Nord Stream
The new gas supply route for Europe

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

## Nord Stream Espoo Report: Key Issue Paper Seabed Intervention: Works and Anchor Handling

February 2009

English version | Key Issue Paper
Seabed Intervention Works and Anchor Handling

ENG

Please note:

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

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

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## Abbreviations and definitions

| | |
|---|---|
| EEZ | Exclusive Economic Zone |
| GRT | Greifswald Receiving Terminal |
| HDPE | High-density Polyethylene |
| ISB | In-service Buckling |
| KP | Kilometre Post |
| PAH | Polycyclic Aromatic Hydrocarbons |
| PBCS | Portovaya Bay Compressor Station |

# 1 Introduction

Disturbance of the seabed during construction of the Nord Stream twin pipelines will be caused by various kinds of ‘earthworks’ to ensure that the pipeline has a stable foundation on the seabed and by placing of anchors that are used to move the lay vessel forward during pipe-lay.

In order to reduce the seabed disturbance caused by earthworks on the seabed (the so-called intervention works) as much as possible, an extensive, iterative route optimisation process has been carried out based on highly detailed geophysical, geotechnical and environmental surveying. Nevertheless, at certain locations intervention work on the seabed is still necessary, such as trenching the pipeline into the seabed, the placement of rock berms and dredging at the landfalls.

Intervention works are necessary due to the varying seabed conditions that exist along the Nord Stream route. The intervention works entail various methods required to ensure that the pipeline integrity is maintained with respect to pre-defined acceptable limits for span lengths, pipe stresses and off-bottom clearances. The intervention works on the seabed are thus required to protect the pipelines against potential failure. It is normal practice to minimise intervention works (and hence seabed disturbance) as much as possible for economic reasons but this in turn acts to minimise impacts on the environment and human activities.

Disturbance of the seabed also may occur during pipe-lay due to moving of the anchors that are used to keep the lay vessel in position. An anchored lay vessel is controlled by up to 12 anchors that are handled by tugs.

In the following, the background and the extent of the activities causing the seabed disturbance are presented in further detail. An introduction is given to the geological and morphological conditions that cause the need for intervention works on the seabed. On this basis the considered intervention works are presented and the necessary intervention works in the individual countries are summarised.

Although all efforts are taken to minimise the disturbance of the seabed, impacts to the physical, biological and socioeconomic environment can not be completely ruled out. A summary of the unavoidable impacts is provided along with the methods that have been used to assess the impacts.

# 2 Background and Baseline

## 2.1 Geology of the Baltic Sea

### 2.1.1 Geological conditions

The Baltic Sea is situated on the so-called Eurasian continental plate providing relatively stable geological conditions. The geology of the Baltic Sea comprises bedrock covered by sediments. The most important geological feature in the Baltic Sea region is a large depression within the oldest crystalline basement. This depression forms a basin with a fill of sedimentary bedrock becoming progressively thicker and younger towards south (**Figure 2.1**). These younger rocks are softer than the Precambrian rocks, and they have been worn down during glaciations. On top of the bedrock, less ancient quaternary sediments have been deposited.

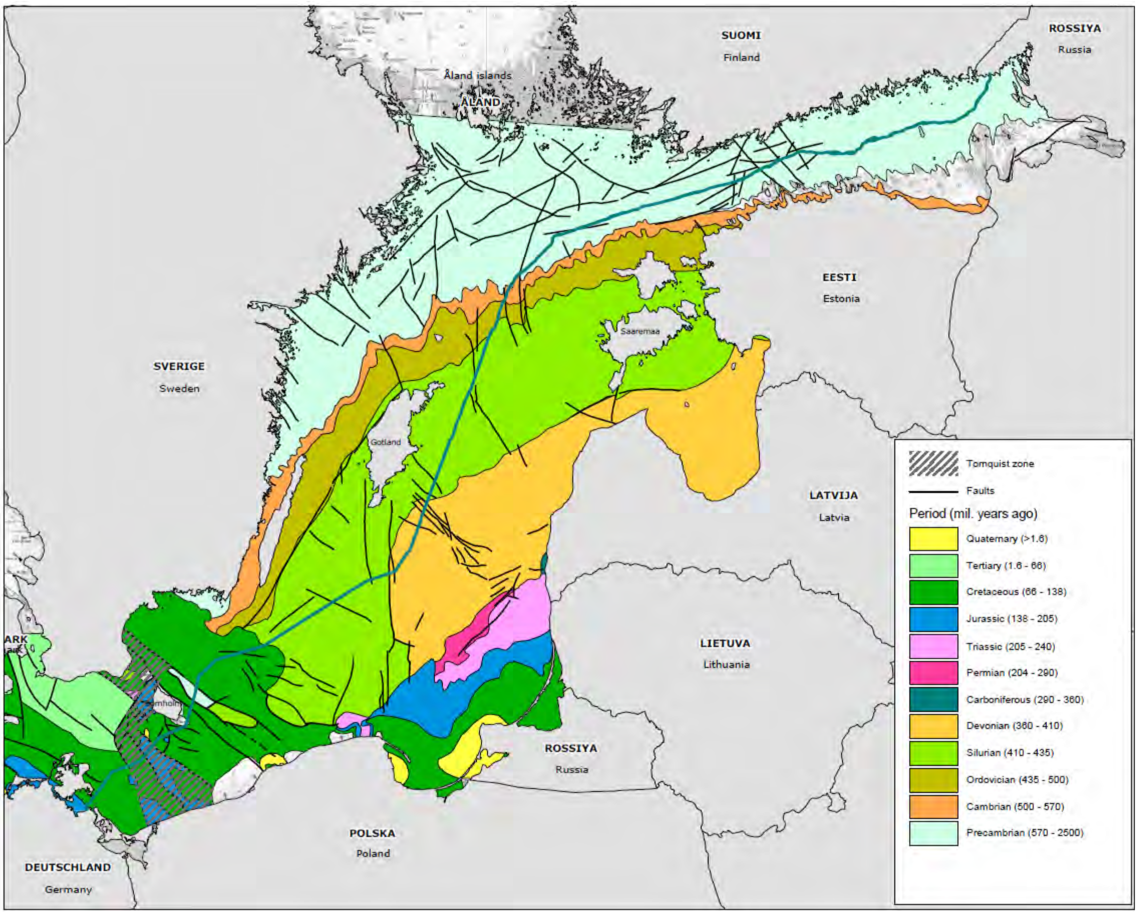


**Figure 2.1 Bedrock geology in the Baltic area**

The surface of the bedrock is a result of fluvial and glacial erosion. Troughs and valleys, form pronounced features of the Baltic seabed morphology. The troughs and valleys have been formed by erosion of less-resistant bedrock layers.

Quaternary sedimentary deposits cover the sea floor of the Baltic Sea almost completely. These deposits were formed during the last ice age and during different post-glacial Baltic Sea development stages. The distribution of sediments in the sea floor is a result of the Quaternary geological history of the Baltic Sea until the present-day distribution of areas of sedimentation or erosion. Bedrock without a cover of younger sediments is found only in near-shore areas in the northern Baltic proper and Gulf of Finland or where steep slopes are present on the seabed.

The glacial deposits are dominated by glacial till comprised of a mixture of grain sizes, from clay to boulders. The majority of the tills were deposited under glaciers, and are hard and possess high strengths due to the pressure of the overlying ice. The thickness of till deposits varies from a few metres to several tens of metres. Exposed till is found on top of or at the sides of topographical heights and on steep slopes at the sea bottom. Late-glacial and post-glacial sediments occur upon the glacial deposits. The late-glacial sediments are mainly clay, silt and sand. These deposits are covered by even younger deposits of mainly clay and silt.

The distribution of sediments in the Baltic Sea floor is governed by a number of factors, such as water depth, wave size, current pattern etc. Two general zones can be outlined, ‘zone of sedimentation’ and ‘zone of erosion or non-deposition’.

Zones of sedimentation include areas such as deep basins or sheltered areas, such as the Gulf of Finland and the Northern Baltic Proper (see **Figure 2.2**), whereas zones of erosion or non-deposition are found in areas exposed to wave- or current-induced water motion, such as south and south-west of Gotland.

The most recent sediments in the uppermost layers in the sedimentation zones consist typically of clay and mud with a high organic and water content. The fine-grained sediments retain a loose texture due to the low-energy sedimentary environment and their high organic content. Even weak currents can transport the sediments into deeper or sheltered areas, which act as accumulation areas for these sediments. The thickness of the deposits varies considerably. These young and loose sediments are characterised by a low bearing capacity and may provide stability problems depending on the seabed topography.

### 2.1.2 Water depths

The Baltic Sea is a semi-enclosed area connected to the North Sea through the Danish Belt Sea. The Baltic Sea comprises five main regions out of which the Nord Stream pipelines are planned to pass through the Baltic Proper and the Gulf of Finland, see **Figure 2.2**.

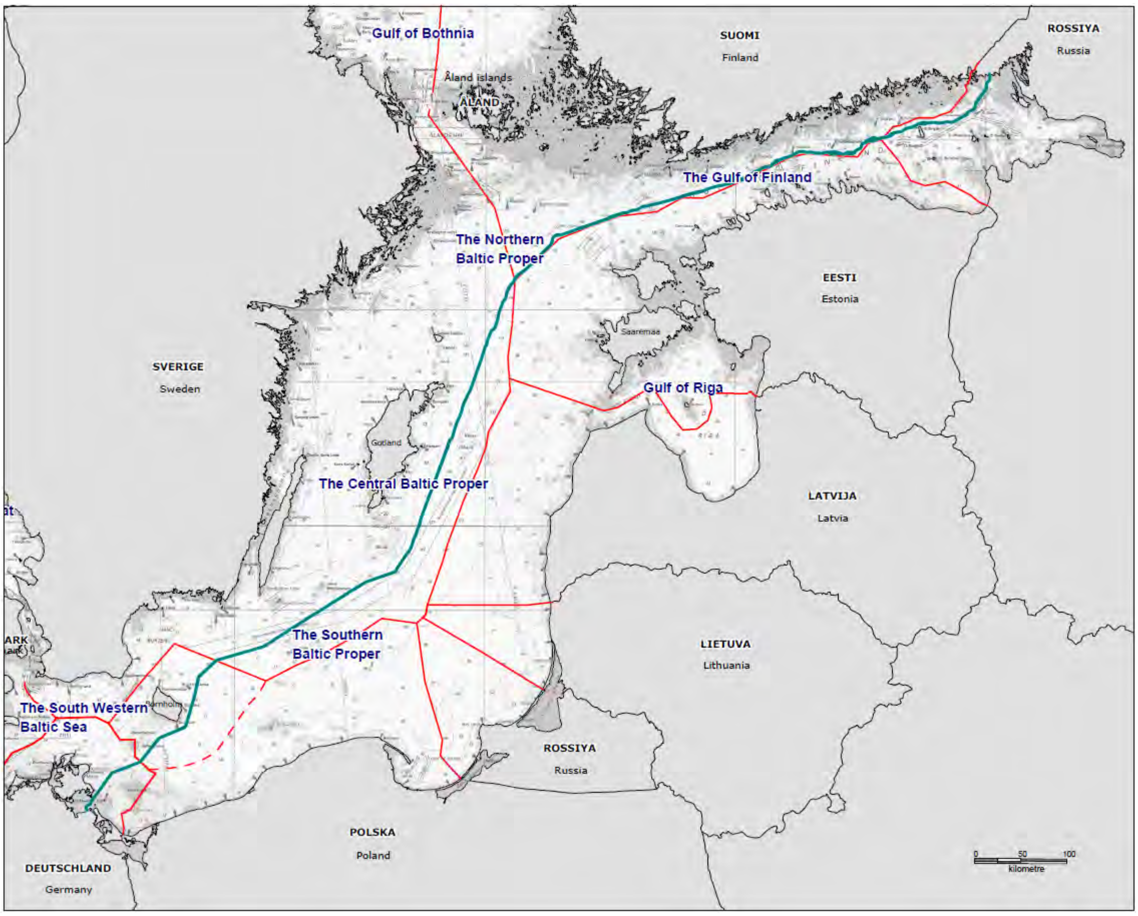


**Figure 2.2 Nord Stream pipeline route through the Baltic Sea**

The internal bathymetry divides the Baltic Sea into several sub-basins or deeps, which are separated by shallow areas (**Figure 2.2**).The deepest areas, with depths up to 459 m, are found in the Northern Baltic Proper and the Central Baltic Proper, while the shallow area of the Bornholm Strait in the South Western Baltic Sea has a maximum depth of 45 m. The maximum depth of the Gulf of Finland is 123 m.

The depth along the Nord Stream pipeline route gradually increases through the Gulf of Finland (**Figure 2.3**). The water depth along the surveyed route alignment varies from 43 m to 203 m close to the border between the Finnish and the Swedish exclusive economic zones (EEZs). From there the water depth gradually decreases towards the German landfall. The decrease in water depth is interrupted locally by deep basin structures, such as the Fårö Deep, the Gotland Deep and Bornholm Basin. The deeps are separated by intermittent bank structures, such as Gotska Sandön Bank and Hoburgs Bank.

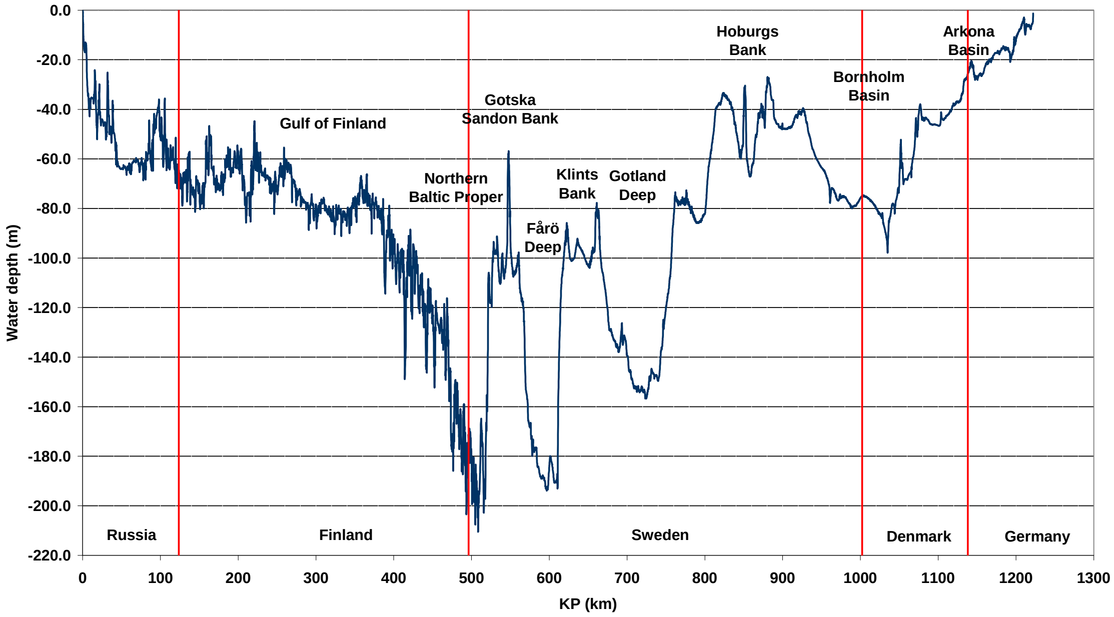


**Figure 2.3 Bathymetry along the surveyed route corridor**

The rough seabed in the Gulf of Finland and the Northern Baltic Proper, in combination with hydrodynamic conditions under which very soft sediments have deposited, provide a challenge to the construction of the pipeline and necessitate intervention works at the seabed.

## 2.2 Pipeline Route Development

### 2.2.1 Investigations of the Seabed

A general picture of the geological conditions along the seabed throughout the Baltic Sea was developed from available literature and information collected from relevant institutions within the countries surrounding the Baltic Sea. However, the routing of the pipeline and the design of necessary seabed intervention works has been selected on the basis of detailed investigations of the seabed carried out in connection with the Project preparation.

Several geophysical surveys were carried out to investigate the seabed topography which will ultimately dictate pipeline alignment. These surveys were used to map the water depth, seabed morphology and the geological conditions at and below the seabed surface in the pipeline corridor.

The survey equipment used to carry out the geophysical surveys included echo-sounders for bathymetry mapping, side-scan sonar used to determine the type of seabed sediment and sub-bottom profilers used to map the geological layering below the seabed surface (**Figure 2.4**).

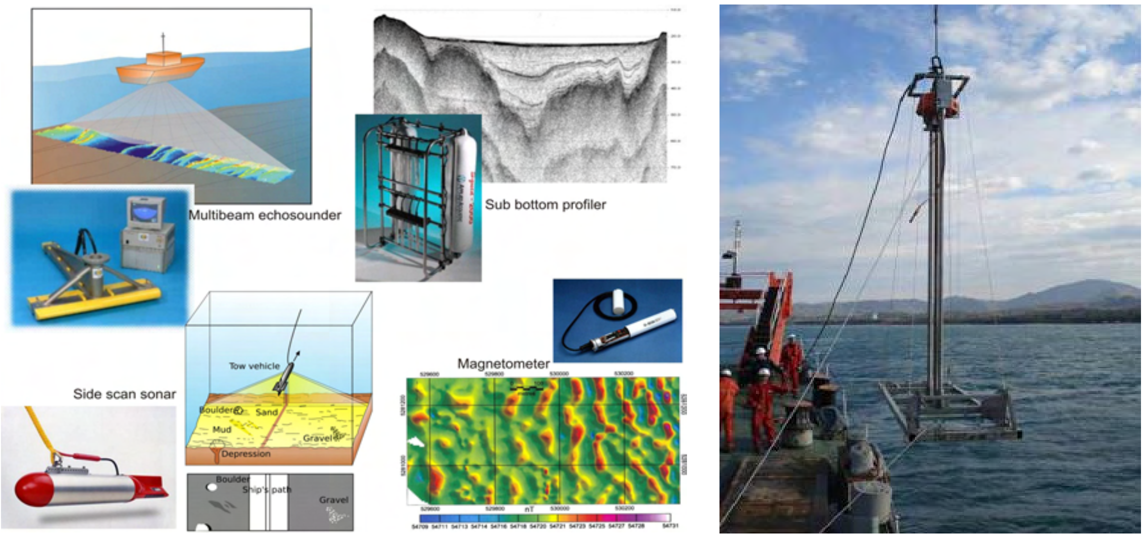


**Figure 2.4 Surveying the seabed – methods and equipment**

Geotechnical surveys were carried out in addition to the geophysical surveys. These surveys were used to gather data to allow the pipeline engineers to establish pipeline and seabed stability.

The geotechnical testing comprised different kinds of core sampling where core samples were extracted up to several meters below the seabed surface for analysis in laboratory. In situ testing and laboratory tests have been carried out to determine the geotechnical engineering properties of the subsurface.

### 2.2.2 Route Selection and Optimisation

The seabed topography and the present situation of the deposited sediments and sedimentary conditions along the pipeline route have been interpreted based on the data obtained from the geophysical and geotechnical surveys.

As indicated above, the seabed is not a flat, featureless plain as it has a varying topography with cliffs, trenches, etc. While the two large pipelines can be laid around curves, they are relatively inflexible and cannot twist and turn to avoid all such seabed features. Careful mapping of the seabed has identified the optimal route for the pipelines and minimises the need for seabed intervention works.

An example showing rough seabed topography and efforts to optimise routing to avoid crossing of outcrops of rock or hard till or erosion conditioned seabed features is shown in **Figure 2.5.**

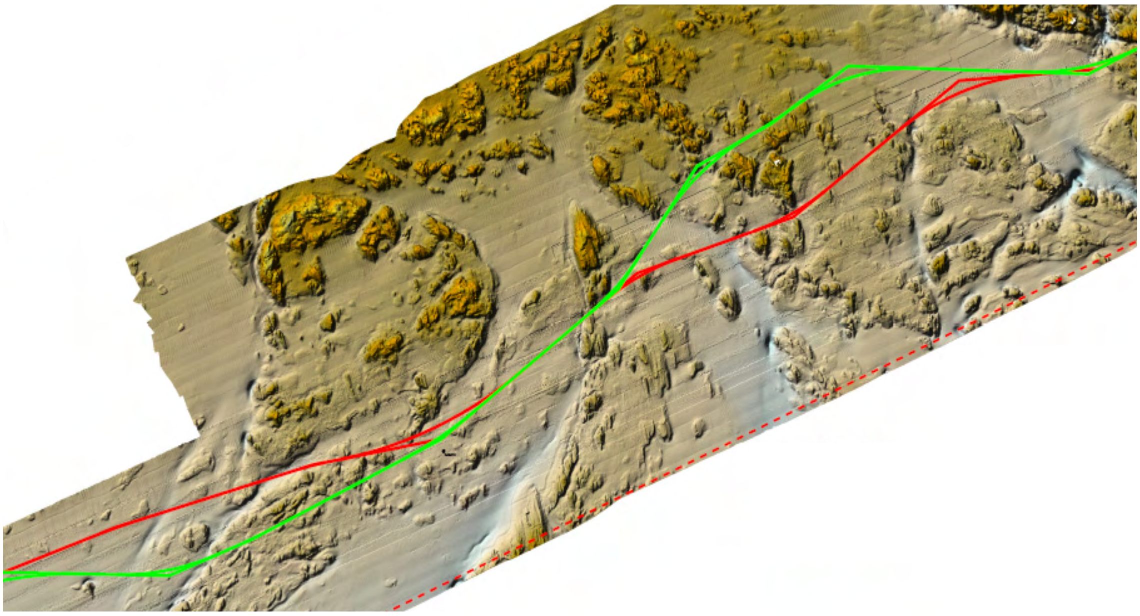

**Figure 2.5** **Example of optimisation of the pipeline route in the Gulf of Finland. The direct route (red line) has been replaced by a route requiring less rock placement (green line)**

A further element in appraising the route alternatives has been the technical considerations that must be taken into account in developing the preferred route. Alongside protection of the environment, a primary objective of the project has been to ensure the integrity of the pipeline.

Determining the best route for the pipeline has therefore been a complex process stretching over the different project phases, from the feasibility studies to the detailed design phase. Selection of the preferred route has progressed alongside project design taking into account information and circumstances applying at each stage, all in a continuous optimisation process.

## 2.3 Necessary Works on the Seabed

Despite the extensive route optimisation carried out, the need for seabed preparation and modification cannot be avoided completely. Such seabed intervention works are traditionally carried out by *trenching* (and *dredging*) or by *rock placement*. At a few certain locations, however, the load of the gravel exceeds the bearing capacity of the soil below, and stability can not be obtained. At these locations alternative solutions have to be introduced, i.e. installation of additional *support structures*.

The Project decided early in the consideration of technical alternatives that no *blasting* of rock will be performed during pipeline installation works because of its significant potential environmental impact. Similarly *cutting* has not been considered as an alternative option due to the environmental reasons, as well as the fact that the nature of the seabed in certain areas means that cutting is not a viable option.

**Figure 2.6** provides a graphical illustration of the way considerations of the different methods for preparing/modifying the seabed have been applied during pipeline design.

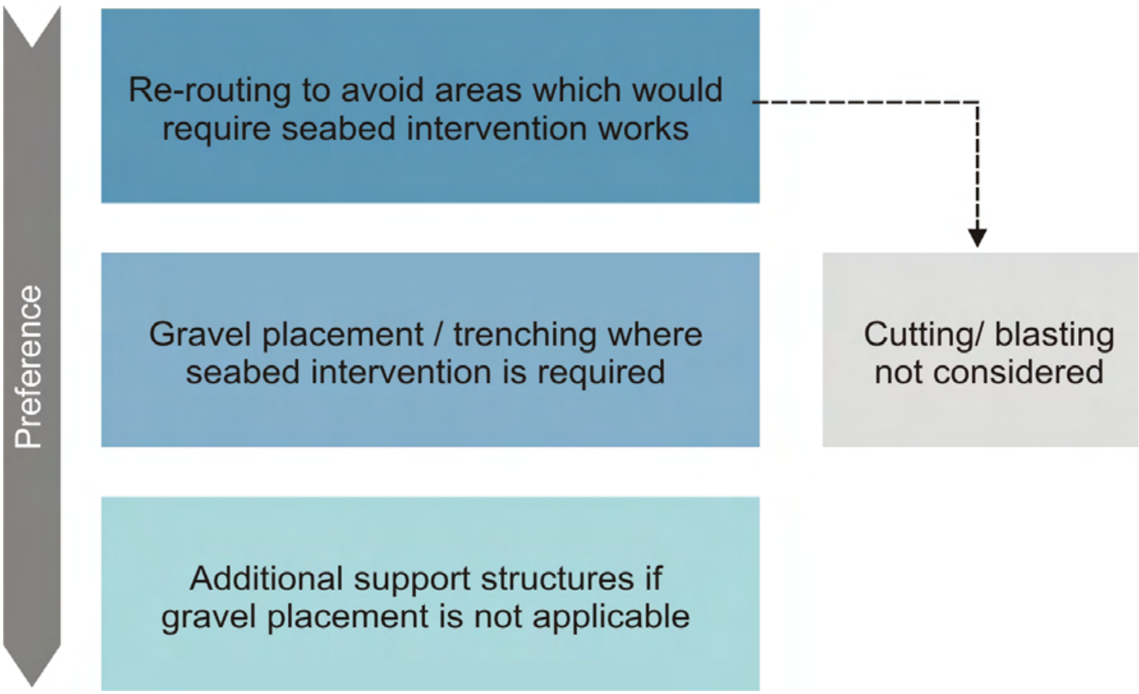


**Figure 2.6 Preference for method for preparation/modification of the seabed**

Finally, the pipe-lay itself and the necessary anchor handling related to the pipe-lay will also cause local disturbance of the seabed, however this is not classified as intervention works.

# 3 Activities Causing Seabed Disturbance

## 3.1 Seabed Intervention Works

Due to the seabed conditions in the Baltic Sea seabed intervention works are required at certain locations before and after pipe-lay to ensure that the pipelines have a stable foundation on the seabed and are protected to avoid the following:

- Excessive stress of the pipelines due to freespans (on an uneven seabed the pipelines may "ride" from crest-to-crest of the harder outcrops and be unsupported and thus sag in the middle)
- Excessive movement of the pipelines due to e.g. wind, waves, currents and temperature variations
- Impacts from shipping traffic

To ensure the integrity of the pipelines, the following solutions will be employed where necessary:

- Trenching, dredging and backfilling
- Placement of fill material, rock (gravel) placement
- Placement of (prefabricated) support structures

For all three solutions, the Project has carefully evaluated and selected the methods and equipment to be the most technically and environmentally appropriate.

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

- Phase 1 – This phase comprises intervention works to be carried out before pipe-laying
- Phase 2 – This phase comprises intervention works to be carried out after pipe-laying, but before pressure-testing
- Phase 3 – This phase comprises intervention works to be carried out after pressure-testing

### 3.1.1 Trenching

The offshore installation of the pipelines in some areas (especially in shallow waters) require additional stabilisation and/or protection against hydrodynamic loading (e.g. waves, currents) which can be obtained by trenching the pipeline into the sea bottom and (if required) backfill the trench.

Trenching can be performed either prior to pipeline installation as a pre-cut trench (*pre-lay*) or following the pipe-lay operation after the pipeline has been laid on the sea bottom (*post-lay*).

**Pre-lay**

Pre-lay trenching will be carried out by dredging (underwater excavation) in the shallow near-shore areas in Germany and Russia because of low water depth and the required burial depth of the pipelines. In the German near-shore area, the pipelines will be covered for protection against anchoring ships and grounding ships, in compliance with authority requirements as well as to ensure on-bottom stability. Dredging (underwater excavation) 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. **Figure 3.1** shows an example of a hydraulic backhoe dredger mounted on a pontoon.

**Figure 3.1 Hydraulic backhoe dredger mounted on a pontoon**

### Post-lay

Post-lay trenching is the most widely used trenching method in deeper water. 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.

Typically, post-lay trenching can be carried out in minimum water depths of 15 to 20 m and up to a trench depth of 1.5 m.

Post-lay trenching will be carried out by ploughing. The removed material will be left on the sea bottom immediately adjacent to the pipeline, and generally the trench will not be backfilled. However, partial, natural backfilling will occur due to currents. Post-lay trenching will be carried out in parts of the Swedish and Danish EEZs where hydrodynamic loads may otherwise compromise the pipeline stability.

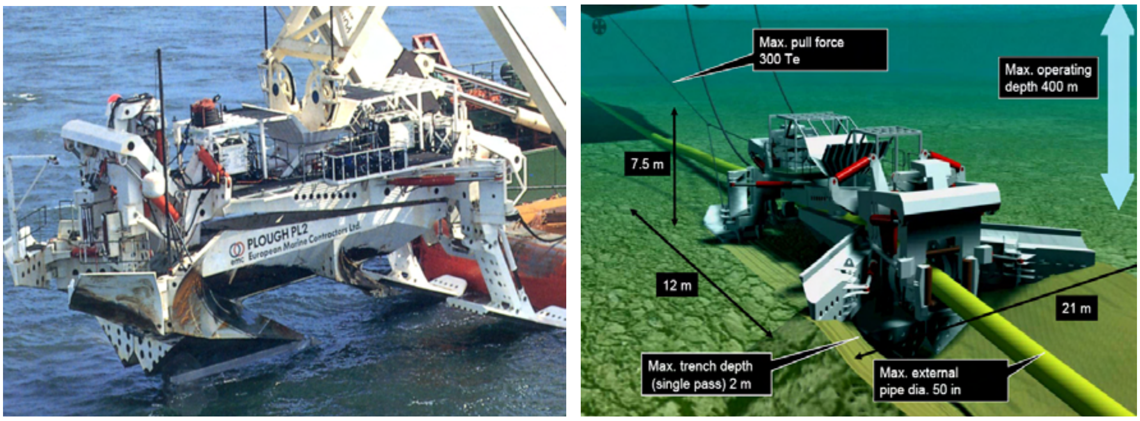


**Figure 3.2** **Pipeline plough on a support vessel (left) and in operation on the seabed (right)**

Ploughing will be carried out using a pipeline plough (**Figure 3.2**) 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 from the mother vessel which will then pull the plough through the seabed, producing the trench. Typically the mother vessel is capable of pulling the plough on its own however depending on the overall tow force required and the capability of the mother vessel, additional tugs can be used in tandem if required.

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.

**Backfilling of Pipeline Trench**

Natural backfilling of the trench, i.e., by sediment movements due to waves and currents, will occur along some sections of the trenched 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. The material will be removed, stored temporarily and used for backfill.

### 3.1.2 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.

Gravel placement will be taken forward as the main intervention method for free-span correction. Gravel placement will be carried out using material extracted from quarries on land. Types of gravel placement works that are envisaged for seabed intervention include gravel supports (*pre-lay* and *post-lay*) and gravel cover (*post-lay*).

Rock placement will take place in Russia, Finland and Sweden, where the seabed is rough. **Figure 3.3** shows a specialised fall pipe vessel used for rock placement and a fall pipe placing a gravel support on the seabed.

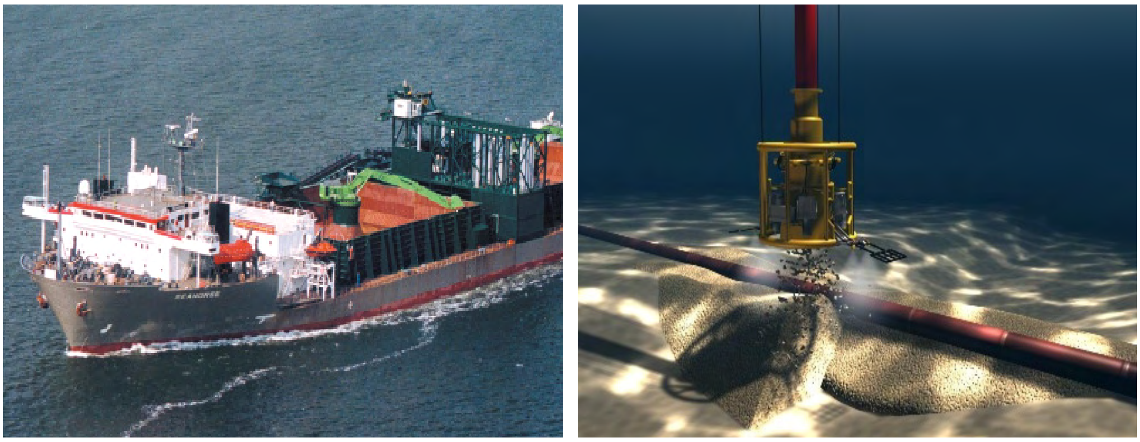

**Figure 3.3 Flexible fall pipe vessel (left) and a close-up of a fall pipe distributing rocks around a pipeline (right)**

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 has been 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 sensors and nozzles to allow very precise shaping of each gravel support.

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 locations where pipe sections are welded together (tie-in)
- Gravel supports for cable crossings

### 3.1.3 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 3.4**.

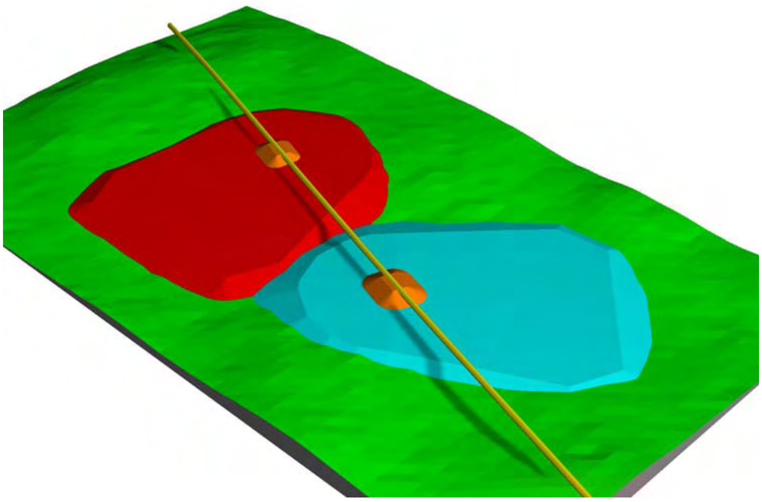

**Figure 3.4 Counter-fill (red and blue) for additional stability under rock berms (orange)**

Under certain seabed conditions, in soft clay with a low bearing capacity, the required pipeline stability can not at all be obtained by rock placement as the load of the gravel exceeds the bearing capacity of the soil below. Under these circumstances special support structures in combination with rock placement may be required.

The exact details of such structures are yet to be designed however one concept is shown in **Figure 3.5**. In this example the structure may be composed of a base steel frame and two light, foldable mud-mats, which are connected by hinges. A number of light-weight, high-density polyethylene (HDPE) pipes filled with foam are fixed on top of the mud-mats. This structure is then covered by a gravel layer, on top of which the pipeline is laid. The minimum required dimensions are 11 m x 18 m.

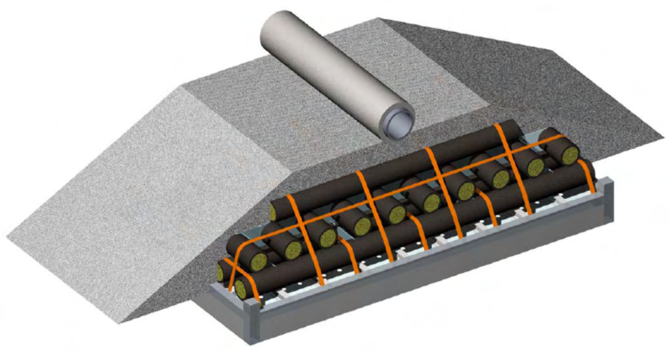

**Figure 3.5 Support structure constructed of foldable mud-mats, foam-filled HDPE pipes and gravel**

It is expected (January 2009 status) that the use of the special support structures may be necessary at certain locations in the Gulf of Finland (in the Russian EEZ). However, efforts are undergoing to eliminate the use of these supports.

### 3.1.4 Construction of Landfalls

The starting point of the Nord Stream pipelines is at the site of the compressor station at Portovaya Bay in Russia. The terminating point of the Nord Stream pipeline is the receiving facilities in Lubmin. In order to bring the pipelines onshore extensive construction works will take place in the shallow areas at the landfalls.

**Russian Landfall**

The Russian landfall will be located approximately 1.5 km downstream of the Portovaya Bay Compressor Station (PBCS). The landfall location is shown in **Figure 3.6**.

**Figure 3.6 Landfall location in Portovaya Bay**

The Russian near-shore sector is in an area susceptible to ice gouging, and therefore the pipeline will be buried into a trench. The pipeline will be laid in a trench providing a soil cover of approximately 2.0 m above the pipeline top along the whole area. Each line will be laid in a separate trench (**Figure 3.7**).

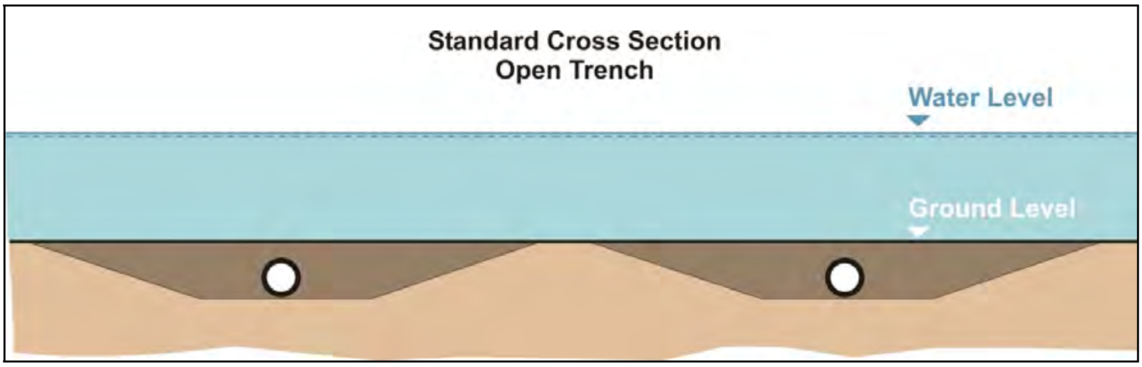


**Figure 3.7 Standard cross section – open trench in the Russian landfall area**

During construction the open trenches will be protected by dykes one on the external side of each line in the shallow water areas against scouring due to wave actions. A winch mounted on land will pull in the pipelines ashore from the pipe-laying vessel (**Figure 3.8**).

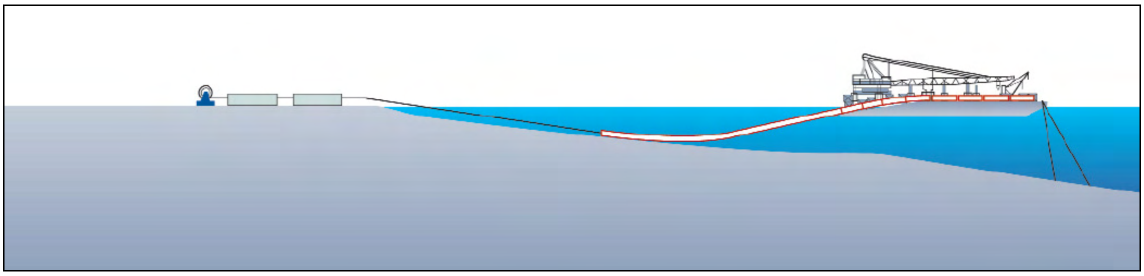

**Figure 3.8 Schematic of shore-mounted winch pulling the pipeline towards shore from the pipe-laying vessel**

After pipe-laying the trenches will be backfilled, the embankments will be removed, and the sites will be cleared and re-established. The trench will be backfilled both from the shore by excavators using the excavated soil and the dyke material, and by offshore pontoon-based excavators.

When a pipeline is pulled ashore the shallow water pipe-laying vessel continues pipe-laying in the trench for approximately 1.8 km where the water depth is 14 m and from where the offshore pipe-laying vessel will continue the pipe-lay operation away from the shore.

**German Landfall**

The German landfall will be integrated in the Greifswald Receiving Terminal (GRT). The landfall location is shown in **Figure 3.9**.

**Figure 3.9 Landfall location at Greifswalder Bodden**

Like the pipelines at the Russian landfall, the Nord Stream pipelines are laid in an excavated trench at water depths of less than 15 m at the German landfall. At depths of more than 15 m they are laid directly on the seabed.

Consequently in the whole of the Greifswald Bodden, across the Greifswalder Boddenrandschwelle (a glacially formed threshold making the entrance to the bay) and beyond the two pipelines will be laid in one excavated trench, on a length of about 27 km. The dredging of the trench will be carried out with mechanical equipment.

The excavated soil will be transported by barges to a dumping site near the island of Usedom. The top soil will be excavated and stored separately, to allow for backfilling in the area of its origin.

In the immediate coastal area, a temporary cofferdam will be constructed, extending approximately 550 m offshore to a water depth of about 2.5 m. The dam will protect the trenching works and the pipes when they are winched ashore from the laying vessel. The excavated material from within the cofferdam will be stored in a cofferdam compartment.

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 (ships and anchors). Therefore, dredgers will re-dredge suitable material from the storage site, transport the material to the trench and backfill the trench (see **Figure 3.10**).

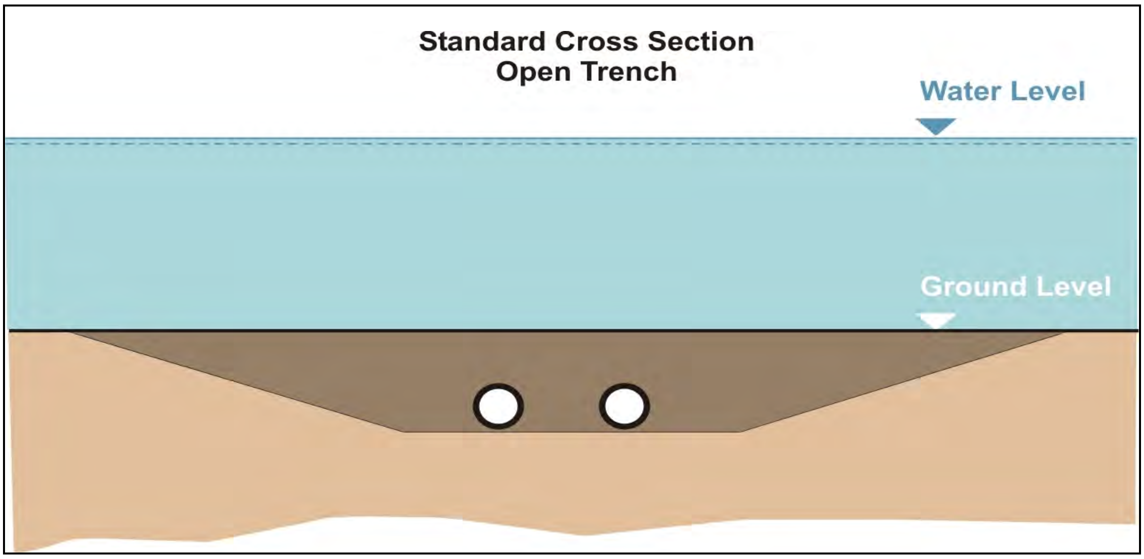


**Figure 3.10 Standard cross section – open trench in the German landfall area**

The soil cover of the pipelines will vary from 2 m at the landfall point on the coast, up to more than 5 m beneath the sea floor when crossing two shipping lanes, but is generally 1 – 1.5 m in other areas of the Greifswald Bodden and Greifswalder Boddenrandschwelle.

Finally the cofferdam ditch will be back-filled with the stored excavated material. Surplus soil from the cofferdam will be shipped to the offshore dumping site or be used for on shore landscaping.

## 3.2 Pipe-lay and Anchor Handling

Pipe-laying will be carried out by both anchored and dynamically positioned pipe-lay vessels. 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, and pipe-lay will therefore not disturb the seabed. The Project has taken great effort to secure the availability of the dynamically positioned pipe-lay vessel for parts of the pipe-lay, as its availability is very limited.

Oppositely, in the event where an anchored lay vessel will perform the lay, the anchors may cause seabed disturbance. An anchored lay vessel is kept in position by up to 12 anchors, each weighing up to 25 tonnes. Independent anchor-handling tugs will manoeuvre the anchors, which are directly connected to and controlled by a series of cables and winches. The tugboats will place the anchors on the seabed at positions around the lay vessel to move the lay vessel forward. A typical anchor pattern is shown on **Figure 3.11**.

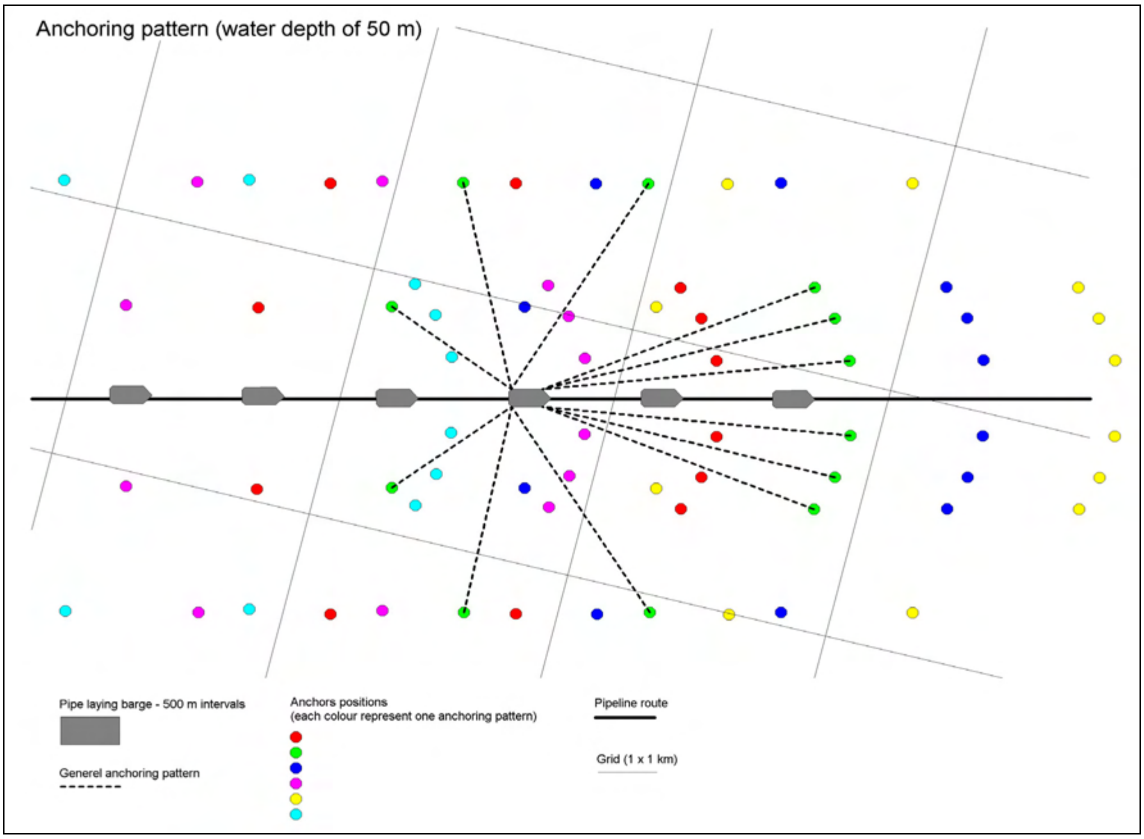


**Figure 3.11 Anchor patterns on the seabed as the pipe-lay vessel moves forward**

## 3.3 Extent of Intervention Works

The extent of anticipated seabed intervention works (January 2009 status) are summarised in the following chapters. It should be noted that volumes may change slightly during the final detailed design phase and following pipeline installation, when the actual extent of post-lay intervention works can only be finalised.

### 3.3.1 Russia

An overview of the locations and types of intervention works to be carried out in the Finnish EEZ is presented in **Figure 3.12** (overleaf).

In Russian waters the pipelines experience high compressive loads due to temperature and pressure. For this reason, there is a risk that lateral buckling will occur, causing the pipeline to move sideways, and upheaval buckling, causing a pipeline to move upward and lose contact with the sea bottom could occur. To mitigate buckling, rock will be placed over long sections to limit pipeline movement. Buckling is not anticipated along the other pipeline sections and therefore the total rock amount for the Russian section is higher than that of the other countries.

**Table 3.1** shows the rock placement and dredging volumes. The total number of rock placement locations will be 123 and 124 for the north-west and the south-east pipeline, respectively. **Figure 3.13** shows the size distribution of the rock placements.

With the exception of the dredging in the landfall area (**Section 0**), no other trenching is anticipated within Russian waters.

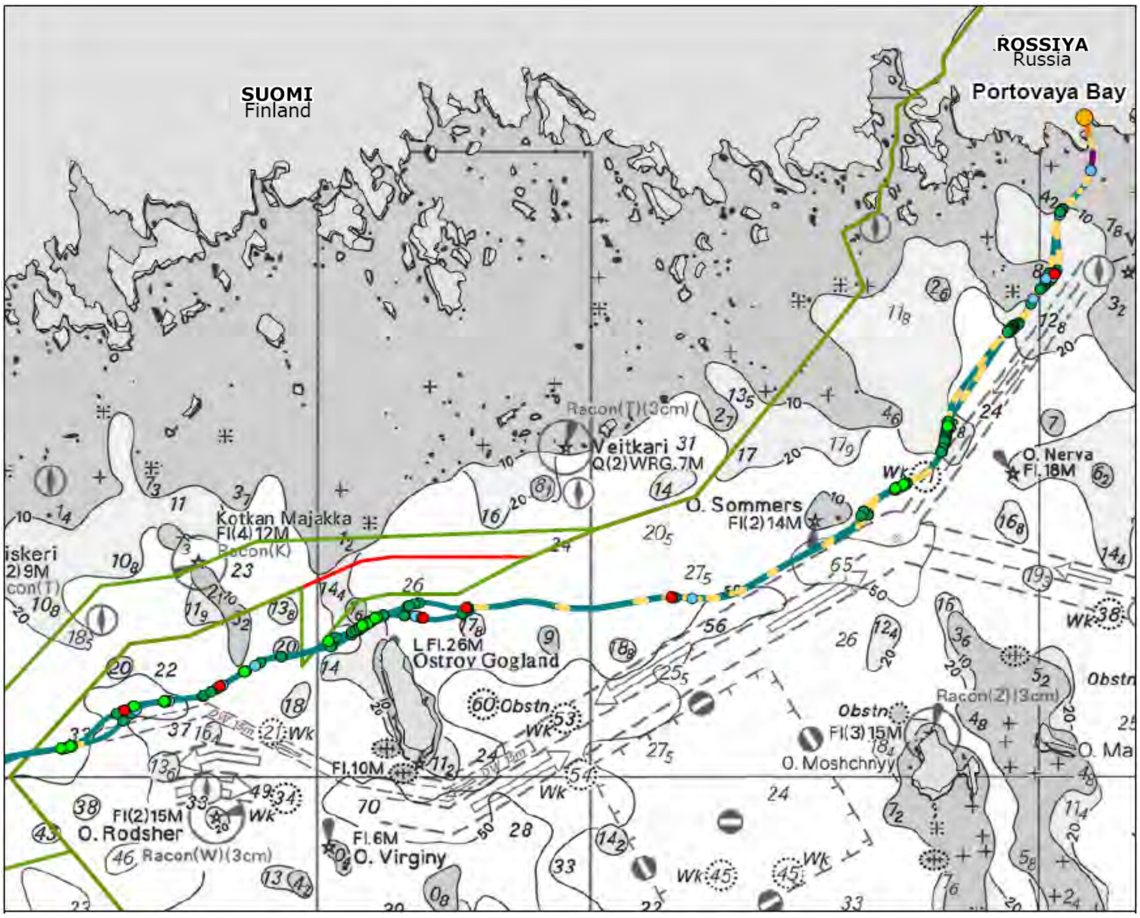


**Figure 3.12 Overview of types and locations of seabed intervention works in Russian waters. The light green dots indicate Phase 1 works; the dark green dots indicate the Phase 2 works. Phase 3 works are indicated by blue and yellow (ISB) dots. The red dots indicate the special support structures and the orange line at the landfall indicate the dredging. Locations are approximate and subject to final optimisation**

**Table 3.1 Summary of gravel volumes for rock placement and dredging in Russian waters. Quantities are approximate and subject to final optimisation**

| | North-west pipeline | | South-east pipeline | |
|---|---|---|---|---|
| **Rock placement** | **Volume ($m^3$)** | | **Volume ($m^3$)** | |
| Phase 1 | 32,956 | | 31,450 | |
| Phase 2 | 37,796 | | 45,580 | |
| Phase 3 | 15,010 | | 12,578 | |
| Mitigation of buckling | 572,573 | | 556,801 | |
| **Total** | **658,335** | | **646,409** | |
| **Dredging** | **Length (km)** | **Volume ($m^3$)** | **Length (km)** | **Volume ($m^3$)** |
| | 1.756 | 88,600* | 1.756 | 85,800* |
| *Volumes are calculated based on a cross section of ~50 $m^2$ for each trench | | | | |

In addition three support structures are anticipated on the north-west pipeline and five support structures are anticipated on the south-east pipeline (January 2009 status). As already mentioned, efforts to eliminate the use of these supports is ongoing.

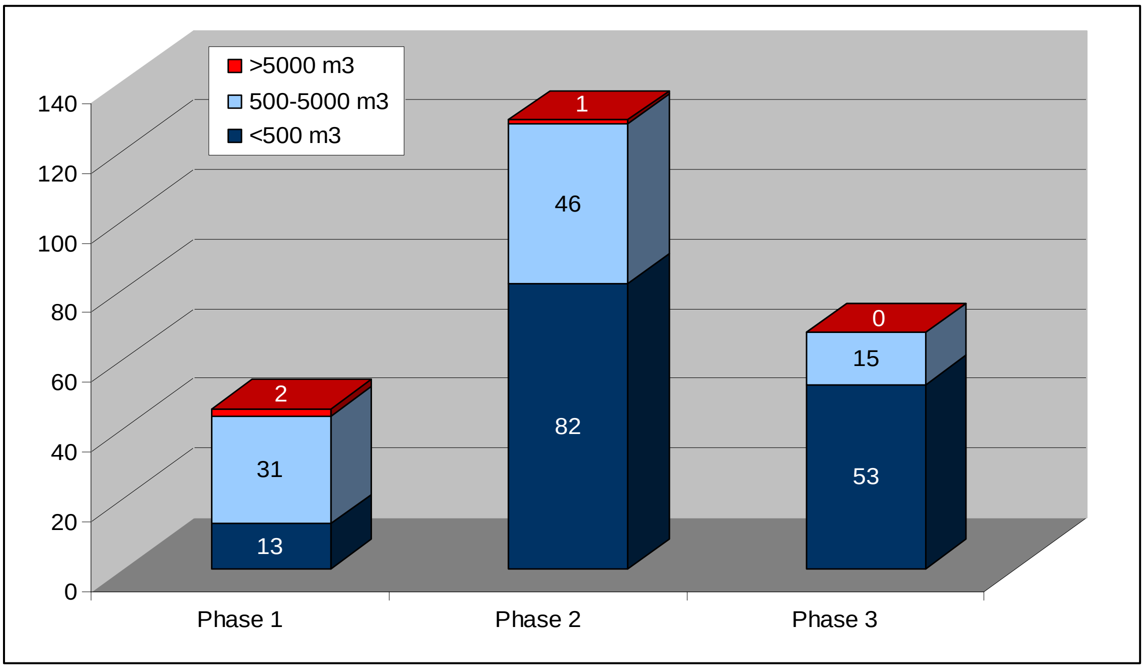


**Figure 3.13 Summary of the size distribution of the rock placements in Russian waters. The columns show the number of localities where rock placements of**

**different size are carried out pre lay (phase 1), before pressure test (phase 2) and before operation (phase 3)**

### 3.3.2 Finland

An overview of the locations and types of intervention works to be carried out in the Finnish EEZ is presented in **Figure 3.14**.

A summary of required gravel volumes for rock placement are shown in **Table 3.2.** The total number of rock placement locations is 100 and 83 for the north-west and the south-east pipeline, respectively. **Figure 3.15** shows the size distribution of the rock placements. No support structures are anticipated. Also, no dredging or trenching will take place within Finnish waters.

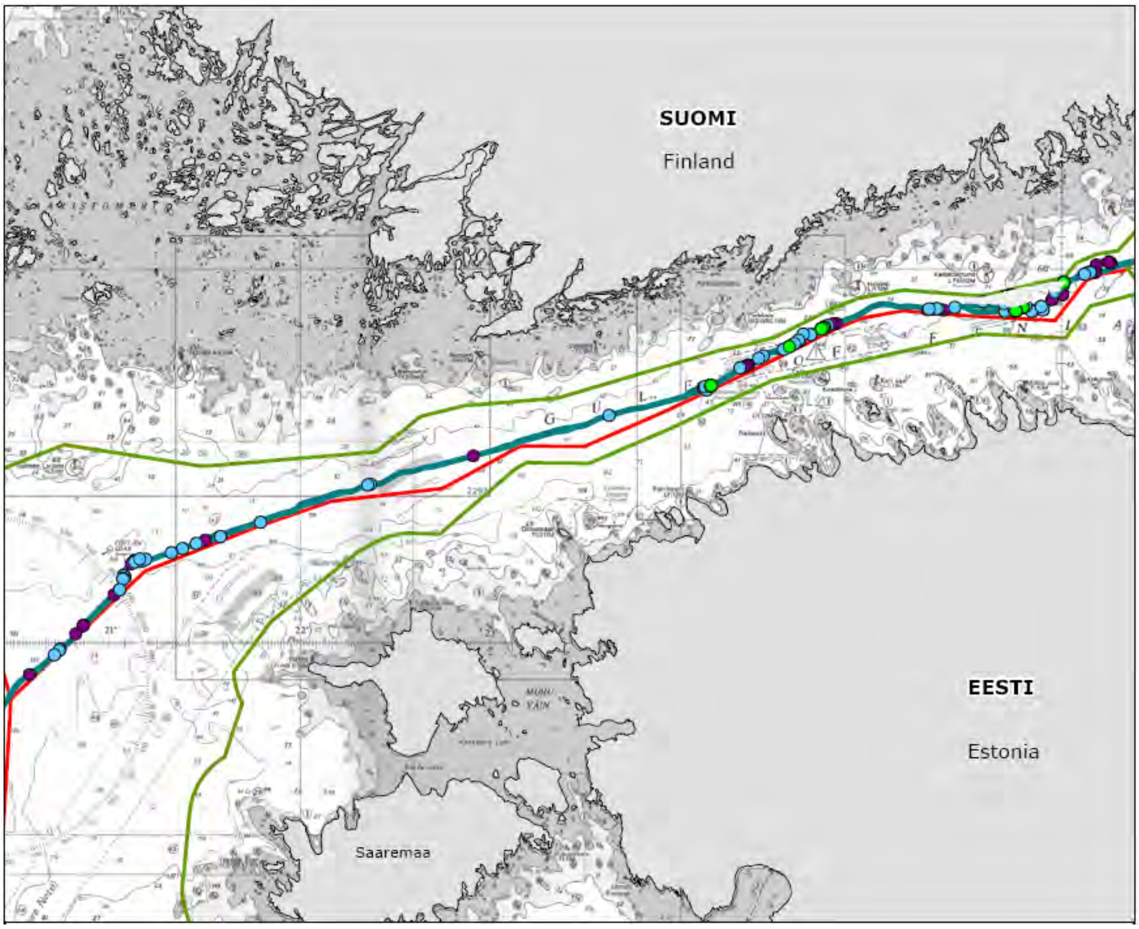


**Figure 3.14 Overview of types and locations of seabed intervention works in Finnish waters. The light green dots indicate Phase 1 works and the blue dots**

**indicate the Phase 2 works. Phase 3 works are indicated by purple (fatigue) and orange (on-bottom stability) dots. The pink dot indicates the tie-in basement (Phase 1). Locations are approximate and subject to final optimisation**

**Table 3.2 Summary of gravel volumes for rock placement in Finnish waters. Quantities are approximate and subject to final optimisation**

| | **North-west pipeline** | **South-east pipeline** |
|---|---|---|
| **Rock placement** | **Volume ($m^3$)** | **Volume ($m^3$)** |
| Phase 1 | 31,955 | 5,782 |
| Phase 1 – tie-in basement | 37,000 | 37,000 |
| Phase 2 | 80,151 | 50,567 |
| Phase 3 – fatigue | 29,927 | 26,225 |
| Phase 3 – on-bottom stability | 1,144 | 972 |
| **Total** | **180,176** | **120,546** |

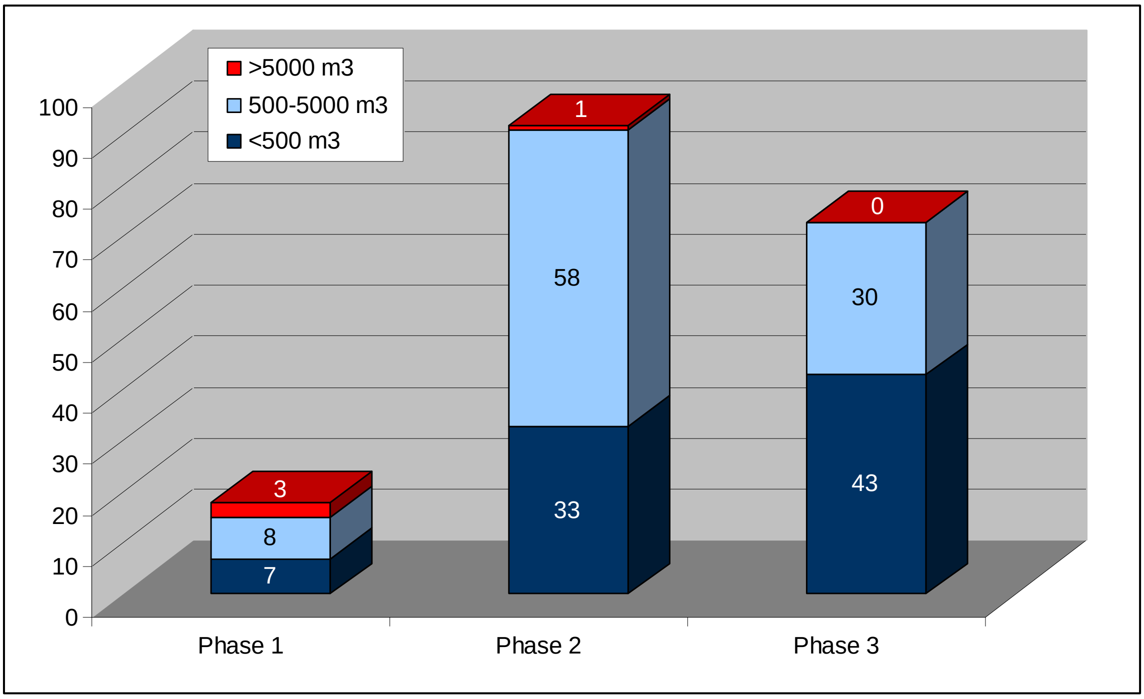


**Figure 3.15 Summary of the size distribution of the rock placements in Finnish waters. The columns show the number of localities where rock placements of different size are carried out pre lay (phase 1), before pressure test (phase 2) and before operation (phase 3)**

### 3.3.3 Sweden

An overview of the locations and types of seabed intervention works to be carried out in the Swedish EEZ is presented in **Figure 3.16**.

A summary of required gravel volumes for rock placement and trenching are shown in **Table 3.3**. The total number of rock placement locations is 43 and 48 for the north-west and the south-east pipeline, respectively. **Figure 3.17** shows the size distribution of the rock placements. No support structures are anticipated. Also, no dredging will take place within Swedish waters.

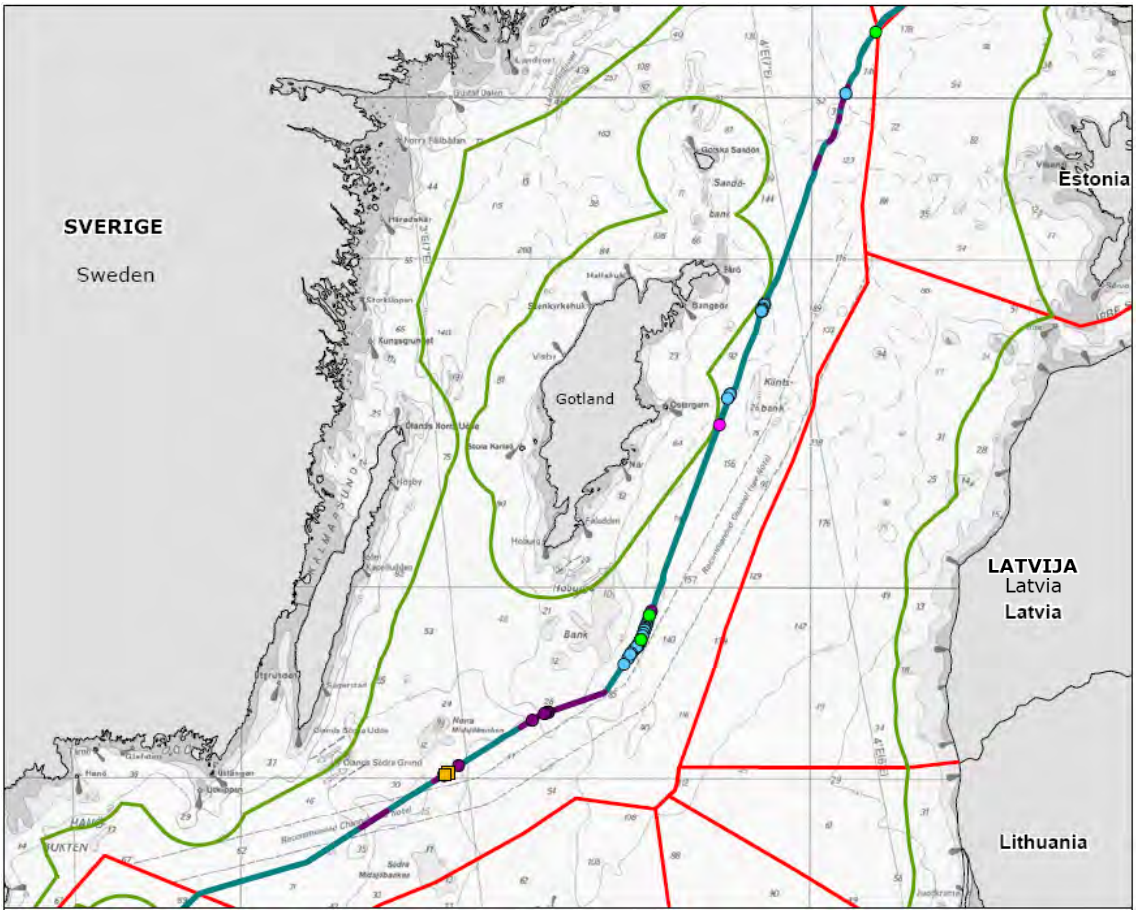


**Figure 3.16 Overview of types and locations of seabed intervention works in Swedish waters. The light green dots indicate Phase 1 works and the blue dots indicate the Phase 2 works. Phase 3 works are indicated by purple (fatigue) and orange (on-bottom stability) dots. The pink dot indicates the tie-in basement (Phase 1) and the purple lines indicate post-lay trenching. Locations are approximate and subject to final optimisation.**

**Table 3.3 Summary of gravel volumes for rock placement and trenching in Swedish waters. Quantities are approximate and subject to final optimisation**

| | North-west pipeline | | South-east pipeline | |
|---|---|---|---|---|
| **Rock placement** | **Volume ($m^3$)** | | **Volume ($m^3$)** | |
| Phase 1 | 377 | | 317 | |
| Phase 1 – tie-in basement | 0 | | 0 | |
| Phase 2 | 17,473 | | 28,192 | |
| Phase 3 – fatigue | 3,144 | | 6,145 | |
| Phase 3 – on-bottom stability | 1,794 | | 1,794 | |
| **Total** | **20,993** | | **34,654** | |
| **Trenching** | **Length (km)** | **Volume ($m^3$)** | **Length (km)** | **Volume ($m^3$)** |
| | 67.3 | 481,758* | 69.2 | 505,479* |
| *Volumes are calculated based on a cross section of ~7.2 $m^2$ | | | | |

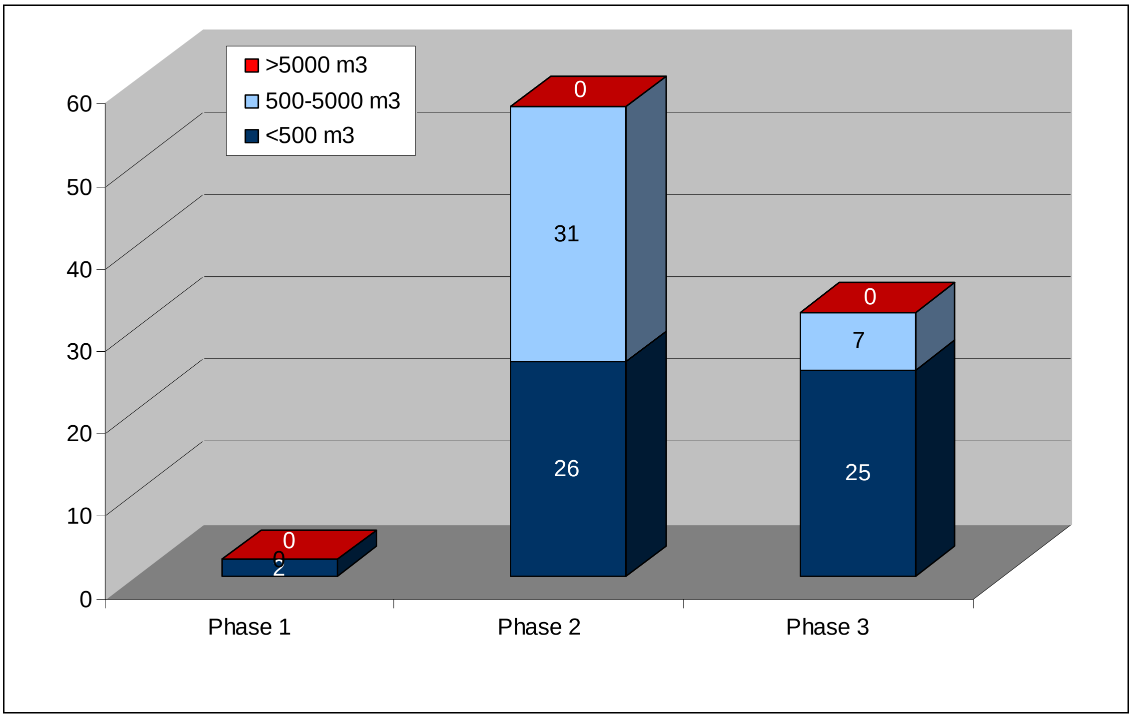


**Figure 3.17 Summary of the size distribution of the rock placements in Swedish waters. The columns show the number of localities where rock placements of different size are carried out pre lay (phase 1), before pressure test (phase 2) and before operation (phase 3)**

### 3.3.4 Denmark

An overview of the locations and types of seabed intervention works to be carried out in Danish waters is presented in **Figure 3.18**. A summary of required volumes for trenching are shown in **Table 3.4**. No dredging or rock placement will take place within Danish waters. Also, no support structures are anticipated.

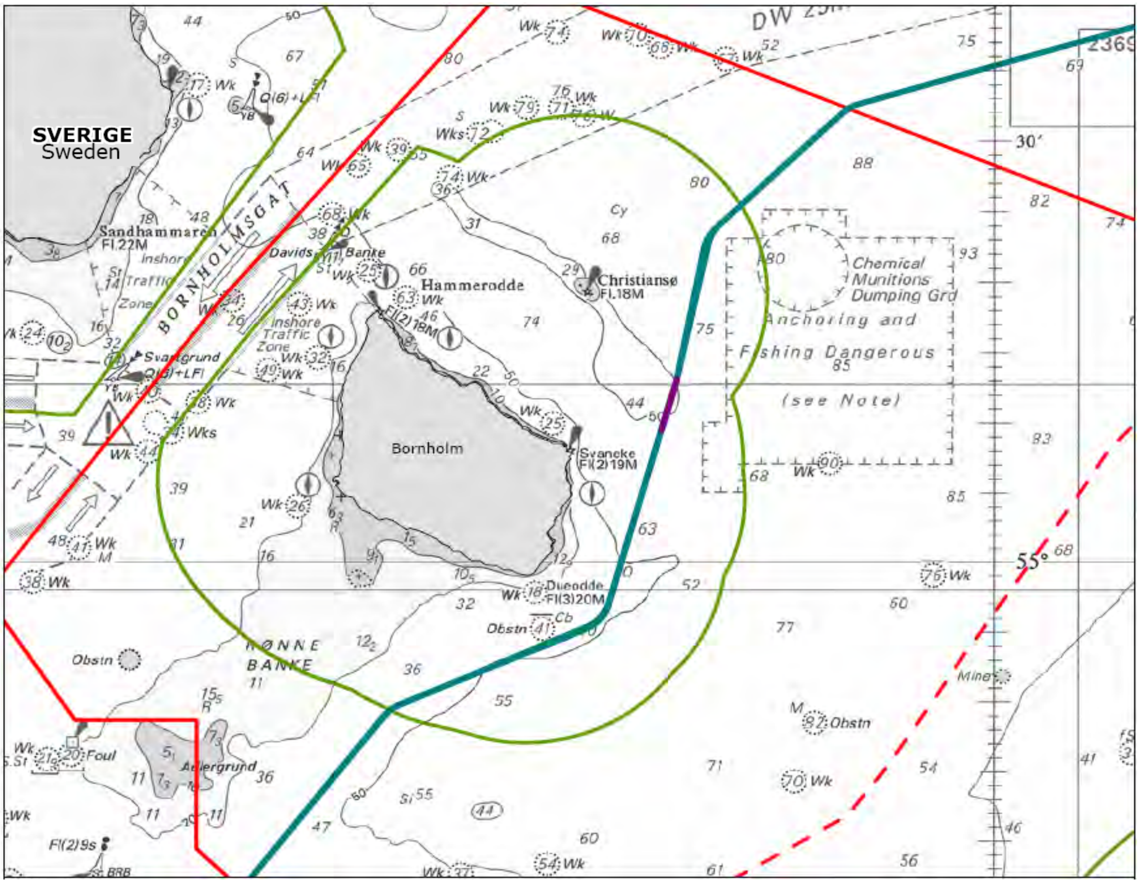


**Figure 3.18 Overview of types and locations of seabed intervention works in Danish waters. The purple line indicates trenching. Locations are approximate and subject to final optimisation**

**Table 3.4 Summary of trenching in Danish waters. Numbers are approximate and subject to final optimisation**

| | North-west pipeline | | South-east pipeline | |
|---|---|---|---|---|
| **Trenching** | **Length (km)** | **Volume ($m^3$)** | **Length (km)** | **Volume ($m^3$)** |
| | 10 | 62,528* | 15 | 93,482* |
| *Volumes are calculated based on a cross section of ~6.2 $m^2$ | | | | |

### 3.3.5 Germany

An overview of the locations and types of seabed intervention works to be carried out in German waters is presented in **Figure 3.19**. Dredging will be required in a large part of the German sector. Dredging volumes are shown in **Table 3.5**. No trenching, rock placement or support structures are anticipated in the German EEZ.

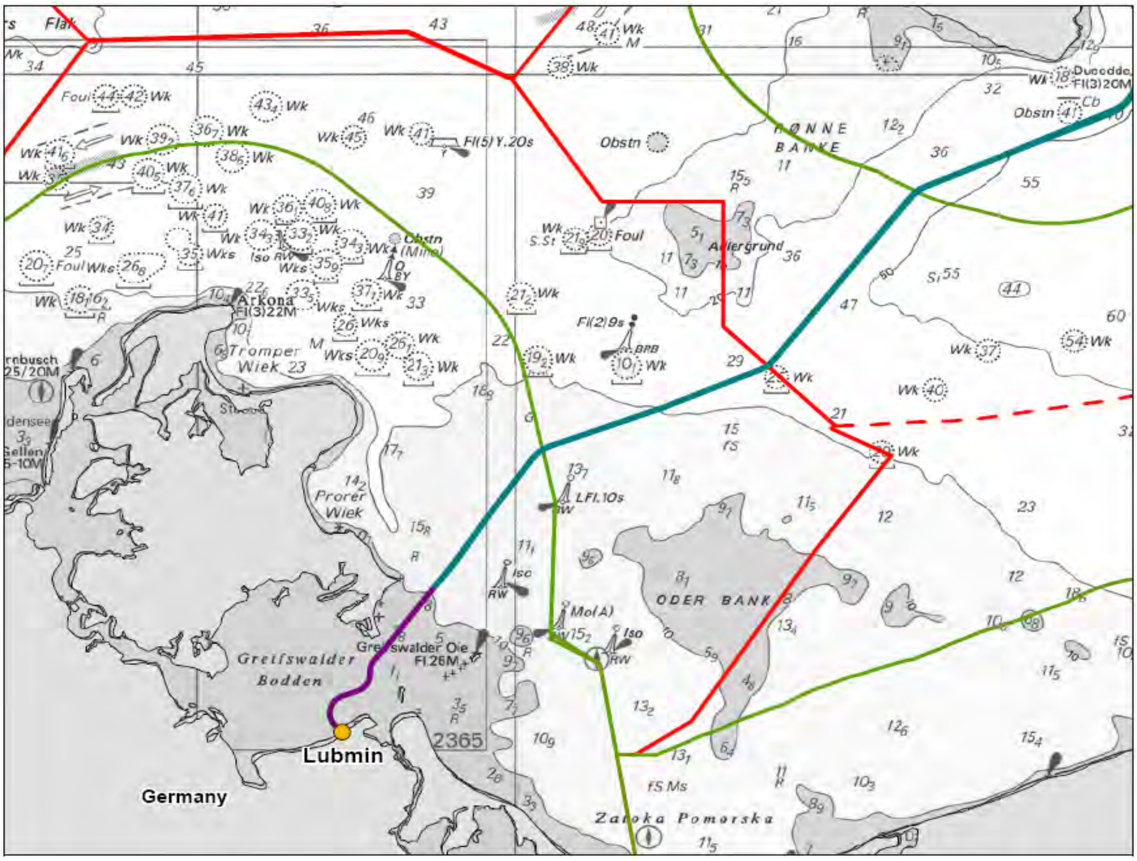


**Figure 3.19 Overview of types and locations of seabed intervention works in German waters. The purple line indicates pre-lay dredging. Locations are approximate and subject to final optimisation**

**Table 3.5 Summary of dredging in German waters. Numbers are approximate and subject to final optimisation**

| | North-west pipeline and south-east pipeline | |
|---|---|---|
| **Dredging** | **Length (km)** | **Volume (m³)** |
| | 27 | 1,850,000* |
| * One trench for both pipelines. Volume is calculated based on a cross section of ~68.5 m² | | |

# 4 Assessment of Impacts

## 4.1 Potential Environmental Impacts

The seabed disturbance will directly impact the water column and the seabed. A zone of physical disturbance at each side of the pipelines will occur during the construction works. Above this, physical disturbance will also occur due to anchor handling inside the anchor corridor to a maximum of 1 km on each side of the pipeline.

The assessments referred to in the following focus on impacts outside the zone of immediate physical disturbance. The spreading of sediments may cause impacts to the physical and biological environment just as the social and socioeconomic environment may be impacted (**Figure 4.1**).


**Figure 4.1 Cause of impacts**

The impacts on the physical environment may affect the following receptors:

- Water column
- Seabed

The spreading of sediments will cause additional suspended matter in the water column. Environmental surveys carried out have included chemical analyses of a large quantity of samples of the seabed from the countries involved. These analyses have been used to quantify the possible concentration and spreading of contaminants due to the seabed disturbance. The suspension of sediments containing contaminants may cause a change in the water quality depending on the solubility of the contaminants. After re-settlement of the suspended sediments a new sediment layer will cover the seabed locally.

Associated impacts on the biological environment may affect the following receptors:

- Plankton
- Benthos
- Fish

- Sea birds
- Marine mammals and
- Nature conservation areas

Impacts on the biological environment are all connected with the above changes in the physical environment e.g. changes in turbidity or water quality or the additional sedimentation on the seabed.

Associated impacts on the social and socioeconomic environment may affect the following receptors:

- Fisheries
- Tourism
- Cultural heritage

## 4.2 Assessment Methodology

An excess concentration of 1 mg/l will hardly be visible in the water because naturally occurring concentrations in the Baltic Sea are typically in the range of 1 – 4 mg/l during normal weather conditions and significantly higher during stormy conditions. A significant rise of the visible turbidity is assessed to correspond to a concentration of suspended matter above 10 mg/l.

The magnitude of the sediment spreading during the construction works has been calculated by mathematical modelling. The modelling of sediment spreading has included dredging in the near shore areas, post-trenching by ploughing and rock placement. Sediment spreading during the pipe-lay and the related anchor-handling has also been modelled.

Disturbance of the seabed must be anticipated in the immediate vicinity of the pipelines due to the construction activity itself. This disturbance occurs as spoil heaps along the pipelines where trenching is carried out, as rock piles and where construction works are carried out in the landfall areas. The width of this disturbance zone is assessed to be at maximum 100 m on each side of the pipelines (**Figure 4.2**). Only particles that are capable of being transported outside this physical disturbance zone have been modelled.

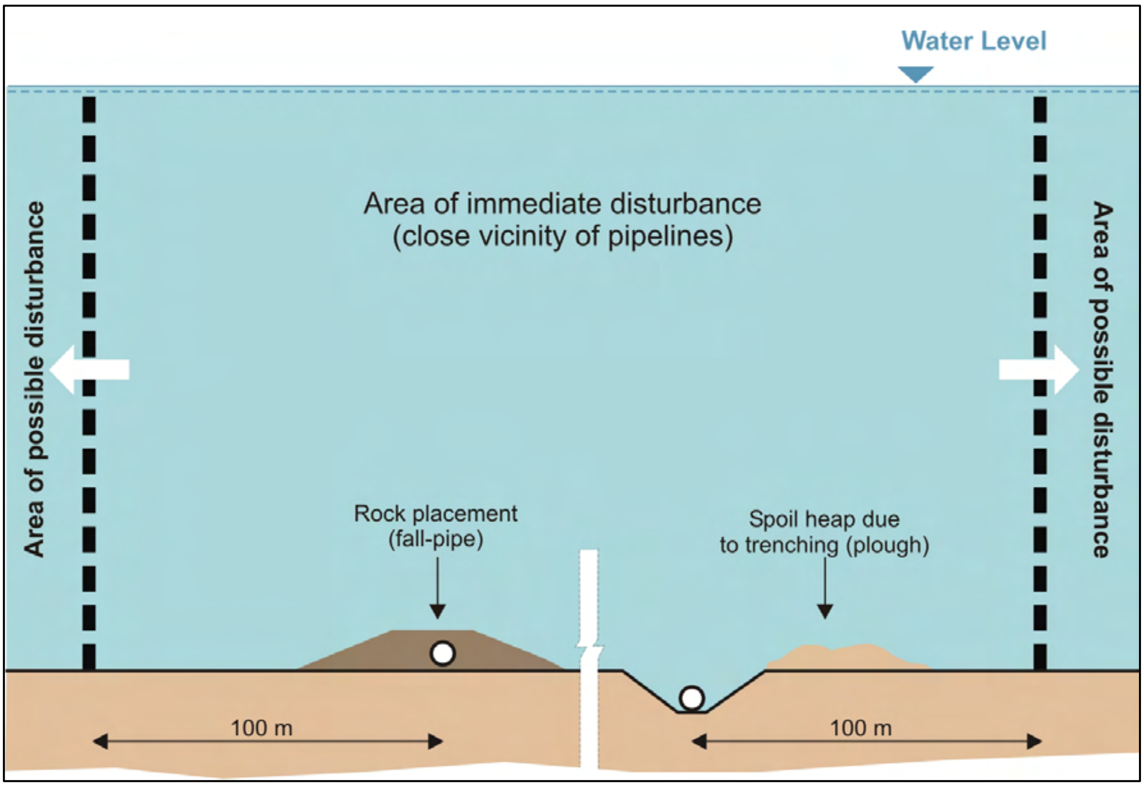


**Figure 4.2 Disturbance in the close vicinity of the pipelines**

### 4.2.1 Spill Rate of Sediment during the Intervention Works

Experience from other construction works at sea have demonstrated that the total spill percentage for dredging operations can be kept below 5% of the dredged mass. For dredging works the sediment is lifted through the water column and placed on a barge or as dams. The numerical modelling of dredging works has been based on a spill percentage on the safe side, well above the above mentioned 5%.

No data on the spill percentage is available for trenching operations. However, when trenching by plough sediment it is not lifted through the water column to be stored or disposed of. The spill when ploughing has been estimated at approximately 2% of the handled mass of seabed materials.

The material used for rock placement is very coarse, and it is anticipated that any sediment spill from rock placement activities is related to suspension of the local sediment caused by the induced momentum of the rock material placed on the seabed. For rock placement the amount of suspension is taken to be proportional to the placed rock volume and the suspension rate to be proportional to the placement rate.

To conclude, the spill is higher for dredging works than for trenching. In addition, the spill occurs close to the water surface when dredging. The modelling of spill has been based on conservative assumptions concerning the speed of the works in the different areas. In any case the spill rate is significantly smaller for rock placement.

### 4.2.2 Spreading of Sediment during Pipe-lay directly on the Seabed

During the pipe-laying process, sediments from the seabed may be suspended due to the currents generated in front of the pipeline when it is lowered through the water column near the seabed and the pressure from the pipeline when it touches down on the seabed.

The suspension of sediment during the pipe-laying process has been estimated based on analytical considerations to determine the order of magnitude of the suspension for a worst-case scenario with respect to sediment composition.

The pipelines will be laid from a lay vessel moving forward with a slow horizontal speed of 2 – 3 km a day, giving an even slower vertical velocity of the pipelines. Only very small amounts of sediment, around 600 kg/km, have been found to be suspended during pipeline layout directly on the seabed. Compared with suspension during the intervention works, this is negligible. Therefore, sediment spreading from the pipe-laying directly on the seabed has not been included in the mathematical modelling of spreading and sedimentation.

### 4.2.3 Spreading of Sediment from Anchor Handling

During displacement of the anchors from one position to another, the anchors and wires will be lifted from the seabed and moved through the water column to a new position by tugboats.

The activities that may create suspension of sediment are the lay down of anchors on the seabed the sweeping of anchor wire across the seabed during movement of the lay vessel and the extraction of the anchors from the seabed when they are being recovered and moved to a new position.

In soft sediment, it is expected that the anchors will sink into the sediment when they hit the seabed. When the anchor is pulled to give the desired holding capacity, no significant suspension of sediment to the water column is expected. When the lay vessel is moving forward, the anchor wire will be sweeping across the seabed. This movement may create some suspension of sediment, even though the movement of the anchor wire is very slow.

When the anchor is pulled back again, some sediment may stick to the anchor and be suspended in the water column.

In total, based on conservative assumptions the release of sediment has been estimated to reach up to 400 - 1,800 kg per anchor position. Sediment spreading from anchors has not been modelled, since significant sediment spreading will be limited to the close vicinity of each individual anchor.

### 4.2.4 Spreading of Sediments

The spreading of sediment spill is governed by a number of factors including currents and waves and sediment characteristics. The main sediment parameter governing the distance each particle travels is the settling velocity. Generally, fine-grained particles have the lowest settling velocities, allowing a wider spreading of the sediment with the currents. The grain size distribution of seabed sediments and other applied geotechnical parameters are based on physical analysis of a large number of seabed sediment samples.

Numerical particle analysis models have been used to simulate the transport and fate of the suspended or dissolved substances in three dimensions. Information on current velocities and water levels is acquired from readily available hydrodynamic models that have been calibrated over decades and take into account the corresponding meteorological changes.

To study the variability, different meteorological conditions have been considered, representing calm, average and rough conditions in relation to spreading of sediment.

The results of the model simulation are analysed in terms of:

- Total amounts of suspended sediment
- Area and average duration of suspended sediment concentration
- Area of seabed sedimentation and sedimentation rate
- Contaminant spreading due to sediment spreading

Modelling of the impacts from trenching locations and rock placement locations has been carried out along the whole pipeline route. Below, a trenching location in Sweden and a rock placement location in Finland have been selected to illustrate typical results of the modelling.

**Figure 4.3** shows the model results for sediment brought into suspension when ploughing the pipeline south of Hoburgs Bank in Sweden. The modelled concentrations of suspended sediment are shown at six different time steps. The modelling shows that the duration of the increased sediment concentration is very short.

**Figure 4.4** shows the modelled concentrations of contaminants (exemplified by PAH) from a rock placement at Kalbädagrund in Finland, close to the Estonian border. Similar to **Figure 4.3** six time steps have been shown and exemplify the short duration of the impact.

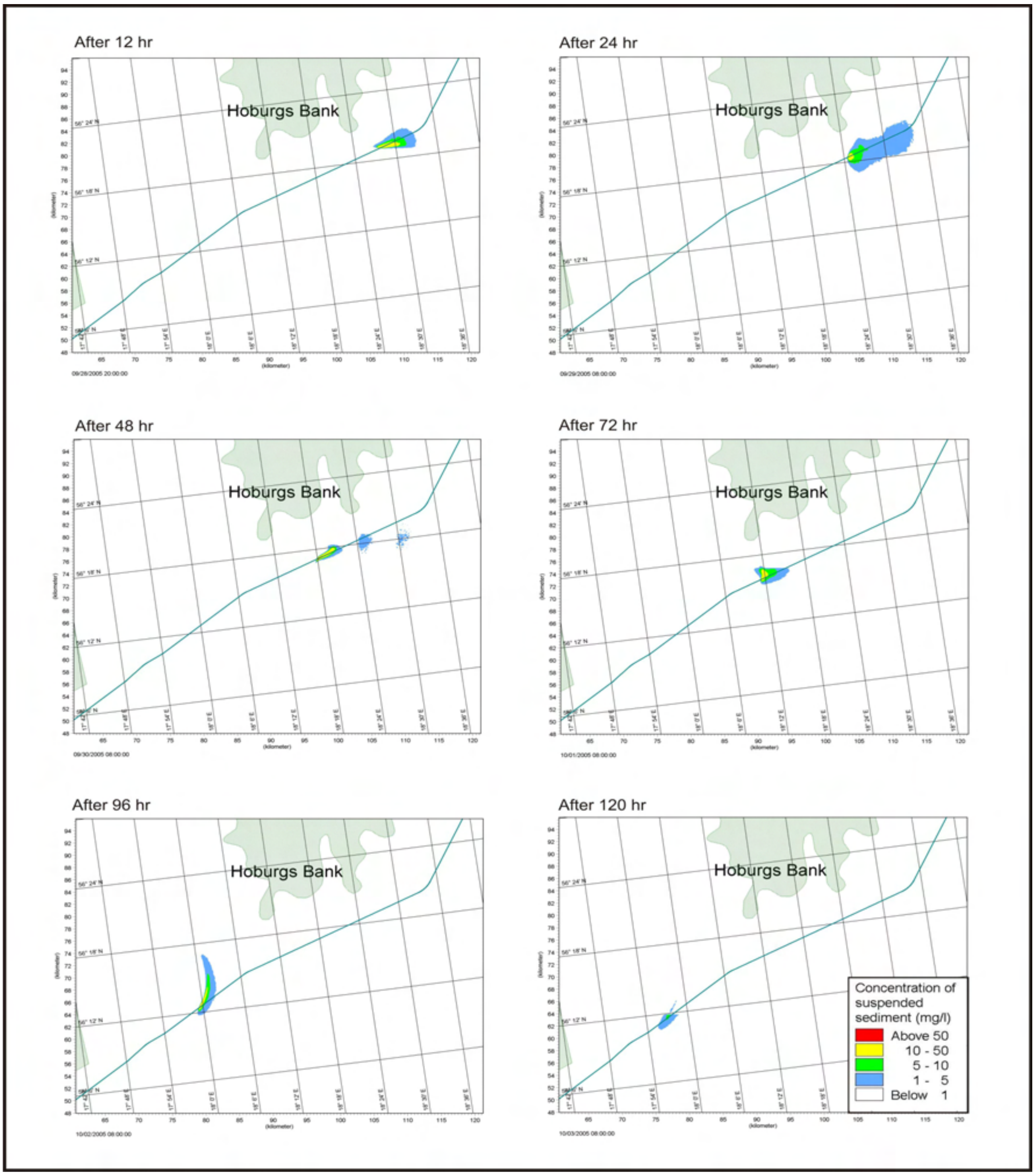


**Figure 4.3** **Modelled concentration of suspended sediment during pre-lay trenching at Hoburgs Bank in normal weather conditions. The timescale is from start of trenching. The trenching is carried out continuously from 0 hr to 108 hr in three sections**

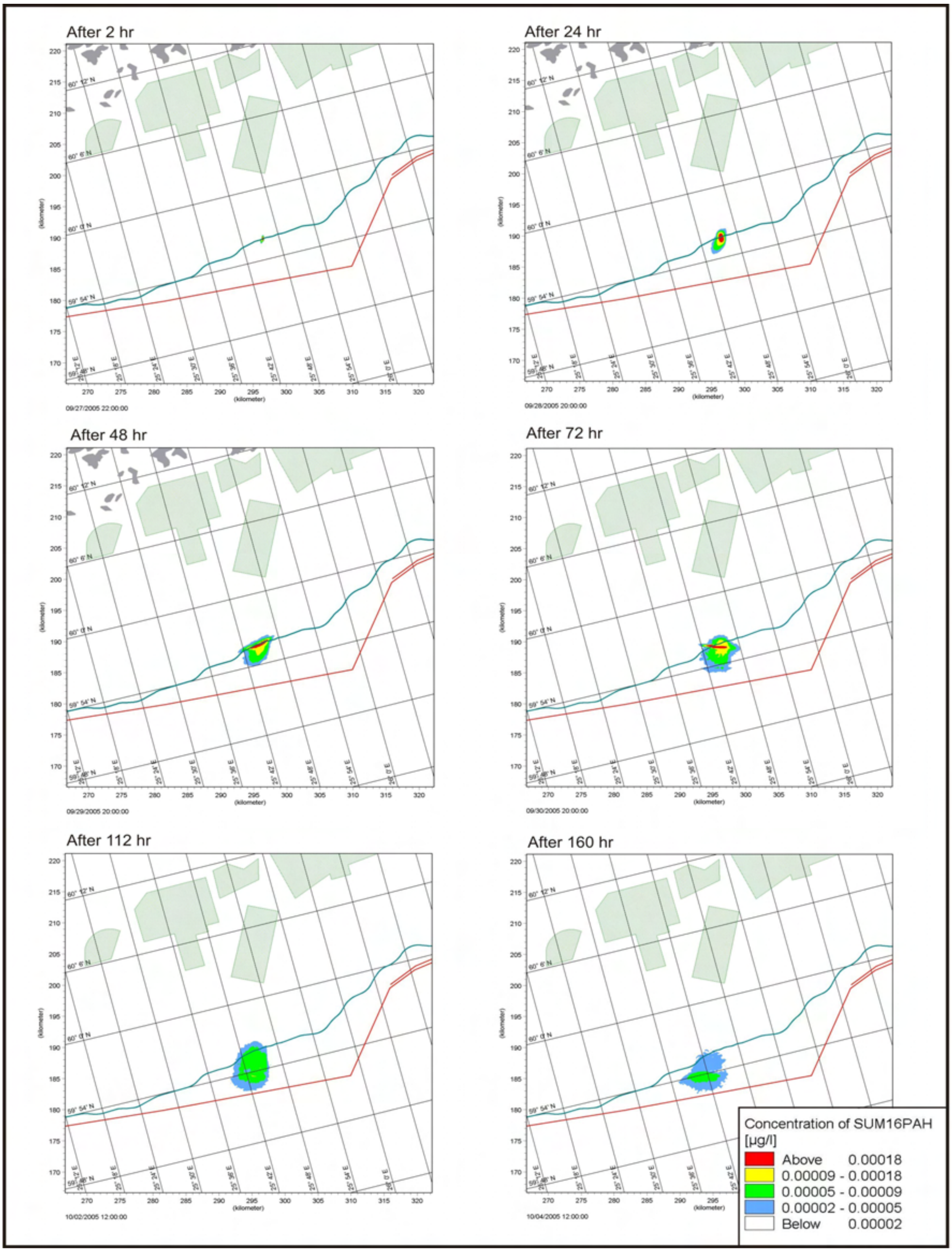


**Figure 4.4 Modelled concentration of PAH during pre-lay rock dumping at Kalbådagrund in Gulf of Finland at normal weather conditions. The timescale is from start of rock dumping. The rock dumping is carried out continuously from 0 hr to 88 hr at 4 positions**

## 4.3 Environmental Impacts

### 4.3.1 Summary of Impacts

A detailed discussion of the environmental impacts is outside the scope of this review as this is the scope of the national EIAs and the main Nord Stream Espoo Report. However, in the following is given an overview of the assessed impacts on the physical, environmental and social and socioeconomic environment following the physical disturbance of the seabed.

According to the impact assessment procedure the assessments of scale, duration and intensity is summarised in an assessment of the magnitude of an impact. The magnitude and the sensitivity of the object determine the overall significance of an impact.

In case impacts are indistinguishable from the background level neither magnitude nor significance is noted in the tables below. Impact that are assessed as being insignificant are noted in the tables, but are not further commented on.

#### Physical Environment

In **Table 4.1** is given an overview of the impacts on the physical environment. Only impacts directly related to the disturbance of the seabed are summarised. Therefore impacts on the atmosphere caused by vessels carrying out construction works (i.e. air pollution) are not included.

The impacts on the physical environment covered by the table are mainly related to the water column as changes of the seabed morphology and sedimentation are closely linked to impacts of the biological and socio-economic environment.

**Table 4.1 Impacts on the physical environment**

| Effect | Scale | Duration | Intensity | Magnitude | Sensitivity | Overall significance of impact |
|---|---|---|---|---|---|---|
| ***Seabed*** | | | | | | |
| Physical alteration by seabed intervention works | Local - regional | Long-term | Low | Low | Low | Minor |
| Physical alteration due to pipe-laying and anchor handling | Local | Long-term | Low | Low | Low | Minor |
| ***Water column*** | | | | | | |
| Increase in turbidity by seabed intervention works | Regional | Short | Low | Low | Low | Minor |
| Increase in turbidity from pipe-laying and anchor handling | – | – | – | – | – | Insignificant |
| Release of contaminants due to seabed intervention works | Regional | Short | Low | Low | Low | Minor |
| Release of nutrients due to seabed intervention works | – | – | – | – | – | Insignificant |

Seabed intervention works will result in the physical alteration of the seabed, which is assessed to be of **minor** significance wherever these works occur. Dredging and sheet piling in the German EEZ will cause the release of contaminants from seabed sediments, as well as causing physical alteration of seabed. Both these impacts are assessed to be of **minor** significance.

Seabed intervention works on the seabed will result in the disturbance and subsequent re-suspension of sediments together with any compounds that are associated with the sediments. This will give rise to an increase in turbidity levels as well as the release of contaminants in the water column. The increase in turbidity and release of contaminants due to seabed intervention works has been assessed to have a **minor** impact on the water column in the areas where these works take place.

### Biological Environment

The assessment of impacts on the biological environment related to the disturbance of the seabed are summarised in **Table 4.2**. It should be mentioned, that similar to impacts on the atmosphere impacts from noise generated by activities that cause the disturbance of the seabed are deemed outside the scope of this summary.

**Table 4.2 Impacts on the biological environment**

| Effect | Scale | Duration | Intensity | Magnitude | Sensitivity | Overall significance of impact |
|---|---|---|---|---|---|---|
| ***Plankton*** | | | | | | |
| Suspended matter | → | → | → | → | → | Insignificant |
| Release of contaminants | → | → | → | → | → | Insignificant |
| ***Marine benthos*** | | | | | | |
| Increase in turbidity – pipe-laying, rock placement support structures | Regional | Short term to long term | Low - medium | Low | Low - high | Minor moderate* |
| Release of contaminants, pipe-laying rock placement, support structures, anchor handling | Local | Long term | Low | Low | Low – high* | Minor |
| Release of nutrients | → | → | → | → | → | Insignificant |
| Physical loss of seabed habitats pipe-laying (incl. tie-in), rock placement, anchor handling | Local | Short term – long-term | Low - medium | Low | Low – high* | Minor – moderate* |
| Smothering (lateral seabed slomps) | Local | Short term | Medium | Low | Low – high* | Minor moderate* |
| ***Fish*** | | | | | | |
| Increase in turbidity seabed intervention works | → | → | → | → | → | Minor - moderate |
| Release of contaminants, seabed intervention works | → | → | → | → | → | Minor - Moderate |

| Effect | Scale | Duration | Intensity | Magnitude | Sensitivity | Overall significance of impact |
|---|---|---|---|---|---|---|
| Physical alteration of the seabed, rock placement, pipeline presence | Local | Long-term | Medium | Low | Low - high | Minor - moderate |
| ***Birds*** | | | | | | |
| Increase in turbidity pipe-laying, anchor handling, intervention works | Local - regional | Short term | Low | Low | Low – high* | Minor – moderate* |
| Loss of seabed habitat | Local | Short term | Low | Low | Low – high* | Minor – moderate* |
| ***Marine mammals*** | | | | | | |
| Increase in turbidity pipe-laying, anchor handling, intervention works | → | → | → | → | → | Insignificant |
| Release of contaminants pipe-laying, anchor handling, intervention works | → | → | → | → | → | Insignificant |
| ***Nature conservation areas*** | | | | | | |
| Increase in turbidity pipe-laying, anchor handling, intervention works | Regional ** | Short term** | Low** - medium* | Low** - medium* | High** * | Insignificant - moderate |
| Physical alteration of the seabed pipe-laying, anchor handling, intervention works | → | → | → | → | → | Insignificant |
| *Applies to the section of the pipelines that crosses sensitive nature areas in Germany<br>** Applies to impacts on the Skala Hally nature conservation area in Russia | | | | | | |

Seabed intervention works, including dredging, trenching, rock placement, installation of support structures and hyperbaric tie-ins, as well as pipe-laying and anchor handling, will give rise to a number of impacts on marine benthos. Marine benthos have the potential to become smothered, have filter feeding organs clogged with sediment and light levels may be reduced thereby preventing photosynthesis by flora.

An increase in turbidity due to seabed intervention works and pipe-laying will have a **minor** impact on marine benthos along most of the pipelines' route, with anchor handling contributing to this impact. However, in the areas of the Pomeranian Bay, Oderbank and the Boddenrandschwelle in the German EEZ this impact is **moderate** due to the high sensitivity of benthos species in these areas.

Seabed intervention works, pipe-laying and anchor handling will also cause the release of contaminants along the entire pipelines' route, which has been assessed to be of **minor** significance.

Along the entire pipelines' route, seabed intervention works, pipe-laying and anchor handling will all contribute to the physical loss of seabed habitats. This impact will be **minor** everywhere except the areas of Pomeranian Bay, Oderbank and the Boddenrandschwelle in the German EEZ, where impacts will be **moderate**.

Smothering (lateral sediment slumps) will occur as a result of seabed intervention works and pipe-laying in Russian, Swedish, Danish and German EEZs. Impacts will be minor except in the areas of the Pomeranian Bay and Oderbank in the German EEZ where impacts will be **moderate**.

Seabed intervention works related to hyperbaric tie-ins will contribute to the physical loss of seabed habitats in areas where they occur. The significance of this impact on benthos is assessed to be **minor**.

Seabed intervention works in the German EEZ are predicted to have a **minor** to **moderate** impact on fish in terms of both an increase in turbidity and the release of contaminants. In the Swedish EEZs rock placement is predicted to have a significant impact on fish due to physical alteration of the seabed; this is also assessed to be of **minor** to **moderate** significance.

Seabed intervention works including dredging, trenching, rock placement, installation of support structures and sheet piling, are predicted to have direct and indirect impacts on sea birds in the Russian, Swedish, Danish and German EEZs. In the Russian and German EEZs, significant impacts will be an increase in turbidity and loss of seabed habitats; these impacts are assessed to be of **minor** to **moderate** significance.

Anchor handling in the German EEZ is predicted to have an impact of **minor** to **moderate** significance on sea birds due to the loss of seabed habitat.

In the Russian EEZ, seabed intervention works are expected to cause a significant increase in turbidity affecting the nature conservation area of Skala Hally only. This impact is assessed to be of **moderate** significance. In Germany, seabed intervention works will result in an increase in turbidity, which is expected to impact on the habitats or fauna associated with a nature conservation area in this EEZ. Impacts of this nature are only expected where the pipelines' route runs within a few kilometres of the protected site. **Moderate** impacts are expected.

### Social and Socioeconomic Environment

Impacts on the social and the socio-economic environment are summarised in **Table 4.3**.

**Table 4.3 Impacts on the social and socioeconomic environment**

| Effect | Scale | Duration | Intensity | Magnitude | Sensitivity | Overall significance of impact |
|---|---|---|---|---|---|---|
| ***Fisheries*** | | | | | | |
| Seabed disturbance related to intervention works and anchor handling | → | → | → | → | → | Insignificant |
| ***Tourism and recreation*** | | | | | | |
| Seabed disturbance related to pipeline construction and presence | → | → | → | → | → | None |
| ***Cultural heritage*** | | | | | | |
| Seabed intervention works, pipe-laying and anchor handling | → | → | → | → | → | Insignificant |
| ***Offshore infrastructure*** | | | | | | |
| Seabed intervention works, pipe-laying and anchor handling | → | → | → | → | → | Insignificant |

The impacts on fisheries from seabed intervention works are only related to effects on the water column. Potential impacts related to effects related to seabed alteration are further dealt with in the Key Issue Paper on Fish and Fisheries.

No impacts on tourism and recreational activities from the seabed disturbance are foreseen.

All precautions are taken to avoid disturbance of cultural heritage on or below the seabed and impacts are therefore assessed to be insignificant. The crossing or passing of other infrastructure is taken care of during the planning and design phases in consultation with the owners of such infrastructure. Impacts are therefore assessed to be insignificant.

### 4.3.2 Summary of Landfall Areas Impacts

Impacts related to the specific activities taking place in the landfall areas in Russia and Germany respectively are summarised.

**Russian Landfall**

**Figure 4.5** shows the modelled deposition of spilled sediments from the marine earth works in the Portovaya Bay, at the Russian landfall approach. The modelled sedimentation is the “gross sedimentation”. Due to the shallow water conditions in the area, a significant part of the settled spilled sediments will subsequently be re-suspended by currents and waves and be transported to other areas. Therefore, part of the settled spilled sediments will gradually be transported to other areas, and the layer of spilled sediments indicated by the model result will be thinner, but more wide-spread in the area.

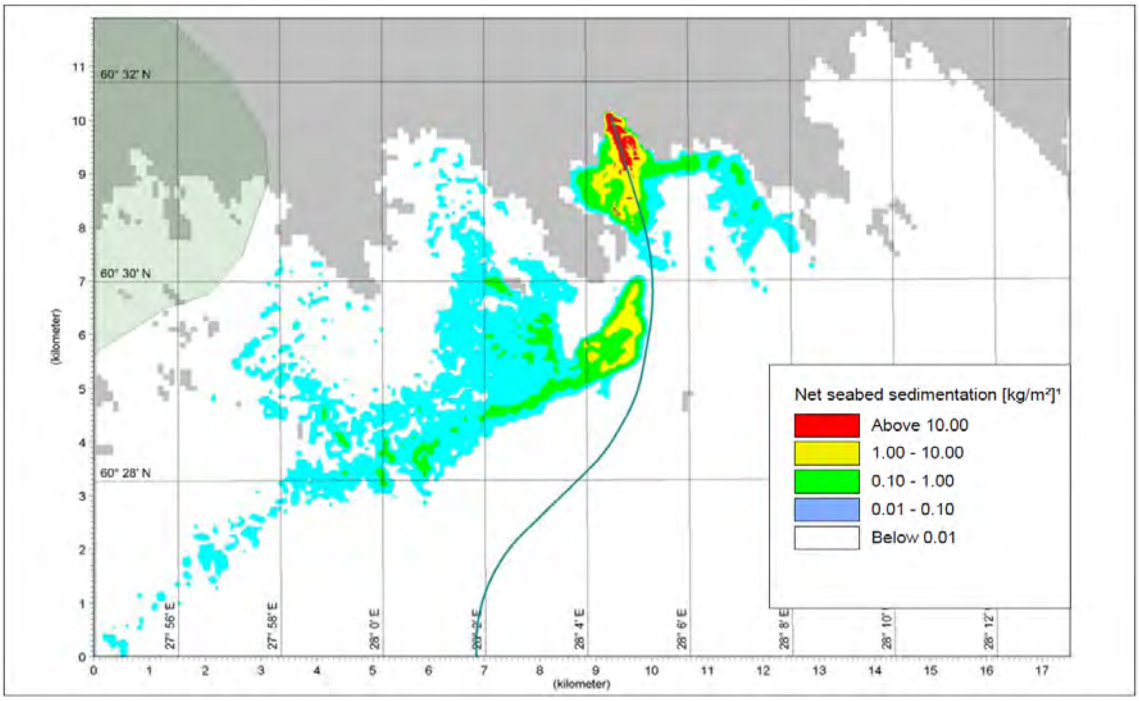


**Figure 4.5** **Net seabed sedimentation (kg/m$^2$) during dredging operations in the Portovaya Bay**

In **Figure 4.6** the result of a numerical modelling of sediment concentration caused by sediment spill in connection with dredging for the offshore pipelines in the Russian landfall area is shown. The modelling shows that a concentration of 1 mg/l will occur for more than 72 hours in Portovaya Bay. An area where concentrations above 1 mg/l occur, will be limited to a more narrow area around the pipeline. The maximum concentrations will, however, only be reached during a relatively short time period.

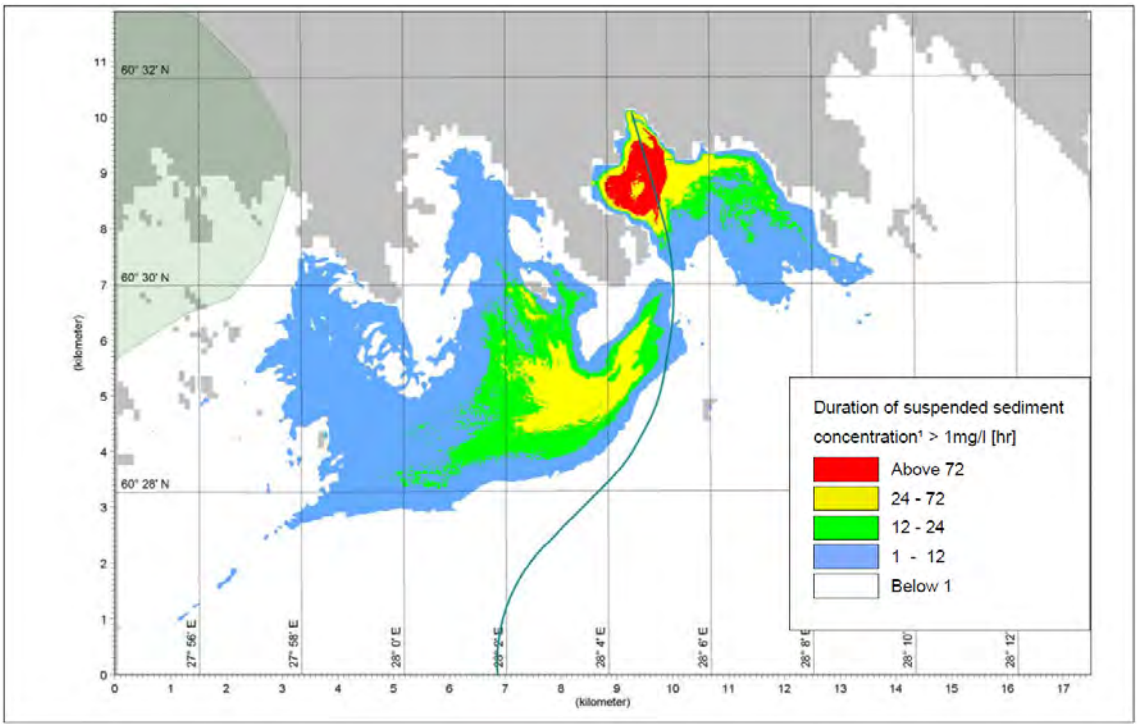


**Figure 4.6** **Duration of suspended sediment with a concentration > 1 mg/l during dredging operations in the Russian sector**

**German Landfall**

The pipe-lay in an open trench will cause a temporary change in relief conditions of the seabed. Upon completion of the work, the original relief will be restored and no lasting impacts on the hydrography are expected.

Simulations have been made at wind speeds of 5 and 10 m/s for all wind directions, but, as the wind events fall mainly within the calm range, the focus has been on the impact associated with the 5 m/s wind scenario, just as it is assumed that dredging activities will cease or be greatly reduced during high wind speeds. **Figure 4.7** and **Figure 4.8** present visual representations for maximum turbidity and sedimentation rates for wind speeds of 5 m/s from all directions over a 5 day period. It should be noted that the modelling shows a composite picture, as the results of winds from all directions are included. In addition it is assumed that all dredgers will operate simultaneously at the same location.

The sediment spreading simulations show that that the majority of excavation and transportation activities connected with the pipe-laying in a trench could lead to sedimentation deposits of between approx. 3 and 1 mm in the immediate vicinity (up to approx. 50 m), between approx. 0.7 and 0.5 mm at distances of approx. 100 m, approx. 0.3 mm at distances of approx. 150 m, and less than 0.1 mm at a distance of 500 m.

In the case of sediment that increases turbidity only slightly (mainly sand), suspended matter content of 1,000 mg/l could occur up to a distance of approx. 100 m, while content of 100 mg/l could occur at distances of up to approx. 500 m. Sediments that increase turbidity to a greater extent (silty sands, some of which have a higher organic content) could cause suspended matter content of between 50 and 500 mg/l to drift distances of between 500 and (in some cases) more than 2,000 m from the source (i.e. the dredger or dumping barge).

To conclude, the construction activity for pipe-laying in an open trench is expected to have small to medium-scale impacts for only short periods. In the immediate vicinity of construction work, moderate impacts could arise. In a wider radius of up to approx. 500 m, minor to very minor impacts will arise.

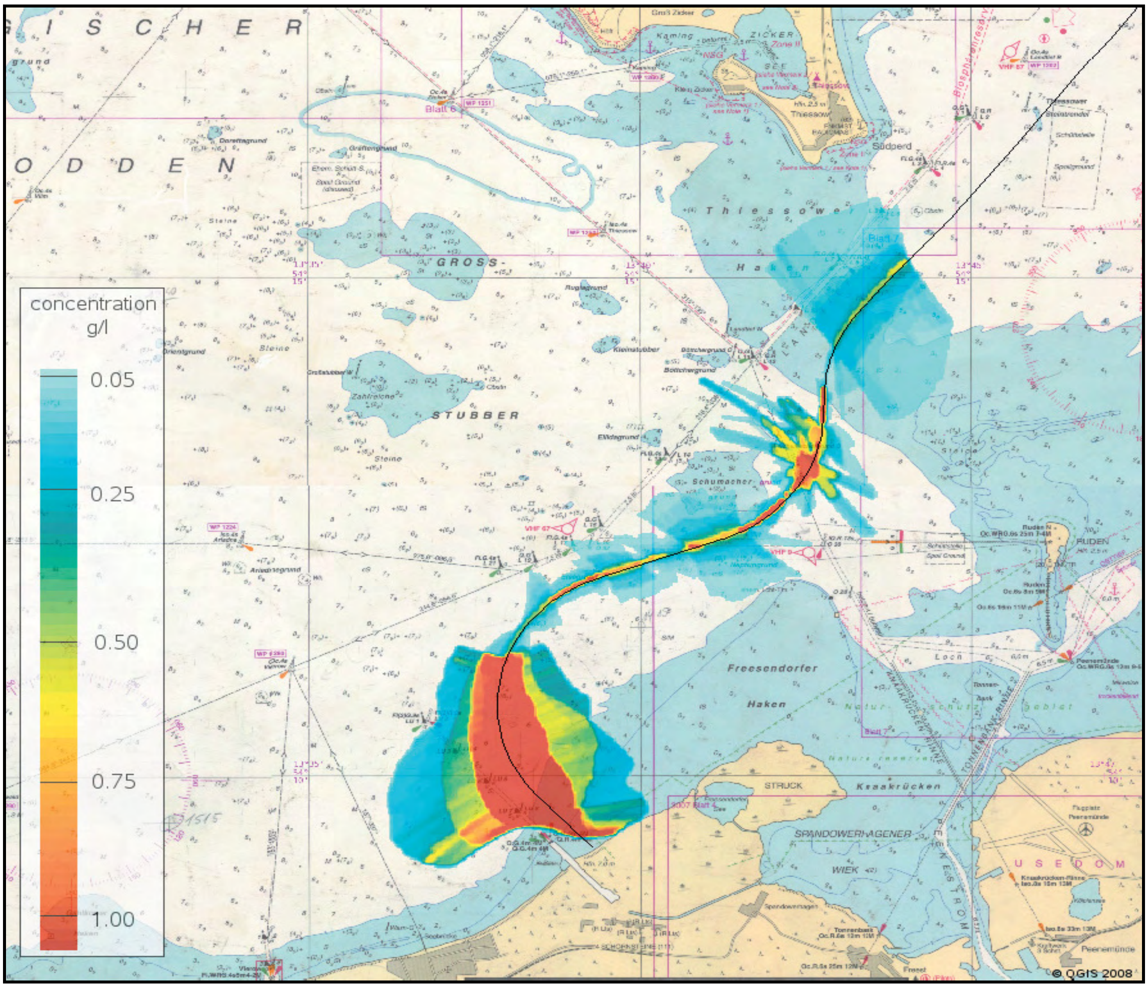


**Figure 4.7 Summary of the maximum turbidity (in g/l) areas for all wind directions with a wind speed of 5 m/s and an interference interval of 5 days**


**Figure 4.8** **Summary of sedimentation rates (in kg/m$^2$) for all wind directions with a wind speed of 5 m/s and an interference interval of 5 days**

### 4.3.3 Transboundary Impacts

Impacts on the physical, biological and socio-economic environment in the individual countries of origin that are passed by the proposed Nord Stream pipelines' route are summarised above. The impacts are in general assessed to be either insignificant or minor at the most. The potential of these impacts to cause transboundary effects are assessed in the following.

**Intervention Works**

As described earlier the requirements for intervention works vary between the five countries of origin. Rock placement will mainly be needed on the part of the route that traverses the Gulf of

Finland and the Northern Baltic Proper, whereas dredging and trenching will be required at the landfalls and in the part of the route that traverses the Central and Southern Baltic Proper.

The impact range of most seabed intervention works taking place in each of the individual countries of origin will not have a range to cause impacts on the physical environment in the other countries of origin. However, theoretically, intervention works taking place very close to the border to another country of origin may be able to cause impacts on the other side of this border. Such cross-border impacts from intervention works will in any case be of low magnitude and low significance.

The distance between the pipeline route and the EEZ borders of Latvia, Lithuania and Poland is so great that no recognisable impacts due to intervention works in these countries are foreseen.

Due to the proximity of the pipeline route to the Estonian EEZ, contaminant modelling with special attention to possible cross-border impacts has been undertaken. Increased turbidity in Estonian waters due to seabed intervention works will definitely be insignificant. Modelling of possible spreading of contaminants as a consequence of the sediment spreading has proved that concentrations will be low and the impact is deemed minor. As all assumptions are conservative the impact on Estonian waters most likely will be insignificant.

Impacts to the biological environment due to disturbance of the seabed caused by intervention works are closely associated with the impacts on the physical environment. Except for a few locations in the countries of origin deemed highly sensitive to impacts, the general assessment is that impacts to the biological environment caused by seabed disturbance are insignificant or minor. Following the argumentation above, cross border impacts are also assessed to be insignificant.

**Anchor Handling**

Seabed disturbance caused by the pipe-lay and anchor handling will be more or less similar in all countries of origin. Cross-border impacts caused by anchor handling on one side of a border will be the same as impacts caused by the similar activities on the other side of the border. Cross-border impacts in the countries of origin caused by anchor-handling are assessed to be insignificant.

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. Alternatively, a dynamically positioned lay vessel with no anchors will be used. Cross-border impacts in Estonia from Finland due to anchor handling are therefore not expected.

Cross-border impacts on Latvia, Lithuania and Poland due to anchor handling are similarly deemed insignificant due to the great distance between the pipeline corridor and the EEZ borders.

Impacts to the biological and the socio-economic environment due to anchor-handling are generally believed to be insignificant. Following the argumentation above, cross-border impacts are also assessed to be insignificant.