks need to be examined. In summary these are:

- Ship collisions between the construction vessels and other vessels using the Baltic Sea
- Construction activities leading to the unearthing of unexploded munitions or chemical warfare agents (CWA)
- Fishing vessel equipment becoming snagged on the pipelines, leading to damage to trawling equipment, and in extreme cases of incorrect handling, to loss of a fishing vessel
- Failure of the pipeline (from a number of potential causes) leading to a gas release, which may be ignited and impact vessels using the Baltic Sea

The consideration of each of these maritime related hazards is described further in the following sections.

3 Assessment of Maritime Risks

3.1 Ship collisions

All commercial and military vessels travelling in the territorial waters of Russia, Denmark and Germany or in the EEZ of Russia, Finland, Sweden, Denmark and Germany (through which pipeline construction is planned) will be advised about the activity by their national coastguard authorities in consultation with Nord Stream.

Construction vessels that are free to manoeuvre, such as pipe carriers and supply vessels, present no more risk than other vessels active in the area. All 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. Construction vessels make a negligible contribution to the total number of vessels, as at any one time there are around 2,000 vessels in transit in the Baltic Sea.

The launch of the HELCOM Automatic Identification System in 2005, traffic separation schemes and ship reporting systems introduced in the Baltic, e.g. Gulf of Finland Reporting System, have had a positive effect on the safety of navigation and might have contributed to the reduced number of collisions over the recent years, especially in the Gulf of Finland.

Figure 2.2 presented previously showed a typical pipe-lay barge. When operating and in position neither the pipe-lay barge nor anchor handling vessels, are able to manoeuvre freely. During construction activities a safety (exclusion) zone will be implemented around the construction vessels (as shown in **Figure 3.1**) in addition to the normal navigational measures used by merchant shipping.

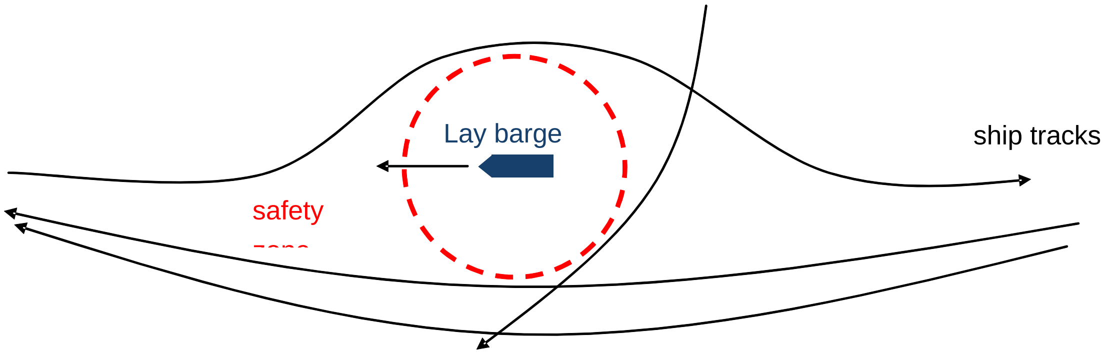


Figure 3.1 The exclusion zone enforced around the pipe-lay barge

Furthermore, it is standard procedure to issue Notice to Mariners warnings well in advance of construction activities and these are backed up by regular Navtex (telex) warnings and verbal warnings broadcast on marine VHF radios. VHF radios are used for a wide variety of purposes, including summoning rescue services and communicating with harbours and marinas, and operate in the VHF frequency range. Experienced native speakers will be employed on the lay vessels in order to allow communication with local vessels.

In addition, a visual and radar watch is kept at all times. The construction vessels are fitted with ARPA (Automatic Radar Plotting Aid) radar systems that automatically plot the course of passing vessels, raising an alarm if a potential collision situation exists. The AIS (Automatic Identification System) also assists the identification of passing vessels and provides information on position, course and speed. These aids are particularly effective in poor visibility.

Nonetheless, Nord Stream has assessed the risks posed the members of the public (i.e. crews and passengers) on passing vessels arising from potential ship collisions and has shown that the risks are extremely low.

Military exercises are carried out in the Baltic by NATO and a number of the Baltic States, including practice areas for bombing, mine-laying practice or submarine exercises. A specific project study has identified the areas along the pipeline route where military exercises are undertaken. Nord Stream has established contact with the relevant national defence/naval authorities to inform them about the construction activities and subsequent operations. The intention is to agree that the length of pipelines that may be crossed by military vessels will be minimised, and more generally to agree on arrangements to ensure any potential for military activities to impact the pipeline are minimised. The pipeline will be marked on the relevant nautical charts to ensure shipping in the vicinity of the pipeline is aware of its precise location.

Collisions with military vessels have not been specifically addressed in the quantitative risk assessment as the required data on these vessels is not readily available because they are not required to carry AIS (Automatic Identification System). However, military vessel traffic is relatively small compared to the amount of commercial traffic and hence the addition of military vessels would not be expected to increase the ship pipeline interaction frequencies significantly. In addition military vessels generally have a higher level of manning and better developed watch-keeping than commercial vessels and are therefore less likely to be involved in collisions.

3.2 Unexploded munitions or chemical warfare agents

In 1947, after the end of World War II, chemical warfare agents (CWA) were dumped on the seabed, primarily in the Gotland dump site and Bornholm basin site. The concern in relation to these chemical warfare agents is the potential for them to be disturbed during construction and the agent impacting people or the marine environment. Similar concerns exist in relation to unexploded World War II munitions.

Munitions screening surveys have been performed to establish the locations of potentially unexploded munitions and or CWA that could constitute a danger for the pipeline or the environment during the installation works and the operational life of the pipeline system.

The survey involved:

- Identifying and mapping targets that may represent potential munitions and may have the potential to influence pipeline design, installation and long term integrity
- Performing a visual inspection and classification of targets to identify potential munitions
- Integrating anomalies and objects/targets identified from previous investigations and correlating with public domain data.
- Soil sampling in the vicinity of the chemical munitions dump site

On the basis of such surveys, the pipeline has been routed to avoid munitions wherever possible and alternatively, to remove them. The ‘security corridor’ dimensions (25 m on either side of the route) are based on detailed analysis of the effects of underwater explosions which address the propagation of the shock wave, the pipeline loading and the pipeline response (in terms of local and global deformation modes, strain of the pipe steel and the elasto-plastic behaviour of the concrete coating). The analysis is based on a theoretical 2000 kg charge (the largest actual unexploded ordnance ever found in the Baltic Sea is 935 kg charge weight and most are less than 300 kg) and shows that such an explosion within 12 m of the pipeline would not result in a gas release. Saipem is contracted to lay the pipeline to a tolerance of +/- 7.5 m and hence this will ensure that any exploding munitions on the edge of the corridor could not damage the pipeline.

There is also a remote possibility that munitions could be disturbed during installation operations and drift onto the pipe after installation. However near-bottom currents at the dump sites are reported to be too weak to move heavy munitions and this risk is considered to be low.

Chemical warfare agents have been the subject of two specific studies by the National Environmental Research Institute (NERI) of Denmark, which included interviews with interested stakeholder groups on Bornholm (e.g. the fishermen’s association, Natural Conservation Society and deep-sea divers).

Whilst dumping killed fish stock in 1947 and fishermen have caught CWA since that time, there have been no reports of acute occupational accidents for at least the past decade in the Danish media. Much of the CWA material will have decayed to a harmless state since 1947; there are currently plenty of fish at the dump sites and the studies showed that there are generally limited environmental concerns.

In addition there has been comprehensive soil sampling and analysis of the sediment in the area of the pipeline route in the vicinity of the dump sites. The laboratory results have not revealed any point sources of contaminants in the pipeline route. The results appear to give an indication of a diffuse low level background contamination given the history of the area. The detected concentrations are very low and below levels which affect the marine environment. The maximum concentration levels give no evidence of any existing conflict with the pipe-laying route (which has specifically avoided known wrecks which may contain munitions and CWA).

3.3 Trawling & risk to fishing vessels and pipeline

Nord Stream has ongoing dialogue with Baltic Sea fishing organisations and authorities to discuss and agree action required to coordinate fishing and construction activities.

To address issues related to fishing activities across all countries involved, a Fishing Working Group (FWG) was established within Nord Stream to organise and co-ordinate all fishing related activities. The FWG also defines and implements a common policy within the national task forces of the countries of origin and other affected countries. The policy will be based on studies, tests and risk assessments undertaken by FOGA, SINTEF, Rambøll and DNV.

Experience with numerous offshore pipelines in the North Sea show that fishery and offshore pipelines can co-exist safely. However, the situation in the Baltic Sea is potentially different, in terms of trawling gear types, size of vessels/engines and seabed conditions. Therefore, trawl gear pipeline interaction during the operations phase need to be assessed carefully.

During construction, fishing activity must be temporarily suspended within a safety zone around the pipe-lay barge and support vessels. It is also standard practice to carry a fisheries representative on one of the construction vessels to harmonise activities when required and to provide information to the fishermen both before the start and during of the operation.

During normal pipeline operation trawling will be carried out in areas around the pipelines. In the areas where the pipeline is buried in a trench, or rock placement has been undertaken to cover the pipeline, trawling can be carried out without risk of trawling gear interfering with the pipeline. However, if the pipe is unburied, the trawl board or clump weight could potentially interfere with the pipeline when trawling at the bottom of the sea.

In most cases it will be pulled over, but there is a potential for the trawl equipment to become snagged on the pipeline, especially where there are free spans or where the approach angle to the pipeline is small. This may lead to damage to the trawling equipment or high forces being exerted on the trawl wire which could result in the wire breaking and subsequent loss of the gear. The type of sediment also influences the likelihood of snagging as it affects the extent to which the pipeline settles into the seabed, and the extent to which a trawl board may cut into the seabed if dragged along the pipe.

Snagging may lead in extreme cases of incorrect handling to loss of a fishing vessel and its crew, as occurred in UK waters in 1997. However, the final capsize of the vessel occurred during the recovery of the snagged gear and not as a result of the actual snagging. This emphasises the importance of providing information and training to the fishermen about what to do and not to do in case of snagging or hooking of the trawling gear.

Nord Stream has examined and still is examining these issues in some considerable detail. This has included:

- The identification of fishing techniques, fishing vessels and gear used in the Baltic Sea (FOGA)
- A pipeline trawl gear interaction study (Snamprogetti) focussing on pipeline integrity. This considered the following pipeline trawl gear interaction phases:
    - Impact, including impact energy evaluation (assessment of bare steel pipe worthiness to withstand impact forces and, separately, concrete capacity to dissipate trawl gear kinetic energy)
    - Pull-over, including interaction force calculations and analysis of pipe response during and after trawl gear interference. Interaction loads from the largest expected trawl equipment are considered for the pipe response analysis
    - Hooking/snagging, including the analysis of pipe response after lift off from the seabed
- An assessment of the risk of trawling gear damage (Rambøll). This took into account trawling time per haul, the trawl speed and the number of trawls per day in order to estimate the number of trawls crossing the pipeline and the associated risks
- An overtrawlability scale model test with up to 2 metre free spans performed by SINTEF in Hirtshals, Denmark, during the period 16-19 December 2008. Fishing organizations from GER, DK, FIN, SWE, POL, NL and representatives of BS-RAC, FOGA and DNV participated

The initial analysis of trawling gear damage estimated the frequency of damage due to pipeline snagging to be low, and the frequency of loss of a fishing vessel as extremely low in case of incorrect handling. Nonetheless, given the importance of this issue, and the assumptions based on engineering judgment which are a necessary part of such an analysis, Nord Stream has initiated further studies and sensitivity analyses to ensure the robustness of this conclusion.

The analysis of trawling has shown the pipeline can withstand trawl gear interaction in terms of initial impact and being pulled over the pipeline where the pipeline rests on the seabed. The greatest forces would be exerted on the pipeline if trawl gear becomes snagged (hooked) under the pipeline. The trawl gear would fail before any damage would be caused to the pipeline.

Nonetheless, given the small residual risk, Nord Stream will ensure the number of free spans is reduced to a minimum; that training and information on the risks of fishing near the pipelines is provided to fishermen; and that the pipeline is plotted on nautical charts. Nord Stream is also considering mitigation measures as well as restrictions in certain areas where the pipeline might pose a risk to fishing vessels and their crew. This is being discussed at a national level.

3.4 Failure of the pipeline

The Nord Stream pipelines will be designed and operated according to the code DNV OS-F101, Submarine Pipeline Systems, issued by Det Norske Veritas (DNV), Norway. This provides criteria and guidance on design, materials, fabrication, manufacturing, installation, pre-commissioning, commissioning, operation and maintenance of pipeline systems.

The DNV code and guideline structure is widely used due to the code’s comprehensiveness and in-depth coverage of a very broad range of topics. The use of DNV design codes has been an established practice for offshore design houses for the last several decades. The DNV code for submarine pipelines is currently used for all marine pipeline designs in the Danish and Norwegian North Sea oil and gas developments and also is being used extensively on a global basis.

The Nord Stream pipelines are made of high grade carbon steel and have a nominal diameter of 48” and a constant internal diameter of 1,153 mm. The pipelines will be constructed of line pipes with a length of 12.2 m that are welded together. The pipeline wall thickness varies between 26.8 mm and 41.0 mm, which together with the three-layer polyethylene anti-corrosion coating (4 mm) and concrete coating (60 to 110 mm thick), means the pipelines are extremely robust.

A diagrammatic representation of the pipeline, anticorrosion coatings and concrete coating is shown in **Figure 3.2**.

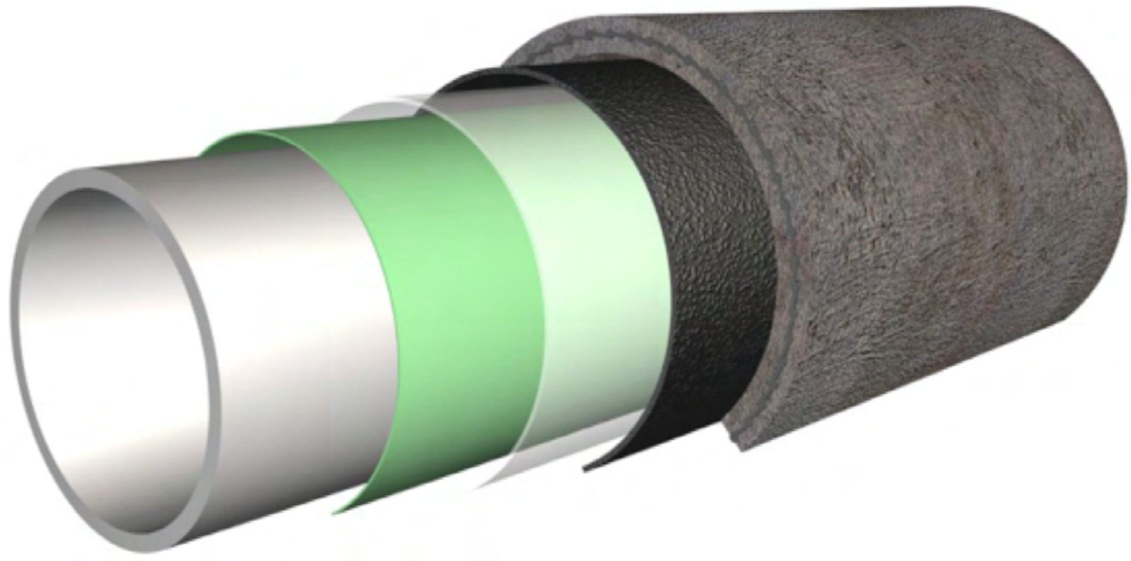


Figure 3.2 Concrete coating on top of the three-layer anticorrosion coating

Onboard the pipe-lay barge the welding of new single pipes onto the continuous pipe string will be performed as either a semi- or fully-automated welding process. An example of field-joint welding and testing is shown in **Figure 3.3**. This also shows the size of the pipelines.

Figure 3.3 Welding (left) and automatic ultrasonic testing (right) of a field joint

For the pipeline operation, the following potential causes of pipeline failure have been considered:

- Corrosion (internal and external)

- Material and mechanical defects
- Natural hazards, e.g. current and wave action, storm
- Other/unknown, e.g. sabotage, accidental transported mines
- External interference, e.g. fishing, navy and commercial ship traffic, etc.

These were derived based on a hazard identification exercise and a literature review of gas pipeline incidents. Identification of the potential causes of incidents is important as this can affect how an event may develop. For example, pipeline damage caused by a sinking ship is generally likely to result in a greater damage (e.g. gas release) than a dropped anchor, due to the far greater mass of a ship.

Each of these potential causes of failure is further discussed below.

Corrosion

Internal and external corrosion failures are considered to be a negligible contributor to the overall failure rate for the following reasons:

- The gas is dry (and thus the potential for internal corrosion is reduced)
- External corrosion protection, comprising a primary system (high quality anticorrosion and concrete coatings) and secondary system (cathodic protection by sacrificial anodes)
- High class steel has been selected to prevent H_2S- induced corrosion
- Large pipe wall thickness (which reduces the likelihood of corrosion causing a failure before it is detected)
- Use of intelligent pigging for planned periodic inspection (allowing the identification of any potential corrosion before it becomes critical)

Material & mechanical defects

This category comprises both material defects in the steel pipe (plate manufacturing defects or defects in the longitudinal pipe weld) and construction faults (typically critical defects in the girth welds). Historical experience shows such events to be extremely rare causes of pipeline failures, particularly for modern pipelines where advanced pipe technology and quality control, as well as welding technology and control procedures are applied. Therefore, the frequency of release due to mechanical defect is considered negligible as the following measures have been adopted:

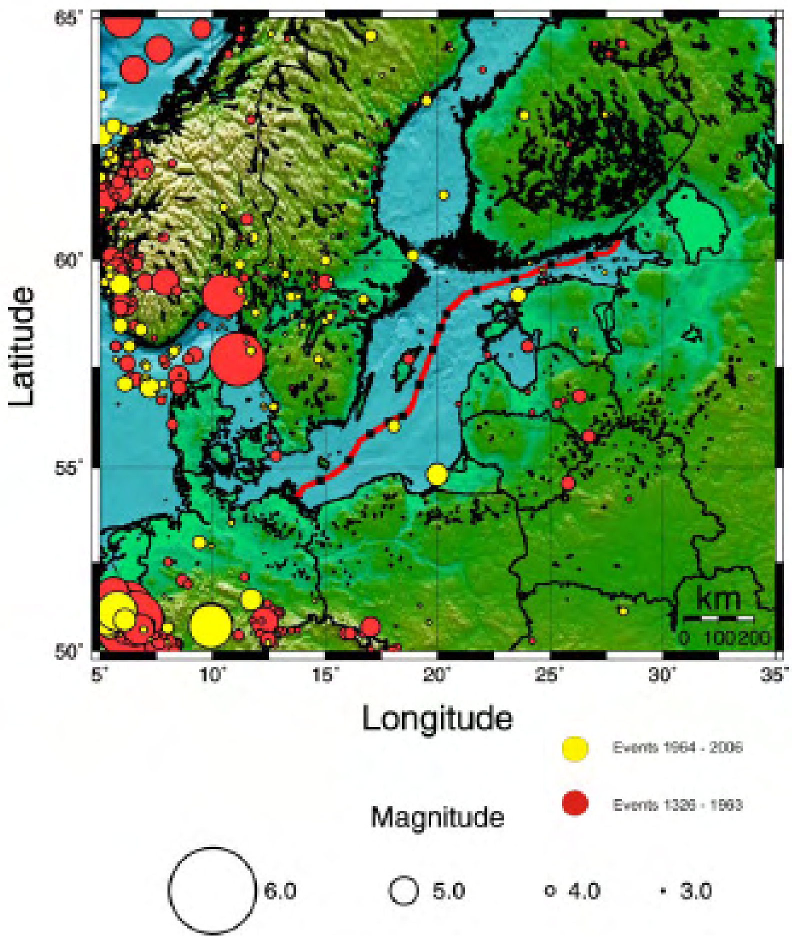
- All materials, manufacturing methods and procedures will comply with recognised standards, practices and/or purchaser specifications
- Non Destructive Examination at the fabrication site (pipe mills) will be performed according to DNV standards
- Pressure testing of each single pipe joint is undertaken at the pipe mill
- Automated Ultrasonic Testing and approval of each weld on board the pipe-lay barge prior to laying the pipe on the seabed
- Continuous monitoring of the stress on the pipe during the laying operation to ensure the integrity of the pipeline
- Continuous monitoring of the touch down point of the pipe on the seabed by remotely operated vehicle to provide visual confirmation of the integrity of the pipeline on the seabed
- Intervention works (rock placement and post trenching) to ensure final stabilization of the pipelines on the seabed
- Pressure testing of the pipelines system will be undertaken after installation offshore

Differing levels of inspection are also undertaken; by supplier's and installation contractors' inspectors, Nord Stream inspectors and DNV inspectors (for Germany also SGS-TÜV).

Natural hazards - Earthquake

Geological data have been collated and evaluated and an extensive seismic hazard assessment has been performed.

Figure 3.4 shows the historical data and distribution of seismic activity from the 14th century until 2006. Southern Finland, the Baltic Sea, and surrounding regions (i.e., northern Germany, Poland, Lithuania, Latvia, and Estonia) are almost aseismic. Based on these results it has been concluded that seismic activity is not the governing design load for the pipeline (engineering judgement). Nonetheless, given the robustness of the pipeline it is expected that it would require a severe earthquake to cause a significant failure. In such an event, the major impacts on people are unlikely to be related to the release of gas from the pipelines but from the likely tsunami that may result.



.Figure 3.4 Seismicity of Study Area

Natural hazards - Landslides

The generation of landslides that could potentially affect the pipeline integrity has been qualitatively evaluated at the outset of the Project for the entire pipeline route. It was concluded that the pipelines are not threatened by landslide.

The occurrence of a landslide is due to the coexistence of various conditions such as:

1) Thick layers of very soft sediments lying on steep slopes

2) Slope angles able to trigger the development of soil instability

3) Triggering mechanisms causing the landslides (e.g. seismic loads, wave loads, rapid accumulation of soft sediments)

No such conditions have been found along the pipeline routes. In addition the proposed pipeline routing is far from any significant cross slope.

Natural hazards – Extreme storm

The following metocean design conditions have been used for the detailed design of the Nord Stream pipelines for 1, 10 and 100 years return periods.

- Seasonal and whole year directional extremes of wind, waves and currents
- Directional significant wave height
- Wave and current climate for fatigue analysis
- Air temperature extremes and climate at landfall locations
- Persistence of storm and calm conditions for on site operations
- Variability of the sea level
- Hydrological sea water parameters (temperature, salinity and density)

Occurrence and extension of ice coverage**Figure 3.5** shows a typical example of the extreme wind speed and wind direction data for 1, 10 and 100 year return periods at one location of the pipeline.

The conditions providing the largest load for various points along the route have been selected as design conditions. The pipeline had been designed to withstand the maximum forces exerted by a 100 year storm (DNV-Code requirement).

It should also be noted that in the event of extreme weather during construction, the pipe carriers, rock placement and supply vessels will shelter in the nearest designated safety area, e.g. harbour or port. The pipe-lay barges are much larger and can generally ride out a storm without leaving for shelter, although it may be necessary to lay the pipe down before the onset of severe weather. In extreme conditions the pipe-lay barges could also move to a sheltered location for the duration of the storm. There are no reported incidents of a pipe-lay barge sinking or capsizing.

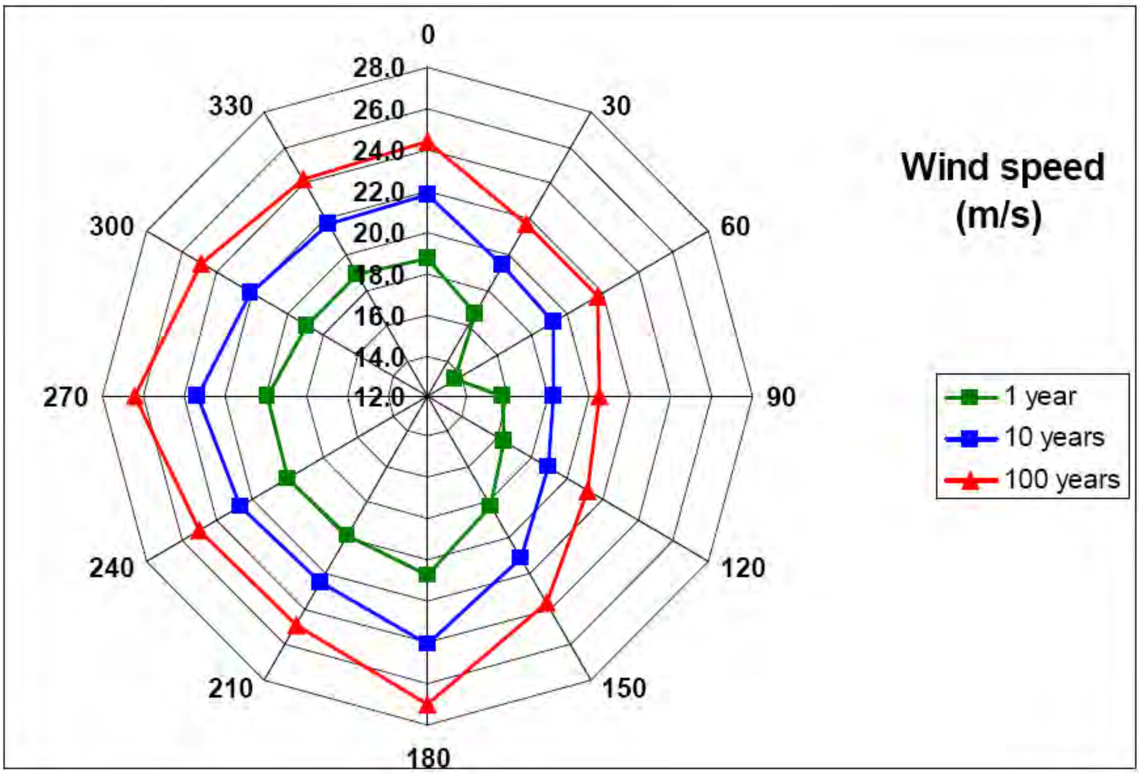


Figure 3.5 Directional wind speed extremes for 1, 10 and 100 year return periods

Natural hazards – Historical experience

The PARLOC 2001 database contains incidents and related loss of containment events from offshore pipelines operated in the North Sea. It reports 13 incidents due to natural hazards (10 were due to current and wave action, 1 resulted from storm damage, 1 was due to scouring and 1 was due to subsidence. However, none of these caused loss of containment (release) from steel pipelines, and only 3 lines sustained damage (but only to their coating). The Nord Stream pipelines are designed against natural hazards due to current and wave action as per DNV RP F109.

Overall, the contribution of natural hazards to pipeline failure is considered negligible.

External interference

It is only the external interference from ship related incidents which is considered to be a significant contributor to potential pipelines failures for the Nord Stream Project. This has therefore been the subject of considerable scrutiny and detailed analysis, including consideration of:

- Dropped objects

- Dropped anchors
- Dragged anchors
- Sinking ships
- Grounding ships (where relevant).

For each identified section where a specified level or greater of ship activity exists, the interaction frequency and pipeline damage frequency has been estimated for the operations phase. These critical pipelines sections are considered to be those where the frequency of ships crossing the pipeline exceeds a criterion value of 250 ships/km/year. This value corresponds to less than 1 ship/km/day and is used to distinguish those pipeline sections corresponding to intense ship traffic.

The frequency of interaction is thus the frequency with which contact is made with the pipeline (e.g. by a dragging anchor or sinking ship), irrespective of the damage to the pipeline that may be caused as a result (which is assessed separately in pipeline damage assessments).

This interaction frequency assessment takes into account the following:

- The pipeline size and location
- The location and width of shipping lanes
- The ship traffic intensity, crossing angles, and the distribution of ship classes and types based on Automatic Identification System (AIS) data
- Ship characteristics (e.g. length, beam, weight, speed, anchor mass)
- Cargo ship containers sizes and weights
- Ship accident and incident data (e.g. frequency of collisions, machinery failures and steering failures which may result in emergency anchoring)
- Various conditional probabilities (e.g. that a sinking is in the vicinity of the pipeline)

The pipeline damage assessment aims to:

- Quantify pipeline damage and the associated pipeline failure rate at the critical pipeline locations identified in the interaction scenario frequency assessment
- Define pipeline protection measures, if any, at the critical pipeline locations where the pipeline failure rate exceeds the Nord Stream Project acceptance criteria

The pipeline failure rate at the critical locations is calculated by summing the failure rates associated with the different interference mechanisms taking into account the interaction scenarios (dropped objects, dropped anchors, dragged anchors, sinking ships and grounding ships) and pipeline configurations (exposed, buried or protected). This failure rate is actually the rate at which damage to the pipeline is estimated to occur; only a proportion of damage events are expected to results in gas release (for example, some damage may be a dent in the pipeline which prevents pigging until a repair is made).

The analysis includes calculation of the kinetic energy of the falling object (ship, container, anchor), the mechanical behaviour of the soil under surface loads and of the pressure transmitted to the pipeline, calculation of the resistance of the pipe to tackle impact forces, impact energy, local forces and global bending moments, and a damage and pipe failure probability assessment.

Based on these analyses, no gas release is expected in the case of dropped objects or anchors. For dragged anchors, 30% of the damage cases are assumed to result in gas release (all full bore ruptures). In the case of damage from sinking or grounding ships, all damage is assumed to result in gas release (the majority of which are assumed to be full bore ruptures). However, these analyses have shown that the estimated frequency of major pipeline release is very low; hence such an event is extremely unlikely to occur in the lifetime of the pipeline. Therefore no additional protection of the pipeline is required.

In general there are no permanent restriction zones along the pipeline. The only exemption is the nearshore approach in Germany where the pipeline runs parallel to the shipping channel. Here a 200 m safety corridor has been established together with the German authorities, because there are frequent, regular maintenance works (ensuring sufficient depth of the shipping channel) in the shipping channel in the vicinity of the pipeline.

3.5 Consequence Analysis – Gas Release

For the pipeline operations phase, the detailed analyses have focused on the consequences of a subsea gas release. This involves several stages, from underwater release rate and associated depressurisation calculations, through the effects at sea surface and the atmospheric modelling of gas dispersion, to the assessment of the physical effects of the final outcome scenario. There are several outcomes to consider (e.g. jet fire, flash fire, explosion, harmless dispersion) depending on whether an ignition takes place (immediate or delayed) and on the degree of confinement. This in turn means consideration has to be given to:

- Size of rupture (pinhole, hole or full bore rupture)
- Type of material released (i.e. natural gas)

- Process parameters (i.e. pressure and temperature that determine the outflow rate)
- Water depth
- Atmospheric conditions (i.e. atmospheric stability and wind speed)
- Likelihood of ignition

Final estimation of the likely casualties in the event of an ignited release is based upon the exposed populations, taking account of the typical numbers of people on the different vessels (cargo ship, tanker, passenger vessel etc) and their vulnerability (e.g. only people on open decks are expected to be killed in the event of being engulfed in a flash fire).

In the extremely unlikely event of a major sub sea gas release, the gas will be released to the water column and rise to the surface as a gas plume. On the surface there will be region where the gas disperses into the air. The size of this region will vary depending on the water depth of the release, the nature of damage and pipeline operating conditions at the time of damage. The extent of the gas cloud from a major gas release depends on the actual nature of the damage and the weather conditions (primarily wind speed and stability).

According to “Offshore Risk Assessment”, J.E. Vinnem, Springer, 2nd edition, no loss of buoyancy of a vessel should occur when passing over the gas plume.

Natural gas is much lighter than air and therefore will rise quickly. Therefore the risk that people onshore are affected by an offshore gas release is extremely low. Also there are no villages in the close vicinity of the areas where the pipelines reach the shore in Russia and Germany.

The quantitative assessment has estimated the individual risks to people on passing vessels and shown them to be well below the project risk acceptance criteria for risks to members of the public. Indeed, it has been shown that the risk to passengers on passing vessels is lower than the chance of their being killed by lightening. The individual risk is greatest for cargo ship crews, but again is very low (far less than their chance of dying from cancer or in a road accident).

The risk of environmental impacts due to damage of a vessel resulting in release of hazardous cargo is also very low. For such a scenario to take place a combination of number of events will have to occur:

- The pipeline must be damaged to such an extent that a major gas release (full bore rupture) occurs – an extremely unlikely event
- A ship has to pass the gas cloud before information of gas release is distributed to the ship traffic (i.e. before ships can be warned to avoid the affected area)
- The gas cloud has to be ignited by the passing vessel

- The ship must be damaged to such an extent that a release of its cargo occurs (this is extremely unlikely in a flash fire scenario as no significant overpressures are generated)

It should be noted that the frequency of ship collisions with subsequent release of oil or other type of hazardous material is much higher than the estimated frequency of failure of the pipeline leading to a gas release.

3.6 Emergency Response

The pipeline emergency response plan (PERP) will be in place prior to commissioning of the first pipeline. Agreement will be reached with the relevant authorities, on how to distribute information to the ship traffic during the first hours of a gas release, what information chains to be followed, what information nets are available and to define points of contact for Nord Stream and possible further actions (i.e. redirection of ship traffic etc.). It also needs to be agreed how Nord Stream can quickly receive the necessary permits to evaluate the damage and carry out relevant repair activities. The consultations will be initiated as soon as all permit applications have been submitted. The Nord Stream Operations HSE & Interface Manager for European Regulations will be responsible for developing the PERP and be the contact point for the authorities.

The following emergency response arrangements are currently envisaged:

- The emergency response centre will be located at Nord Stream's headquarter in Zug and operated by Nord Stream core staff
- Chain of information
    - Upstream and downstream control rooms
    - Authorities. The details will be developed in close cooperation with all relevant authorities
- Operational actions:
    - Evaluation of situation
    - If major gas release is confirmed, the inlet valve to the damaged pipeline will be closed to stop gas supply to the open system
    - Information of upstream and downstream facilities

- Reduction of gas volume in the pipeline to a minimum by pressure reduction down to minimum at Greifswald receiving terminal (WinGas/E.ON-Ruhrgas)
- Close outlet valve
- Pipeline will slowly fill up with water until the equilibrium is reached with hydrostatic pressure

• In parallel to the operational actions all affected parties, especially maritime authorities and air forces, will be informed (the most important action is to provide information to ship traffic about the location of the emergency situation to avoid ships crossing the area of the damaged pipeline)

• Mobilisation of survey vessel to evaluate damage of the pipeline

• Nord Stream has joined the StatoilHydro Repair Club to have access to relevant equipment for subsea repairs

4 Summary and conclusions

We all recognise that, as an inescapable fact of life, we are surrounded by hazards – all with a potential to give rise to unwanted consequences. No human activity is without risk. Some of the risks we face may be from naturally occurring hazards (e.g. earthquakes, lightning strikes), other arise as a results of industrial processes (e.g. refining oil to produce fuel for use in motor vehicles), while others may arise from individual lifestyles and are risks we take willingly to secure some wanted benefits (e.g. driving or flying).

Risks need to be considered in the context of the benefits derived from taking the risk. When fully operational, the two pipelines will transport 55 billion cubic metres of gas per year from the gas fields of Russia to end markets in Europe, providing a source of energy for consumers and businesses for the next 50 years.

Nord Stream intends to design, build and operate its pipelines safely. However it recognises that the construction and operation of the pipelines give rise to hazards which present risks to the public/third parties, workers, equipment and the environment. Hence Nord Stream has comprehensively assessed the risks as a basis for demonstrating their acceptability.

The results of the comprehensive analyses of the risks to people and the environment during the construction and operation of the Nord Stream pipelines show that *no risks are considered unacceptable* when compared to the risk tolerability criteria set for the Project. This is not surprising given that natural gas pipelines are used worldwide and considered as a safe means of transporting large volumes of gas. For example, there are more than 122,000 km of gas pipelines in Europe (1); over 548,000 km of natural gas pipelines in the US (2); 21,000 km of pipelines are used to transmit natural gas in Australia (3); and there are many more kilometres of gas pipelines in Russia and Canada. Offshore pipelines have only minimal and temporary impact on the environment during installation and hardly any impact during operation. More than 6,000 km of pipelines are operated in the North Sea, some of which have been in operation since the 1970s, which indicates the feasibility and impact of the offshore pipeline.

During pipeline operation the risk to third parties arises as a result of the potential for pipeline failure, gas release and ignition, impacting people on vessels in the impacted area. This risk has been shown to be very low. The dominant cause of pipeline failure is dragging anchors (or sinking ships for some sections). However, the pipeline will be marked on the relevant nautical charts to ensure shipping in the vicinity of the pipeline is aware of its location.

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(1) European gas pipeline incident data group. www.egig.nl

(2) The US Central Intelligence Agency. The world factbook

(3) Australian pipeline industry association website. www.apia.net.au

Risk assessment is a predictive technique, usually making use of historical data, modelling, assumptions and expert judgement and as such there is always a degree of uncertainty in the risk estimates. Where significant gaps in knowledge exist, risk assessment and risk management decisions tend to be suitably cautious, providing higher levels of protection as the significance and level of uncertainty about the risk increases.

The assessments discussed above show that the estimated levels of risk are significantly below the risk tolerability criteria agree for the Project, and therefore even if the results were increased by an order of magnitude, they would remain broadly acceptable.

Unplanned events, such as a fuel/oil spill, the disturbance of conventional munitions and pipeline failure, have the potential to result in transboundary impacts (i.e. to impact upon resources/receptors in countries other than the country in which the event takes place). However, the total risk impact (which for pipeline operation is the sum total of all the national impacts), including the impact on the fishing industry and commercial shipping, has been shown to be low.