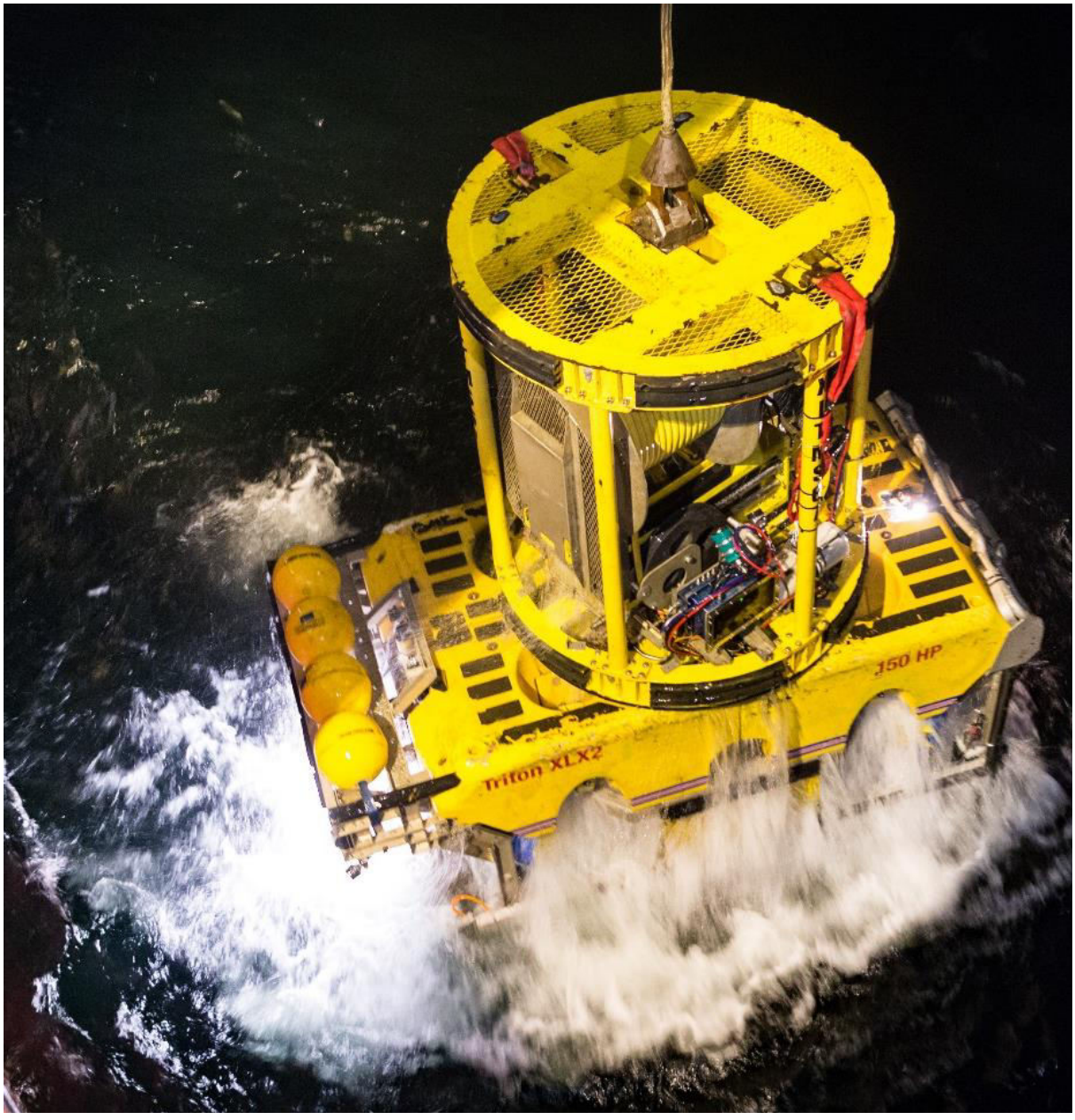
Nord Stream 2
Committed. Reliable. Safe.

Background Paper: High-Tech Baltic Sea Surveys

Nord Stream 2 AG | Jan-19



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Introduction

Survey operations are the cornerstone of massive international infrastructure projects like the Nord Stream 2 project. Each of the survey stages plays a pivotal role in enabling the project to move forward safely, providing critical information for engineering, route optimisation, Environmental Impact Assessments (EIAs) and permitting, environmental management and monitoring, financing and insurance, quality control, construction and operations.

Building the Nord Stream 2 Pipeline involves laying 200,000 individual pipe sections that weigh 24 tonnes each along a 1,230-kilometre Baltic Sea route that passes through the waters of five countries: Russia, Finland, Sweden, Denmark and Germany. Construction began in the summer of 2018, and by January 2019, over 870,000 man hours had already been devoted to surveying the seabed. This has so far involved contractors from 8 countries using 49 different vessels that have surveyed more than 59,000 line kilometres. Additionally, more than 2,300 geotechnical samples have been taken to confirm the seabed geology.

Eight additional construction support survey vessels have also repeated and confirmed the findings of the initial surveys prior to commencing pipelay, ensuring that all construction activities are monitored, and construction has had minimal impact on the seabed.

The entire pipeline route from Russia to Germany has been surveyed. The initial route corridor was selected based on an exhaustive desk study considering existing survey data along with environmental, technical and geopolitical constraints. This initial corridor was mapped over a width of at least 1.5 kilometres and is being systematically narrowed down based on survey data to comprise a 50-metre corridor around the pipeline. This area is thoroughly surveyed to ensure there are no unexploded munitions that could constitute a danger during the construction and the operational life of the pipeline. Our aim is to avoid munitions wherever possible, so once munitions and their potential danger to the pipeline are identified, the route is generally optimised to avoid them.

However, some of the munitions had be removed to ensure the safe construction and operation of the pipeline. Generally, these were secured and properly disposed of on shore. Where this wasn’t possible, they were cleared via in-water detonation. All UXO that were removed in sensitive areas were surrounded by a state-of-the-art bubble curtain to minimise the effects of the sound propagation.

There will also need to be a safe distance between the two existing Nord Stream pipelines. This distance will vary based on installation and operational safety requirements and seabed topography.

A range of surveys at each stage of the project cover everything from the sea shore to depths of more than 200 metres in the middle of the Baltic Sea, so a variety of vessels and equipment is required. This includes vessels as small as canoes, all the way up to state-of-the-art deep-water survey boats.

Advanced Technology

The advanced technology available to the survey teams is impressive. Tools include multibeam echo-sounders that bounce sound waves off the seafloor to indicate water depth; side-scan sonars used to identify wrecks, obstructions, boulders and rocks; and acoustic sub-bottom profilers for mapping the soil variations up to 40 metres below the seabed. This technology makes it possible to form an accurate picture of the water depths, seabed formations and objects both on and below the seabed.

Nord Stream 2 has also been able to secure the services of many high-performance survey vessels, for example the Fugro Pioneer, used for reconnaissance geophysical surveys, is one of the most modern survey vessels in the world. It can cover approximately seven kilometres of seabed per hour, adding up to 160 surveyed line kilometres a day.

Compared to the first Nord Stream project, which was completed in late 2011, the survey process is moving much more swiftly for Nord Stream 2. Not only has the survey team benefitted from past experience of working in the Baltic Sea, but data acquisition and analyses have improved significantly. It is now possible to build three-dimensional models of the seabed and the objects it holds, for example. By placing cameras on remotely operated vehicles (ROVs), a visual picture of the seabed is acquired, and this information can be merged with the digital terrain model for further visual inspection. Such resolute, high-quality data are invaluable for engineering, route optimisation and the EIA process.

A newly developed SROV supplied by contractor MMT has also produced one of the most resolute data sets available, allowing all items greater than 20 cm x 20 cm or greater to be mapped along a 130-metre-wide corridor centred on both pipelines. The speed of acquisition, coupled with the high resolution and detailed sub-bottom profiles, have provided our engineers with an excellent data set to assist with the routing and design of the pipeline.

In shallow water, remote autonomous vehicles (AUV’s) have also been used to assist with mapping of the seabed, allowing these areas to be mapped without the usual constraints to personnel or vessels.

Survey Stages

Surveys began in late 2015. The entire process has been supplemented by separate environmental baseline surveys and monitoring conducted by our permitting division for the EIAs. These were carried out along the route between 2015 and 2016 as part of the project's planning phase and included water quality measurements, a survey of physical and chemical characteristics of surface sediments, a survey of macrozoobenthos (richness, frequency, biomass), and the measurement of water currents and underwater noise.

During this period, the survey work has been ongoing, progressing through the planned 11 stages. Whilst all the surveys have been completed for the base case, additional surveys following the same sequence are ongoing where there are alternative route options.

Pre-construction:

> **Reconnaissance: Mapping the best route (status: complete)**

The purpose of the reconnaissance survey was to identify the best possible route for the pipelines based on geological and anthropogenic features. The seafloor is not a flat, featureless plain, it has a varying morphology with rocky outcrops, cliffs, trenches, etc. Careful mapping of the seabed helps to identify the best possible route for the pipeline, minimising the need for intervention. The survey covered a corridor of varying widths (from 1.5 km to 5 km) and used a variety of techniques, including side-scan sonar, sub-bottom profiler, multibeam echo-sounder and magnetometers.

> **Geotechnical: Detailing geological features (status: complete for base case)**

Geotechnical surveys were performed to optimise the pipeline route and detail design including the required seabed interventions to ensure the long-term integrity of the pipeline system. Cone penetrometer (CPT's) and Vibrocorer (VC) locations were selected to ensure a detailed understanding of the geological and soil strengths for engineering purposes along the planned routes. Vertical profiles were also carried out to measure the seawater temperature, salinity and conductivity.

> **Detailed corridor: Identifying objects on route (status: complete for base case)**

Underwater features and geological outcrops on the seabed make route planning complicated. The pipeline needs to be stable, but there are "free spans" where rock will have to be placed under the pipeline for support on the seabed. The survey team conducted detailed seabed surveys to identify potential objects along the planned route. From past experience with the existing Nord Stream pipeline, this could include anything from dumped cars and household items to unexploded munitions (UXO) left over from World War II, and even undiscovered shipwrecks.

These most recent assessments complement the first phase of offshore geophysical seabed surveys which took place in winter 2015-16 in German, Danish, Finnish, Swedish and Russian waters. Four types of surveys were carried out:

- State of the art Quad multibeam echo-sounder to determine the water depths across the seabed.
- Side-scan sonar to identify wrecks, obstructions, boulders and rocks at the seabed.
- Magnetometer towed behind the vessels acting like a giant metal detector to find metal objects on the seabed.
- Sub-bottom profiler to map the harder layers beneath the seabed.

> UXO detection: Finding munitions (status: complete for base case)

The Baltic Sea was used as a dumping ground for munitions after past conflicts, particularly World War II. There are up to and estimated 150,000 mines believed to be resting on the Baltic seafloor. To ensure safe installation and operation of the pipeline, munitions along the pipeline route are thoroughly surveyed. Probably the most difficult section of the route is in Finnish waters, where the seabed is geologically complex, with highly variable relief and a high density of munitions left over from World War II. During the first project, 142 munitions were cleared from the pipeline route altogether, 49 of which were found in the Finnish section.

A munitions screening survey is used to identify any potential unexploded munitions that could constitute a danger to the pipeline or the environment during the installation and/or the operational life of the pipeline system. The survey is conducted along a 15-metre wide installation corridor centred on each pipeline design route and expanded even wider where the pipeline may be trenched or intervention works such as rock placement may be required. This work includes a detailed gradiometer survey. All magnetic anomalies over a calibrated threshold are then visually investigated using video and still cameras mounted on an ROV. The detailed geophysical survey within this area will also be used to identify potential munitions on the seabed close to the pipeline route, and the route will be optimised to avoid munitions wherever possible.

> Visual inspection: identifying specific objects (status: complete for base case)

Work class ROVs with state-of-the-art lighting systems and underwater cameras are used to take high resolution images of the objects on the seabed. In some instances, 3D images can be generated to enable specialists to identify objects that may be of cultural heritage significance.

> Detailed geotechnical: exhaustive seabed analysis (status: complete for base case)

Additional geotechnical data is acquired in areas where the pipeline engineers require detailed soil information. This can include places where the pipeline crosses over cables

or other pipelines, or where support for the pipeline is needed over complex seabed terrain. Samples have been obtained down to 10 metres below the seabed to ensure that any seabed intervention is designed correctly.

> **Cultural heritage: assessing potential sites (status: complete for base case)**

In this stage, visual surveys by ROVs outfitted with video cameras or multibeam echo-sounders are performed to identify different kinds of objects on the seabed, such as shipwrecks and munitions. Side-scan sonar data from the reconnaissance survey was reviewed to assess the potential underwater cultural heritage (UCH) sites (such as shipwrecks) in relation to the proposed pipeline routing, and those with historical and archaeological importance are considered in NSP2 pipeline routing optimisation as part of national EIA procedures. Wherever such objects are found, the relevant authorities are notified immediately for further investigation.

During construction:

> **Route clearance & seabed intervention: preparing the path (status: ongoing)**

Prior to construction the seabed needs to be clear of any objects that would affect the integrity of the pipeline. Where possible items will be avoided. If they cannot be avoided, items will be removed from the route. Rock placement surveys will be conducted to confirm the status of the seabed prior to and after rock placement or any removal of objects.

All UXO that could affect the safety of the pipeline or its installation have been removed. In some areas the pipeline was rerouted to avoid items that can't be made safe.

> **Anchor route surveys: ensuring safe corridor for pipelay vessels (status: complete in Germany, ongoing in shallow Russian waters)**

Prior to the installation of the pipelines, an anchor corridor survey will be or has been undertaken on sections of the route where the pipeline is to be installed by anchored lay vessel to ensure that there is a free corridor for anchors and anchor wires. Current planning is to utilise anchored lay vessels only within the Russian and German nearshore area. Elsewhere offshore, a dynamically-positioned laybarge that requires no anchoring will be used.

The anchor corridor survey will mainly be conducted in a 1-kilometre wide corridor. The width of the survey corridor will depend on the selected pipelay vessel and water depth. This survey stage will identify and catalogue all obstructions in the corridor to be avoided during pipelay and anchoring operations. The survey will – among other things – collate and integrate existing survey data to develop the detailed scope of work, identify and map potential munitions, geological features and environmental constraints that may

have the potential to influence pipeline installation works, and identify and map areas with any features of cultural heritage to be avoided or safeguarded.

> **Construction support: ad hoc surveys for changing underwater conditions (status: ongoing)**

In the dynamic underwater environment, the seabed can change, and further surveys will be carried out as the pipe is laid to ensure the route remains clear and safe. Full survey capability will be available to perform touch-down monitoring for any ad hoc survey activities that may arise during pipeline construction.

As part of this a pre-lay survey will be performed just prior to the start of pipe laying to confirm the previous geophysical survey and to ensure that no new obstacles are found on the seabed. A pre-lay survey includes: ROV-based bathymetric and visual surveys to establish the seabed conditions prior to seabed intervention works (placement of rock supports or trenching works) and along the installation corridor (where the pipeline will be laid on the seabed).

Post-construction:

> **As-laid/post-lay: insuring pipeline integrity (status: planned)**

As a final record of the pipeline installation, an as-laid survey will be conducted after seabed intervention, trenching, and rock placement and all other construction works have been completed. The survey will confirm that the pipelines have been installed correctly. It also establishes that the required depth of burial has been achieved, the extent of backfill and rock placement is as designed, and that the integrity of the pipelines is maintained. The survey also typically includes a visual inspection of the pipeline by ROV.

Post-lay surveys will be made after the pipeline has begun delivering gas to ensure that it remains correctly installed and stable. The surveys will establish the as-laid position and condition of the pipelines and will include bathymetry and side-scan sonar measurements and visual inspection by ROV.

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About Nord Stream 2
Nord Stream 2 is a planned pipeline through the Baltic Sea, which will transport natural gas over some 1,230 km from the world's largest gas reserves in Russia via the most efficient route to consumers in Europe. Nord Stream 2 will largely follow the route and technical concept of the successful Nord Stream Pipeline. The new pipeline will have the capacity to transport 55 billion cubic metres of gas per year, enough to supply 26 million European households. This secure supply of natural gas with its low CO_2 emissions will also contribute to Europe's objective to have a more climate-friendly energy mix with gas substituting for coal in power generation and providing back-up for intermittent renewable sources of energy such as wind and solar power.
www.nord-stream2.com