Chapter 4

Description of the Project
## Description of the Project

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4 Description of the Project

4.1 Introduction

The aim of this chapter is to describe the Nord Stream project in sufficient depth to enable the scope and extent of the project to be understood, and for all potential sources of impacts, including all sources of transboundary impacts, to be identified.

4.1.1 Scope of project activities

The project activities included in the scope of this Espoo EIA report is presented in Figure 4.1. A distinction is made between Nord Stream project activities that are (1) within the scope of the EIA report, (2) associated with the EIA but not assessed as part of this EIA report and (3) outside the scope of this EIA report.

In general, the scope of the Espoo EIA report comprises all project activities that occur offshore in the countries of origin and activities that are associated with bringing the pipelines onshore.

The footnotes to Figure 4.1 explain the justification for not assessing certain project-related activities at this time. It should however be noted that some of these activities are still mentioned in the description of the proposed Nord Stream project that follows in this Section for completeness reasons, even though they are not addressed further in this report.
Figure 4.1 Project activities included in the scope of the Espoo EIA report

- Pipeline decommissioning
- Pipeline operation and maintenance
- Landfill construction
- Interconnection with other users and commissioning
- Potential incidents and decommissioning
- Transboundary environmental impacts in the Baltic Sea
- Cable crossings and landings
- Offshore logistics
- Offshore installation (pipe-laying and anchor-handling)
- Water generation and handling
- Transport of the pipe by sea
- Pipe pre-lay and post lay surveys
- Detailed intervention works – Rock
- Production, reckoning and dredging
- Establishment of landfills
- Stockyards
- Transport of pre-transportable units
- Manufacturer of Flankers in Russia
- Gas treatment plant in Erevani (Georgia)
- Transport of pre-transportable units
- Stockyards in France
- Establishments of Flankers in France
- Pipe, concrete weight
- Pipe, concrete weight
- Pipe, concrete weight
- Scope within the project
- Scope outside the project
- Associated activities
- Establishments of Flankers in Germany
- Establishments of Flankers in Russia
- Establishments of Flankers in Erevani (Georgia)
4.1.2 Project Overview

The Nord Stream pipeline will run from Portovaya Bay near Vyborg on Russia’s Baltic Sea coast through the Gulf of Finland and the Baltic Sea to Lubmin in the Greifswald area on the northern coast of Germany. The Nord Stream pipeline route is depicted in Figure 4.2 and in Atlas Map PR.

![Figure 4.1 The Nord Stream pipeline route through the Baltic Sea. The dark green line indicates the pipeline route. The red lines indicate the exclusive economic zones of the countries around the Baltic Sea, and the green lines indicate the limit of the territorial waters. The dotted red line indicates the midline between Denmark and Poland.](image)

The Nord Stream pipeline will consist of two 48-inch steel pipelines. The pipelines are referred to as the ‘north-west’ and ‘south-east’ pipelines to distinguish their orientation relative to each other. Each pipeline has a total offshore length of about 1,222 km.
Landfall facilities in Russia and Germany will connect the two pipelines to the Russian and European gas networks. Onshore pipeline sections in Russia (approximately 1.5 km) and in Germany (approximately 0.5 km) will connect the offshore sections of the pipelines with the landfall facilities. The onshore sections are also known as dry sections.

The pipelines will be connected to a compressor station at the Russian landfall in Vyborg, which will be equipped with metering and pressure-control facilities. Similarly, the pipelines will be connected to a receiving terminal in Greifswald in Germany, which also will be equipped with a metering station and pressure-control facilities.

The main characteristics and operating conditions of the pipelines are shown in Table 4.1 below. The pipelines will have three offshore design pressure segments according to the pressure drop caused by the friction losses along the pipelines. This is further explained in Section 4.8.2. The kilometre post (KP) refers to the location along the pipeline length starting from the Russian landfall at KP 0.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>55 bcm/y (27.5 bcm/y per pipeline)</td>
</tr>
<tr>
<td>Gas</td>
<td>Dry, sweet natural gas</td>
</tr>
<tr>
<td>Design pressure (1)</td>
<td>KP 0 to KP 300: 220 barg</td>
</tr>
<tr>
<td></td>
<td>KP 300 to KP 675 (earlier KP 800): 200 barg</td>
</tr>
<tr>
<td></td>
<td>KP 675 (earlier KP 800) to KP 1222: 170 barg</td>
</tr>
<tr>
<td>Offshore design temperature</td>
<td>-10 to 60 °C</td>
</tr>
<tr>
<td>Offshore operating temperature</td>
<td>-10 to 40 °C</td>
</tr>
</tbody>
</table>

Each pipeline will comprise of steel pipes that are welded together and protected by anticorrosion coating and concrete coating. The inner diameter of the pipes will be consistent throughout the entire length of the pipelines in order to facilitate maintenance operations.

The wall thickness of the pipelines will vary correspondingly to the pressure drop along the pipelines, meaning that there will be three different offshore pipeline wall thicknesses (34.6, 30.9 and 26.8 mm). In the near-shore (~ 0.5 km) and dry sections the wall thickness will be in Russia 41.0 mm and in Germany 30.9 mm.

(1) Previous pipeline studies included an intermediate service platform (ISP), for which design pressure sections were established. Subsequently the ISP has been engineered out of the Nord Stream pipeline project and the design pressure sections have been re-established. This means that the section change previously at KP 800 has been moved to KP 675.
The outer diameter will vary because of the differing wall thickness of the steel pipes (determined based on maximum allowable operating pressure) and the varying thickness of the concrete weight-coating over the length of the pipelines (determined based on requirements for on-bottom stability). The maximum outer diameter of the pipelines will be approximately 1.4 m.

The pipeline dimensions are shown in Table 4.2.

Table 4.2 Pipeline dimensions

<table>
<thead>
<tr>
<th>Property</th>
<th>Value (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner diameter of steel pipe</td>
<td>1,153 mm</td>
</tr>
<tr>
<td>Wall thickness of steel pipe</td>
<td></td>
</tr>
<tr>
<td>Section 220 barg:</td>
<td>34.6 mm</td>
</tr>
<tr>
<td>Section 200 barg:</td>
<td>30.9 mm</td>
</tr>
<tr>
<td>Section 170 barg:</td>
<td>26.8 mm</td>
</tr>
<tr>
<td>Thickness of concrete coating</td>
<td>60 to 110 mm</td>
</tr>
<tr>
<td>Total length (per pipeline)</td>
<td>~ 1,222 km</td>
</tr>
</tbody>
</table>

The Nord Stream pipeline has been designed for an operating life of 50 years.

4.1.3 Time Schedule – Planning and Execution

The main activities during the different phases of the lifetime of the pipeline system are described in the following sections and include:

- Feasibility study
- Conceptual design
- Engineering surveys and munitions screening
- Detailed pipeline design
- Environmental study, risk assessments and permitting
- Setting up infrastructure and logistics
- Construction of the pipelines, including:
  - Surveying (to gather specific information on the pipeline corridors)
  - Seabed intervention works (to ensure that the pipelines have a stable foundation on the seabed)
  - Construction activities at the landfalls in Germany and Russia
- Crossings of existing offshore cables and pipelines
- Offshore pipe-laying, including tie-in (coupling) of the different offshore sections

- Pre-commissioning (flooding, cleaning, gauging, pressure-testing, dewatering and drying of the pipeline system using seawater)
- Commissioning (filling the pipelines with gas)
- Operation, including inspection and maintenance of the pipeline and environmental monitoring
- Decommissioning of the pipeline system

The project was initiated in 1998 with a feasibility study\(^{(1)}\), in which international engineering companies, Russian research institutes and the Russian-Finnish company North Transgas Oy, conducted surveys and maritime research in the Baltic Sea. The study for the offshore section, confirmed the technical feasibility of the pipeline project. Based on this study, a conceptual design for the pipeline was carried out.

The detailed engineering design phase was initiated in 2006 along with environmental studies and international consultation on EIA. Also, development of a logistics infrastructure concept was initiated, leading to selection of suitable harbours for the project.

The international consultation process on EIA started on 14 November 2006, when a project information document on the planned pipeline through the Baltic Sea was submitted to the responsible environmental authorities of Denmark, Finland, Germany, Russia and Sweden in accordance with the Espoo Convention.

Provided that all permits are granted within the expected time frame, the installation of the pipelines will be initiated in April 2010. At present, the duration of the total installation campaign comprising both pipelines is expected to be about three years.

A time schedule for the Nord Stream project is shown in **Figure 4.3**.

Installation will commence with the two landfalls, which will be constructed to accommodate both pipelines at the same time to minimise environmental impacts. Also pre-lay seabed intervention works will be carried out for both pipelines in the beginning of the construction phase.

Construction of the offshore sections of the two pipelines will be carried out separately, at different times due to availability of pipe-lay vessels. The north-west line will be ready for gas delivery in September 2011, and the south-east pipeline is planned to come on stream in November 2012.

According to the present time schedule, the time frames for the different parts of the construction will be as follows:

- Construction works at the two landfalls in Russia and Germany are estimated to take about 4½ and 9 months, respectively
- Laying of the north-west pipeline will take around 11 months, whereas laying of the south-east pipeline will take around 14 months. The shorter installation of the north-west line is due to the fact that parts of the pipeline will be laid simultaneously by two deep-water lay vessels. Only one deep-water lay vessel is planned for laying the south-east pipeline. A shallow-water lay vessel will be used at the German landfall.
• Seabed intervention works along the route, including both pre-lay and post-lay activities (i.e., ‘earthworks’ taking place before and after pipe-lay, respectively), are planned to be carried out in campaigns throughout the entire construction phase. Pre-lay activities will take around five months for each pipeline, including tie-in basements at KP 300 and KP 675. Post-lay activities will take place both before and after pre-commissioning and will be carried out over a period of 14 months for the north-west pipeline and 21 months for the south-east pipeline.

• Pre-commissioning activities are expected to take approximately five months for each pipeline. This includes approximately two weeks for each tie-in and one month for discharge of pressure-test water for each pipeline.

• Commissioning of the pipelines, including gas-filling, will take approximately one month for each pipeline.

The construction time schedule in Figure 4.3 is a general time schedule showing one possible scenario for the installation activities. The stated start date of April 2010 and completion date of November 2012 will not change, however the various phases in between may change subject to further optimisation during detailed design and construction.

The time schedule takes into account various time restrictions in the construction window for the different sections along the pipeline route. This is further specified in Table 4.3 below.

Table 4.3 Restrictions along the Nord Stream pipeline (assumed for construction schedule)

<table>
<thead>
<tr>
<th>Zone</th>
<th>From KP</th>
<th>To KP</th>
<th>Restrictions</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfall Russia</td>
<td>0</td>
<td>7.5</td>
<td>Restrictions due to spawning</td>
<td>Mid April – mid June</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Restrictions due to weather</td>
<td>December – April</td>
</tr>
<tr>
<td>Zone 1</td>
<td>7.5</td>
<td>300</td>
<td>Restrictions due to weather</td>
<td>December – April</td>
</tr>
<tr>
<td>Zone 2</td>
<td>300</td>
<td>675</td>
<td>No restrictions along pipeline route</td>
<td></td>
</tr>
<tr>
<td>Zone 3*</td>
<td>675</td>
<td>1196</td>
<td>Restrictions for constructions works in the offshore part of Natura 2000 area</td>
<td>January – mid May</td>
</tr>
<tr>
<td>Landfall Germany</td>
<td>1196</td>
<td>1222</td>
<td>Restrictions for constructions works in the offshore part Natura 2000 area</td>
<td>January – mid May</td>
</tr>
</tbody>
</table>

*The Swedish Board of Fisheries has requested that no construction work is undertaken during cod spawning season (May 1st to October 31st) north of Bornholm (approximatively KP 950-1020.5). This request will be complied with as far as this is practically possible.


4.2 Pipeline Route

This chapter describes the route development process that has taken place during the past decade and presents the details of the proposed route.

4.2.1 Development of the Pipeline Route

Determining the optimal route for the pipeline has been an evolving process. The initial route was based on a desk study; geophysical reconnaissance surveys in 2005; and detailed geophysical, geotechnical and environmental sampling in 2006. The desk study was based on the North Transgas survey and feasibility study conducted in 1998-1999. An additional reconnaissance survey was performed in 2007 to evaluate potential alternative routes and to extend parts of the 2005 survey corridor. The proposed pipeline route was based on this extensive survey coverage.

During 2007 and 2008, route selection has been ongoing based on consultation with the authorities in the five transitory countries (the ‘countries of origin’). The route selection has been supported by further detailed geophysical investigations, a geotechnical sampling programme and in-situ testing and environmental sampling.

Detailed design and the above-mentioned investigation programmes have resulted in a number of potential optimisations of the route to further minimise seabed interventions. Minimisation of seabed interventions has been a key criterion during development of the route as it is desirable for economic, technical and environmental reasons: as less material will be placed or rearranged on the seabed, less environmental impact will be achieved and less economical and technical resources will be needed to perform the installation.

This has resulted in the route selection presented below. While this route remains subject to further optimisation (based on detailed design and further investigations), it broadly comprises the proposed routing of the pipeline. For a description of route alternatives that have been considered previously, please refer to Chapter 6 on alternatives.

4.2.2 Details of the Pipeline Route

The Nord Stream Route passes through the exclusive economic zones (EEZs) of Russia, Finland, Sweden, Denmark and Germany. In Russia, Denmark and Germany the pipeline also passes through territorial waters (TWs). For details on the route please refer to Table 4.4 and Table 4.5 and Atlas Map PR-1.
Table 4.4 Details of lengths of the north-west pipeline in the countries of origin. Lengths are approximate and subject to final optimisation

<table>
<thead>
<tr>
<th>North-west line</th>
<th>Classification</th>
<th>Section length [km]</th>
<th>National length [km]</th>
<th>Cumulative KP [km]</th>
<th>Dry/offshore section [km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia</td>
<td>Dry section</td>
<td>1.5</td>
<td>1.5</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>TW</td>
<td>121.8</td>
<td>123.2</td>
<td>123.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EEZ</td>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>EEZ</td>
<td>375.3</td>
<td>375.3</td>
<td>498.5</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>EEZ</td>
<td>506.4</td>
<td>506.4</td>
<td>1004.9</td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>EEZ</td>
<td>49.4</td>
<td>137.1</td>
<td>1142.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TW</td>
<td>87.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>EEZ</td>
<td>31.2</td>
<td>81.1</td>
<td>1223.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TW</td>
<td>49.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dry section</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
<td>0.5</td>
</tr>
</tbody>
</table>

The depth profiles of the pipelines through the Baltic Sea from Russia to Germany are depicted in Figure 4.4 and Figure 4.5. The maximum depth of the pipelines will be located at KP 508, where the depth is -213 m and -210 m for the north-west and south-east pipeline, respectively.
Figure 4.4  Depth profile for the north-west pipeline. Depths are approximate and subject to final optimisation

Figure 4.5  Depth profile for the south-east pipeline. Depths are approximate and subject to final optimisation
The pipelines will run almost parallel along the floor of the Baltic Sea with a general separation distance of 100 m. However, the route optimisation due to uneven seabed means that local separation distances may vary over the length of the pipelines.

The separation distances between the two pipelines are seen in Figure 4.6. The minimum distance will be 6 m at the German landfall, and the maximum distance will be 2,950 m at KP 134 in the Finnish EEZ.

Figure 4.4 Separation distance between the two pipelines. Distances are approximate and subject to final optimisation
4.2.3 Pipeline Route in Russia

The Nord Stream route in Russian waters is indicated in Figure 4.7. The length of the Nord Stream pipeline in Russian territory is approximately 123 km.

From the landfall at Portovaya Bay, the Nord Stream route takes a south-western direction out of the bay whereafter it turns more westwards and passes north of Gogland close to the Russian/Finnish EEZ/TW border.

![Figure 4.7 The Nord Stream route in Russian waters. The dark green line indicates the pipeline route. The red lines indicate the exclusive economic zones, and the green lines indicate the limit of the territorial waters](image-url)
4.2.4 Pipeline Route in Finland

The Nord Stream route in the Finnish EEZ is shown in Figure 4.8. The length of the route in the Finnish EEZ is approximately 375 km. The route passes outside Finnish territorial waters, close to the Finnish and Estonian EEZ border.

South-east of Kalbådagrund, the route runs south around the geological structure known as the Kalbådagrund and runs close to the boundary of the Finnish EEZ. The route thus avoids passing in close proximity to any shallow areas.

Figure 4.8 The Nord Stream route in Finnish waters. The dark green line indicates the pipeline route. The red lines indicate the exclusive economic zones, and the green lines indicate the limit of the territorial waters.
4.2.5 Pipeline Route in Sweden

The Nord Stream route in Swedish waters is shown in Figure 4.9. The length of the route is approximately 506 km.

The Nord Stream route enters the Swedish EEZ north-east of Gotland. The route passes east of Gotland, just outside the territorial border but clear of the main shipping route east of Gotland. South of Gotland, the route traverses the shallow area of Hoburgs Bank. South of Hoburgs Bank the route turns towards south-west and traverses Norra Midsjöbanken and the main shipping route before entering into Danish waters.

Figure 4.9 The Nord Stream route in Swedish waters. The dark green line indicates the pipeline route. The red lines indicate the exclusive economic zones, and the green lines indicate the limit of the territorial waters
4.2.6 Pipeline Route in Denmark

The Nord Stream route in Danish waters is shown in Figure 4.10. The route passes east and south of Bornholm. The length of the route is approximately 137 km of which 88 km are located in Danish territorial water.

The Nord Stream route enters Danish waters north of a chemical munitions dumping ground east of Bornholm. It follows a south-western direction in order to avoid the risk areas for the dumping ground, arrives into the territorial waters and turns south-south-west passing Christiansø.

At the southern tip of Bornholm, Dueodde, the route turns southwest and passes south of Bornholm, leaving the territorial water and continues to Germany in a route parallel to Rønne Banke. The route leaves Denmark south-east of Adler Grund.

![Figure 4.10 The Nord Stream route in Danish waters. The dark green line indicates the pipeline route. The red lines indicate the exclusive economic zones, and the green lines indicate the limit of the territorial waters](image-url)
4.2.7 Pipeline Route in Germany

The Nord Stream route in German waters is shown in Figure 4.11. The route length is approximately 81 km of which 50 km are located in German territorial waters.

The route enters the German EEZ south-east of Adlergrund and continues north of Oder Bank. North-west of Oder Bank the route enters the German TW and continues in a south-western direction into the shallow waters of Greifswalder Bodden, where the landfall is located.

![Figure 4.2](image.png)  
**Figure 4.2** The Nord Stream route in German waters. The dark green line indicates the pipeline route. The red lines indicate the exclusive economic zones, and the green lines indicate the limit of the territorial waters.
4.3 **Detailed Design**

This Chapter describes pertinent features of the engineering design and materials design of the Nord Stream pipeline project and the independent third party certification that will be applied.

4.3.1 **Engineering Design**

**Design Criteria**

The Nord Stream project will follow applicable national legislation and regulations of each of the countries of origin (refer to Section 4.2.2). In general, these national legislative acts and regulations provide few specific technical requirements for offshore pipelines, but refer to internationally recognised codes and standards.

**Codes and Standards**

The Nord Stream pipeline is designed and will be operated according to the code DNV OS-F101, Submarine Pipeline Systems, issued by Det Norske Veritas (DNV), Norway. The 2000 version with the 2003 amendments and corrections are applied. DNV OS-F101 provides criteria and guidance on design, materials, fabrication, manufacturing, installation, pre-commissioning, commissioning, operation and maintenance of pipeline systems.

The DNV OS-F101 principle code is supported by other international codes and the following DNV recommended practices:

- RP F102 Pipeline Field Joint Coating and Field Repair of Linepipe Coating
- RP F103 Cathodic Protection of Submarine Pipelines by Galvanic Anodes
- RP F105 Free Spanning of Pipelines
- RP F106 Factory Applied External Pipeline Coatings for Corrosion Control
- RP F107 Assessment of Pipeline Protection Based on Risk Principles
- RP F110 Global Buckling of Submarine Pipelines
- RP F111 Interference Between Trawl Gear and Pipelines
- RP E305 On-bottom Stability Design of Submarine Pipelines

The DNV code and guideline structure is widely used because of the code's in-depth coverage of a very broad range of topics. The use of DNV design codes has been an established practice for offshore design companies for the last several decades. The DNV code for submarine pipelines DNV OS-F101 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. DNV OS-F101 likewise has been applied in studies for other projects in parts of the Baltic Sea.


**Engineering Design Contractor**

The Italian company SES (Saipem Energy Services, former Snamprogetti S.p.A. of the Eni Group) has been appointed engineering contractor for the detailed design of the Nord Stream project. The Eni Group is one of the largest contractors in the oil and gas industry and has been responsible for the technical design of both the Langeled and Blue Stream gas pipelines between Norway and England and between Russia and Turkey, respectively.

**Mitigation in Design**

The conceptual design of the Nord Stream Pipeline project has been an adaptive process, incorporating into the routing and the design of the project mitigating measures which has been identified as a result of previous pipeline experience, consultation, environmental impact assessment (EIA) and quantified risk assessment (QRA). The routing and conceptual design alternatives that have been considered before arriving at the basic concept that is presented in this chapter are described in Chapter 6 (Alternatives).

**Independent Verification and Certification**

Nord Stream AG has assigned independent third-party experts to witness, audit and participate in all aspects of the project design and implementation.

The companies DNV and SGS/TÜV have been appointed to perform independent third-party verification during the design phase of the Nord Stream project, i.e., to verify the quality of engineering work.

Surveillance and verification activities associated with manufacture, fabrication, installation and pre-commissioning has also been assigned to a third party in conjunction with Nord Stream AG representation as deemed appropriate. Subsequently, DNV will be involved in all processes of surveillance and inspection and will provide final certification of compliance for the overall pipeline system. SGS/TÜV will be involved in all processes of surveillance and inspection of the German section of the pipeline.
The third parties will monitor all activities and make an independent statement, or certificate of compliance, which establishes that the project has been designed, fabricated, installed, pre-commissioned and handed over in accordance with the relevant international codes and standards.

4.3.2 Pipeline Materials Design and Corrosion Protection

The Nord Stream pipelines will be constructed of individual steel line pipes that will be welded together in a continuous laying process. The line pipes will be internally coated with an epoxy-based material. The purpose of the coating is to reduce hydraulic friction, thereby improving the flow conditions.

An external three-layer polyethylene coating will be applied over the line pipes to prevent corrosion. Further corrosion protection will be achieved by incorporating sacrificial anodes of aluminium and zinc. The sacrificial anodes are a dedicated and independent protection system in addition to the anticorrosion coating.

A concrete weight-coating containing iron ore will be applied over the line pipe’s external anticorrosion coating. While the primary purpose of the concrete coating will be to provide on-bottom stability, the coating will also provide additional external protection against foreign objects, such as impacts by fishing gear.

The present status (October 2008) of the specifications for the above-mentioned materials and the expected quantities required for the construction of the Nord Stream pipelines are outlined below. These specifications may be subject to further optimisation during detailed design.

**Line Pipe**

The pipelines will be constructed of steel line pipes with a length of 12.2 m that are welded together. The line pipes will be submerged arc, single seam, longitudinally welded SAWL 485 I FD\(^{(1)}\) grade carbon steel line pipe, as per DNV OS-F101 (see Section Codes and Standards), with a nominal diameter of 48” and a constant internal diameter of 1,153 mm. The wall thickness of the steel pipes is based on maximum allowable operation pressure and therefore varies in four thicknesses between 26.8 – 41.0 mm. The wall thickness will be distributed as indicated in Table 4.6 and Table 4.7.

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\(^{(1)}\) Designation for the pipeline material specification: SAWL = process of manufacture (submerged-arc welding, one longitudinal weld seam); 485 = specified minimum yield stress (SMYS), in MPa; I = level of non-destructive testing (I = level I); FD = supplementary requirements (F = fracture arrest properties, D = enhanced dimensional requirements).
Table 4.1 North-west pipeline wall thickness (WT) distribution. Lengths are approximate and subject to final optimisation

<table>
<thead>
<tr>
<th>From KP [km]</th>
<th>To KP [km]</th>
<th>Length [km]</th>
<th>Pipe WT [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.5</td>
<td>0.5</td>
<td>41.0</td>
</tr>
<tr>
<td>0.5</td>
<td>300.0</td>
<td>299.5</td>
<td>34.6</td>
</tr>
<tr>
<td>300.0</td>
<td>675.0</td>
<td>375.0</td>
<td>30.9</td>
</tr>
<tr>
<td>675.0</td>
<td>1222.6</td>
<td>547.6</td>
<td>26.8</td>
</tr>
<tr>
<td>1222.6</td>
<td>1223.1</td>
<td>0.5</td>
<td>30.9</td>
</tr>
</tbody>
</table>

Table 4.2 South-east pipeline wall thickness (WT) distribution. Lengths are approximate and subject to final optimisation

<table>
<thead>
<tr>
<th>From KP [km]</th>
<th>To KP [km]</th>
<th>Length [km]</th>
<th>Pipe WT [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.5</td>
<td>0.5</td>
<td>41.0</td>
</tr>
<tr>
<td>0.5</td>
<td>300.0</td>
<td>299.5</td>
<td>34.6</td>
</tr>
<tr>
<td>300.0</td>
<td>675.0</td>
<td>375.0</td>
<td>30.9</td>
</tr>
<tr>
<td>675.0</td>
<td>1221.7</td>
<td>546.7</td>
<td>26.8</td>
</tr>
<tr>
<td>1221.7</td>
<td>1222.2</td>
<td>0.5</td>
<td>30.9</td>
</tr>
</tbody>
</table>

Buckle Arrestors

To minimise the risk of pipe collapse during installation, buckle arrestors (pipe reinforcement) will be installed at specific intervals in susceptible areas. The buckle arrestors will be welded into the pipelines in those areas that are susceptible to propagation buckling, i.e., deeper sea areas. Risk of collapse is during installation only.

The buckle arrestors will be made of the same steel alloy as the line pipes and will be equal in length to the line pipes. However, these pipes will have a greater wall thickness, with machined thinner wall ends to match the adjoining line pipe, as illustrated in Figure 4.12.
Buckle arrestors will be used along a 305 km stretch of the pipeline, more specifically from KP 420 to KP 520, from KP 550 to KP 610, from KP 675 to KP 800 and from KP 1000 to KP 1020. The spacing between the buckle arrestors will be 927 m (equal to 76 line pipes).

**Welding of Line Pipes**

Welding consumables similar and compatible to the composition of the line-pipe material will be used. The weld properties will have a minimum steel grade equal to that of the line pipe. No other materials will be added during welding.

**Internal Antifriction Coating**

The line pipes will be internally coated with an antifriction coating to increase flow capacity of the pipeline system. The internal coating of a line pipe is illustrated in Figure 4.13. The coating will be an epoxy-based red-brown, high-gloss paint.
The epoxy will be comprised of the following components:

- Epoxy base (epoxy resin, pigments, extenders, additives and organic solvent)
- Curing agent (aliphatic/cycloaliphatic amine or polyamide)

The coating will have a thickness of ~90 to 150 µm and cover the entire line pipe length, except for an internal cutback of ~50 mm at the pipe ends to allow for heat transfer during welding. This cutback will remain uncoated after welding.

The internal coating will be applied at the line pipe manufacturing site.

**External Anticorrosion Coating**

An external coating will be applied over the line pipes to prevent corrosion. The external anticorrosion coating will be a three-layer polyethylene (3LPE) coating. The coating principle is illustrated in Figure 4.14 below.

![Figure 4.14 Three-layer polyethylene (3LPE) external anticorrosion coating principle. The coating consists of an inner layer of fusion-bonded epoxy (dark green), an adhesive layer in the middle (light green) and a top layer of polyethylene (black)]](image)

The 3LPE external anticorrosion coating will comprise of:

- Inner layer: fusion bonded epoxy (FBE)
- Middle layer: adhesive
- Outer layer: high density polyethylene (HDPE) base with additives
The minimum overall thickness of the coating will be 4.2 mm and cover the entire line pipe length, except an external cutback of approximately 200-250 mm at the pipe ends, which will be kept free of coating to facilitate welding and inspection.

The external anticorrosion coating will also be applied at the line pipe manufacturing site.

**Concrete Weight Coating**

The line pipes also will be externally coated with concrete. The concrete coating will be applied over the anticorrosion coating, as shown in Figure 4.15, and will give the pipelines sufficient weight to remain stable on the seabed, both during the installation phase and during the operation of the pipelines.

Both ends of the line pipes will be kept free of concrete coating to allow for welding of the joints at the lay vessel. After welding, these joints will be protected against corrosion (see Section on Field Joint Coating).

![Concrete coating on top of the three-layer anticorrosion coating](image)

**Figure 4.15** Concrete coating on top of the three-layer anticorrosion coating

The concrete comprises of a mix of cement, water and aggregate (inert solid material such as crushed rock, sand, gravel). The concrete coating will be reinforced by steel bars welded to cages with a minimum bar diameter of 6 mm. Moreover, iron ore aggregate will be added to increase the density of the weight coating. The coating process is illustrated in Figure 4.16.
Figure 4.16 Concrete-coating process

The cement used for the concrete will be a Portland cement suitable for marine use. The Portland cement will be specified in accordance with ASTM C 150 Type II. No additives will be used in the concrete mixture, but silica fume\(^{(1)}\) may be added up to 10% of the cement weight. The maximum chloride in the mix will be less than 0.4%. No admixtures or curing membranes will be used.

The concrete coating will have a thickness of 60-110 mm and a density of maximum 3,040 kg/m\(^3\). Iron ore constitutes 70% of the weight of the coating. The remaining 30% is concrete (cement and aggregate).

The concrete coating will be applied by an impingement process at weight-coating plants. For more details refer to Chapter 4.4. A pre-defined number of line pipes will have anodes attached during the concrete coating process (see Section on Cathodic Protection).

**Field Joint Coating**

Concrete-coated line pipes will be transported to the lay vessel, where they will be welded together. Before the lay-down procedure takes place, a field joint coating will be applied externally around the welded pipe joints to fill in the remaining space between the concrete coating on each side of the field joint and to protect the joint against corrosion.

\(^{(1)}\) Silica fume (or microsilica) is a by-product of the reduction of high-purity quartz with coal in electric furnaces in the production of silicon and ferrosilicon alloys. Silica fume is also collected as a by-product in the production of other silicon alloys such as ferrochromium, ferromanganese, ferromagnesium and calcium silicon.
The field joint coating will have a length of about 0.8 m\(^{(1)}\), representing approximately 7% of the overall pipeline length. **Figure 4.17** shows a field joint prior to coating.

![Figure 4.17 A typical field joint before coating. The three-layer polyethylene anticorrosion coating and the concrete coating are visible on the line pipes](image)

The field joint coating system will comprise a heat-shrink sleeve made of high-density polyethylene. The welded field joint will be heated prior to application of the heat-shrink sleeve. The heat-shrink sleeve is formulated to be cross-linkable, which gives it elastic properties and enables it to fit tightly around the steel pipe joint. Because of the cross-linking, the material will contract to its original length when cooling down, thereby fitting closely around the field joint preventing any voids.

Since the heat-shrink sleeve is not thick enough to fill the entire annulus between the concrete at either side of the field joint, a carbon steel sheet or a polyethylene former will be installed around the field joint. The carbon steel sheet or the polyethylene former will overlap the concrete coating and be permanently secured by carbon steel straps (for the carbon steel sheets) or welded polyethylene (for the polyethylene formers). Two-component polyurethane foam will be injected into the void between the heat-shrink sleeve and the steel sheet former

\[(1)\] The length of the field joints will vary in areas with lay down heads and buckle arrestors.
through a port created on top of the former. The foam will rise and cure to fill the joint volume. The foam is able to withstand fishing trawl impact.

**Figure 4.18** shows the fitting of the infill former in the field joint coating station at the lay vessel along with a field joint after coating.

The heat-shrink sleeve will be approximately 2 mm thick and have a density of about 900 kg/m³. The polyurethane foam will have a density of approximately 160 kg/m³ when in place. The field joint coating will be flush with the concrete.

**Cathodic Protection**

To ensure the integrity of the pipelines over their design operational life, secondary anticorrosion protection will be provided by sacrificial anodes of a galvanic material. This secondary protection will be an independent system that will protect the pipelines in case of damage to the external anticorrosion coating.

The design of the cathodic protection system takes into account various parameters specific to the Nord Stream pipeline – such as pipeline installation operations, lifetime of the pipeline and possible increased coating degradation due to Baltic Sea environmental characteristics – to ensure that the required amount of protection current for the entire pipeline design life is provided.

The performance and durability of different sacrificial alloys in Baltic Sea environmental conditions has been evaluated with dedicated tests conducted by DNV (Section for Failure Investigation and Corrosion Management).
The tests showed that the salinity of seawater has a major effect on the electrochemical behaviour of aluminium alloys. In particular it was observed and reported that low salinity concentrations in seawater dramatically decreased the electrochemical performance of tested samples. During testing, no major effect on electrochemical performance due to H₂S (i.e., oxygen-free conditions) was reported. H₂S is present in the sediment as well as in the sea water in certain parts of the Baltic Sea through which the pipeline will traverse (see Chapter 8 Baseline).

In the light of the test results zinc alloy has been selected for parts of the pipeline route with very low average salinity. This is the case in parts of the Russian, Finnish and Swedish exclusive economic zones. For all other sections indium-activated aluminium will be used.

The cathodic protection system will thus comprise of:

- Zinc and indium-activated aluminium bracelet anodes (two half-shells per anode)
- Anode electrical continuity cables (two cables per half shell)
- Cartridge/materials necessary to perform the cable welding between anodes and pipes

Figure 4.19 shows a typical anode mounted on a pipeline.

Figure 4.19  A sacrificial anode is mounted in a gap in the concrete coating and directly attached to the pipe
The dimensions of the anodes depend on various parameters, such as the pipeline dimension, the thickness of the concrete weight coating, the design life of the pipeline, the type of coating, the environment characteristics and the anode material.

It is intended that there will be seven different designs of aluminium anodes and four different designs of zinc anodes. The thickness of the aluminium anodes will vary between 50 - 100 mm, the length will vary between 400 - 520 mm and the weight will vary between 199.9 – 459.9 kg per anode. The zinc anodes will have a thickness varying between 50 - 100 mm, a length varying between 408 - 494 mm and a weight varying between 529.2 – 1,177.7 kg per anode.

Besides the aluminium and zinc the anodes will also contain small amounts of other metals and impurities. Both types of anodes will contain cadmium (<0.01%) and the zinc anodes will additionally contain lead (<0.01%).

The number of anodes to be installed in each country of origin and the corresponding quantities of aluminium and zinc alloy is listed in Table 4.8. The anodes will be spaced 5-12 line pipes apart.

### Table 4.8 Number of anodes to be installed in the five countries of origin. Quantities are approximate and subject to final optimisation

<table>
<thead>
<tr>
<th>Type</th>
<th>Unit</th>
<th>Russia</th>
<th>Finland</th>
<th>Sweden</th>
<th>Denmark</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>[no]</td>
<td>58</td>
<td>2,980</td>
<td>8,326</td>
<td>2,457</td>
<td>1,773</td>
</tr>
<tr>
<td>Zinc</td>
<td>[no]</td>
<td>2,206</td>
<td>3,111</td>
<td>891</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Total material consumption**

The expected material consumption required for the pipeline sections in each of the five countries of origin is summarised in Table 4.9 below.
Table 4.9  Summary of material consumption in the countries of origin. Quantities are approximate and subject to final optimisation

<table>
<thead>
<tr>
<th>Material</th>
<th>Russia</th>
<th>Finland</th>
<th>Sweden</th>
<th>Denmark</th>
<th>Germany</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total length of 2 pipelines (km)</td>
<td>246.9</td>
<td>749.7</td>
<td>1,012.4</td>
<td>274.1</td>
<td>162.1</td>
<td>2,445.2</td>
</tr>
<tr>
<td>Steel (t) (incl. buckle arr.)</td>
<td>250,530</td>
<td>715,275</td>
<td>833,810</td>
<td>213,800</td>
<td>127,000</td>
<td>2,140,415</td>
</tr>
<tr>
<td>Internal epoxy coating (t)</td>
<td>247</td>
<td>749</td>
<td>1,014</td>
<td>274</td>
<td>163</td>
<td>2,447</td>
</tr>
<tr>
<td>External 3LPE coating (t)</td>
<td>5,162</td>
<td>15,615</td>
<td>21,006</td>
<td>5,672</td>
<td>3,366</td>
<td>50,822</td>
</tr>
<tr>
<td>Concrete weight coating (t)</td>
<td>193,755</td>
<td>714,064</td>
<td>1,042,494</td>
<td>289,531</td>
<td>211,162</td>
<td>2,451,006</td>
</tr>
<tr>
<td>Anodes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium (t)</td>
<td>14</td>
<td>1,011</td>
<td>3,436</td>
<td>936</td>
<td>825</td>
<td>6,222</td>
</tr>
<tr>
<td>Zinc (t)</td>
<td>1,673</td>
<td>2,845</td>
<td>1,126</td>
<td>0</td>
<td>0</td>
<td>5,644</td>
</tr>
<tr>
<td>Field joint coating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layer 1: HSS (t)</td>
<td>101.2</td>
<td>307</td>
<td>415</td>
<td>112</td>
<td>67</td>
<td>1,003</td>
</tr>
<tr>
<td>Layer 2: PU (t)</td>
<td>698.4</td>
<td>2,522</td>
<td>3,716</td>
<td>1,044</td>
<td>673</td>
<td>8,653</td>
</tr>
</tbody>
</table>

4.4 Logistics

Large-scale offshore pipeline construction work requires considerable support from onshore support facilities, such as weight-coating plants and interim stockyards. In addition to weight-coating and storage of line pipe, the support facilities will provide general storage for supply of consumables to the offshore fleet, and managerial support for Nord Stream AG and its contractors. Helicopter support both for the installation phase and for the operational phase may also be required.

In this Chapter the details of the logistical concept of the Nord Stream project are described.

4.4.1 Logistics Concept

The concept has been developed specifically for the project and includes:

- Transport of anti-corrosion coated pipes and concrete weight coating materials to the weight-coating plants
- Transport of weight-coated pipes to the interim stockyards
- Transport of weight-coated pipes to the lay vessels from the weight-coating plants and interim stockyards
• Transport of material for rock placement from quarry to rock placement location

The logistics concept has been designed to reduce the onshore and offshore transportation. The use of existing facilities has been favoured in order to avoid new construction wherever feasible. A primary focus in the development of the logistics concept, therefore, has been on minimising environmental impacts and reducing costs.

The following chapters describe the present status (November 2008) of the planned logistical setup. It should be noted that the suppliers for the second pipeline (the south-east pipeline) have not yet been selected. Therefore, logistics may be adapted to accommodate any changes. The concept is also based on expected readiness and availability of the sites.

Preparation of the facilities will comply with national legislation and requirements and will be subject to independent, national permitting. Information about these onshore facilities, however, is included here to give a better overview of the project logistics.

4.4.2 Transport of Line Pipe and Coating Material to the Weight-coating Plants

Line pipe for the north-west pipeline will be produced at pipe mills in Russia and Germany. At the mills, they will be internally coated with flow coating and externally coated with anti-corrosion coating before they are transported to weight-coating plants in Kotka in Finland and Sassnitz-Mukran in Germany, where weight-coating will be applied. The locations of the weight-coating plants are shown in Figure 4.24.

Pipes for the north-west pipeline will be manufactured by Europipe, Germany (75%), and OMK, Russia (25%), as result of an international tendering process. Manufacturing contracts for the south-east pipeline have not yet been awarded. Due to the large diameter and wall thickness of the pipes only a few pipe fabrication sites worldwide are capable of producing them.

The majority of the pipes will be transported directly by train from the manufacturing sites to the weight-coating plants. Train deliveries (for the north-west pipeline) to Kotka began in June 2008 and will continue until October 2009. Deliveries for the south-east pipeline will take place from January 2010 to March 2011. Trains with pipes will arrive at Sassnitz-Mukran (in Germany) continuously from May 2008 to December 2011 (so far estimated for both pipelines).

A small portion of the pipes produced in Germany (corresponding to 34 shiploads, or 10% of the pipeline length) will be transported by ship from Bremen or Mukran to Kotka. The load-ins at Kotka will take place from October 2008 to March 2009 for the north-west pipeline but have not yet been determined for the south-east pipeline.

Materials for the concrete coating, such as cement and aggregate, will also be supplied to the weight-coating plants from mainly local sources and transported by train. Iron ore will be transported by ship, such as the example shown in Figure 4.20. Cement and aggregate will be

Figure 4.20  Typical vessel for iron ore transportation (MS Splittnes)

Iron ore will be transported from Narvik in Norway to Kotka with large cargo ships. Deliveries to Sassnitz-Mukran will be directly with mid-sized cargo ships. Alternatively, it is possible to deliver iron ore with large cargo ships to Rostock where it will be reloaded into small vessels. The harbour in Rostock has facilities to store the iron ore, if necessary. It is anticipated that the total load-in to Kotka from ships will amount to 10 vessels and the load in to Sassnitz-Mukran will amount to 35 vessels (total for both pipelines).

All line pipes will be stored in stockyards close to the weight-coating plants and subsequently transported to the plants, where the steel cage reinforced concrete weight-coating will be applied. Figure 4.21 shows the first stock of pipes at the Kotka site.
After coating, the line pipes will be stored again, close to the weight-coating plants. From here, they will be transported directly to the lay vessel or to the interim stockyards in Finland and Sweden, which are closer to the middle section of the pipeline route to minimise the sailing distances to the pipe-laying vessels.

4.4.3 Weight-coating Plants and Interim Stockyards

The choice of locations for the weight-coating plants and interim stockyards (see Figure 4.24) was based on thorough analysis of a wide range of factors to minimise onshore and offshore transportation requirements, thereby minimising environmental impacts.

Nord Stream AG and its contractors finally selected five locations from a short-list of 68 harbours located throughout the Baltic Region. The feasibility of these harbours was then evaluated based on factors such as distance to pipe-fabrication sites, train connections and other infrastructure, water depth in the harbour, other industrial use of the site and distance to the pipeline route, mainly to reduce transportation distances on all levels.

Modification of the harbour areas will be performed by local contractors. The construction of the weight-coating plants and associated infrastructure has been assigned to EUPEC, a French company with more than 40 years experience in pipe coating.

EUPEC will also run both the Kotka and the Sassnitz-Mukran weight-coating plants, and their scope of work will include interim trans-shipment and handling and storage of pipes across the Baltic region. The planned logistical processes may be optimised by EUPEC if necessary, e.g., in case of:

- Hard winters (ice)
- Breakdown of equipment
- Shortage of supplies
The weight-coating plants will also be used as stockyards for pipes before and after concrete coating. The layout of the combined weight-coating plant and stockyard in Sassnitz-Mukran is shown in Figure 4.22.

![Figure 4.22 Planned weight-coating plant and interim stockyard at Sassnitz-Mukran in Germany](image)

The weight-coating plants and adjacent stockyards in Kotka and in Sassnitz-Mukran will occupy an area of 35 hectares and 50 hectares, respectively. The weight-coating plants will apply coating to about 100,000 pipes per pipeline. It is anticipated that Kotka will have a total production capacity of 35,000 pipes for the north-west pipeline, whereas Saasnitz-Mukran will have a total production capacity of 65,000 pipes. The production capacity will be approximately 1,000 pipes per week. The tendering for the outstanding amount of line pipes for the south-east pipeline will be carried out at a later stage in the project.

As mentioned earlier, weight-coated line pipes for construction of the middle section of the pipelines will be transported to interim stockyards by coaster vessels for logistical reasons. The planned locations of the interim stockyards will be:

- Hanko area in Finland
- Slite (Gotland) in Sweden
- Karlskrona in Sweden

The location of the stockyards is shown in Figure 4.24.
An overview of the pipe shipments between the weight-coating plants and the stockyards is shown in Table 4.10.

Table 4.10  
Expected load in and load out periods for the weight-coating plants (Kotka and Sassnitz-Mukran) and stockyards (Hanko, Slite and Karlskrona)

<table>
<thead>
<tr>
<th>Location</th>
<th>North-west pipeline</th>
<th>South-east pipeline</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load in period</td>
<td>Load out period</td>
</tr>
<tr>
<td></td>
<td>Start</td>
<td>End</td>
</tr>
<tr>
<td>Kotka</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15 Nov</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>20 Dec</td>
<td>2010</td>
</tr>
<tr>
<td>Hanko</td>
<td>1 Oct</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slite</td>
<td>1 Jul</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>31 Oct</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>29 Mar</td>
<td>2011</td>
</tr>
<tr>
<td></td>
<td>1 Jun</td>
<td>2012</td>
</tr>
<tr>
<td>Karlskrona</td>
<td>1 May</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>15 Aug</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>20 Aug</td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mukran</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
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</tbody>
</table>

The weight-coated pipes will be loaded out from the coaster vessels into the stockyard by mobile harbour cranes. Handling of pipes in the stockyards will be carried out by cranes, front loaders, reach stackers and trucks. Harbour cranes will reload the pipes from the stockyards to the pipe-carrier vessels. Different types of equipment for moving line pipes are shown in Figure 4.23.
4.4.4 Offshore Pipe Supply

Figure 4.24 shows the locations of the weight-coating plants and stockyards. The distance from the weight-coating plants and stockyards to the pipe-laying vessel is <100 nautical miles (nm) at all times. This has been found to be the most optimal solution since this is the distance that one pipe-supply vessel can travel per day on a roundtrip from the stockyard to the lay vessel and back. This means that only three pipe-supply vessels will be needed to bring pipes to the lay vessels in a reasonable time as long as the maximum sailing distance of 100 nm is maintained.
Figure 4.24 Location and perimeter of operations (approximately 100 nautical miles) for the two combined weight-coating plants and stockyards (Kotka and Mukran-Sassnitz) and the three interim stockyards (Hanko area, Slite and Karlskrona)

Based on the operation radius of the different stockyards, the logistics of pipe supply will follow the schedule illustrated in Figure 4.25 below.

Figure 4.25 is valid only for the north-west pipeline, both landfalls and a contingency. The outstanding scope of work (i.e., the offshore part of the south-east pipeline) is not included.
Figure 4.25 Pipe-supply logistics. The specifications refer to percentages of the total length of the offshore pipeline (~1,222 km). The drawing considers line pipe for the north-west pipeline only, both landfalls and a contingency. Line pipe for the remainder of the south-east pipeline is not included.

For construction of the north-west pipeline, the load out from Kotka to Hanko will be 22,700 pipes and the load out to Karlskrona and Slite from Sassnitz-Mukran will be 52,700 pipes. The load out corresponds to approximately three coaster vessel per day from the weight-coating plants during pipe-laying periods. The average load of a pipe-carrier is approximately 250 pipes per trans-shipment.

The load out directly to the lay vessels will be about 24,600 pipes from both Kotka and Sassnitz-Mukran (12,300 each). Different sizes of pipe-supply vessels will be used depending on the lay vessel. For the Saipem Castoro Sei in Figure 4.26, pipe-supply vessels with a capacity of approximately 80 pipes will be used. For the lay vessel Solitaire, which is planned to be used in the Gulf of Finland, larger pipe carriers with a capacity of approximately 250 pipes will be used.

For more information regarding lay vessels, please refer to Section 4.5.4 on pipe-laying.
4.4.5 Transportation of Rock Placement Material

Material for pre-lay rock placement (see section 4.5.2 on seabed intervention works) will be extracted from a quarry in the Kotka area. A quarry in this area is preferred, because the majority of rock material required for the Nord Stream pipeline will be used for seabed intervention works in the Gulf of Finland.

The crushed rock will be transported from the quarry to the nearby port where it will be stored before load out. The rock will be placed on the seabed by fall pipe vessels that are able to place the rock very accurately on the seabed through the use of fall pipes. For pre-lay works for both pipelines, the Tideway Rollingstone and the Boskalis Seahorse (Figure 4.27) or Sandpiper may be used.

The contractor for the rock supply logistics for the pre-lay will be a joint venture between the companies Tideway JV and Boskalis Offshore. These companies have experience from other major offshore construction works, including projects in Russia and the Øresund Link between Copenhagen and Malmö.

Contracts for the post-lay works have not yet been awarded.
4.5 Construction

This chapter describes the activities that will take place during construction of the Nord Stream pipeline. Activities include:

- Surveying (to gather specific information on the pipeline corridors)
- Seabed intervention works (to ensure that the pipelines have a stable foundation on the seabed)
- Construction activities at the landfalls in Germany and Russia
- Crossings of existing offshore cables, including pre-lay preparations
- Offshore pipe-laying
- Tie-in (coupling) of the different offshore sections

The main contractor for the construction of the Nord Stream pipelines will be Saipem UK Ltd of the Eni Group. Dry sections and tie-ins are included in the scope of work, and it is intended that Saipem will manage all sub-contractors.

4.5.1 Route, Engineering and Construction Surveys

Several marine surveys have been and will be conducted in connection with the Nord Stream pipeline to gather specific information on seabed conditions, topography, bathymetry and
objects such as wrecks, boulders, ordnance, etc. This information has been and will be used for route planning, detailed design and assessment of installation methods. The following chapters provide a short overview of the surveys that already have been performed and the surveys that will be performed before, during and after installation of the pipeline.

The surveys have been concentrated around three different corridors:

- **Anchor corridor (+/- 1 km on either side of the specified route alignment).** Within this corridor, anchors from the lay vessel may be laid during installation of the pipeline.

- **Installation corridor (+/- 7.5 m on either side of the specified route alignment).** This corridor is based on the specified installation tolerance for normal pipe-lay defined in the contract with the installation contractor (also refer to Chapter 5.5.1 on Risk Assessment).

- **Security corridor (+/- 25 m either side of the specified route alignment).** This corridor is based on the effects of underwater explosion on the pipeline, e.g. due to munitions on the seabed. The corridor width has been based on engineering analyses of munitions types found in the Baltic Sea and the distance at which an explosion can cause damage to the pipeline. The analyses have performed by the design contractor and verified by the certifying authority (also refer to Chapter 5.5.1 on Risk Assessment).

**Surveys Performed for Detailed Design**

The following surveys have been performed in order to facilitate detailed design.

*Reconnaissance survey*

A reconnaissance survey was carried out by PeterGaz in 2005 to facilitate selection of the preliminary pipeline route based on information on geological and anthropogenic features. A 2 km wide corridor was surveyed with full geophysical spread. The objectives were:

- To establish seabed topography, shallow geological model and identify active geomorphological processes in the area

- To identify and map potential geological features, environmental constraints, anthropogenic remains (cultural heritage, munitions, debris) and third-party infrastructure that have the potential to influence pipeline design and long-term integrity

*Engineering, geophysical and geotechnical survey*

Engineering, geophysical and geotechnical surveys were performed during 2004 to 2008 to provide the required data to optimise the pipeline route and detailed pipeline design (including the seabed intervention measures required to ensure the long-term integrity of the pipeline system). These surveys are still ongoing (December 2008). The objectives are/were:
• To refine the seabed topography and shallow geological model along the selected route

• To refine the accuracy and information on anthropogenic remains and on the configuration of third-party infrastructure

• To perform a detailed assessment of soil types and their variability, definition of the soil characteristics in terms of geotechnical parameters for detailed design, including the assessment of pipeline/seabed interaction (pipeline stability, embedment and pipeline on-bottom configuration), foundation of rock berms to be installed as pre-lay or post-lay intervention, assessment of trenchability and the soils' chemical properties

The geophysical surveys and geotechnical investigations were conducted through several steps following the route adjustment and optimisations. Nominally 250 m wide corridors were investigated with geophysical equipment and geotechnical sampling was performed along the pipeline centre line.

*Munitions screening survey*

Munitions from World War I, World War II and other conflicts in the Baltic region were dumped in the Baltic Sea. A munitions screening survey has been performed to identify the presence of potentially unexploded munitions and/or chemical warfare agents in the installation corridor. Such munitions could constitute a danger for the construction workers, the pipeline and the environment during the installation works and the operational life of the pipeline system. The survey objectives were:

• To identify and map targets that may represent potential munitions and may have the potential to influence pipeline design, installation and long term integrity

• To perform a visual inspection of targets and classification to identify potential munitions

• To integrate anomalies and objects identified and targets from previous investigations and correlation with public domain data

*Other surveys*

In addition to the surveys already mentioned, cultural heritage surveys and numerous environmental field investigations (including sampling of water, seabed sediments, plankton (phyto- and zooplankton), macrozoobenthos (seabed fauna), fish and surveys of marine mammals and birds) have been carried out in the period from 2005-2008.

An overview of the overage of the different surveys that have been performed during the engineering and munitions screening surveys are shown in Figure 4.28.
Surveys to be Performed Prior to Construction

These surveys will be performed prior to commencement of the construction works. The surveys are currently scheduled to be performed during the permitting process.

Anchor corridor survey

Prior to the installation of the Nord Stream pipelines, an anchor corridor survey will be undertaken to identify and catalogue obstructions within the lay-vessel anchor corridor. The survey will mainly be conducted in a 1 km wide corridor to each side of the route alignment. In shallower waters (less than 100 m), the survey corridor will be reduced to 800 m. The anchor corridor survey started on 15th of November 2008 and will be finished by September 2009.

The objectives for the anchor corridor survey are:

- To map potential hazards to anchoring and the environment and provide the basis for an anchoring risk assessment
- To identify hazards such as potential munitions, anthropogenic debris, geological features, obstructions and existing infrastructure
- To identify and map areas and features of cultural heritage to be safeguarded
The anchor corridor survey will comprise four phases as follows:

Phase 1: Geophysical survey
- Bathymetric survey in a 2x2 m grid
- Sidescan sonar survey, frequency 600 kHz, 75 m range, 50 m line spacing in high risk sections of the route (extending from Finnish Russian boarder to approx. KP 395)
- Sidescan sonar survey, frequency 300 kHz / 600 kHz, 125 m range, 100 m line spacing in the lower risk sections of the route. In the event that potential munitions are located additional infill lines at 50 m spacing will be performed
- Towed magnetometer survey using a caesium single-sensor magnetometer
- Evaluation of targets and development of initial anchoring philosophy

Phase 2: Visual inspection
- ROV based visual inspection of cultural heritage and suspected anthropogenic objects (munitions, barrels, general debris)
- Evaluation of results and refinement of anchoring philosophy

Phase 3: ROV based gradiometer survey
- In discrete critical areas magnetometer survey will be performed utilising an ROV based gradiometer array survey will be performed

Phase 4: Expert evaluation of survey findings
- Review of video inspections by marine warfare experts to correlate survey findings to munitions deployed within the Baltic Sea

Where munitions, cultural heritage and other potentially dangerous debris are identified, anchor exclusion zones will be established. The installation contractor will then develop anchor patterns and procedures to ensure that the areas of concern are not impacted by the anchors or the sweep of the anchor wires. In critical sections the anchor patterns will be submitted to the relevant authorities. This is further described in Section on Anchor Corridors and Anchor Handling.

The anchoring procedures will be risk assessed as far as the potential risk to safety and environment. Based on the results of the risk assessment various mitigation measures will be
developed. These may include the use of buoyancy on the anchor wires, 'live anchors' i.e. tugs rather than placing the anchors on the seabed or munitions clearance.

**Munitions clearance**

As a result of the munitions survey already performed for the installation corridor, munitions have been identified on locations in Russia, Finland and Sweden. It is anticipated that more munitions will be identified during the anchor corridor survey. All munitions identified within the 50 m wide security corridor will be cleared, whereas all munitions identified within the anchoring corridor will be cleared if deemed necessary following expert assessment by the installation contractor as described above in the anchor corridor survey scope.

Over the last decade, the collective navies of the Baltic States have developed methods that are both safe and effective for the clearance of mines and other explosive underwater ordnance on the seabed of the Baltic. These methods have also been used by other national navies around the world to dispose of ordnance in past theatres of warfare. The basic principles of the method involve placing a small charge next to the identified live or suspected live ordnance on the seabed using a small, specially developed ROV. These charges are then detonated from a surface support ship located at a safe distance from the target.

Each type and model of mine will be identified and confirmed during the pre-detonation inspections. The amount of explosive material contained within the munitions will be determined based on historical data. The appropriate amount of charge necessary to detonate the mine in situ while minimising impact on the surrounding area shall be calculated in accordance with standard procedures. The main objective of the clearance operations is to clear ordnance that pose a threat to pipeline installation or that may have a future detrimental impact on seabed conditions and environment. It is envisaged that the clearance will be performed in two phases, firstly the security corridor, followed by selected munitions within the anchor corridor.

A clearance plan will be developed in close conjunction with relevant national authorities. The clearance plan will:

- Identify hazards and any conditions requiring extraordinary mitigation measures
- Provide procedures for the clearance of the munitions with individual processes identified for each munitions type
- Apply appropriate mitigation with emphasis on the surrounding environment
- Provide marine mammal observation and fisheries liaison personnel
- Provide the lines of communication with the relevant authorities and interested parties
Include the necessary survey and monitoring to demonstrate that clearance operations have been successful.

**Surveys to be Performed in Relation to Construction**

The following surveys will be performed in direct relation to the construction works.

**Pre-lay survey**

A pre-lay survey will be performed just prior to the commencement of construction work. The scope of the pre-lay survey is to confirm the previous route survey and to ensure that no new obstacles are found on the seabed. A pre-lay survey comprises:

- ROV-based bathymetric survey to establish seabed conditions prior to seabed intervention works. Such surveys will be performed along the pipeline route to and from the theoretical touchdown points at both ends of the proposed rock berm
- ROV-based bathymetric survey including intervention and adjacent shoulders, i.e., theoretical touchdown points where the pipeline will be in contact with the natural seabed
- ROV-based bathymetric surveys to establish the extent of berm settlement and the necessity of additional rock placement prior to pipeline installation
- ROV-based pre-lay visual inspection survey

**Construction support survey**

Full survey capability will stand by to perform any ad hoc survey activities that may arise during pipeline construction. It will comprise:

- Full geophysical spread: multibeam echosounders, sidescan sonars, sub-bottom profilers and magnetometers
- ROVs for visual inspection work

**As-laid survey**

To document the pipe-laying, an as-laid survey will be performed once the pipelines have been laid on the seabed by the pipe-laying vessel. The survey will establish the as-laid position and condition of the pipelines and will comprise:

- Bathymetry and side-scan sonar measurements
- Visual inspection by ROV
**As-built survey**

As a final documentation of the pipeline installation, an as-built survey will be conducted. It will be carried out after seabed intervention, trenching, rock placement, etc., i.e., after the pipelines have been completed. The survey will demonstrate that the pipelines have been installed correctly. Therefore, it must establish that the required trench depth has been achieved, the extent of backfill and rock placement is as designed, and that the integrity of the pipelines has been maintained. The survey typically includes a visual inspection of the pipeline by ROV.

A typical survey vessel and an ROV are depicted in **Figure 4.29**.

![Typical survey vessel and ROV](Image)

**Figure 4.29** Typical survey vessel, the Saipem *Grampian Surveyor* (left) and ROV ready for launch (right). Photos by Saipem S.p.A

### 4.5.2 Seabed Intervention Works

Seabed intervention works comprises the 'earthworks' undertaken on the seabed to protect the pipelines against failure and to minimise impacts on the environment and human activities. The interventions entail various methods for achieving a more level foundation for the pipelines. A level seabed allows the pipeline to be installed within acceptable limits for span lengths, pipe stresses and off-bottom clearances.

Seabed intervention works will take place before and after pipe-laying. During the engineering phase, the requirements for protection of the pipelines will also be considered. First, this chapter describes the general reasons and requirements for seabed intervention works and the methods that may be used. It then describes the locations and methods of seabed intervention works to be used in the five countries of origin.
Requirements and Alternatives for Seabed Intervention Works

Once the pipelines are laid, the pipe wall thickness and concrete coating will provide substantial protection of the pipelines. However, the pipelines will have varying needs for additional protection along the route to avoid:

- Stress due to free-span development caused by an uneven seabed
- Excessive movement due to hydrodynamic loading
- Excessive movement (lateral and upheaval buckling) due to compressive pipeline loading
- Impacts from shipping traffic
- Impacts from fishing gear, e.g., trawls

In areas where one or more of these factors are possible, this additional protection usually is achieved by trenching the pipelines into the seabed or by rock placement.

As a point of departure, hydrodynamic stability is ensured by adequate concrete weight coating. The required coating thickness for hydrodynamic stability ranges from 60 mm up to a maximum possible thickness of 110 mm, depending on location.

Acceptable span lengths and heights depend on the structural parameters of the pipelines, the soil conditions, waves and currents. The areas with non-allowable freespans along the pipeline route as per DNV RP F105 on freespanning of pipelines (see Section on Codes and Standards) have been identified from the bathymetrical/geophysical surveys. In some areas along the pipeline route, the sea bottom is rough. Outcrops of hard till or crystalline bedrock with sedimentary deposits between the outcrops pose difficulties to pipeline installation, insofar as the pipelines may ‘ride’ from crest-to-crest of the harder outcrops and sag in the middle. The pipelines may be stressed excessively in these sections if the seabed is not properly prepared prior to pipeline installation.

Studies of the type and size of fishing gear used in the Baltic Sea have been carried out and indicate that fishing gear is unlikely to inflict serious damage to the pipelines. The pipeline has been designed to withstand impacts from trawl boards up to 3,000 kg as per DNV RP F111 on interference between trawl gear and pipelines (see Section on Codes and Standards).

To ensure the integrity of the pipelines, the following methods in general are considered technically feasible:

- Re-routing of pipelines
- Peak removal (dredging away hard outcrops or ‘crests’)
• Placement of fill material, rock placement
• Trenching, dredging and backfilling
• Placement of prefabricated support structures

In general, the seabed intervention works for the entire pipeline will be carried out in three phases:

• Phase 1 – pre-lay (performed before pipe-laying)
• Phase 2 – post-lay (performed before pressure-testing)
• Phase 3 – post-lay (performed after pressure-testing to prevent in-service buckling/fatigue)

Seabed intervention works are defined depending on the phase of construction during which they take place:

• Pre-lay works for statics: intervention works carried out before pipe-laying for stress/freespan correction (to reduce overstress in the different load conditions due to long freespans caused by seabed unevenness)
• Post-lay works for statics: the purpose of these works is the same as for the pre-lay works, but they are carried out between the pipe-laying and pressure-testing phases
• Post-lay works for fatigue: these intervention works are carried out after pipe-laying for stress/freespan correction (to reduce fatigue damage)
• Post-lay works for in-service buckling: These intervention works are required in the Russian section to prevent buckling of the pipeline (lateral and upheaval)

Intervention works, such as rock berms, are designed as those typically used in the North Sea where there is active fishing activity. Therefore, the rock berms themselves will be overtrawlable. It should be noted, however, that in areas where the seabed profile is irregular the pipeline will not be in continuous contact with the seabed. In these areas, the pipelines most likely will not be overtrawlable due to the presence of freespans exceeding the critical height of typically being 0.5 m. Therefore, in these sections permanent restrictions for fishing across/along the pipelines may be requested for safety reasons. Unacceptable freespans can also develop during the operations phase of the pipelines. If this occurs, it may be requested to implement temporary restrictions for fishing until these freespans have been rectified. The inspection and required maintenance of the rock berms will take place at specific intervals throughout the operations phase (see also Section on External Inspection Surveys).
Temporary fishing restrictions will also be required during installation operations due to the presence of pipe-laying and rock placement vessels.

**Trenching**

Trenching methods are distinguished as ‘pre-trenching’ methods (a trench is excavated before pipe-laying) and ‘post-trenching’ methods (the pipeline is sunk into a trench made after pipe-laying). The preferred trenching method for the Nord Stream pipeline is post-trenching by ploughing.

*Pre-trenching*

Pre-trenching by dredging (underwater excavation) may be carried out in the near-shore areas in Germany and Russia because of low water depth and the required burial depth of the pipelines. In the German area, the pipelines will be covered for protection against anchoring ships and grounding ships, in compliance with authority requirements, and to ensure on-bottom stability.

Dredging in shallow areas will be carried out by mechanical equipment. The types of dredgers that may be used are backhoe dredgers, trailing suction hopper dredgers, bucket ladder dredgers and grab dredgers. Backhoe dredgers are most suited to the excavation of near-shore trenches. Re-dredging and reinstatement will be achieved optimally by using trailing suction hopper dredgers or split barges. Final selection of equipment will be based on soil conditions and minimising the environmental impact of intervention works.

**Figure 4.30** shows an example of a hydraulic backhoe dredger and a small trailing suction hopper dredger.
Figure 4.30  Hydraulic backhoe dredger (left) and trailing suction hopper dredger (right)

Post-trenching

Post-trenching is the most widely used trenching method, for environmental and economic reasons. Post-trenching requires excavation only immediately underneath a pipeline, whereas pre-trenching involves excavation over a much larger width to allow for installation tolerances. With pre-trenching, there is also a risk of natural backfilling before pipeline installation.

Post-trenching will be carried out by ploughing. The removed material will be left on the sea bottom, and the trench will not be backfilled. However, partial, natural backfilling will occur due to currents.

Figure 4.31  Pipeline plough PL2 on a support vessel (left) and in operation on the seabed (right)
Ploughing will be carried out using a pipeline plough (as shown in Figure 4.31) deployed onto the seabed from a mother vessel above the pipeline. The pipeline will then be lifted by hydraulic grippers into the plough and supported on rollers at the front and rear ends of the plough. The rollers will be equipped with load cells to control the loading onto the pipeline during trenching. Towlines will be connected to the plough. Between one and three tugboats are used to pull the plough through the seabed, producing the trench.

Trenching by pipeline plough requires a mother vessel with an A-frame for launching and retrieving the plough. The mother vessel will also hold all control systems for the plough. An example of such a vessel is the Saipem Far Sovereign, shown in Figure 4.50 in Section 4.5.4.

Post-lay trenching can only be carried out at water depths of minimum 15 to 20 m and only up to a depth of 1.5 m.

Backfilling of pipeline trench

Natural backfilling of the trench, i.e., by sediment movements due to waves and currents, will be allowed to cover some sections of the pipelines. However, forced or artificial backfilling will be required in areas where active protection will be necessary. At the landfalls in Russia and Germany, the pipelines will be buried entirely in the seabed to ensure that coastal sediment-transport mechanisms will not affect their stability. If dredging is used to make the trench, the material will be removed, stored temporarily and used for backfill.

Rock Placement

‘Rock placement’ is the use of coarse gravel and small stones to locally reshape the seabed, thereby providing support for the pipeline to ensure its long-term integrity. Rock placement may also be complimented by the installation of concrete mattresses at selected locations, see examples in Figure 4.43 in Section 4.5.5.

Figure 4.32 shows a specialised rock placement vessel and a fall pipe during rock placement at the seabed.
Gravel and stones will be transported by the fall pipe vessel to each position where rock placement is required. The rock material will be loaded into the fall pipe by conveyors on the ship. The rock material will fall through the fall pipe, which runs through the water column. The geometry of each gravel support will be carefully designed by the engineers to minimise the amount of gravel to be used. The shape of the gravel filling will depend on seabed conditions (type and bearing capacity of the sediment), local bathymetry and currents, etc. The lower end of the fall pipe is equipped with nozzles to allow very precise shaping of each gravel support. The rock-placement process will be supervised by survey equipment mounted to the end of the fall pipe, and the final geometry will be verified by surveying.

Gravel works are primarily required as follows:

- Gravel supports for freespan correction (pre-lay and post-lay)
- Gravel cover (post-lay) for additional stabilisation of the pipeline after pipe-laying (for certain sections)
- Gravel basement at KP 300 and KP 675 where pipe sections are welded together (tie-in)
- Gravel supports for cable crossings

In principle, rock placement of the pipelines above the seabed may also be considered a means to provide local protection from dropped or dragged anchors and to some extent from extent ship grounding. However, the bulk of rock placement activities will be performed to restrict stress due to freespan development and to ensure local dynamic stability.

The rock material must be chemically and mechanically stable for the entire lifetime of the pipeline. Unweathered, virgin rock of basalt, gabbro or granite type will be used. The average
size of the rock material will be 50 mm but range from 20-100 mm. Material for rock placement will be extracted from quarries on land. It is a prior condition that the material used must not contain any contaminants, such as heavy metals, that can be dissolved in the brackish water environment of the Baltic Sea.

Rock for pre-lay works may be rapakivi granite (also known as ‘Baltic Brown’), which will be extracted from a quarry in the Kotka area (see also Section 4.4.5). However, when the fall pipe vessels are being mobilised to the Baltic Sea, they may come with a full load of Norwegian rock. At this stage of the project, the extraction site for post-lay works is undecided.

**Special Support Structures**

Geotechnical stability issues may occur in areas with sloping seabed or with soft clay with low bearing capacity. In these areas, additional rock placement will be carried out as counter-fill around the required rock berms, as shown in Figure 4.33.

![Figure 4.33 Counter-fill (red and blue) for additional stability under rock berms (orange)](image)

However, under certain difficult conditions, e.g., when the natural seabed has a very low bearing capacity, the amount of counter-fill required becomes rather large. At certain locations, gravel dumping to ensure stability will not be feasible because the load of the rock will exceed the bearing capacity of the soil beneath it. Under these circumstances, alternative solutions must be introduced. This will be necessary at certain locations in the Gulf of Finland (Russian EEZ). As mentioned earlier, the seabed in the Gulf of Finland is extremely rough, and relatively extensive pipeline support will be required to limit freespans. This area is also characterised by very soft clays with low bearing capacity. In addition, the load of the pipelines, especially during pre-commissioning, will be highest along the route in this particular area.
Therefore, in spite of all efforts to re-route the pipelines, support structures alternative to rock berms will be required at three locations on the north-west pipeline and at five locations on the south-east pipeline in the Russian EEZ.

The following construction methods for support structures are described below:

- Rigid mud-mats
- High-density polyethylene (HDPE) pipes
- Foam bricks
- Steel frame on rigid mud-mats

Light, rigid mud-mats covered by gravel will be used as shallow pipeline supports. Two solutions are shown in Figure 4.34.

In the figure, the berm on the left is installed before pipe-laying. A number of light-weight, high-density polyethylene (HDPE) pipes filled with foam are fixed on top of a rigid mud-mat. This structure is then covered by a gravel layer, on top of which the pipeline is laid.

The berm on the right also includes foam-filled HDPE pipes on top of a rigid mud-mat, all of which is covered by a layer of gravel. The gravel support around the pipeline is installed after pipe-laying.

![Figure 4.34 Pre-lay (left) and post-lay (right) support structures constructed of rigid mud-mats, foam-filled HDPE pipes and gravel](image)

If a higher support is needed, a light structure of HDPE pipes (Figure 4.35, left) can be built to ensure, to the greatest possible extent, that the bearing capacity of the seabed is used for the load of the pipeline and not for the weight of the support structure itself.
Figure 4.35  Support structures constructed of HDPE pipes (left) and foam bricks (right)

The core of the support structure may be covered by a gravel layer as shown in Figure 4.36 (left).

Figure 4.36  Gravel-covered support structure (left) and support structure constructed of a rigid mud-mat base with a steel structure and HDPE pipes on top (right)

As an alternative, a light and deep support structure, comprised of a steel frame on a rigid mud-mat, can be constructed (Figure 4.36, right). The required flexibility of the support is achieved by covering the steel frame with a bearing plate with a light 'mattress', e.g., HDPE pipes.

During detailed design the necessity of support structures will be further evaluated.

Overview of Seabed Intervention Works

The extent of anticipated seabed intervention works (October 2008 status) are summarised in the following figures and tables. It should be noted that volumes may change slightly during the final detailed design phase.
Russia

In Russian waters, both pipelines (north-west and south-east) are characterised by a high value of longitudinal compressive force due to high temperature and pressure loads. For this reason, there is a risk that in-service buckling (ISB) phenomena (both lateral buckling, causing a pipeline to snake sideways, and upheaval buckling, causing a pipeline to move upward and lose contact with the sea bottom) could occur. The ISB and could cause over-bending of the pipeline or critically long freespans with high clearance (vertical distance between bottom of pipe and the sea bottom). To mitigate ISB, gravel will be dumped over long sections and in appropriate locations to limit potential critical displacement and, therefore, potential overstress. ISB is not anticipated along the other pipeline sections. Because of ISB phenomena, the total gravel amount for the Russian section is higher than that of the other countries.

An overview of the locations and types of intervention works to be carried out in Russian waters is presented in Figure 4.37.

Table 4.11 shows the amount of gravel required for rock placement and support structures in Russian waters. Table 4.12 shows the size distribution of rock placement and support structures in Russian waters. Dredging volumes are shown in Table 4.18.
Figure 4.37  Overview of types and locations of seabed intervention works in Russian waters. The light green dots indicate the pre-lay works (Phase 1); the dark green dots indicate the post-lay works for statics (Phase 2); the blue dots indicate the post-lay works for fatigue (Phase 3) and the red dots indicate the special support structures. The orange line at the landfall indicate the pre-lay dredging and the yellow lines indicate post-lay works for in-service buckling (Phase 3). Locations are approximate and subject to final optimisation.
Table 4.11  Summary of gravel volumes for rock placement and support structures in Russian waters. Quantities are approximate and subject to final optimisation

<table>
<thead>
<tr>
<th></th>
<th>Gravel volume (m$^3$)</th>
<th>Support structures</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>South-east pipeline</td>
<td>North-west pipeline</td>
</tr>
<tr>
<td>Pre-lay works (Phase 1)</td>
<td>31,450</td>
<td>32,956</td>
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<tr>
<td>Post-lay works for statics (Phase 2)</td>
<td>45,580</td>
<td>37,796</td>
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<tr>
<td>Post-lay works for fatigue (Phase 3)</td>
<td>12,578</td>
<td>15,010</td>
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<tr>
<td>Post-lay for mitigation of ISB (Phase 3)</td>
<td>556,801</td>
<td>572,573</td>
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<tr>
<td>Total</td>
<td>646,409</td>
<td>658,335</td>
</tr>
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</table>

Table 4.12  Summary of size distribution of rock placement and support structures in Russian waters. Quantities are approximate and subject to final optimisation

<table>
<thead>
<tr>
<th>Number and size of rock placement locations</th>
<th>South-east pipeline</th>
<th>North-west pipeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-lay works (Phase 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;500 m$^3$</td>
<td>6</td>
<td>7</td>
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<tr>
<td>500 – 5000 m$^3$</td>
<td>15</td>
<td>16</td>
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<tr>
<td>Total</td>
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<td>23</td>
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<tr>
<td>Post-lay works (Phase 2)</td>
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<td>&lt;500 m$^3$</td>
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<td>42</td>
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<tr>
<td>500 – 5000 m$^3$</td>
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<td>&gt; 5000 m$^3$</td>
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<tr>
<td>&gt; 5000 m$^3$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>33</td>
<td>35</td>
</tr>
<tr>
<td>Total number of rock placement locations</td>
<td>124</td>
<td>123</td>
</tr>
</tbody>
</table>
Finland

An overview of the locations and types of intervention works to be carried out in the Finnish EEZ is presented in Figure 4.38.

A summary of required gravel volumes for rock placement and support structures in the Finnish EEZ is shown in Table 4.13. The size distribution of rock placement and support structures in the Finnish EEZ is shown in Table 4.14.

No support structures are anticipated in the Finnish EEZ.

The gravel volume for on-bottom stability will be only a low percentage of the total gravel volume. Therefore, no figures for gravel volumes for on-bottom stability are presented in Table 4.13. Table 4.18 shows trenching volumes in the Finnish EEZ.
Overview of types and locations of seabed intervention works in the Finnish EEZ. The light green dots indicate the pre-lay works (Phase 1); the blue dots indicate the post-lay works for statics (Phase 2) and the purple dots indicate the post-lay works for fatigue (Phase 3). The orange dots indicate post-lay for on-bottom stability (Phase 3) and the pink dot indicate the tie-in basement (Phase 1). Locations are approximate and subject to final optimisation.

Summary of gravel volumes for rock placement and support structures in the Finnish EEZ. Quantities are approximate and subject to final optimisation.

<table>
<thead>
<tr>
<th>Support structures</th>
<th>Gravel volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>South-east pipeline</td>
</tr>
<tr>
<td>Pre-lay works (Phase 1)</td>
<td>5,782</td>
</tr>
<tr>
<td>Post-lay works for statics (Phase 2)</td>
<td>50,567</td>
</tr>
<tr>
<td>Post-lay works for fatigue (Phase 3)</td>
<td>26,225</td>
</tr>
<tr>
<td>Post-lay for on-bottom stability (Phase 3)</td>
<td>972</td>
</tr>
<tr>
<td>Number and size of rock placement locations</td>
<td>South-east pipeline</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Pre-lay works (Phase 1)</td>
<td></td>
</tr>
<tr>
<td>&lt;500 m³</td>
<td>5</td>
</tr>
<tr>
<td>500 – 5000 m³</td>
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</tr>
<tr>
<td>&gt; 5000 m³</td>
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</tr>
<tr>
<td>Post-lay works (Phase 2)</td>
<td></td>
</tr>
<tr>
<td>&lt;500 m³</td>
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</tr>
<tr>
<td>500 – 5000 m³</td>
<td>22</td>
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<tr>
<td>&gt; 5000 m³</td>
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<tr>
<td>Post-lay works (Phase 3)</td>
<td></td>
</tr>
<tr>
<td>&lt;500 m³</td>
<td>24</td>
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<td>500 – 5000 m³</td>
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<td>&gt; 5000 m³</td>
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<tr>
<td>Total</td>
<td>38</td>
</tr>
<tr>
<td>Total number of rock placement locations</td>
<td>83</td>
</tr>
</tbody>
</table>

**Table 4.14** Summary of size distribution of rock placement and support structures in the Finnish EEZ. Quantities are approximate and subject to final optimisation.
**Sweden**

An overview of the locations and types of seabed intervention works to be carried out in the Swedish EEZ is presented in Figure 4.39.

A summary of the required gravel volumes for rock placement and support structures in the Swedish EEZ is shown in Table 4.15 and Table 4.16 shows the size distribution of rock placement and support structures in the Swedish EEZ. Trenching volumes are indicated in Table 4.18. No support structures are anticipated in the Swedish EEZ.

![Figure 4.39](image)

**Figure 4.39** Overview of types and locations of seabed intervention works in the Swedish EEZ. The light green dots indicate the pre-lay works (Phase 1); the blue dots indicate the post-lay works for statics (Phase 2) and the purple dots indicate the post-lay works for fatigue (Phase 3). The orange dots indicate post-lay for on-bottom stability (Phase 3); the pink dot indicates the tie-in basement (Phase 1) and the purple lines indicate post-lay trenching. Locations are approximate and subject to final optimisation.
Table 4.15  Summary of gravel volumes for rock placement and support structures in the Swedish EEZ. Quantities are approximate and subject to final optimisation

<table>
<thead>
<tr>
<th>Support structures</th>
<th>Gravel volume (m$^3$)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>South-east pipeline</td>
<td>North-west pipeline</td>
</tr>
<tr>
<td>Pre-lay works (Phase 1)</td>
<td>317</td>
<td>377</td>
</tr>
<tr>
<td>Post-lay works for statics (Phase 2)</td>
<td>28,192</td>
<td>17,473</td>
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<tr>
<td>Post-lay works for fatigue (Phase 3)</td>
<td>6,145</td>
<td>3,144</td>
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<tr>
<td>Post-lay for on-bottom stability (Phase 3)</td>
<td>1,794</td>
<td>1,794</td>
</tr>
<tr>
<td>Tie-in basement (Phase 1)</td>
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<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>34,654</strong></td>
<td><strong>20,993</strong></td>
</tr>
</tbody>
</table>

Table 4.16  Summary of size distribution of rock placement and support structures in the Swedish EEZ. Quantities are approximate and subject to final optimisation

<table>
<thead>
<tr>
<th>Number and size of rock placement locations</th>
<th>South-east pipeline</th>
<th>North-west pipeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-lay works (Phase 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;500 m$^3$</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>500 – 5000 m$^3$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>&gt; 5000 m$^3$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>Post-lay works (Phase 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;500 m$^3$</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>500 – 5000 m$^3$</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>&gt; 5000 m$^3$</td>
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<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31</strong></td>
<td><strong>26</strong></td>
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<tr>
<td>Post-lay works (Phase 3)</td>
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<td>500 – 5000 m$^3$</td>
<td>5</td>
<td>2</td>
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<td>&gt; 5000 m$^3$</td>
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<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16</strong></td>
<td><strong>16</strong></td>
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<tr>
<td><strong>Total number of rock placement locations</strong></td>
<td><strong>48</strong></td>
<td><strong>43</strong></td>
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</table>
Denmark

An overview of the locations and types of seabed intervention works to be carried out in Danish waters is presented in Figure 4.40.

There will be no rock placement or support structures in the Danish EEZ. Trenching volumes are shown in Table 4.17.

Figure 4.40 Overview of types and locations of seabed intervention works in Danish waters. The purple line indicates post-lay trenching. Locations are approximate and subject to final optimisation.
Germany

An overview of the locations and types of seabed intervention works to be carried out in German waters is presented in Figure 4.41. Dredging will be required in a large part of the German sector. Dredging volumes are shown in Figure 4.18. No rock placement or support structures are anticipated in the German EEZ.

Figure 4.41 Overview of types and locations of seabed intervention works in German waters. The purple line indicates pre-lay dredging. Locations are approximate and subject to final optimisation.
Table 4.17 and Table 4.18 summarise the largest rock placement volumes (> 5,000 m³) and the largest trenching volumes along the entire pipeline route.

Table 4.17  Summary of rock placement > 5,000 m³ along the entire pipeline route. Quantities are approximate and subject to final optimisation

<table>
<thead>
<tr>
<th>Country</th>
<th>KP</th>
<th>Length (m)</th>
<th>Width (m)</th>
<th>Height (m)</th>
<th>Support (m³)</th>
<th>Counterfill (m³)</th>
<th>Volume (m³)</th>
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</thead>
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<tr>
<td><strong>Russia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>line</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-lay</td>
<td>110.0</td>
<td>5</td>
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<td>5</td>
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<tr>
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<td>15</td>
<td>3</td>
<td>4.76</td>
<td>1412</td>
<td>4,091</td>
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<td>162.9</td>
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</tbody>
</table>
Table 4.18  Summary of trenching and dredging volumes (m$^3$) along the entire pipeline route. Quantities are approximate and subject to final optimisation

<table>
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<tr>
<th>Country</th>
<th>From KP</th>
<th>To KP</th>
<th>Number km</th>
<th>Volume m$^3$</th>
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</thead>
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<td><strong>Sweden</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-lay trenching south-east pipeline</td>
<td>526.4</td>
<td>529.2</td>
<td>2.8</td>
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</tr>
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<td>529.3</td>
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<td>8,846</td>
</tr>
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<td>56,981</td>
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<td>2.6</td>
<td>28,720</td>
</tr>
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<td>531.6</td>
<td>534.1</td>
<td>2.5</td>
<td>27,300</td>
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<td>539.4</td>
<td>540.2</td>
<td>0.8</td>
<td>8,409</td>
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<td>546.0</td>
<td>550.1</td>
<td>4.0</td>
<td>44,117</td>
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<td>558.5</td>
<td>562.2</td>
<td>3.8</td>
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<td>804.2</td>
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<td>834.6</td>
<td>3.1</td>
<td>19,006</td>
</tr>
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<td>843.8</td>
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<td>888.6</td>
<td>7.1</td>
<td>43,955</td>
</tr>
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<td>927.1</td>
<td>13.6</td>
<td>84,319</td>
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<td><strong>Denmark</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-lay trenching south-east pipeline</td>
<td>1,043</td>
<td>1,058</td>
<td>15</td>
<td>93,482</td>
</tr>
<tr>
<td>Post-lay trenching north-west pipeline</td>
<td>1,043</td>
<td>1,053</td>
<td>10</td>
<td>62,528</td>
</tr>
<tr>
<td><strong>Germany</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-lay dredging</td>
<td>1,196</td>
<td>1,222</td>
<td>26</td>
<td>1,800,000</td>
</tr>
</tbody>
</table>
4.5.3 Crossing of Infrastructure (Cables and other Pipelines)

The Nord Stream pipeline will cross a number of active telecommunications- and power-transmission cables on the seabed. An overview of cables that are currently in operation is provided in Atlas Map IN-1, and an overview of cable owners can be found in Atlas Map IN-2.

The list is based on information from various published charts and through contact with cable owners. All cables and cable positions have been fixed by the surveys by interpretation of the magnetometer survey and ROV inspections. All cables indicated on nautical maps have been accounted for.

In addition to the known active cables, a number of out-of-use cables and planned/future cables have been identified on the basis of the same sources. Surveys have also identified some targets that could be cables. The out-of-use/unknowns have not been included in the lists below.

In some cases Nord Stream AG has been informed from others that there are plans for further cables/pipelines. Such future/planned installations are not included in the lists below.

No existing pipelines have been identified along the Nord Stream route. However, pipeline connections between Finland and Estonia and also between Poland and Denmark are under consideration. If and when other pipeline connections gain approval, North Stream AG will take into account the project details from an engineering perspective in consultation with engineering contractor Saipem Energy Services (former Snamprogetti S.p.A.) and third-party certifying agency (DNV).

Crossings by other pipelines can be carried out by various methods. It is anticipated that crossings will follow a generic design based on separation and protection concepts. Actual factors such as pipeline diameter, seabed conditions, considerations of planning and infrastructure, etc., will form part of a minimum pre-requisite for the design. Crossing design could be based on rock placement or placement of a protective support at the crossing location.

Cables to be Crossed

Table 4.19 to Table 4.22 provide an overview of cables to be crossed by the Nord Stream pipelines. The list is based on information from various published charts and consultation with cable owners.
### Table 4.19  Active cables crossed by the Nord Stream pipeline in the Russian EEZ

<table>
<thead>
<tr>
<th>Name</th>
<th>Route</th>
<th>Type</th>
<th>Owner</th>
<th>Crossing point on Atlas Map IN-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCS B5</td>
<td>Kotka (FIN) – Ruchiy (RUS)</td>
<td>Telecom</td>
<td>TeliaSonera</td>
<td>1</td>
</tr>
</tbody>
</table>

### Table 4.20  Active cables crossed by the Nord Stream pipeline in the Finnish EEZ

<table>
<thead>
<tr>
<th>Name</th>
<th>Route</th>
<th>Type</th>
<th>Owner</th>
<th>Crossing point on Atlas Map IN-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCCBF</td>
<td>St. Petersburg (RUS) - Kaliningrad (RUS)</td>
<td>Telecom</td>
<td>Russian Military</td>
<td>1a</td>
</tr>
<tr>
<td>FEC 2</td>
<td>Lautasaari (FIN) - Randvere (EST)</td>
<td>Telecom</td>
<td>Elisa</td>
<td>2</td>
</tr>
<tr>
<td>EE-SF2</td>
<td>Kaivopisto (FIN) - Leppneeme (EST)</td>
<td>Telecom</td>
<td>TeliaSonera</td>
<td>3</td>
</tr>
<tr>
<td>Pangea Seg 3</td>
<td>Helsinki (FIN) – Tallinn (EST)</td>
<td>Telecom</td>
<td>Linx</td>
<td>4</td>
</tr>
<tr>
<td>EE-SF3</td>
<td>Lautasaari (FIN) - Meremoisa (LAT)</td>
<td>Telecom</td>
<td>TeliaSonera</td>
<td>5</td>
</tr>
<tr>
<td>Estlink</td>
<td>FIN-EST</td>
<td>Power</td>
<td>Energia</td>
<td>6</td>
</tr>
<tr>
<td>FEC 1</td>
<td>Porkkala (FIN) - Kakumäe (EST)</td>
<td>Telecom</td>
<td>Elisa</td>
<td>7</td>
</tr>
<tr>
<td>UCCBF</td>
<td>St. Petersburg (RUS) - Kaliningrad (RUS)</td>
<td>Telecom</td>
<td>Russian Military</td>
<td>7a</td>
</tr>
<tr>
<td>Pangea Seg 3</td>
<td>St. Petersburg (RUS) – Kaliningrad (RUS)</td>
<td>Telecom</td>
<td>TeliaSonera</td>
<td>8</td>
</tr>
<tr>
<td>EE-S1</td>
<td>Tahkuna (EST) - Stavsnäs (SWE)</td>
<td>Telecom</td>
<td>TeliaSonera</td>
<td>9</td>
</tr>
</tbody>
</table>
Table 4.21  Active cables crossed by the Nord Stream pipeline in the Swedish EEZ

<table>
<thead>
<tr>
<th>Name</th>
<th>Route</th>
<th>Type</th>
<th>Owner</th>
<th>Crossing point on Atlas Map IN-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV-S1</td>
<td>S.Jarflotta (SWE) - Busnieki (LAT)</td>
<td>Telecom</td>
<td>Lattelecom</td>
<td>10</td>
</tr>
<tr>
<td>Baltkom</td>
<td>Hultung/Gotland (SWE) - Ventspils (LAT)</td>
<td>Telecom</td>
<td>BC Fiber</td>
<td>11</td>
</tr>
<tr>
<td>BCS EW</td>
<td>Sandviken (SWE) – Sventoji (LIT)</td>
<td>Telecom</td>
<td>TeliaSonera</td>
<td>12</td>
</tr>
<tr>
<td>SWEPOL</td>
<td>SWE - POL</td>
<td>Power</td>
<td>SvenskaKrafntä</td>
<td>13</td>
</tr>
<tr>
<td>HVDC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SWEPOL</td>
<td>SWE - POL</td>
<td>Power</td>
<td>SvenskaKrafntä</td>
<td>14</td>
</tr>
<tr>
<td>MCRC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.22  Active cables crossed by the Nord Stream pipeline in the Danish EEZ

<table>
<thead>
<tr>
<th>Name</th>
<th>Route</th>
<th>Type</th>
<th>Owner</th>
<th>Crossing point on Atlas Map IN-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>DK - RU1</td>
<td>Karslunde (DEN) - Kingisepp (RUS)</td>
<td>Telecom</td>
<td>TDC</td>
<td>15</td>
</tr>
<tr>
<td>DK - PL2</td>
<td>Bornholm (DEN) - POL</td>
<td>Telecom</td>
<td>TDC</td>
<td>16</td>
</tr>
<tr>
<td>Baltica Seg 1</td>
<td>Bornholm (DEN) - POL</td>
<td>Telecom</td>
<td>Polish Telecom</td>
<td>17</td>
</tr>
</tbody>
</table>

No cables will be crossed in the German EEZ.

Crossing Agreements

Based on the completed list of cables, all owners of active cables were approached with the aim of reaching mutual crossing agreements covering liabilities and procedures for crossing methods. According to the agreements, Nord Stream AG will be required to provide crossing designs and installation procedures to the satisfaction of the owners prior to installation.

Regarding out-of-use cables, Nord Stream AG will follow standard industry practice, which involves cutting/removing such cables as necessary and safeguarding free ends to ensure that fishing gear will not become entangled. Removal/cutting of out-of-use cables will be reported to owners, if known, or to nautical authorities.
The draft crossing agreement used by Nord Stream AG is based on the industry standard prepared by the International Cable Protection Committee (ICPC), which is used worldwide for telecom cables.

**Technical Solutions**

The crossings will be designed according to agreements between Nord Stream AG and individual cable owners.

Crossings will be constructed to ensure that the pipelines and cables remain a safe distance from each other. Crossing methods will also avoid the cables being unduly stressed or loaded due to the pipelines. At most crossings, cables on the seabed will be covered/buried, and the pipelines will be elevated and supported by concrete mattresses or rock berms. In all instances, corrosion potential will be taken into account, and the necessary precautions will be implemented.

As mentioned above, abandoned cables will be cut if necessary and the section of the cable removed. Cutting and retrieval of sections of abandoned cables may be carried out using a grapnel deployed from a smaller vessel, i.e., a survey vessel, or by a larger dedicated cable vessel, such as the vessel shown in **Figure 4.42**.

![Example of cable installation and handling vessel](image-url)
Crossing without intervention

In the event that the soil cover over a buried cable is sufficiently thick and stable enough to guarantee the required separation between the cable and the pipelines during the lifetime of the pipelines, a cable may be crossed without intervention.

The separation distance between the cable and the pipelines must take into account settlement of the pipelines under worst-case load conditions. The local soil conditions according to interpretation of the surveys must be considered.

Elevation of pipeline

A crossing can be accomplished by elevating the pipelines by a support of concrete mattresses as seen in Figure 4.43 or by rock placement on top of or to either side of a cable. The dimensions of such rock berms depend on the actual position of the cable to be crossed, but they usually cover the width of the installation corridor. The support height will be selected in order to guarantee the agreed minimum separation between the cable and the pipelines.

The support height must account for settling of the present embedment of the cable, as well as freespan vibrations of the pipeline. It may be necessary to support the pipelines on both sides of the cable to limit stress or vibrations.

After pipe-laying, the pipelines at specific locations also may be fixed by rock placement over a distance on either side of the cable to prevent movement due to trawling, in-service buckling or loads from waves and currents. Final decisions on such requirements will be taken during the detailed design phase.

**Figure 4.43  Concrete support mattresses**

(1) Concrete for mattresses will be of the same type as the concrete used for coating of the pipeline. The chemistry of the support mattresses is therefore compliant with environmental constraints.
4.5.4 Installation Processes, Vessels and Equipment

Pipe-laying Process

Pipe-laying will be performed as a conventional S-lay. This method is named after the profile of the pipe as it moves across the stern of the lay vessel and onto the ocean floor, which forms an elongated "S". The individual line pipes will be delivered to the pipe-laying vessel, where they will be assembled into a continuous pipe string and lowered to the seabed. An overview of a typical pipe-laying process is presented in Figure 4.46, which also shows the S-lay principle.

The pipeline will be exposed to different loads during installation that must be controlled by the installation vessel. Such loads are mainly hydrostatic pressure, tension and bending. These loads are also influenced by wave and current loading on the vessel and on the pipe itself. An installation analysis will be conducted to simulate the conditions during laying of the pipeline and to ensure that the load effects are within the strength design criteria of the specific pipe.

A typical S-lay system has three main components:

- The stinger, which extends the ramp to reduce the length of the sag bend (Figure 4.44 left). The overbend usually starts behind the tensioners and describes the curve under which the pipeline is entering the water
- The tensioner, which reduces the stress in the overbend and sag bends (Figure 4.44 right). The sag bend describes the bending under which the pipeline is laid on the seabed. In very shallow water and calm weather conditions, the tensioner might also be replaced by a clamp
- The positioning system, which controls the vessel’s position. The vessel position must be kept under the specified tension needed to keep the sag bend within the bending limitations of the pipe. Furthermore, the positioning system also ensures the pipeline is laid within its approved installation corridor on the seabed
The process onboard the lay vessel comprises the following general steps, which take place in a continuous cycle:

- Welding of pipe
- Non-destructive testing of welds
- Field joint preparation
- Laying on seabed

Onboard the pipe-laying vessel, welding of new, single pipes onto the continuous pipeline will be performed as either a semi- or fully automated welding process. An example of field-joint welding is shown in Figure 4.45.

Field-joint welds will be checked using non-destructive testing. Non-destructive testing of field joints historically has been performed by means of X-ray examination. This process in recent years has been superseded by automatic ultrasonic testing (Figure 4.45), which is also a superior and safer method for non-destructive testing on the Nord Stream pipeline project. Automatic ultrasonic testing will be used to locate, measure and record defects. Welding-defect acceptance criteria will be established prior to the start of construction and will be subject to approval by appointed certifying agencies.
After welding and non-destructive testing, the field joints will be protected against corrosion. All critical processes onboard the lay vessel will be inspected by the contractor's QA/QC crew, and thereafter inspected by representatives of the certification company and Nord Stream AG.

Deep-water lay vessels will be capable of welding two joints simultaneously. Therefore, when the jointing process is complete, the vessel will be moved forward a distance corresponding to the length of one or two pipe sections (12.2 or 24.4 m). Following this move, new pipe sections will be added to the pipeline as described above.

As the lay vessel is moved forward, the continuous pipeline will exit at the rear end of the vessel into the water. The pipeline will be supported by a ‘stinger’ extending 40-100 m behind and below the vessel. The stinger has the function of controlling and supporting the pipe configuration. The pipeline running from the stinger to the touchdown location on the seabed will be kept under tension at all times, thereby avoiding the risk of buckling and damage to the pipe. The average lay rate is expected to be in the order of 2-3 km per day, depending on weather conditions. Figure 4.46 shows an overview of a typical pipe-laying process.
Both pipelines will be constructed in specific sections for subsequent tie-in. Abandonment and recovery operations involve the leaving and later retrieval of the pipeline somewhere along its route. Abandonment of the pipeline might become necessary if weather conditions make positioning difficult or cause too much movement within the system. Abandonment of the pipeline can also be a planned operation within the installation sequence, e.g., to exchange the pipe-laying vessel.

An abandonment and recovery head will be welded on the pipeline to seal off the pipeline to prevent water from entering the inside of the pipeline. The pipeline is then lowered to the seabed with a wire connected to an abandonment and recovery winch on the lay vessel and left on the seabed. A typical abandonment and recovery head is shown in Figure 4.47. Recovery is more or less the reverse operation of abandonment. The abandoned pipe will be picked up by the lay vessel and repositioned on the lay vessel by means of the wire connected to the abandonment and recovery head on the pipeline and the winch on the lay vessel.

Upon completion of an entire pipeline section (e.g. from KP 300 to KP 675) the pipeline section will be left on the seabed in a process similar to abandonment. However, instead of a simple abandonment and recovery head, a pipeline lay-down head will be used. A typical lay-down head is illustrated in Figure 4.48.
Typical lay-down heads will be complete and pre-loaded with dewatering pigs in preparation for pre-commissioning (see Chapter 4.6 on pre-commissioning).

**Figure 4.47** Typical abandonment and recovery head

**Figure 4.48** Typical 48” lay down head
Pipe-laying Installation Zones

The pipelines will be subdivided into three offshore zones and two near-shore zones – in total five installation zones per pipeline. The three offshore zones are defined in Table 4.23 and correspond to the different pressure zones as described in Chapter 4.1.

Table 4.23  Pipeline installation zones

<table>
<thead>
<tr>
<th>Zone</th>
<th>Description</th>
<th>Start KP</th>
<th>Finish KP</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRF</td>
<td>Landfall Russia, Russian shore approach and near-shore</td>
<td>0</td>
<td>7.5</td>
</tr>
<tr>
<td>1</td>
<td>Gulf of Finland</td>
<td>7.5</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>Central part of the route</td>
<td>300</td>
<td>675</td>
</tr>
<tr>
<td>3</td>
<td>South-western part of the route</td>
<td>675</td>
<td>1196</td>
</tr>
<tr>
<td>LFG</td>
<td>Landfall Germany, German shore approach and near-shore</td>
<td>1196</td>
<td>1222</td>
</tr>
</tbody>
</table>

At present, a final decision on the pipe-laying sequence has not been taken, since it will depend on when the installation work can start. The commencement of the installation work again depends on achieving the construction permits and on agreements with the contractor and subcontractors. It is planned that installation of the two landfalls will be initiated first, i.e., before offshore pipe-laying.

Pipe-laying Vessel Spread

The offshore pipeline installation is expected to be conducted by several lay and support vessels. One or two deep-water lay vessels (anchor-positioned, semi-submersible vessels or dynamically positioned (DP) mono-hull vessels) will be used to lay both pipelines.

An example of a deep-water lay vessel is the Saipem Castoro Sei, which is an anchored lay vessel (Figure 4.49, left). The vessel is kept in position by anchor-handling vessels that manoeuvre the anchors, which are directly connected to and controlled by a series of cables and winches.
A deep-water dynamic positioned lay vessel, such as the Allseas *Solitaire* DP (Figure 4.50, left) will also be used. A dynamically positioned vessel is kept in position by thrusters that constantly counteract forces acting on the vessel from the pipeline, waves, current and wind.

The actual pipe-laying spread will depend on the availability of vessels at the time that the necessary permits are granted. However, according to present status (October 2008) the *Solitaire* will lay the north-west pipeline from KP 7.5 to KP 300 (i.e. in the Gulf of Finland) and the *Castoro Sei* will lay from KP 1196 to KP 300. Vessel spread for laying of the south-east pipeline has not yet been planned.
At the German near-shore sections shallow-water lay vessels will be employed. Shallow-water pipe-laying will be performed as an S-lay similar to deep-water pipe-laying. Shallow-water pipe-laying may be performed by the Saipem Castoro Deci (Figure 4.49, right), which is a flat-bottomed, anchor-positioned lay vessel.

Anchor-handling vessels and survey vessels will support the pipe-laying barge. Two to six anchor-handling vessels will be required per anchor-positioned lay vessel. The anchor-handling vessels are generally quite large, with overall lengths in the 100 m range. The anchors will be positioned 1,000–2,000 m from the lay vessel. Also, one supply vessel per lay vessel will be required. Anchor-handling and supply will be carried out by multipurpose dynamically positioned vessels such as shown in Figure 4.50 (right).

Production Waste

The pipe-laying processes may generate waste that is different from the typical onboard waste such as food waste, deck sweepings, etc. The typical types of waste that are specific to lay vessels are:

- End millings from the pipe end bevelling process
- Flux from the welding process
- Heat-shrink-sleeve cut-offs
- Polyurethane infill from field joint coating
- Concrete
- Oils (from machinery etc.)

Just before welding, the bare line pipe ends will be bevelled to create a profile for welding, which will produce metal scraps. During welding, flux will be added to prevent oxidation of the base and filler materials. Examples of metal scraps from bevelling and typical containers for collecting and storage are shown in Figure 4.51. The waste will be secured in the containers by strap down covers.

Based on the pipe-lay contractors’ experience from a previous project concerning a similar-sized pipeline, approximately 115 tonnes of metal scraps and 25 tonnes of waste oil and sludge is expected to be generated per month of pipe-laying. Pipe-laying for the Nord Stream pipeline will take 11 months for the north-west pipeline and 14 months for the south-east pipeline. It is therefore expected that a total of approximately 2,875 tonnes of metal scraps and 625 tonnes of waste oil will be generated during installation of the pipelines.
The heat-shrink sleeves will be ordered to a specific length for the Nord Stream project. Therefore, apart from the protection sheet, which is removed from the adhesive layer prior to installation, there will be minimal waste from the heat-shrink sleeve itself.

Also, the polyurethane infill has hardly any spills.

![Figure 4.51 Metal scraps from the bevelling process (left) and typical containers (right)](image)

All waste produced by the lay vessels will be handled and disposed of in accordance with MARPOL 73/78 and HELCOM requirements. According to these requirements, the Baltic Sea has special area status, meaning that any dumping or discharge of waste into the sea is prohibited.

All waste produced on the lay vessels will be separated and sent to shore to be properly disposed of by a licensed waste disposal contractor. The disposal will take place in compliance with applicable internationally recognised standards and procedures in conjunction with local legislation. Organic and biodegradable waste may be incinerated at site before being sent to shore for controlled disposal.

The processing facilities where the waste will be delivered depend on the geographical location where the pipe-laying vessel is operating. In any case, when applicable, the contractors will make use of the ports already selected to support the Nord Stream project logistics.

**Anchor Corridors and Anchor Handling**

The two pipelines will be laid and installed separately at the sea bottom. The distance between the two pipelines will generally be about 100 m. However, as already mentioned re-routing due to an uneven seabed means that local separation distances may vary over the length of the lines.
The anchored deep-water lay vessel will be controlled by 12 anchors, each weighing about 25 tonnes. Due to the reach of the anchors, the corridor width on the sea bottom used for pipeline anchoring will be around 2,000 m per pipeline. A typical anchor spread is shown in Figure 4.52.

Figure 4.52  Typical anchor spread

Based on the results of the anchor corridor survey described in Section on Surveys to be Performed Prior to Construction the Nord Stream Project will initiate the following activities:

- Develop a database of the position of munitions and cultural heritage sites along the entire pipeline anchor corridor
- Establish 'no-go zones' around the munitions and cultural heritage sites, and develop anchor patterns for critical sections
- To avoid certain features, anchor patterns could include the use of Yokohama buoyancy attached to the anchor wire to keep the anchor wire clear of the seabed
- Define tensions required to maintain anchor wire catenary
• Establish any special areas along the route where it may be unacceptable to place anchors on the seabed and develop a procedure to use an anchor handling tug to act as “live anchor” instead of normal anchoring

In the discrete sections where the route passing through the Finnish exclusive economic zone approaches to within 0.5 km of the Finland/Estonian exclusive economic zone boundary, the lay vessel station keeping will be complemented by the use of tugs to avoid placing anchors on the seabed within the Estonian exclusive economic zone.

**Preventive Measures and Communications during Pipeline Installation**

To ensure minimum interference with pipe-laying operations from other sea traffic, an exclusion zone will be established around the lay vessel, typically extending 2,500–3,000 m, beyond the position of the lay vessel. Unauthorised ship traffic, including fishing vessels, will not be permitted to enter the zone.

Nord Stream AG will issue a "Notice to Mariners" on the installation activities to the relevant national coast guards throughout the period of construction. The relevant maritime authorities will be kept informed continuously on the installation progress. The coast guard will inform the ship traffic of ongoing activities and traffic limitations, such as exclusion zones, through various media, e.g., broadcasts on Navtext.

A marine captain will be onboard the pipe-laying vessel during installation to monitor all third-party shipping activity. Also, if required standby vessels will perform watch duties accordingly. The anchor-handling tug may perform this activity. Experienced crew will be available for watch duty at all times. The standby vessel will alert vessels in the vicinity and provide details of the exclusion zone coordinates. Any unexpected vessels entering a closest point of approach radius will be monitored closely, and actions will be taken to avoid incidents.

The contractor will pay special attention to areas where shipping lanes and other heavy traffic areas are crossed. The pipe-laying vessel must be able to cross shipping lanes unhindered by other vessels and must be able to position anchors as necessary.

In sensitive areas, pipe-laying and touchdown on the seabed will be followed closely by means of an ROV. This will be the case in areas with cultural heritage, for example.

### 4.5.5 Tie-ins

As mentioned in the previous section, the offshore pipelines will be divided into five offshore zones. The connection of these major pipeline sections – tie-in – will be carried out accordingly at two offshore locations where the water depth is high and at one near-shore location.
On deep water the connections will be carried out as sub-sea connections (hyperbaric tie-in). The two locations correspond with the pressure (and wall thickness) transitions of the pipeline from 220 to 200 barg and from 200 to 170 barg. The near-shore tie-in will be carried out above water during the constructions phase.

At tie-in locations, pipeline sections will purposely overlap and then be cut and aligned for hyperbaric welding. Before a lay vessel finalises and lays down a pipeline section on the sea bottom, a lay-down head will be welded to the end of the pipe head in order to preserve the dry, non-corrosive environment inside the pipeline. The lay-down head (as shown in Figure 4.48) will be cut off during the tie-in procedure to permit subsequent hyperbaric welding.

The underwater tie-ins will be performed by hyperbaric welding during pre-commissioning (see Chapter 4.6 on pre-commissioning) and will take place after flooding and pressure-testing of the pipeline sections.

All underwater tie-ins will be deemed "golden welds", i.e., welds that will not be subjected to system pressure tests. Such welds, however, will be subjected to additional inspection techniques and methods and will be in line with standard industry practice in compliance with the DNV (Det Norske Veritas) code.

An example of a typical lay-down configuration of pipeline sections with lay-down heads prior to tie-in is shown below:

Hyperbaric tie-in will result in a linear configuration as a result of minimal lifting during tie-in:

Above-water tie-in will result in a curved configuration as a result of lifting during tie-in:
Hyperbaric Tie-ins

Hyperbaric tie-ins will be performed at KP 300 and KP 675, i.e. at design pressure and pipeline wall thickness step changes. These sub-sea connections will be performed as hyperbaric welds, i.e., welds performed sub-sea inside a dry welding habitat that encloses part of the pipeline on both sides of the weld. A typical welding habitat is shown in Figure 4.53.

The pipelines will be cut and then aligned for fit-up. The habitat will be placed over the fit-up location and sealed over the pipeline ends. Water will be pumped out of the habitat, and welding subsequently will be performed by the divers/welders.

After the pipes have been welded together, non-destructive testing of the field joint welds will be carried out. There will be no coating at the hyperbaric field joint locations because the corrosion-protection provided by the sacrificial anodes has been deemed sufficient for this part of the pipeline.

A typical example of a dive-support vessel (DSV) that may be used for underwater tie-ins of the pipelines is shown in Figure 4.54.
Above-water Tie-in

Above-water tie-in is anticipated at KP 1196, i.e., at the shallow water/deep water interface in the German section (outside the Natura 2000 area). This above-water tie-in is expected for the north-west pipeline only. No tie-in is anticipated in the Russian near-shore area, as pipe-laying is expected to be performed continuously from the landfall to KP 300.

The two pipeline sections will be laid from opposite directions. The ends of the two pipeline sections will be laid next to each other on the seabed and lifted out of the water alongside the lay vessel as shown in Figure 4.55. The lay-down heads will then be cut off, and the two open ends will be aligned and welded above water.
Figure 4.55 The ends of the pipeline sections are lifted alongside the barge prior to above-water welding

When the tie-in weld and subsequent non-destructive testing and field-joint coating have been completed, the pipeline string will be lowered in a horizontal curve that follows the vertical contour of the lines during lifting, as shown in Figure 4.56. The proposed lay vessel for above-water tie-ins is the Saipem Castoro Deci.

Figure 4.56 Schematic of above-water tie-in
4.5.6 Landfalls

Landfall Construction Methods

The initial works of the entire pipeline project are comprised of pipe-laying activities and the accompanying activities at the two landfall areas in Germany and Russia, respectively. A number of construction activities will be carried out in the landfall areas in order to bring the offshore pipeline ashore. The main activities include:

- Installing a cofferdam (Germany) or embankments (Russia) and dredging in near-shore area
- Preparatory onshore works
- Welding of pipeline sections onboard the shallow-water pipe-laying vessel anchored off the coast, followed by pull-in of the pipelines through the surf zone
- Welding of onshore pipeline sections
- Backfilling over the pipelines
- Demobilisation of the work site and reinstatement of the work area

When the dredging operations are completed at the landfall locations, a wire between the onshore winches and the lay vessel will be installed in order to pull the pipelines in through the surf zone. After pull-in, the pipeline trenches will be backfilled.

The traditional cut-open trench method in combination with a shore pull is described further below. This combination is presently considered the preferred and most likely construction method for the landfalls.

When the cofferdams (see section on German Landfall) or embankments (see section on Russian Landfall) are in place, dredging inside the dammed area as well as offshore in the near-coast area will be carried out to achieve the desired burial depth at and near the shoreline. The types of dredgers that may be used are backhoe dredgers (Figure 4.57, left), trailing suction hopper dredgers (Figure 4.57, right), bucket ladder dredgers and grab dredgers. The burial depth must take into account seabed mobility (scour, sand, waves and ice conditions) and coastal erosion. Onshore, this work will be performed by standard backhoe dredgers. The offshore sections may be dredged by backhoe dredger mounted on a pontoon or by other, suitable equipment.
Figure 4.57  Example of a back-hoe dredger (left) and a trailing hopper suction dredger (right)

A general overview of the installation method is shown in Figure 4.58 below.

Figure 4.58  Typical pulling arrangement
The pipe-laying vessel will be positioned in front of the pipeline trench, and the pipe-string will be pulled towards the beach.

The pipe-laying vessel will be anchored as close as possible to the coastline or to the end of the cofferdam and depending on the vessel's operation draught.

In order to pull in both pipelines, a sufficient pulling winch is needed onshore. A linear winch equipped with a spooling reel is typically used. The winch can be fixed by buried anchors as well as by sheet piles. A typical pull-cable winch is shown in Figure 4.59.

![Figure 4.59 Typical spooling winch for pull-in wire](image)

A pulling wire will be connected to the head of the first pipe section onboard the lay vessel, after which the pull-in operation will commence. During the pull-in operation, onshore hydraulic, linear winches will pull the pipeline towards shore as pipe sections are welded together onboard the lay vessel. The required pull force is a direct function of the length of the pull. Typically, the pull-in operation will take only a few days.
Depending on the seabed sediment in the trench, the pipeline may be pulled along the seabed or floated in on pontoons to protect the pipeline coating. This is shown in Figure 4.60.

Figure 4.60  Pontoons mounted on a pipeline
Once the pipeline has been pulled all the way to the foot of the winch base, reinstatement of the beach and coastal area can be initiated. The tie-in to the onshore pipeline is then a straightforward onshore construction task.

Installation of pipeline mechanical components, such as pig-trap isolation valves, bypass valves and the pig trap itself, will be carried out during the course of pipeline installation at the respective positions. The different components are described further in the following.

**Components**

The following pipeline components to be used at the landfalls are described below:

- Valves
- Pig traps
- Isolation joints
- Anchor flanges

The design of all components will be based on common principals to ensure engineering consistency and ease of installation during the construction phase. All components will be:

- Delivered to site pre-fabricated with line pipe pup pieces\(^{(1)}\) attached to either side. Pup pieces will be mechanically consistent with the line pipe to which they will be welded.
- Pressure tested to a level above normal operating pressure, consistent to that of the line pipe
- Designed for installation and operation at landfall locations in Russia and Germany

**Valves**

There will be two types of valves – double expanded gate valves (DEGV) and top-entry ball valves (TEBV) – each of which has a specific function. Both types will be manufactured in a casting process and subsequently machined for operational tolerances. Hydraulic and electrical valve actuators will be attached and interfaced as separate units:

- DEGV valves function as a double barrier (i.e., double gate) and as a result are used for isolation purposes, i.e., before pig traps for pigging operations

\(^{(1)}\) Line pipe pup pieces are short pieces of line pipe that are attached to either side of the components, to facilitate easier welding of the component onto the rest of the pipeline.
• TEBV valves function as a single barrier and are used for most operations, except for isolation. The TEBV valves are the primary source of emergency shutdown (refer to Section on Emergency Shutdown). An example of a gate valve during installation is shown in Figure 4.61.

![Gate valve during installation](Photo: Petrolvalves)

**Figure 4.61 Gate valve during installation (Photo: Petrolvalves)**

**Pig traps**

Pig traps are located at each pipe end. They permit the use of pigs for intelligent surveys. The pig traps will be engineered to allow internal pigs and tools to be launched and received in both directions to ensure maximum access flexibility over the design life. It should be noted that pigging can be performed only in the flow direction. Examples of typical pig traps are shown in Figure 4.62.
Isolation joints

Isolation joints will be of the monolithic type, manufactured in a forging process, and have electrical insulating filler. The joints will essentially act as an electrical barrier between each pipeline and the respective landfall pipe works. The electrical isolation joint isolates the cathodic protection systems of the pipeline from the landfall pipeline system.

An example of a typical isolation joint and a schematic of its components are shown in Figure 4.63.
Anchor flanges

Anchor flanges will be located at the Russian landfall to accommodate expansion forces. They are specifically designed to withstand and contain axial thrusts during the operation of the pipeline. Anchor flanges will be manufactured in a forging process and will be encased in concrete, resulting in an anchor block. The anchor block will be located below-ground to ensure anchoring and maintain stability (Figure 4.64).

Figure 4.64  Concrete anchor blocks are constructed on site

Anchor flanges will not be used at the German landfall. Instead, the pipelines will be constructed as an omega-shaped expansion loop.

Russian Landfall

An overview of the construction works at the Russian landfall is provided below. A detailed description of the construction works can be found in the EIA for the Russian landfall site.

Construction works (removal, disposal and backfilling of seabed materials)

The scope of work at the Russian landfall can be divided into two separate construction areas: those that are related to crossing of the shore line and those that are based at the lay vessel. Crossing of the shore line include construction of the landfall section, crossing the shoreline and pipe-laying from a designated point onshore to a water depth of 14 m. Pipe-laying at water depths greater than 14 m will be carried out from the lay vessel.

The pipelines will be buried in the near-shore area and the onshore section for protection against exposure due to erosion, human activity and ice.
A winch mounted onshore will pull in the pipelines from the pipe-laying vessel, as shown in **Figure 4.65**. The pipelines will be pulled along two previously excavated trenches and may be supported by buoyancy aids.

![Schematic of shore-mounted winch pulling the pipeline towards shore from the pipe-laying vessel](image)

**Figure 4.65**  Schematic of shore-mounted winch pulling the pipeline towards shore from the pipe-laying vessel

Construction activities in the near-shore section and when crossing the shoreline in the landfall area include:

- Preparatory works
- Trench excavation
- Operations related to pipe-laying
- Backfilling of the trench
- Completion of construction

Preparatory works in the landfall area include:

- Construction of embankments
- Preparation of site for onshore winch
- Mounting of onshore winch used to pull the pipelines to shore

A trench will be dug for each of the two pipelines. In the shallow, near-shore area, embankments will be constructed on each side of the trenches for protection against currents and waves.
Figure 4.66  Construction of an embankment in the section crossing the shore line

The embankments will stretch from a point onshore at 0.5 m above sea level to a water depth of approximately 2 m. They will be comprised of stones and gravel and also serve as platforms for land equipment used to excavate trenches in the shoreline section, as shown in Figure 4.66.

The two pipeline trenches will be excavated with a constant width of 4-5 m and with a distance between the axes of the trenches of 20 m. A standard cross-section of the two parallel pipeline trenches is shown in Figure 4.67. The pipelines will be buried in the near-shore area in Russia for protection against exposure due to erosion, human activity and ice.

Figure 4.67  Standard cross section – open trench in the Russian landfall area
Onshore trenching activities are performed by standard back-hoe dredgers, an example of which is shown in Figure 4.68. The offshore sections may be dredged by a back-hoe dredger mounted on a pontoon.

The excavated soil will be put in heaps along the sides of the trenches and used for backfilling of the pipeline after pipe-laying.

Figure 4.68  A typical back-hoe dredger (‘At Your Service’ of the company MPTC)

The lay vessel will be anchored close to the coastline. When the trenches are completed, a wire between the onshore winches and the lay vessel will be installed to pull the pipeline ashore. The onshore winches will be mounted on a foundation of reinforced concrete slabs that have been laid on a prepared surface at the end of the trench of each pipeline.

During the pull-in operation, the onshore winches will pull the pipeline along the seabed towards the shore as pipe sections are welded together onboard the lay vessel. The pipelines may be supported by buoyancy aids during the pull-in operation. After pull-in, the pipelines will be backfilled and tied in to the onshore pipeline.

After pipe-laying and backfilling of the trenches, the embankments will be removed, and the sites will be cleared and re-established.
Pipeline section until Portovaya Bay Compressor Station

The dry section in Russia includes two pipelines, pig launchers/receivers and connections to the upstream Gazprom facilities. The two parallel pipelines will run from the shoreline into the pig launchers/receivers. Shutdown valves will be installed on the 48” main pipelines as well as on the 28” branch pipelines. The final design is subject to change during the detailed engineering phase.

German Landfall

An overview of the construction works at the German landfall is provided below:

- Site preparation
- Cofferdam
- Construction of support and foundations
- Pipeline installation
- Reinstatement
- Pipeline section until Greifswald Receiving Terminal

A detailed description of the construction works can be found in the EIA for the German landfall site (reference to follow).

Site preparation

The German landfall will be integrated in the Greifswald Receiving Terminal (GRT), all of which will be surrounded by a fence. Site preparation of the landfall area will take place, in so far as it is not completed within the Greifswald Receiving Terminal construction scope. The landfall location is shown in Figure 4.69.

Site preparation will include clearing the worksite of debris and obstructions to allow safe installation of the pipelines, associated equipment, valves, supports and support foundations.

The worksite will be graded as necessary for the installation of temporary and permanent concrete foundations and facilities.
Site preparation will further consist of:

- Construction of all access routes and areas necessary for the transportation and off-loading of materials and equipment at the worksite

- The installation of temporary boundary fences for segregation and safety reasons. The fencing will ensure that impacts due to construction works are confined to the construction area

- The construction of drainage systems within the onshore worksite as required to ensure that work areas remain in a suitable condition

To minimise the amount of dredging and hence the impact on the coastline, a cofferdam – an enclosure constructed from sheet piling – will be installed. An example of a cofferdam is shown in Figure 4.70. The actual "opening" towards the sea will be as wide as the cofferdam itself. However, a wider area must be fenced off for safety reasons. The effective fenced-off area between the dunes will cover an area of ~11,000 m² to accommodate the worksite, office, workshop facilities and storage area.
Cofferdam

The cofferdam will be constructed between the specially protected ‘Grauduene’ sand dune areas and the sea. It will begin approximately 150 m inland from the shoreline and extend approximately 550 m offshore at a water depth of approximately 1.5 m.

Two options for the construction of the cofferdam are under consideration:

Option 1: An offshore cofferdam comprising three parallel sheet-pile walls forming two separate channels will be constructed. Its overall length will be 550 m. One channel, measuring 9.5 m wide, will be trenched to accommodate the pipelines. The other 9.5 m wide channel will be used to store the excavated soil. The total width of the cofferdam will be 19 m (Figure 4.71). The storage channel will be further strengthened by piles forming a combi-wall. The piles will support a steel frame, which will function as a bridge for piling and excavation equipment. In the onshore section, there will be a 150 m long cofferdam comprised of two sheet pile walls.
The order of construction activities to install the cofferdam and the piling will be as follows:

Onshore, sheet piling will be installed for the pipeline trench only and all excavated material will be stored at the side of the construction strip.

Piling and sheet piling for the storage trench will begin onshore, shortly before the coastline. Piling works will be carried out normally from the prepared construction strip onshore (Figure 4.71).

When the cofferdam reaches the coastline, installation activities will be carried out from the top of the cofferdam. Therefore, the first steel-frame bridge will be installed on top of the piles that have already been driven, and the piling equipment will be brought into position. Piling, sheet piling and assembly works will take place towards the open sea. Once a new section of the cofferdam has been installed, a new bridge will be set up and work can proceed further towards the open sea.

![Figure 4.71 Change of cofferdam construction type at shoreline transition](image)

Option 2: A cofferdam comprised of two parallel walls forming a 9.5 m wide trench will be constructed. The length of the cofferdam will be approximately 550 m.
Onshore, sheet piling will be installed for the pipeline trench, and all excavated material will be stored on the side of the construction strip.

Offshore, the cofferdam will be comprised of a parallel, pre-installed Bailey bridge (Figure 4.72 and Figure 4.73). A Bailey bridge is a modular steel structure that can be installed quickly and easily. It will be supported by steel piles and provide access to the cofferdam for all works. The piling of the steel pipes supporting the first bridge modules will begin onshore, and piles and additional bridge modules will subsequently be added in the offshore direction until the required length of the bridge is achieved.

When installation of the bridge has been completed, piling equipment will use it to install the sheet piling for the cofferdam.

A silt screen between the cofferdam and the breakwater of Lubmin harbour may have to be installed before the start of excavation works. The silt screen will isolate the area between Lubmin harbour breakwater and the cofferdam from the open sea thereby protecting it from high currents and scouring. The silt screen and cofferdam will also avoid turbidity outside of that area.
When sheet pile installation and installation of the silt screen (if necessary) is completed, excavators will access the Bailey bridge and begin excavation of the cofferdam. The excavated soil will be temporarily installed in an isolated area adjacent to the Bailey bridge.
Construction of supports and foundations

Depending on the installation method of the pipelines, a number of supports and foundations will be required. Among these are supports of the above-ground pipeline sections, a temporary anchor point for the winch used to pull in the pipelines, and a retaining wall backfilled with soil to cover the pipelines. The retaining wall will be the transition point from above-ground to the underground pipeline sections (Figure 4.74).

![Retaining wall at transition point between above-ground and underground pipeline sections](image)

**Figure 4.3** Retaining wall at transition point between above-ground and underground pipeline sections

The concrete foundations will be pre-cast and transported to the construction site by truck or will be cast directly in their final positions.
Pipeline installation

The pipelines will be installed according to the general installation method as described above. When reaching the shallow angled S-section at the coastline the pipe string will be pulled onshore.

For installation of the dry sections, temporary supports will be established for the single line pipes between permanent supports that have already been constructed. Single line pipes will then be delivered to the site by trucks, lifted onto the supports by crane, positioned, aligned and subsequently welded together (Figure 4.75). Non-destructive testing of each weld and field-joint coating will be carried out. When the entire section is completed, the temporary supports will be removed.

![Figure 4.75 Onshore installation of pipeline](image)

The offshore installation of the pipelines in shallow-water conditions has special technical demands (laying equipment) and high safety requirements (e.g., protection against mechanical impact or buoyancy). Therefore, both pipelines between the end of the cofferdam (~ KP 1222) and the tie-in location (~ KP 1196) will be laid one after the other in a single, pre-cut trench and buried (see Figure 4.76).
The trench will be dredged to the designed depth. Backhoe dredgers and trailing suction hopper dredgers are the preferred equipment for dredging works. Equipment selection will be based on soil conditions and the type of dredger to be used. The box-cut method, which results in a slope of approximately $H : L = 1 : 3$, will be used primarily. In areas with more stable soil conditions, a slope more steep than $H : L = 1 : 3$ may be acceptable and would minimise the dredging volume.

The excavated soil will be conveyed onto barges and then transported to a site for intermediate storage or permanent disposal. Different soil types will be disposed of separately in designated areas. Material with a high content of organic matter, which cannot be disposed of offshore, will be transported to an onshore spoil ground.

After dredging, the accuracy of the trench bottom will be inspected. If there are obstacles or uneven areas in the trench, a clean cut will be carried out using a bed leveller or a small backhoe dredger.

**Figure 4.76 Standard cross section – open trench**
After the pipelines have been laid into the prepared trench, the trench will be filled with soil from
the storage site. Therefore, a number of trailing suction hopper dredgers will re-dredge suitable
material at the storage site, transport the material to the trench and fill the trench. Barges,
loaded by backhoe dredgers at the storage site, may also be used.

Reinstatement
After installation of the respective pipeline sections, backfilling of the cofferdam and the
extraction of piles and sheet piles will take place to restore the soil surface to its prior condition.
This will be done in reverse order to the construction works described above.

Further backfilling will be conducted over excavations at locations where temporary supports
and foundations have been removed as well as around the supports and pig trap foundations.

As a long-term reinstatement issue, pipeline overburden in the area of the coastline must be
monitored. In the event of local erosion, backfilling of the eroded material will be performed.

Pipeline section until Greifswald Receiving Terminal
The above-ground sections of the pipelines will be positioned on supports, which shall be steel
plates cast into concrete support foundations. The support philosophy is to allow expansion and
contraction without overly restraining the pipelines and inducing internal stresses. The supports
shall be designed to accommodate the largest calculated pipeline displacements.

Approximately 15 m after the end of the S-curve, there is an omega-shaped expansion loop
capable of compensating for any possible pipeline expansion throughout the lifetime of the
pipelines. Downstream of the first bend up to the pig receivers, the clearance between the
pipelines will be approximately 10.5 m. The expansion loops will be used to align the pipelines
to the tie-in position at the Greifswald Receiving Terminal, but they will also serve as expansion
points, as the pipelines expand and contract under pressure and temperature variations.

Each pipeline will terminate at a fully welded pig receiver, which will be approximately 15 - 20 m
in length. The pig receivers will be isolated from the pipelines by a double expanding gate valve.
Each pipeline will be isolated by an emergency shutdown valve weighing more than 100 tonnes.

An isolating joint between the two pipeline isolation valves will ensure electrical isolation
between the anode-protected sub-sea section of the pipeline and the above-ground pipeline.

A barred-tee (a specially designed reducing fitting, which prevents pipeline pigs from passing
through the bypass line) will also be installed between the two pipeline isolation valves
connected to the 38” (950 mm) diameter bypass line, which supplies the process gas to the
Greifswald Receiving Terminal. The bypass line is isolated by an actuated valve weighing more
than 50 tonnes.
4.6 Pre-commissioning

After installation of the pipelines, pre-commissioning and underwater tie-ins will be performed before the pipeline system can enter into operation. Pre-commissioning activities will include: flooding, cleaning and gauging of the pipelines, a system pressure test, underwater tie-ins and dewatering and drying of the pipelines.

The pipelines will be flooded with filtered seawater taken in at the Russian landfall. In total, 1,270,000 m$^3$ of seawater per pipeline will be used. At the landfall, a temporary pumping system will pump the water into a supply line at a depth of 10 m. This system will also be used for the discharge of water during the dewatering operation.

It is essential that the water is not discharged in an enclosed or semi-enclosed water body because this might not ensure optimum mixing conditions. Therefore, Greifswalder Bodden is not a preferred option. Consequently, the most feasible site is Portovaya Bay. In addition, the natural water is less saline at Portovaya Bay, which is an advantage during pre-treatment of the water.

The entire process of pre-commissioning each pipeline, including tie-ins, will take approximately five months. This comprises two months for flooding, cleaning and gauging the pipeline, 1.5 months for testing and underwater tie-in and 1.5 months for dewatering and drying the pipeline.

If future conditions suggest a deviation from or alteration of the plan as established herein, Nord Stream AG will contact the coordinating authority without delay and pursue, in close cooperation, the appropriate steps to adjust this document or future execution plan accordingly.

4.6.1 Flooding, Cleaning and Gauging

The pipeline will be flooded, cleaned and gauged internally by means of "pigs". A pig is a device for inspection, cleaning, product separation or other purposes. Examples of pigs are shown in Figure 4.77. The pig is sent down the pipeline from pig launchers and propelled by the pressure of the water (or gas during operation) in the pipeline. The pigs will be arranged in a "pig train" that will include at least four cleaning and gauging pigs. Some water will be introduced ahead of the first cleaning pig to wash away debris.
The debris will consist of dust that has collected in the pipeline during construction. The majority of this dust will be comprised of rust (iron oxide) and occasional welding flux from the joint welding and some internal epoxy coating and cement dust from the lay vessel may also be present. The amount of debris is expected to be only a few cubic metres. The pigs will push this debris into pig traps/pig receivers, from which it will be collected and then properly disposed of onshore. When applicable, the contractors will make use of the ports already selected to support the Nord Stream project logistics.

The water used for flooding will be water treated with an oxygen scavenger (e.g. sodium bisulphite, NaHSO$_3$) and with sodium hydroxide (NaOH). The expected concentrations of the chemicals in the pre-treated water will be 70 ppm and 230 ppm, respectively. The oxygen scavenger will eliminate oxygen corrosion and the sodium hydroxide will raise the pH-value to above 10 and thereby inhibit the growth of anaerobic bacteria. These treatment products are natural substances that already exist in seawater. The treatment is therefore regarded to be environmentally friendly and other pipeline projects (e.g. the Franpipe and Haltenpipe) have proven the usability.

The seawater to be filled into the pipeline will be filtered before it is pumped into the pipelines.

The flooding of each of the pipelines will be carried out in the following sequence:

- Flooding of Section 1 from KP 0 to KP 300 from the Russian landfall
- Flooding of Section 2, from KP 300 to KP 675 from Russian landfall through Section 1
- Flooding of Section 3 from KP 675 to the German landfall through Section 1 and Section 2 from the Russian landfall.
Bypasses (temporary pipes) will be installed to bridge between the sections of the pipeline thereby facilitating the flow of hydro-test water from one section to the next. This is illustrated in Figure 4.78. Some ship and diving activity will be required in the Finnish and Swedish exclusive economic zones in relation to the transfer of filling water and later tie-in of the pipelines.

![Figure 4.78 Flooding, cleaning and gauging operation](image)

### 4.6.2 System Pressure-testing and Tie-in

To establish the integrity of the pipelines, pressure-testing (pre-service hydro-testing) will be performed. Once the pipelines are filled with water it is necessary to stabilise the pressure and temperature. After the pressure and temperature are stabilised, the pressure will be increased by injecting more water into the pipeline until the required holding pressure is achieved.

Typically, a 24-hour holding period follows, during which the pressure is monitored to verify that there are no leaks.

During the water-filled period and after pressure-testing, underwater tie-ins of the pipeline sections will take place at KP 300 and KP 675 by hyperbaric welding.
4.6.3 Dewatering – Discharge of Water

After tie-in, dewatering of the pipeline sections will be performed by sending dewatering pigs with sealing discs through the pipelines to push out the water. Discharge will take place at the Russian landfall, meaning that the dewatering pigs will move from the German landfall towards the Russian landfall as shown in Figure 4.79.

![Figure 4.79 Dewatering and drying from the German landfall to the Russian landfall](image)

The water from the pipelines will be discharged into the sea. The water will be discharged through a temporary discharge line from the Russian landfall at a water depth of approximately 10 m.
Discharge after pressure testing will be 1.27 million m$^3$ of water from each of the two pipelines. Numerical dilution and dispersion models$^{(1),(2)}$ were being applied to confirm that there are no significant environmental impacts are to be expected from the discharge of the water. The results are presented in Chapter 9 (Impact assessment for ecological sub-region I).

It is expected that most of the precipitation resulting from the caustic soda will be received during dewatering. The theoretical total amount is 50 to 80 tons. Most of it will be in front of the dewatering pigs received in Russia and disposal will be on a proper dumpsite. Some of the precipitation will freeflow in the water and will be washed out into the sea through the disposal line.

Further details of pre-commissioning and modelling of impacts can be found in the background memo on pre-commissioning$^{(3)}$.

### 4.6.4 Drying

The water that remains inside the pipeline after dewatering will be dried using temporary air compressors located at the German landfall. Drying is needed to avoid hydrate formation (ice) and to avoid off specification gas during initial operations.

### 4.7 Commissioning

Commissioning comprises all activities that take place after pre-commissioning and until the pipelines commence natural gas transport, including filling the pipelines with natural gas. Prior to the activity of gas-in, all pre-commissioning activities must be completed successfully and the pipeline will be filled with dry air that is close to atmospheric pressure.

To avoid an inflammable mixture of atmospheric air and natural gas, the pipelines will be partially filled with nitrogen gas (inert gas) immediately prior to being filled with natural gas. During gas-in, the nitrogen gas will create a separation zone that moves through the pipeline.

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$^{(1)}$ Near-field modelling has been carried out using the CORMIX model. CORMIX is a comprehensive software system for the analysis, prediction and design of outfall mixing zones resulting from discharge of aqueous pollutants into diverse water bodies. CORMIX has been developed under several cooperative funding agreements between the US EPA, the US Bureau of Reclamation, Cornell University, Oregon Graduate Institute (OGI), University of Karlsruhe, Portland State University and MixZon Inc.

$^{(2)}$ Far-field modelling has been carried out with the MIKE 3 HD/AD model. The purpose of the modelling is to clarify if there will be a build-up in concentration in discharged water within the Portovaya Bay and at what distance from the discharge point the pH and oxygen level will normalise due to sufficient mixing. Mike 3 is a fully dynamic 3D modelling system with a "Hydrodynamic" module handling the movement of the water and a "Advection/Dispersion" module handling the transport of the released additives.

and as such acts as a buffer between the atmospheric air and the natural gas, ensuring that there is no interaction between the gas and the air. This is illustrated in Figure 4.80.

In general, 30% of the pipeline length will be filled with nitrogen (a distance of approximately 400 km). This distance will be sufficient to ensure no interaction between gas and air during gas-in. The temperature of the nitrogen gas will be approximately 5 °C.

Figure 4.80  Overall commissioning principle

Both nitrogen gas and natural gas injection will take place from the compressor station located onshore in Russia.

The entire filling operation will be documented in detailed work procedures prior to commencement of this activity. These procedures will be developed during the detailed design phase and will include all activities necessary to complete pre-commissioning and achieve start-up status.

4.8 Operations Concept

Nord Stream AG will be the owner and operator of the pipeline system. An operations concept and security systems have been developed to ensure the safe operation of the pipelines in any situation, including avoiding over-pressurisation, managing and monitoring potential gas leaks and ensuring material protection. The details of the facilities and the operations concept are described in the following chapters.

4.8.1 Main Pipeline System Facilities

The main Nord Stream pipeline system facilities are located at the landfall facilities in Russia and Germany, the main office in Zug, the Portovaya Bay Compressor Station and the Greifswald Receiving Terminal.

The Portovaya Bay Compressor Station will be located approximately 1.5 km upstream of the landfall facilities in Russia. The Portovaya Bay Compressor Station will be owned and operated by OAO Gazprom. The Greifswald Receiving Terminal will be located downstream and
immediately adjacent to the landfall facilities in Germany. The Greifswald Receiving Terminal will be owned and operated by WINGAS GmbH.

The landfall facilities in Russia and the Portovaya Bay Compressor Station are separate sites, but the landfall facilities in Germany and the Greifswald Receiving Terminal will be integrated in a single site. The main components at the landfall facilities will be pipeline pig launchers and receivers, together with isolation and emergency shut down valves. Pipeline pig launchers and receivers are used to clean and inspect the pipelines, and isolation and emergency shut down valves are used to ensure that the pressure in the pipelines is not exceeding the maximum allowable operating pressure.

Corporate activities are based in Zug, Switzerland, and managed by the executive directors of Nord Stream AG. These activities include monitoring performance against targets for health, safety and environment and business coordination with upstream and downstream third parties (OAO Gazprom and WINGAS GmbH).

The Nord Stream pipeline system will be monitored and controlled from the main control room located at the Nord Stream AG head office in Zug. The main control room will be manned 24 hours per day, 365 days per year. There will also be a back-up control room in Zug, to be used in the event that the main control room becomes unusable, e.g. due to a building fire.

There will be a Nord Stream AG branch office in Moscow, Russia. This office will have full pipeline system parameter monitoring, relayed from the main control room in Zug via the Nord Stream supervisory control and data acquisition (SCADA) system.

There will be a local operator room at each of the Nord Stream landfall facilities, but these will normally be unmanned and in monitoring mode only. However, they can be manned if local manual control of the plant is necessary (e.g. during intelligent pigging operations and certain maintenance operations).

4.8.2 Segmented Pipeline Design Pressure

The pipeline system has been designed in accordance with Det Norske Veritas Offshore Standard "DNV OS-F101 – Submarine Pipeline Systems". This standard allows the pipeline to be divided into sections with different design pressures and without physical barriers between the sections, provided that an appropriate pressure control system is installed.

This is an advantage for long pipelines such as the Nord Stream pipeline because the inlet pressure is rarely the same as the outlet pressure due to the length of the pipeline, i.e. there is a natural pressure drop from inlet to outlet. This pressure drop is illustrated by the blue line in Figure 4.81.
The Nord Stream pipeline system will be divided into three sections with design pressures of 220 barg (bar gauge), 200 barg and 170 barg. The red line in Figure 4.81 illustrates the design pressures.

Normal operating pressure is everything between (design pressure + safety margin) and 100 barg. The normal operating pressure covers all typical operating scenarios. This does not mean that lower values are not allowed, but they will only appear in special situations such as start up.

The green line in Figure 4.81 represents the steady state shut-in settle-out pressure, which corresponds to the pressure in the pipeline when the inlet and outlet valves are simultaneously closed, i.e. when the pipeline is full of gas but with no flow.

Figure 4.81 is based on maximum design flow rate conditions.

Figure 4.81 The Nord Stream pipeline operation concept for the three pressure segments

Per the DNV pipeline standard, the Nord Stream pipeline system pressure control system comprises:

- A pressure regulating system
- A pressure safety system
The pressure regulating system is designed to ensure that the local design pressure of each pipeline section is not exceeded during normal operation (see also Section on Pipeline Pressure Regulation).

The pressure safety system is designed to ensure that the local maximum pressure for each pipeline section is not exceeded during incidental situations. Examples of such incidental situations are closure of the pipeline outlet valve or failure of the pressure regulating system. The maximum pressure to which the pipeline can be subjected under these conditions is called the incidental pressure. The incidental pressure can be a minimum of 5% and a maximum of 10% above the design pressure. For the Nord Stream pipeline, the incidental pressure is 5% above design pressure.

The pressure safety system has two components to ensure the system’s reliability: Pressure Safety System 1 is the primary protection system, and Pressure Safety System 2 is the backup protection system. The pressure regulating system and the pressure safety system function independently of one another (see also Section on Pipeline Pressure Safeguarding).

4.8.3 Pipeline Control System

The Nord Stream overall pipeline control system comprises the following functions:

- Pipeline pressure regulation
- Pipeline pressure safeguarding
- Pipeline leak detection
- Pipeline parameter monitoring
- Telemetry and telecommunications
- Fire and gas detection and protection
- Emergency shut down

A short introduction to each is given in following sections.

Pipeline Pressure Regulation

The Portovaya Bay Compressor Station and the Greifswald Receiving Terminal control the pipeline pressure and gas flow rate. These facilities have their own monitoring systems. In addition, the pressure regulation system will automatically alert the manned control rooms at Portovaya Bay and Greifswald if the normal operating pressure parameters of the pipeline system is threatened. Because of its capacity to advise the compressor station and receiving
terminal to adjust gas flow rates, the Nord Stream control system has ‘indirect’ pressure regulation functionality.

**Pipeline Pressure Safeguarding**

If steps to modulate the gas flow rate are not taken at the compressor station and/or the receiving terminal and the pipeline pressure continues to rise, the pressure safety system function will intervene. The pressure safety system will automatically block the pipeline inlet in the event of the pipeline system moving outside its normal operating pressure envelope (e.g. overpressure). Because of its capacity to shut down the pipeline inlet in the event of overpressurisation, the Nord Stream control system has ‘direct’ pressure safeguarding functionality.

**Pipeline Leak Detection**

If the Nord Stream leak detection system detects a leak, it will automatically alert the emergency shutdown system to shut down one or both pipelines (as appropriate to the nature of the leak). The alert is sent via the Nord Stream supervisory control and data acquisition (SCADA) system. The SCADA system displays the pipeline operating parameters at the Nord Stream plant locations, including the main control room in Zug and the two landfall facilities, as well as at other Nord Stream AG and third-party locations where such information is required, i.e., Portovaya Bay Compressor Station control rooms, Greifswald Receiving Terminal control rooms, Nord Stream AG branch office in Moscow.

It will be possible to detect leaks down to 1%-2% of throughput. Leak detection is more difficult in gas pipelines than in liquid pipelines because of the effects of compressibility. Very small leaks offshore might not be detected by the system when they are smaller than the accuracy of the measurement and calculations. Both will be fine-tuned constantly during operation so the accuracy will increase with time and operating experience.

Refer to Section on **Emergency Shutdown** for more information about emergency shut down in the case a leak is detected.

**Pipeline Parameter Monitoring**

The Nord Stream SCADA system also provides pipeline gas temperature safeguarding functionality. Automatic shutdown temperatures have been established for Nord Stream, and the SCADA system will alert the Greifswald Receiving Terminal control room if gas temperatures are in danger of approaching the established high- or low-temperature margins.

Normal operating temperature is the temperature within the design limits: That means inlet temperature ≤ 40 °C and outlet temperature ≥ -5 °C (short time) or -1 °C (permanent). In extreme hot summers in Russia the inlet temperature might increase and the gas flow might
need to be reduced in that time (typically during the hot hours during the day) not to exceed the maximum inlet temperature. In extreme cold winters in Germany the outlet temperature may decrease and the gas flow may need to be reduced in that time not to exceed the lower temperature limit, but also other corrective actions might be taken. Both scenarios have no impact on the environment or the safety of the pipeline.

Besides the temperature, pipeline instrumentation continuously also measures gas composition, inlet and outlet flow and pressure.

**Telemetry and Telecommunications**

The pipeline system communications infrastructure will permit fast, reliable and secure exchange of data (telemetry) and voice messages (telecommunications) between the various plants, control rooms and other locations, some of which are separated by significant distances.

In addition to normal means of communication (telephone, telefax and Internet communications) between all Nord Stream AG, OAO Gazprom and WINGAS GmbH plant and office locations, it is envisaged that communication between landfall facilities in Russia and the main control room in Zug will be via primary and secondary satellite links. It is also expected that communication between the German landfall facilities and the main control room in Zug will be via a primary fibre-optic link and a secondary satellite link. These links will tie in to existing satellite and land-based (fibre-optic) network infrastructure. A schematic of the communication is shown in Figure 4.82.

To facilitate the communication of pipeline system parameters (especially gas flow rate and gas composition), dedicated fibre-optic lines will be installed onshore between the Russian landfall facilities and the Portovaya Bay Compressor Station and onshore between the German landfall facilities and the Greifswald Receiving Terminal.
Figure 4.82  Pipeline operation will be controlled from the main control room in Zug, Switzerland, via satellite communication

Fire and Gas Detection and Protection
The landfall facilities in Russia and Germany will have local fire and gas detection and protection systems.

Emergency Shutdown
The landfall facilities in Russia and Germany will have local emergency shutdown systems. The systems will be triggered in the case of facilities fire detection, facilities gas detection or pipeline leak detection. A full risk analysis has been carried out for the system.

The amount of time it takes for a leak to be discovered depends, not surprisingly, on the type of leak detection system, the parameters of the pipeline being monitored and the size of the leak. Typically, a small leak of <10 cm might take several hours to detect. A larger leak of >10 cm may be detected in as quickly as a few minutes.
In the event of a significant hazardous event, such as a fire or a gas leak, the pipeline will shut down immediately (or with a very short time delay). In the case of a leak, the emergency shut down valve closure time will depend on the size of the leak and the leak detection time. The time it will take for the emergency shut down valve to close is approximately 3 seconds per inch of pipeline, i.e., approximately 150 seconds (since the pipeline is 48 inches).

Since there are no valves along the route it is not possible to shut down sections of the pipeline. This means that in case of a leak and subsequent shut down, water may enter into the pipeline.

4.8.4 Normal Pipeline Operations

Normal operating conditions are those in which the pipeline system flow rate, pressures and temperatures are all within the pipeline design parameters and in which flow rate is regulated in accordance with the notification requirements of the gas transportation agreement. The operation will take place as follows:

1. Pipeline outlet pressure (or Greifswald Receiving Terminal inlet pressure) will be controlled by the Greifswald Receiving Terminal control valves. These valves will also control line packing, which occurs when pipeline inlet flow is greater than pipeline outlet flow.

2. Pipeline inlet flow rate will be controlled by the number of compressors on line at Portovaya Bay Compressor Station. It is anticipated that the compressors will operate in ‘flow control’ mode, which automatically adjusts compressor speed.

3. The required pipeline inlet pressure (or Portovaya Bay Compressor Station outlet pressure) will be determined by the sum of the pressure at the pipeline outlet plus the pressure drop along the pipeline. With the compressors in ‘flow control’ mode, the compressor speed will adjust automatically to achieve the required compressor discharge pressure.

4. If pipeline inlet flow is greater than pipeline outlet flow, pipeline inventory will increase (line packing).

5. If pipeline inlet flow is less than pipeline outlet flow, then pipeline inventory will decrease (line unpacking).

6. During conditions that result in low pipeline outlet temperatures, the line heaters at Greifswald Receiving Terminal will be used to ensure that the outlet gas temperature does not fall below the specified minimum.

4.8.5 Transportation Operations

Transportation operations mean the daily functioning of the Nord Stream pipeline system in order to transport natural gas through the pipelines. To do this in a reliable and safe manner, the operations department will liaise on a daily basis with OAO Gazprom (regarding operation of the
Portovaya Bay Compressor Station and the upstream fiscal meters) and WINGAS GmbH (regarding operation of the Greifswald Receiving Terminal and the downstream fiscal meters). Installing fiscal meters is standard commercial practice for both the ‘gas seller’ (OAO Gazprom) and the ‘gas buyer’ (WINGAS GmbH) in order to measure the gas entering and leaving the pipeline. Operational gas measurement is also performed in order to perform inventories of the gas present in the pipeline and to detect leaks.

Transportation operations are managed remotely from the main control room in the Zug head office. The main control room is manned 24 hours per day, 365 days per year, by two control room operators. The control room operators will monitor operation of the pipeline within the normal operating envelope (as defined by real-time pipeline flow modelling software), whilst fulfilling daily transportation nomination requirements of OAO Gazprom and avoiding shutdown of the pipeline system due to malfunction of the system.

Procedures for planning and nominating daily transportation volumes, including intra-day adjustments, will be established in the detailed operating manual (to be developed in detail prior to operation and to supplement the gas transportation agreement). The detailed operating manual will also specify the routine communication arrangements between Nord Stream AG, OAO Gazprom and WINGAS GmbH.

The operations group will maintain all transportation records (daily volumes, gas quality, etc.), which will be made available to other groups within Nord Stream AG as required.

### 4.8.6 Maintenance Operations

Maintenance operations mean the daily maintenance and inspection of the Nord Stream pipeline system in order to enable transport of natural gas through the pipelines in accordance with the uptime requirements of the gas transportation agreement.

As part of the maintenance system, Nord Stream AG will have an emergency pipeline repair system in the event of damage to the pipeline. The system will include a repair philosophy, procedures, blockage equipment and material, contracts with vessels and repair companies and agreements with authorities for necessary permits in the different countries and territorial waters.

Planned maintenance and scheduled inspections will be carried out as a minimum in accordance with (1) manufacturers’ requirements, (2) statutory requirements and (3) recognised good industry practice. Planned maintenance and inspections will be carried out in non-winter months whenever possible to avoid working in severe winter weather conditions.

Service companies will perform maintenance activities, which comprise external inspection surveys and internal inspection (pigging).
External Inspection Surveys

Planned survey inspections will be carried out along the length of the pipelines to ensure the integrity of the system. Unacceptable pipeline spanning may develop as a result of waves and currents, requiring correction, e.g. by the placement of rocks, sandbags or mattresses. Anode potential monitoring will also be performed to ensure the integrity of the protection system.

Inspections will be conducted from a survey vessel equipped with different types of sensors, such as cameras and scanners, to inspect the general condition of the pipelines and to detect leaks. This visual/physical leak detection should be considered complimentary to the pressure-based leak detection system described in section on Pipeline Leak Detection. The equipment is typically mounted on remotely operated vehicles, i.e., un-manned, manoeuvrable underwater robots that are operated from the survey vessel. During the first years of operation, these surveys will be performed every one to two years along both pipelines. Later, this frequency will be optimised based on experience. It will take approximately 60 to 90 days to survey one pipeline.

Based on experience from other pipelines it is known that freespans may develop along the pipeline during the operations phase. The freespans may be caused by hydrodynamic impacts, such as currents, eroding the gravel supporting the pipeline. Development of freespans during operation of the pipeline will be investigated as a part of the external inspection. The freespans will be rectified and gravel supports maintained as necessary.

Internal Inspection (Pigging)

During operation of the pipeline system, pigging will be performed if necessary to remove any foreign matter that may have formed, such as hydrate or corrosion products. Pigs or pigs in "trains" will be launched from the landfall facilities in Russia and driven through the pipeline by the gas medium, see Figure 4.77.

It can be expected that during operation the cleaning pigs will push residue from the internal epoxy flow coating and iron oxide to the pig receiver at the German landfall. The amount of solids collected during operational cleaning of a dry gas pipeline operated without any chemical injection will be minimal (less than 1 ton). However, a proper chemical analysis will be carried out, and the debris will be properly disposed at a location for this type of waste. No liquid hydrocarbons are expected to be formed in the pipelines. Measures will be taken to ensure the pipelines are operated within the design boundaries.

At determined intervals, Nord Stream AG will carry out a more in-depth inspection of the pipeline condition. An "intelligent" pig will be sent through the pipeline system to check for any corrosion or changes in pipeline wall thickness caused by third party impacts. The principle of detection is based on magnetic flux in the longitudinal direction of the pipeline. The following defects can be detected: changes in pipe wall thickness (internal and external), dents and changes in material
hardness, transverse cracks in the base metal and metallic objects in the immediate vicinity of the pipelines. The frequency of these inspections is expected to be every three to eight years but will depend on the quality of gas fed into the pipeline system. Nord Stream AG will adjust the frequency of inspections as necessary.

4.8.7 Engineering operations

Engineering operations comprise the engineering support required to ensure (1) the integrity of the Nord Stream pipeline system, particularly with respect to pressure containment, and (2) the safe and reliable daily operation of the pipeline system. Engineering operations cover both routine and/or minor tasks as well as non-routine and/or major tasks.

Engineering operations are based at the head office in Zug, where the engineering group works closely with the operations group. The engineering group has primary responsibility for coordination with inspection and certification agencies/authorities.

Engineering group tasks include:

- Planning and execution of periodic major inspections of the pipeline (using specialist contractors)
- Planning and execution of any modifications, additions or major repairs to any part of the Nord Stream pipeline system (using specialist contractors)
- Technical support for mission critical specialist equipment and systems (e.g., SCADA system, telecom network, pipeline flow modelling software, transportation history database)

4.8.8 Manning Philosophy

All key personnel at the Zug head office and the Moscow branch office will be Nord Stream AG staff.

An engineering workstation will be installed at the main control room in Zug and at the local operation rooms at the German and Russian landfall facilities. From these engineering workstations, the various settings of the pipeline system monitoring, control and safeguarding systems can be checked and/or adjusted by the appropriate level of technical authority.

When skilled manpower is required at Nord Stream landfall facilities (e.g. during maintenance and intelligent pigging operations), it will be provided via a suitably licensed operations and maintenance services contractor, using appropriately qualified and experienced technicians. A Nord Stream operations/HSE supervisor will be present whenever landfall facilities in Germany and Russia are manned.

Nord Stream AG will also enter into service contracts with:
- Vendors to support specialist equipment (e.g. large valves, SCADA equipment, telecom equipment, etc.)

- Specialist inspection and survey companies

- Fabric maintenance companies (e.g. painting, etc.)

Major inspection and maintenance campaigns and major repairs will be planned by Nord Stream AG operations staff at the head office in Zug. Ad-hoc contracts will be awarded for execution of these non-routine activities.

There will be emergency response plans in place for safety and environmental incidents. Such incidents may be handled by Nord Stream AG core staff and its usual service contractors, or they may require the ad-hoc contracting of specialist personnel and/or service companies, depending on the nature of the incident.

The pipeline emergency response plans will be designed to ensure an effective response to emergencies, such as personal injury and illness, damage to assets and adverse environmental impact, and to prevent such emergencies escalating in consequence. Lines of communication for emergency response will also be outlined in the pipeline emergency response plans.

Relevant supervisory and technical personnel based at the Nord Stream AG head office in Zug will make regular visits to the Nord Stream plant locations for the purpose of quality assurance regarding all operational activities.
4.9 Decommissioning

The Nord Stream pipeline is designed to operate for 50 years. The decommissioning programme will be developed during the operations phase, since existing regulations and technical know-how gained over the lifetime of the pipelines must be taken into account. Regardless of decommissioning method, decommissioning will comply with all applicable legal requirements regarding decommissioning at that time.

The current practice for decommissioning is either removal of the pipeline or leaving the pipeline on the seabed after it is cleaned and filled with water. The prevailing industry view is that leaving the pipeline in place involves the least environmental impact because pipeline removal will disturb sediments. Also, the pipeline will have become a habitat and in other ways integrated in the natural surroundings. Nord Stream AG may undertake an EIA of the various alternatives for decommissioning the pipelines nearer the end of operations phase.

The current technological options and preferred methods for decommissioning of offshore installations and pipelines most likely will have changed in 50 years’ time, when the Nord Stream pipelines may be decommissioned. Knowledge about the environmental impact of various decommissioning strategies will be more developed due to considerable decommissioning activities within the North Sea in the coming 50 years. Nord Stream AG will use the prevailing technology available at the time of decommissioning since the technical options are expected will have changed. Finally, the layout of the pipeline (degree of burial in the seabed, etc.) at the time of decommissioning may affect the method of decommissioning and relevant mitigation measures.

The technical life of the pipeline may be extended beyond the expected 50 years design life through the close monitoring and evaluation of degrading mechanisms, such as corrosion and anode consumption, and conducting additional "fit-for-purpose" assessments and recertification.
4.10 References
