# Annex I

VKL-07-30-J800-027

March 2017

# Appendix 1: Outline of the EIA procedure

The EIA procedure consists of a number of steps. These steps and what they entail will be described in the following sections.

## Notification to the Competent Authority

A written notification of the plan is sent to the licensing authority, in this case the Ministry of Infrastructure and the Environment (Rijkswaterstaat). There are no legal requirements for this notification (article 7.27, first paragraph of the Environmental Management Act 'Wet milieubeheer').

## Public Announcement on the EIA Procedure

The Ministry of Infrastructure and the Environment publishes a note indicating that preparations are made for required decisions. In this note, the following is stated (Article 7.27, paragraph 4-5 of the Environmental Management Act 'Wet milieubeheer'):

- Documents concerning the project will be available for consideration, also indicating where and when this happens
- Opportunity is given to submit opinions concerning the project, also indicating to whom, in which manner and within which time limit
- Whether the 'Commission EIA.' or another independent authority is asked to issue an advice concerning the preparations of the project

## Consultation on Advisors and Governmental Authorities

The Ministry of Infrastructure and the Environment will consult the involved governmental authorities and consultancies about the draft Scoping Report of the EIA Consulting the 'Commission EIA' is not required (Article 7.27, paragraph 2 and 7 of the Environmental Management Act 'Wet milieubeheer').

## Final Scoping Report

The Ministry of Infrastructure and the Environment gives an advice concerning the Scoping Report of the EIA. This advice has to be received within six weeks. In this advice the public opinions, advice by the commission and consulted governmental authorities have to be accounted for (Article 7.27, paragraph 7 of the Environmental Management Act 'Wet milieubeheer'). There are no legal requirements for this advice.

## Content of the EIA Report.

Based upon the final scoping document, the EIA Report is drafted. The requirements for the EIA are defined in Article 7.7 and Article 7.23, first paragraph of the Environmental Management Act ‘Wet milieubeheer’. The following subjects have to be described:

- The objective of the project
- A description of the project and the ‘reasonable to take into consideration’ alternatives, including the motivation of the alternatives
- A description of the relevant plans and alternatives which were taken into consideration before
- A description of the current condition of the environment and the expected development of the environment in the project area
- The effects for the environment which could occur by implementing the project and described alternatives, including the motivation and the manner in which these effects were determined and described
- A comparison between the effects and the current environmental situation
- Measurements which could reduce the negative effects
- An overview of the lack of data
- Public summary

## Publication of the EIA Report (including having the EIA report open for view and objections)

For advice the EIA is submitted to the Commissie m.e.r. NCEA). Simultaneously, the EIA is submitted to the Ministry of Infrastructure and the Environment. Within six weeks the Commissie m.e.r. will establish advice (Article 7.30 of the Environmental Management Act ‘Wet milieubeheer’). The EIA Report is published as part of the Water Permit Procedure. Anyone can submit his/her view on the published EIA. This can be undertaken for a period of six weeks (Article 7.32 of the Environmental Management Act ‘Wet milieubeheer’).

## Advice Committee EIA

The Commissie m.e.r. advises on the EIA Report for a period of 6 weeks (Article 7.37 of the Environmental Management Act ‘Wet milieubeheer’).

## Final decision and possibilities for appeal

The Ministry of Infrastructure and the Environment establishes a final decision on the project. In this decision a reasoning is provided on how the effects to the environment are accounted for, which consideration is made for the described alternatives, public views and the established advice by the commission. Furthermore a description is made how the public and community organisations are involved in the project (Article 7.35-7.37 of the Environmental Management Act

‘Wet milieubeheer’). The final decision will be published by the Ministry of Infrastructure and the Environment and submitted for consideration. Since the project is part of the national coordination module (‘rijkscoordinatie regeling RCR), this period (period of views and appeals) is six months. Furthermore the decision will be notified to the consultancies, governmental authorities and those who have submitted opinions (Article 7.38 of the Environmental Management Act ‘Wet milieubeheer’).

## Evaluation

The Ministry of Infrastructure and the Environment requires a monitoring programme to evaluate the actual occurring environmental impacts. If necessary the licensing authority will take additional measures to reduce the environmental impacts (Article 7.39-7.42 of the Environmental Management Act ‘Wet milieubeheer’).

# Viking Link - Marine Mammal Risk Assessment

March 2017

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# Acronyms and references

| | |
|---|---|
| ASCOBANS | Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas |
| AMD | Acoustic Mitigation Device |
| CLV | Cable Lay Vessel |
| CITES | Convention on International Trade in Endangered Species |
| CNS | Central North Sea |
| cSAC | Candidate Special Area of Conservation |
| DP | Dynamic Positioning |
| EEC | European Economic Community |
| EEZ | Exclusive Economic Zone |
| EMF | Electromagnetic Field |
| EPS | European Protected Species |
| EU | European Union |
| FFA | Flora and Fauna Act |
| km | kilometre |
| m | metre |
| MBES | Multibeam Echo Sounder |
| MMRA | Marine Mammal Risk Assessment |
| MMU | Mammal Management Unit |
| MZ | Mitigation Zone |
| NCA | Nature Conservancy Act |
| NGVL | National Grid Viking Link |
| GW | Giga Watt |
| HVDC | High Voltage Direct Current |
| IUCN | International Union for Conservation of Nature |
| JNCC | Joint Nature Conservation Committee |
| PCI | Project of Community Interest |
| PLGR | Pre-lay Grapnel Run |
| PTS | Permanent Threshold Shift |
| RMS | Root Mean Square |
| ROV | Remote Operated Vehicle |

| | |
|---|---|
| SAC | Special Area of Conservation |
| SCI | Site of Community Importance |
| SEL | Sound Exposure Level |
| SNS | Southern North Sea |
| SPA | Special Protection Area |
| SPL | Sound Pressure Level |
| SSS | Side Scan Sonar |
| SBP | Sub Bottom Profiler |
| TTS | Temporary Threshold Shift |
| UXO | Unexploded Ordinance |

# Executive Summary


National Grid Viking Link Limited (NGVL) and Energinet.dk are developing a 1.4 GW HVDC interconnector between Lincolnshire, Great Britain through British, Dutch, German and Danish waters to Denmark. The proposed interconnector has achieved Project of Common Interest (PCI) status under the provisions of EU Regulation No. 347/2013 on guidelines for Trans-European Network for Energy (TEN-E Regulations).

Project activities required at the pre-installation, installation and operation phases of the Viking project have been assessed in relation to their potential impact on marine mammal populations in the North Sea. Cetaceans are protected by the European Habitats Directive (92/43/EEC) as Annex IV and Annex II species and it is an offence to deliberately capture, injure, kill or disturb any European Protected Species (EPS). Seal are listed on Annex II of the EC Habitats Directive to protect breeding colonies and moulting haul out sites.

Nine species of marine mammal have been identified as regularly occurring within the region and include: harbour porpoise; bottlenose dolphin; white-beaked dolphin; minke whale; long-finned pilot whale; common dolphin; Atlantic white-sided dolphin; harbour seal; and grey seal.

The most abundant species in the region are the harbour porpoise and harbour seal. The proposed submarine cable corridor passes through two protected sites which include marine mammals as a conservation objective: Southern North Sea candidate Special Area of Conservation (cSAC) (lists harbour porpoise as its primary feature of conservation interest); and Klaverbank Site of Community Importance (SCI) (primarily designated for reef habitat, but also lists grey seal, harbour seal, and harbour porpoise as qualifying features, but not as primary reasons for the selection of this site).

The potential effects considered in this assessment are: effects of underwater sound from the proposed activities; risk of injury to species from collision; risk of exposure to hydrocarbon or chemical spill; risk of exposure to contaminant release from sediment; potential disturbance from the presence of survey and installation vessels; and potential disturbance from changes in electromagnetic fields.

Following assessment of the impacts to marine mammals, cetacean and pinniped species are most likely to be affected (through disturbance to normal behaviour) by the Multibeam Echo Sounder (MBES) and Sub Bottom Profiler (SBP) during survey operations and vessels using Dynamic Positioning (DP) during installation. Marine mammals are likely to experience a degree of disturbance from anthropogenic activities such as those proposed, and may move away from the area of activity and therefore will not be within the area where potential injury may occur.

Any effects are transient and will move with the survey, installation or maintenance operations (progressing at approximately 3.5 knots) and it is unlikely that there will be a significant impact to the populations of Annex II or Annex IV species or associated conservation objectives of designated sites within the region.

The Habitat Directive requires that no disturbance or injury will occur to Annex II and Annex IV species. Disturbance includes activities that may impair their ability to survive, migrate, breed and nurture their young; and factors that significantly affect the local distribution or abundance of the species.

Following implementation of Best Practice and appropriate project specific mitigation measures taken from the guidance offered from the four jurisdictions (JNCC 2010, 2016a; BMU 2013; Heinis & De Jong 2015; Energinet.dk (Kriegers flat)), the likelihood that marine mammals will be affected by the Project is reduced to an acceptable level. Any effects from the proposed operations will be transient and temporary. The marine mammal assessment has concluded that no significant risk of disturbance or injury (including permanent or temporary hearing loss) to marine mammals is expected during pre-installation survey, cable installation, operation or decommissioning of the Viking Link and therefore all operations will meet the requirements of the Habitats Directive (92/43/EEC).

It is recognised that cumulative effects are likely to result where localised disturbance from more than one activity occurs simultaneously. The disturbance and subsequent displacement of animals from an area surrounding a development has the potential to affect communication, feeding and foraging opportunities and may restrict migration routes. Cumulative effects have been assessed in the individual jurisdiction Environmental Statements / Reports and are considered to be negligible.

# 1 Introduction

## 1.1 Project Background

1.1.1 The proposed Project is a High Voltage Direct Current (HVDC) electrical interconnector with an approximate capacity of 1400MW, which will allow transfer of power between the electricity transmission systems of Denmark and Great Britain, crossing through the Exclusive Economic Zones (EEZ) of UK, the Netherlands, Germany and Denmark (see Figure 1-1).

1.1.2 The proposed interconnector has achieved Project of Common Interest (PCI) status under the provisions of EU Regulation No. 347/2013 on guidelines for Trans-European Network for Energy (TEN-E Regulations).

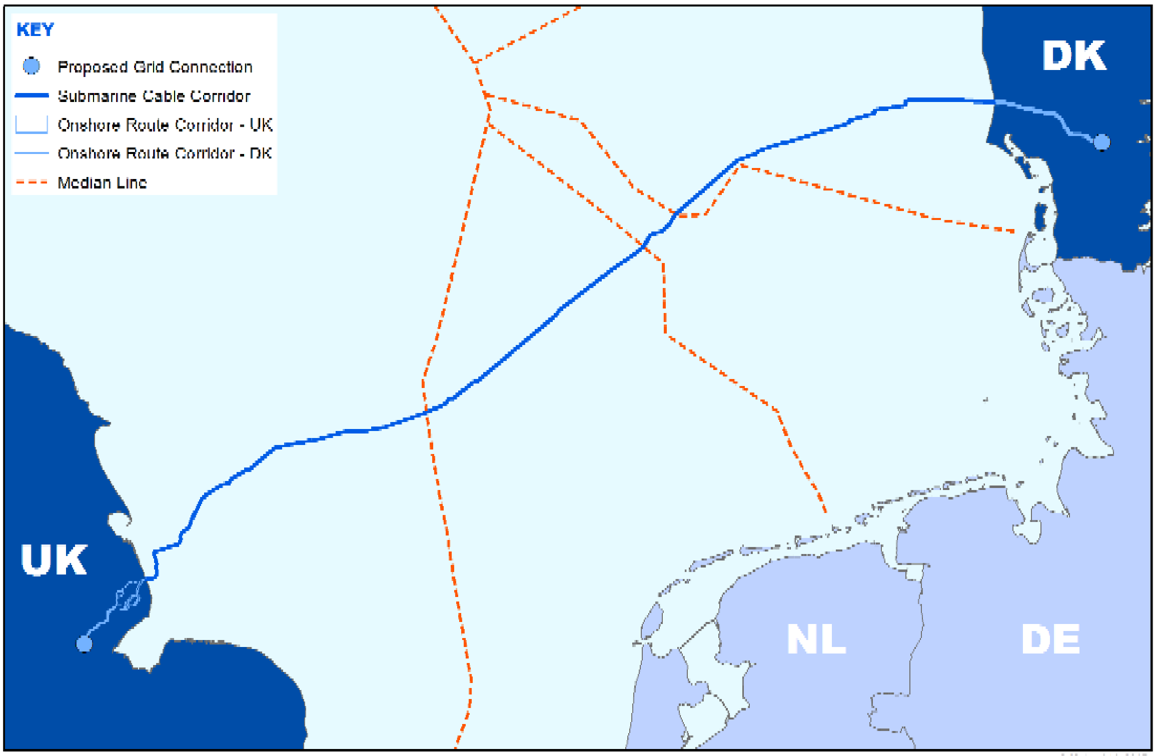





**Figure 1-1 : Location Overview of the Proposed Viking Link Interconnector**

1.1.3 The interconnector will connect the electricity networks of Denmark and Great Britain via a pair of HVDC submarine cables (and potential fibre optic cable for control purposes), allowing electricity to be traded between the two countries. This objective is in line with the European Commission's approach to an integrated energy market to ensure value for money for consumers. Viking Link would enable more effective use of renewable energy, access to sustainable electricity generation and improved security of electricity supplies. Thus it will benefit the socio-economics of both landfall countries.

## 1.2 Purpose of Assessment

1.2.1 The purpose of this Marine Mammal Risk Assessment (MMRA) is to provide the Competent Authorities (and their advisors) within the British, Dutch, German and Danish sectors with sufficient information to determine whether there is a significant risk to marine mammals from the proposed activities. This report therefore considers the level of risk to marine mammals and whether the mitigation measures prescribed in jurisdictional guidelines are appropriate to apply to the proposed activities.

This MMRA considers the implications of the project on marine mammal species listed in Annex II and Annex IV of the by the European Habitats Directive (92/43/EEC). The proposed activities considered include: offshore pre-installation (geophysical) survey; cable installation; cable operation; maintenance and repair and potential post-installation survey activity.

# 2 Jurisdictional Guidelines

2.1.1 For each of the British, Dutch, German and Danish sectors that the Viking Link passes within, there is published guidance for conservation and protection of marine mammals. Guidance considered includes:

- **Great Britain -** JNCC guidelines relating to the deliberate disturbance of marine European Protected Species (JNCC 2008) and JNCC guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys (JNCC 2016a).
- **Germany** - whilst there are guidelines setting out noise thresholds to protect marine mammals (BMU 2013) these relate to piling for offshore renewables (and specifically to the North Sea region) and there are no specific guidelines for activities such as cable installation or vessel movements. Should unexploded ordnance (UXO) have to be cleared using explosives in relation to a project such as a cable installation however then noise mitigation measures would be expected in German waters.
- **Netherlands** - there is more focus on impulsive noise due to piling and a developing framework to assess ecological and cumulative effects of offshore wind farms in this respect (TNO 2015). Impacts from continuous noise including shipping and dredging are not considered likely to result in significant impacts due to the limited range at which effects occur. Although no standards or guidelines have been developed to date to assess the impact of continuous noise on marine mammals in Dutch waters, permit conditions have been applied (e.g. for the construction of Maasvlakte 2 port extension) to monitor underwater sound related to construction activities (Heinis *et al*. 2013). Should UXO clearance be necessary then adequate mitigation measures would be required although there are no specific guidelines.
- **Denmark** - an expert group was established by Energinet.dk to develop guidelines for underwater noise from pile driving and these have been applied to projects such as Kriegers Flak offshore wind farm. There are no generic guidelines relating to underwater noise and disturbance of marine mammals from activities such as shipping movements or dredging.

# 3 Project Description

## 3.1 Planned Activities

Pre-installation Survey Requirements

3.1.1 Although detailed engineering surveys have been completed for the submarine cable corridor, further geophysical and geotechnical sea bed surveys will be completed by the cable installation contractor prior to the commencement of cable installation. These typically take place 3-6 months ahead of installation and will include geophysical survey techniques.

3.1.2 The objectives of these surveys are to confirm that no new obstructions have appeared on the seabed since the original marine surveys were undertaken, and to confirm the viability of the proposed submarine cable corridor with regard to seabed conditions, bathymetry and any other seabed features. The survey will involve a range of standard geophysical survey equipment such as multi-beam echo sounder (MBES) and side scan sonar (SSS). These techniques use sound to record water depth and to map the seabed surface.

3.1.3 The survey will identify possible hazards including potential unexploded ordnance (UXO), pipelines, cables and wrecks. This will be carried out using a marine magnetometer. Use of the magnetometer, depending on the survey scope, will be associated with release of some high frequency acoustic emissions (150kHz to 400kHz), but the magnitude of these emissions is expected to be below other methods (e.g. MBES).

3.1.4 Should UXO be identified it may be necessary to plan controlled detonation(s) to remove the hazard. This would result in a small number of instantaneous, high energy underwater noise (sound pressure) events. This MMRA assumes that one or more events could be necessary.

3.1.5 It is possible, that a sub bottom profiler (SBP) will be used to determine the thickness of sediments. The SBP is not anticipated to be used, but has been included within the Project activities as the requirement cannot be confirmed prior to submission. Shallow SBP systems (e.g. chirp and pingers) inject a pulse of acoustic energy into the seabed and detect the reflections from the sub-surface geological units. From the reflections the thickness of the sediment can be assessed.

3.1.6 Geotechnical survey investigations may be taken to verify ground conditions and may include shallow cone penetrometer testing (CPT), vibrocore and shallow boreholes. Geotechnical operations such as boreholes have been found to operate at approximately 10dB above background noise (ICOE, 2010).

3.1.7 A pre-lay grapnel run (PLGR) operation will be conducted prior to installation to ensure that potential obstacles (e.g. lost fishing gear and marine debris) within the submarine cable corridor are removed. This operation does not involve significant acoustic properties and has been scoped out of this assessment.

### Installation Operations

3.1.8 It is intended to bury the marine cables along their entire length, apart from when it is not possible, for example at crossings with existing cables or pipelines, or where the seabed character is inappropriate for burial. Within Dutch and German waters the submarine cables will be installed within the same trench with nominal separation of 0.2m. Within British and Danish waters, the cable will be installed within two separate trenches assumed to be approximately 50m apart. Cable burial will be achieved using pre or post-lay trenching techniques as described in Table 3-1.

**Table 3-1 : Potential cable installation methods**

| Burial Method | Description |
|---|---|
| Plough | Ploughs are generally used for simultaneous lay and burial operations. There are two principal types of cable plough: displacement ploughs and non-displacement ploughs. Both types of ploughs are towed either by the cable lay vessel or a separate cable burial vessel moving along closely behind the cable ship. |
| Jet Trencher | Jet trenching machines use water jets to disrupt the seabed underneath the cable, forming a trench full of fluidised material. The cable sinks into the trench through the fluidised material under its own weight or is directed into it by a stinger or depressor. |
| Mechanical Trenching | Mounted on tracked vehicles and use chain saws or wheels armed with tungsten carbon steel teeth to cut a defined trench. These machines can work in virtually all sediments, including those with high shear strength and even bedrock. These are often large machines and working in very soft mud or lose ground conditions. |

3.1.9 The cable lay vessel (CLV) is a specialist ship designed specifically to carry and handle long lengths of heavy power cables. The cable lay operation will be performed on a 24-hour basis to ensure minimal navigational impact on other users and to maximise efficient use of suitable weather conditions and vessel and equipment time. CLV's are equipped with dynamic positioning (DP) systems, which enable the ship to be held very accurately in position despite the effects of currents and wind. The CLV may be supported by a cable lay barge and guard vessels.

3.1.10 Where cable burial is not possible it is likely that the cable will be laid and protected by a rock berm or concrete mattresses. The exact details of the installation techniques will be confirmed when the contract for installation is awarded; taking into account the prevailing ground conditions. Rock-placement vessels feature a large hopper to transport the rock, and a mechanism for deployment of the rock on site. The usual mechanisms are:

- side dumping, whereby the rock is pushed or tipped over the side of the vessel;
- flexible fall pipe, where a retractable chute is used to control the flow of rock to the seabed.

3.1.11 The shore-crossings will be accomplished by one of two methods: horizontal directional drilling (HDD); or open-cut trenching.

## Cable Operation

3.1.12 During operation of the cables, emissions to the environment consist of electrically-induced and magnetic fields, and heat. The design of the cables, including lead sheathing and armoured cores, prevents the propagation of electric fields (E fields) into the surrounding environment. Current flowing along HVDC cables also generates a magnetic field (B field), which can permeate through the cable surround and emanate into the surrounding environment. The magnitude of the magnetic field produced is dependent on the amount of current flow.

## In-service Survey Operations

3.1.13 Routine survey of a correctly installed and protected submarine cable is not normally required as the subsea cables will be designed to require minimum maintenance. However, in areas of high seabed mobility, or if post-installation changes in the natural or manmade environment are perceived to have occurred (for example through an increase in adjacent dredging activity), survey of specific areas of the cable system may be initiated. Regular survey of pipeline crossings may be a requirement of a particular pipeline crossing agreement. Periodic inspections may be undertaken to identify cable exposures or spanning.

3.1.14 If required, a survey in shallow waters, 10m depth or less, will be carried out by divers or an ROV using cable tracking and video equipment and operating from a barge or small vessel. If required, a survey in water depths greater than 10m will be carried out from a survey vessel using SSS and ROV deployed instruments, such as cable trackers and video cameras.

## Marine Cable Repairs

3.1.15 Cable repairs to correctly installed and protected marine cables are infrequent but require operations which are similar (although site specific) to installation operations. Cable repairs require operations which temporarily impact upon the environment and the activities of other users of the sea.

3.1.16 The most common reason for repair of a submarine cable is damage caused by third parties, typically caused by trawlers or commercial ships' anchors. Such damage may be localised or widespread depending on the energy of the interaction and the cable may be locally affected, mauled (where something is dragged with force along the cable for a distance) or dragged from the seabed.

3.1.17 A repair may be carried out by a single vessel. A shallow water repair, in less than 10m of water, will typically be performed using an anchored barge. In deeper water, a dynamically positioned cable ship or barge will be used. Vessels carrying out cable repair operations are restricted in their ability to manoeuvre and will display the required navigational lights and signals.

3.1.18 These works may temporarily impinge on the marine environment and the activities of other users of the sea. In relation to marine mammals no effects beyond those associated with pre-installation works are anticipated.

# 4 Legislative Background

## 4.1 Overview

4.1.1 All four jurisdictions that Viking Link passes through are members of the European Union and signatories to European Directives. Marine mammals are legally protected throughout the European Union under Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora commonly known as the Habitats Directive (92/43/EEC). Each jurisdiction implements the Directive through national legislation.

4.1.2 Further information on the protection afforded to marine mammals under the Habitats Directive is provided below. In addition, international conventions and frameworks including International Union for the Conservation of Nature (IUCN) listings, Convention on International Trade in Endangered Species (CITES) and Bonn conventions and ASCOBANS (Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas) apply. The latter in particular is relevant in relation to activities with potential to disturb; this agreement aims to restore and maintain populations of small cetaceans through the co-ordination and implementation of conservation measures.

4.1.3 All jurisdictions will consider marine mammals to be of high conservation importance.

## 4.2 European Habitats Directive

4.2.1 Under 92/43/EEC on the conservation of natural habitats and of wild fauna and flora Article 6(3) of the EC (Habitats Directive), all project-related activities within Special Areas of Conservation (SACs) designated for Annex II species of marine mammals, must be assessed with regard to their implications for the site conservation objectives. The legal obligation under Article 6(3) also extends to ex situ activities i.e. activities outside a SAC must also be assessed.

4.2.2 Under Article 12 of the EC Habitats Directive Member States are further required to establish a system of strict protection for European Protected Species (EPS), as listed in Annex IV across their entire range within the EU, both within and outside Natura 2000 Sites. Marine EPS which occur in the project area include all cetaceans (dolphins, porpoises and whales).

4.2.3 It is an offence to deliberately capture, injure, kill or disturb any EPS listed animal. Disturbance of animals includes activities that are likely to:

- Impair their ability -
    - (i) to survive, to breed or reproduce, or to rear or nurture their young; or
    - (ii) in the case of animals of a hibernating or migratory species, to hibernate or migrate; or
- Affect significantly the local distribution or abundance of the species to which they belong.

4.2.4 In addition to EPS, Annex II of the Habitats Directive lists animal and plant species of community interest whose conservation requires the designation of SACs. Annex II species for which SACs have been designated, or are proposed, include:

- Harbour porpoise (*Phocoena phocoena*);
- Bottlenose dolphin (*Tursiops truncatus*);
- Grey seal *(Halichoerus grypus); and*
- Harbour seal *(Phoca vitulina).*

4.2.5 This assessment therefore specifically considers the implications of the pre-installation (geophysical / sub-bottom profile) survey works, cable installation, cable operation, maintenance and repair activities on Annex II and Annex IV marine mammal species, i.e. all cetaceans, and grey and harbour seal.

### British Legislation

4.2.6 The Habitats Directive is transposed in to British legislation by The Conservation of Habitats and Species Regulations 2010. The Habitats Regulations apply up to 12nm offshore, beyond this the Offshore Marine Conservation (Natural Habitats, & c.) Regulations 2007 apply the Habitats Directive within British Fishery Limits and the seabed within the British Continental Shelf Designated Area.

4.2.7 Additional measures implemented within Britain for the protection of marine mammal species include:

- The Wildlife and Countryside Act 1981 (as amended); and
- Conservation of Seals Act 1970.

### Dutch Legislation

4.2.8 The Habitats Directive is implemented in The Netherlands through the Act on Nature Conservation (ANC) which entered in force on 1$^{st}$ January 2017. This integrates and replaces the Flora and Fauna Act (Flora- en faunawet) and the Nature Conservancy Act 1998 (Natuurbeschermingswet 1998). The Ministry of Economic Affairs is the competent authority for this Project.

4.2.9 The ANC sets out rules for the protection of nature and landscape. Under the Act a permit is required for activities that have significant negative effects on Natura 2000 areas and/or natural monuments. The preferred marine route option in Dutch waters crosses the Natura 2000 site, Klaverbank, and as such the Project has applied for a permit under the Act.

## German Legislation

4.2.10 The Habitats Directive is implemented at both federal and state levels by the:

- Federal Nature Conservation Act (2009) - Sections 34 and 35; and
- Animal Welfare Act (1998).

4.2.11 The Federal Nature Conservation Act aims to regulate and reduce harm to biodiversity in the German North Sea and EEZ with focus on protected species such as marine mammals. Furthermore, the Animal Welfare Act also aims to protect the lives and well-being of animals. No one may cause an animal pain, suffering or harm without good reason.

4.2.12 The Federal Nature Conservation Act applies at a national level. The Bundesländer (Federal States) are responsible for the delineation and management of the protected areas that form the Natura 2000 network. The Federal Government is limited to areas and species beyond coastal waters (12nm) within the Economic Exclusive Zone (EEZ) (12nm – 200nm).

## Danish Legislation

4.2.13 The Habitats Directive is implemented in Denmark through the following relevant legislation:

4.2.14 § 4b in Act on Energinet.dk (Bekendtgørelse af lov om Energinet.dk (LBK nr. 1097 af 08/11/2011)).

4.2.15 The Appropriate Assessment Act (Bekendtgørelse om konsekvensvurdering vedrørende internationale naturbeskyttelsesområder samt beskyttelse af visse arter ved projekter om etablering m.v. af elproduktionsanlæg og elforsyningsnet på havet (BEK nr. 1476 af 13/12/2010)). The Appropriate Assessment Act provides protection of international protected areas and species in connection with projects for offshore electricity production plants and electricity supply grids at sea. The Act no. 1476 requires that a preliminary assessment of impact is submitted before initiation of the pre-investigations and development can take place.

4.2.16 The Habitats Directive Act ("Habitatbekendtgørelsen", Bekendtgørelse om udpegning og administration af internationale naturbeskyttelsesområder samt beskyttelse af visse arter (BEK nr. 926 af 27/06/2016)). All project-related activities within and adjacent to Natura 2000 sites, must be assessed with regard to their implications for the site conservation objectives, as well as possible impacts on protected species (Annex IV species).

# 5 Assessment Approach

5.1.1 To determine whether the proposed activities described in Section 3.1 are likely to have a significant effect on Annex II and Annex IV species, either individually or in-combination with other plans or projects, the following assessment steps were carried out:

- Identification of species present;
- Identify protected areas;
- Cylindrical spreading modelling undertaken to determine the zones of influence of the proposed activities;
- Assess impacts, to determine if the proposed activities are likely to have a significant effect on the species identified as present; and
- Where necessary, apply suitable measures to mitigate adverse impacts identified.

5.1.2 Mitigation measures are the actions or system proposed to manage or reduce the potential negative impacts identified. They should be appropriate, feasible and cost effective. Typically mitigation measures are applied following the hierarchy:

- Avoid or Prevent: In the first instance, mitigation should seek to avoid or prevent the adverse effect at source.
- Reduce: If the effect is unavoidable, mitigation measures should be implemented which seek to reduce the significance of the effect.
- Offset: If the effect can neither be avoided nor reduced, mitigation should seek to offset the effect through the implementation of compensatory mitigation.

5.1.3 Once mitigation has been applied the assessment is repeated to determine whether there remains the possibility of any residual significant impacts. The competent authorities within each jurisdiction may impose conditions or restrictions to the proposals if impacts are considered to be potentially significant. The process is outlined in Figure 5.1 below.

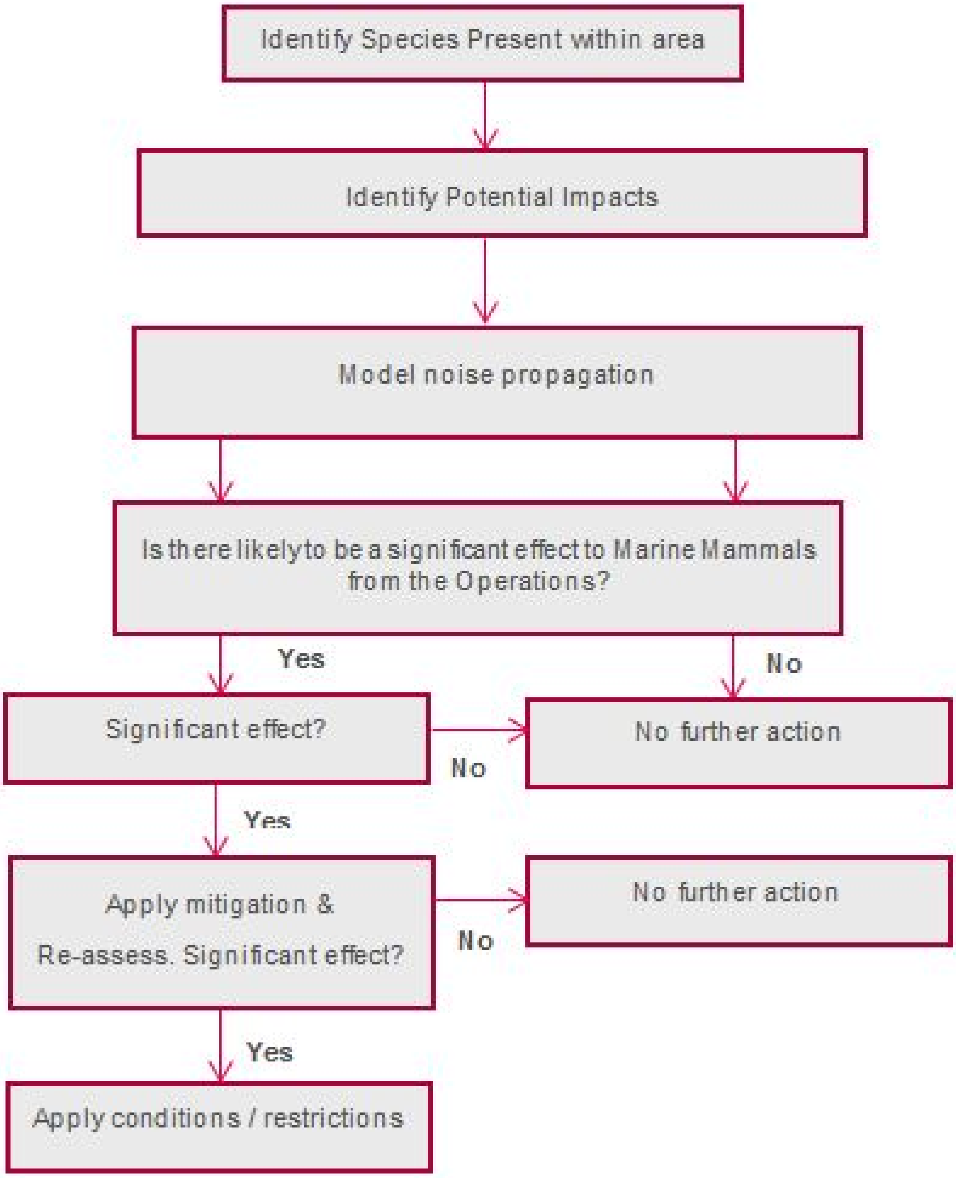



**Figure 5-1: Assessment Process**

# 6 Marine Mammal Baseline

## 6.1 Marine Mammal Species Present

6.1.1 Twenty eight species of cetacean are known to occur in the waters of north-west Europe (Reid *et al.* 2003). However; only seven species of cetacean and two species of pinniped are known to occur regularly in this region, as follows:

- Harbour porpoise *(Phocoena phocoena)*;
- Bottlenose dolphin *(Tursiops truncatus)*;
- White-beaked dolphin *(Lagenorhynchus albirostris)*;
- Minke whale *(Balaenoptera acutorostrata)*;
- Long-finned pilot whale *(Globicephala melas)*;
- Short-beaked common dolphin *(Delphinus delphis)*;
- Atlantic white-sided dolphin *(Lagenorhynchus acutus)*;
- Harbour seal *(Phoca vitulina)*;
- Grey seal *(Halichoerus grypus)*.

6.1.2 Marine mammals are highly mobile species whose range often extends over large areas. Almost all species of cetacean found in the southern and central North Sea are part of larger biological populations whose range extends across continental shelf waters. In order to obtain the best conservation outcomes for many species, it is necessary to consider the division of populations into smaller management units. A mammal management unit (MMU) refers to a geographical area in which the animals of a particular species are found to which management of human activities is applied. If MMUs are defined at a smaller spatial scale than the population, it is important that management takes into account the rates of interchange of individuals between MMUs; that is, the MMUs should not be treated as if they were demographically independent (JNCC 2015).

6.1.3 Cetacean abundance estimates to inform the MMRA have been taken from SCANS II (SMRU 2006) as the submarine cable corridor is almost entirely within SCANS block U, in the southern part of the Central North Sea (CNS). Overall richness (numbers of animals and diversity of species) is relatively low compared to other north-western European waters and both the number of species and the frequency of sightings (taken here as a measure of abundance) tends to decrease southwards through the North Sea, with numbers peaking during the summer months.

6.1.4 Sightings data (Reid *et al.* 2003) and SCANS II (SMRU 2006) suggest that harbour porpoise are the most abundant cetacean species within the waters surrounding the submarine cable corridor and range widely across their North Sea management unit. SCANS II indicates an estimated population of 93,938 animals for the southern Central North Sea population. Harbour porpoise is listed on both Annex II and IV of the EC Habitats Directive and their distribution is linked to the availability of their preferred prey items (gobies, sandeel, whiting, herring and sprat). A study by Hammond *et al.* (2013) indicates that the density of this species within the region surrounding the submarine cable corridor is relatively high at approximately 0.598 individuals per $km^2$ and the mean group size is 1.62 individuals per group. During an aerial survey, a medium density (0.46 – 0.6 animals per $km^2$) of harbour porpoise was recorded in the Klaverbank SCI. To the north of the site, a high density was counted (1.06 – 1.25 animals per $km^2$) (Deerenberg *et al*. 2010).

6.1.5 The harbour porpoise is the most abundant cetacean in Dutch waters; with total number across the Dutch continental shelf estimated to be 41,300 animals in July 2015 (Geelhoed et al 2015). Aerial surveys undertaken in July 2010, October 2010 and March 2011 showed strong seasonal variations in density, with higher numbers of animals present during winter and early spring. During the March survey high densities were found across the whole Dutch continental shelf (DCS), whilst in summer high densities were found near the Brown Ridge, Botney Cut-Dogger Bank and Borkumer Reef. Along the submarine cable corridor densities were estimated to be up to 0.1 – 1.0 animals per $km^2$ in July 2010 and up to 1-1 – 2.0 animals per $km^2$ in March 2011 (Geelhoed *et al*. 2013). These densities were confirmed by aerial surveys in July 2015 which provided density estimates of 0.8 animals per $km^2$ (Geelhoed et al 2015). The submarine cable corridor passes along the southern edge of the high density area associated with the Botney Cut – Dogger Bank, where numbers could be over 15 animals per $km^2$ (Geelhoed et al 2015).

6.1.6 Recent studies indicate that harbour porpoise are located predominantly south of the submarine cable corridor during the winter months (JNCC 2016b). Within the German EEZ, there are aggregation zones for porpoise in spring (January – April) around Sylter Outer Reef and Borkum Reef Ground which are both designated SAC for the species as they have been identified as key foraging areas (Bos *et al.* 2011). Animals appear to move northwards during the summer which is thought to be related to the distribution of preferred prey species, water depth and variables within the water column (Heinänen & Skov 2015). It is not clear to what extent the timing and locations of these hotspots are predictable or persistent.

6.1.7 Within Danish waters, surveys around Horns Rev (15km off the westernmost point of Denmark) between 1999 and 2005 concluded that harbour porpoises are present in high densities all year round approximately 30km from the coast. Furthermore, surveys around the German Blight along the Danish/German border approximately 50-100km from the Wadden Sea have also recorded high densities of harbour porpoise (Teilmann *et al.* 2008).

6.1.8 White-beaked dolphin is the most numerous dolphin species in the North Sea. They are considered to be resident (especially in the western sector) in the CNS, and SCANS II (SMRU 2006) suggests a population of approximately 501 animals are likely to be present within the submarine cable corridor throughout the year.

6.1.9 Minke whale is likely to be present in the submarine cable corridor for part of the year (mainly May to September) as they migrate south during the summer. SCANS II (SMRU 2006) suggests an estimated population of approximately 3,655 animals across submarine cable corridor. Sightings have generally been confined to the Dogger Bank area and Klaverbank SCI in Dutch waters. Species density within this region surrounding the submarine cable corridor is low at approximately 0.023 individuals per $km^2$ with a mean group size of one individual per group.

6.1.10 Long-finned pilot whale has been observed as a rare visitor to the submarine cable corridor. The submarine cable corridor is outside their normal range as they are generally associated with deeper waters.

6.1.11 Bottlenose dolphin sightings are most frequent in coastal areas during the summer. In winter, animals move offshore and are more dispersed. SCANS II (SMRU 2006) does not have a population estimate for bottlenose dolphin in CNS. They are known to be present throughout the CNS, with observations peaking during November although sightings are uncommon. No sightings of this species were recorded in the Hammond *et al.* (2013) study.

6.1.12 The ranges of both the short-beaked common dolphin and Atlantic white-sided dolphin overlap the submarine cable corridor. Atlantic white-sided dolphin are generally associated with deeper waters but have been recorded around Dogger Bank (e.g. Sea Watch Foundation 2016). Short-beaked common dolphin is occasionally encountered but the main part of the range of this primarily oceanic species is to the north and west.

6.1.13 Other cetacean species may occur as rare vagrants.

6.1.14 In addition to these cetacean species, two species of pinniped occur within the CNS and SNS: harbour seal and grey seal. Both species are widespread around North Sea coasts. Seals are central-place foragers, leaving and returning to their haul-out sites on every foraging trip. As such the distribution of seals at sea is limited by the need to return to land periodically.

6.1.15 Harbour seals pupping tends to occur between May and July (Hammond *et al.* 2001) followed by moulting in August which takes approximately 4-5 weeks. During this time they are more frequently observed at haul out sites and are less likely to be offshore. From haul-out sites, harbour seals undertake regular trips to sea, mostly to feed. Although they can make trips of several tens to hundreds of kilometres, they mostly forage within 50 km of their haul out sites (Aarts *et al.* 2016).

6.1.16 There are important breeding and haul out sites for harbour seal around the SNS coast (Thompson et al. 2016). This species is a primary reason for the designation of The Wash and North Norfolk Coast SAC (UK) located approximately 14.5km from the submarine cable corridor. This SAC is a primary area for breeding and hauling out and is the largest colony of harbour seal in British waters, with some 7% of the total population. A survey undertaken during the harbour seal breeding season on the 27$^{th}$ June 2015 identified 1351 pups ashore within The Wash; examination of the series of counts suggests that this is close to the actual maximum number of pups for the season. When compared to previous surveys, harbour seal pup productions has increased at around 8.2% per year since surveys began in 2001 (Thompson et al. 2016).

6.1.17 The harbour seal is the most abundant pinniped in the Netherlands, with an estimated 12400 individuals inhabiting the Dutch section of the North Sea and Wadden Sea in 2015 (Aarts *et al.* 2016). Research combining tracking data from more than 200 harbour seals with aerial survey data of seal hauled-out on land, has been used to estimate harbour seal distribution at sea in relation to habitat preferences in the Dutch North Sea. Seal density was found to be highest near haul-out sites and within areas of approximately 30m water depth, with low mud content.

Distribution varied between seasons, during the spring and summer months (April to September) seals spent more time near the haul-out sites, whereas in the winter months (December to February) harbour seals spent more time at sea, travelled greater distances from their haul-out sites and used haul-out sites that were located closer to the North Sea (Aarts *et al*. 2016).

6.1.18 In the Klaverbank SCI, a medium density (0.46 – 0.6 animals per $km^2$) of seals was observed (Deerenberg *et al.* 2010). Although the Klaverbank SCI, appears to be towards the limit of their range from haul-out sites (given its distance offshore), the findings of the Aarts *et al*. (2016) research suggests that harbour seals could forage as far offshore as this site during the winter months (December – February).

6.1.19 Within Danish waters, this species is the most common pinniped; with haul-outs on single large stones in the Danish Kattegat, in very isolated locations in Limfjord and also within the Wadden Sea (Olsen *et al*. 2010).

6.1.20 Grey seal have a wide distribution across the north-western Atlantic, Baltic and northeast Atlantic seas. The estimated 70,000 individuals in the North Sea account for approximately 50% of the northeast Atlantic population. Grey seal are mainly distributed around and between haul-out sites and foraging areas and are more commonly seen in the CNS and NNS than in the SNS (DTI, 2002). Overall, there are estimated to be approximately 3,000 grey seal in the Dutch North Sea (based on moult counts; Aarts *et al.* 2013). Seal telemetry data suggests that they occur close to the coast (within 50km; Aarts *et al.* 2013) and are unlikely to be present in high numbers within the submarine cable corridor.

6.1.21 During breeding periods onshore grey seal are highly sensitive to disturbance by humans and have a preference for remote sites. Grey seal moulting occurs approximately 3-5 months after the end of the breeding season. In the North Sea region most grey seals spend time on land for several weeks during October to January whilst mating and pupping, and in spring during the moult (February – March). During these times most of the seal population will be on land for most of the time, making densities at sea lower. Grey seals have re-established populations within the Wadden Sea in all three jurisdictions (Dutch, German and Danish) with adult population counts reaching 4,936 in 2015/16 (Common Wadden Sea Secretariat 2016).

## 6.2 Protected Sites for Marine Mammals

6.2.1 Species listed on Annex II of the EC Habitats Directive require the designation of SACs for their conservation. The Directive requires that two cetaceans (bottlenose dolphin and harbour porpoise) and two seal species (grey seal and harbour seal) are maintained at a favourable conservation status.

6.2.2 As marine mammals range widely across the North Sea a list of the protected sites listing marine mammals as a conservation objective within 60km of the submarine cable corridor has been identified. This distance is believed to represent a reasonable compromise between the very wide-ranging behaviour of the species concerned (e.g. grey seal regularly travel in excess of 200km from haul out sites and harbour seal, although generally present within 50km of the coast, may venture over 100km (SMRU 2014)) and the need to limit the listing to those sites most likely to be relevant. The sites are listed in Table 6-1 and shown in Figure 6-1.

**Table 6-1: Designations within 60km of Viking Link route**

| SACs designated for seals and cetaceans | Designating feature | Distance to project area |
|---|---|---|
| Britain - Southern North Sea cSAC | Harbour Porpoise | Project crosses designated area |
| Dutch - Klaverbank SCI | Harbour Porpoise<br>Grey Seal<br>Harbour Seal | Project crosses designated area |
| Britain - The Humber Estuary SAC | Grey Seal | 8.6km |
| Denmark - Sydige Nordsø | Harbour Porpoise<br>Grey Seal<br>Harbour Seal | 9km |
| Britain - The Wash and North Norfolk Coast SAC | Harbour Seal | 14.5km |
| Dutch & German Doggerbank SAC | Harbour Porpoise<br>Grey Seal<br>Harbour Seal | 16km |
| Dainish- Vadehavet National Park Vadehavet med Ribe Å, Tved Å og Varde Å vest for Varde | Harbour Porpoise<br>Grey Seal<br>Harbour Seal | 16.8km |
| Dainish - Sandbanker ud for Thorsminde SAC | Harbour Porpoise | 53km |
| German - Sylter Outer Reef SAC | Harbour Porpoise<br>Grey Seal<br>Harbour Seal | 58.8km |

6.2.3 The submarine cable corridor passes through two protected areas designated for marine mammals: the SNS cSAC (British waters); and Klaverbank SCI (Dutch waters).

6.2.4 The SNS cSAC is located within British waters and the proposed cable corridor passes through the cSAC for approximately 64km. The site is very large and covers an area of 36,958km$^2$ stretching from the CNS north Dogger Bank, southwards to the Strait of Dover. This site has been recognised as an area with predicted persistent high densities of harbour porpoise; with the north of the site being of greater importance during the summer season, and the south being of greater importance during the winter, covering both inshore and offshore waters.

6.2.5 The Klaverbank SCI is located in Dutch waters close to the British/Dutch median line and covers an area of approximately 1,235km$^2$. The submarine cable corridor passes through the northern section of the site for approximately 19km. The area is primarily designated for stony reef habitat (supporting H1170 Open-sea Reef), and is the only area on the DCS where significant quantities of gravel lying on the surface exist. The gravel has a covering of algae including calcareous red algae which supports higher faunal diversity than the surrounding areas (EADNB 2017). The habitat may provide feeding opportunities for grey and harbour seals, and harbour porpoise, which are qualifying features of this site, but not primary reasons for the selection of this site.

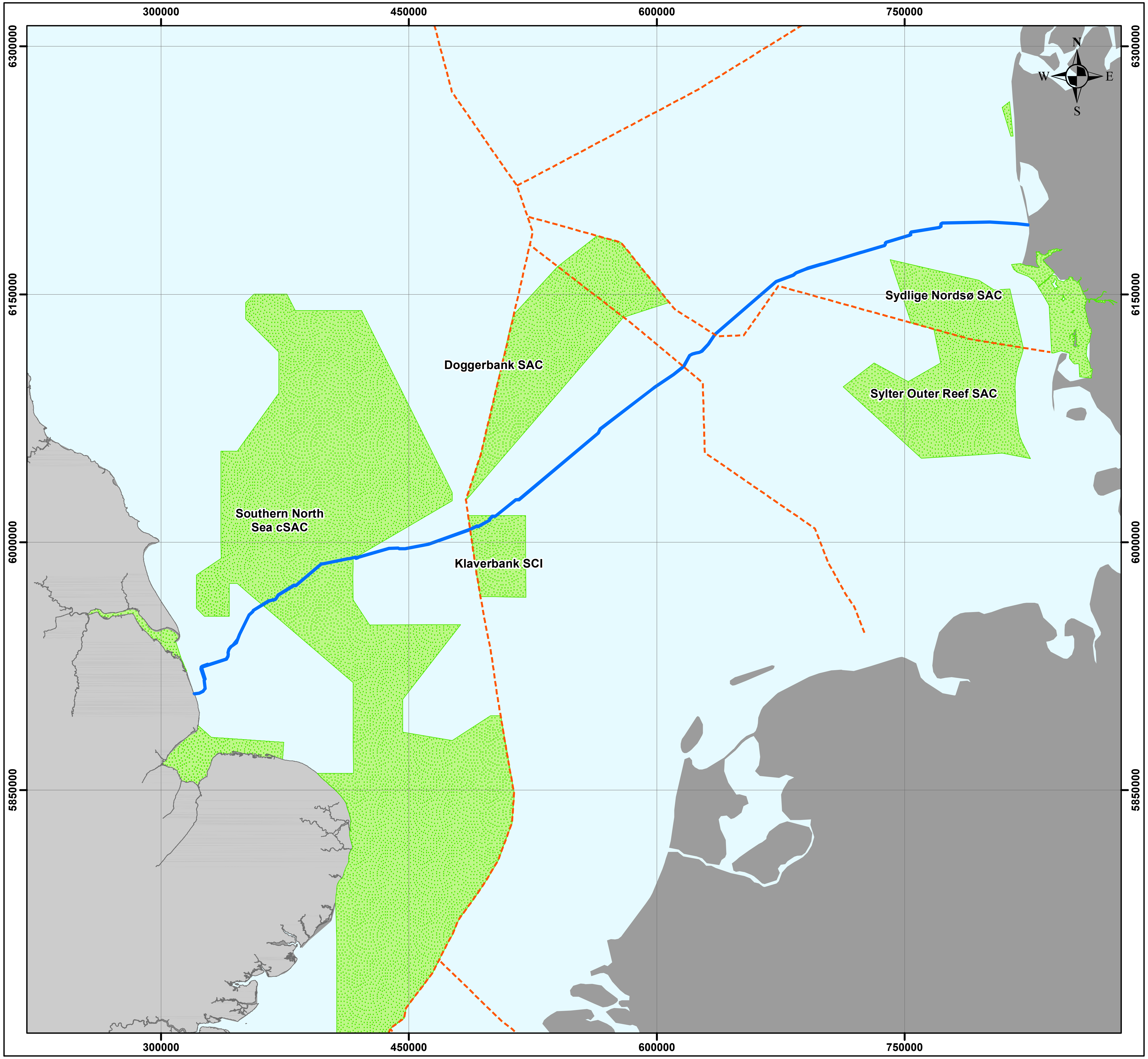
6.2.6 Conservation objectives for the site include maintaining the quality of habitats for marine mammals with appropriate management of human activity in the vicinity of the site. There is limited information with regards to marine mammal population numbers within the SCI. However, Reid *et al*. (2003) observed white-beaked dolphin around this SCI during January, March, April and May and bottlenose dolphin and minke whale were also recorded in small numbers in June. As discussed in Section 6.1.5, the submarine cable corridor passes along the southern edge of the Botney Cut – Dogger Bank area which is noted for high densities of harbour porpoise during summer months.

# Viking Link MMRA

VikingLink

nationalgrid ENERGINET DK

**Figure 6-1: Protected Sites for Marine Mammals within 60km of Viking Link**




## Legend

- Submarine Cable Corridor
- Median Line
- Protected Sites within 60km

NOTE: Not to be used for Navigation

| | |
|---|---|
| **Date** | Tuesday, February 14, 2017 10:27:34 |
| **Projection** | ETRS_1989_UTM_Zone_31N |
| **Spheroid** | GRS_1980 |
| **Datum** | D_ETRS_1989 |
| **Data Source** | Viking, CDA, ESRI, OSOD, JNCC, NE, |
| **File Reference** | J:\P1996\Mxd\Environment\Marine_Mammal\ Figure_6-1_Protected_Sites_v2.mxd |
| **Created By** | Jennifer Arthur |
| **Reviewed By** | Richard Marlow |
| **Approved By** | Jillian Hobbs |

NIRAS Intertek Valued Quality. Delivered.

0 30 60 90 120 km

# 7 Potential Effects on Marine Mammals

## 7.1 Introduction

7.1.1 This section identifies potential effects to marine mammals from the proposed activities outlined in Section 3. These potential effects may be direct or indirect, temporary or permanent, or a combination of these.

7.1.2 Based on a review of marine mammal sensitivities and the protected sites' interest features the following potential significant effects have been identified for the proposed Viking Link activities. These are listed here and summarised individually below:

- Disturbance from underwater noise (all activities except UXO detonations);
- Risk of injury from underwater noise (UXO detonations only);
- Risk of injury from collision;
- Risk of exposure to accidental hydrocarbon or chemical spill;
- Risk of exposure to potential contaminant release from sediments; and
- Potential disturbance from changes in electromagnetic fields.

## 7.2 Potential Disturbance from Underwater Noise

7.2.1 One of the most important environmental concerns related to the proposed activities is the potential effects of underwater sound. This section considers the potential for marine mammals to be affected by noise associated with activities including vessel movements, use of dynamic positioning equipment, survey equipment (e.g. MBES and SBP) and interactions with the seabed. These activities include examples of both continuous and impulsive noise.

7.2.2 Both cetaceans and pinnipeds have evolved to use sound as an important aid in navigation, communication and hunting (Richardson *et al.* 1995). It is generally accepted that exposure to anthropogenic sound can induce a range of behaviour effects to permanent injury in marine mammals. Loud and prolonged noise may mask communicative or hunting vocalisations, preventing social interactions and effective hunting. High intensity noises such as from seismic survey, explosions and pile driving can cause temporary or permanent changes to animals hearing if exposed to the sound in close proximity and, in some circumstances, lead to the death of the receiver (Richardson *et a.,* 1995). Where the threshold of hearing is temporarily damaged it is considered a temporary threshold shift (TTS), and the animal is expected to recover. If there is permanent damage (permanent threshold shift (PTS)) where the animal does not recover, social isolation and a restricted ability to locate food may occur potentially leading to the death of the animal (Southall *et al.* 2007).

7.2.3 Impulsive noise is characterised by high energy over a short period of time. Metrics used to measure impulsive noise are sound exposure level (SEL) and Peak sound pressure level (SPLpeak or SPLpeak-peak). SEL is calculated over the pulse duration, which is commonly defined as the time occupied by the central portion of the pulse, where 90% of the pulse energy resides (Robinson *et al.* 2014). MBES and SBP are an example of an impulsive noise source which may be used during pre-installation and maintenance surveys. Underwater explosions are also impulsive in character but are considered separately due to the much larger energy released and associated risk of injury (see Section 7.3).

7.2.4 Continuous noise is acoustic energy spread over a longer period of time, typically many seconds, minutes or even hours. The amplitude of the sound may vary throughout the duration, but the amplitude does not fall to zero for any significant time. The metric generally applied to continuous sounds is sound pressure level (SPL). SPL is time averaged and most commonly expressed as a root mean square (RMS) value.

7.2.5 In order to evaluate the potential of the project to cause harm to marine mammals, an assessment has been conducted using the Southall *et al.* (2007) approach and the recently published NMFS (2016) approach. Both approaches separate marine mammals into five groups based on their functional hearing, namely: low-frequency cetaceans; mid frequency cetaceans; high frequency cetaceans; pinnipeds in water; and pinnipeds in air (Table 7-1).

**Table 7-1: Marine mammal auditory bandwith**

| Group | Low Frequency Cetaceans | Mid Frequency Cetaceans | High Frequency Cetaceans | Pinnipeds In Water | Pinnipeds In Air |
|---|---|---|---|---|---|
| Auditory band width – Southall et al. (2007) | 7 – 22,000Hz | 150 – 160,000Hz | 200 – 180,000Hz | 75 – 75,000Hz | 75 – 30Hz |
| Auditory band width – NMFS (2016) | 7 – 35,000Hz | 150 – 160,000Hz | 275 – 160,000Hz | 50 – 86,000Hz | 75 – 30Hz |
| Species | Baleen whales | Most toothed whales, dolphins | Certain toothed whales, porpoises | All species | All species |
| Species present in submarine cable corridor | Minke whale | Bottlenose dolphin<br>White-beaked dolphin<br>Long finned pilot whale<br>Common Dolphin<br>Atlantic White-sided Dolphin | Harbour porpoise | Grey seal<br>Harbour seal | Grey seal<br>Harbour seal |

7.2.6 All the cetacean species identified with the potential to be present within the submarine cable corridor are mid frequency cetaceans with the exception of minke whale which, like other baleen whales, is more sensitive at lower frequencies and harbour porpoise which is sensitive at higher frequencies.

7.2.7 The proposed quantitative injury thresholds (defined as PTS or TTS) for each marine mammal functional group defined Southall *et al*. (2007) and NMFS (2016) are presented in Table 7-2.

**Table 7-2: Injury criteria for marine mammals exposed to discrete noise events reviewed by Southall et al. (2007) and NMFS (2016) - Sound Pressure Level (dB re 1µPa (unweighted))**

| Marine mammal group | Southall et al. (2007) SPL dB re: 1µPa (peak) | | NMFS (2016) SPL dB re: 1µPa (peak) | |
|---|---|---|---|---|
| | PTS | TTS | PTS | TTS |
| Low frequency cetaceans | 230 | 224 | 219 | 213 |
| Medium frequency cetaceans | 230 | 224 | 230 | 224 |
| High frequency cetaceans | 230 | 224 | 202 | 196 |
| Pinnipeds (in water) | 218 | 212 | 218 | 212 |

7.2.8 Sound attenuates as it propagates through water and the local oceanographic conditions will affect both the path of the sound into the water column and how much sound is transmitted. Attenuation can be calculated using the equation SPL = SL – 15log (R). In this equation SPL = sound pressure level, R is the distance from a source level (SL) and 15 is attenuation value associated with spreading (MMO 2015).

7.2.9 The assessment considers the likely noise levels associated with the proposed operations (see Section 5.1) and using the equation above calculates the distance from the source that noise levels will diminish to below the NMFS (2016) injury criteria thresholds. The criteria as defined by NFMS (2016) have been used as they either match or are a lower threshold than the Southall *et al.* (2007) criteria.

7.2.10 Anthropogenic activity in the North Sea is relatively high from activities such as shipping, marine aggregate extraction, windfarm operation, oil and gas exploitation and fishing activities. Marine mammals are highly mobile and range widely across the North Sea. Therefore marine mammals within the project area (which currently has less anthropogenic activity) are likely to be habituated to background levels of anthropogenic noise in the North Sea. Only noises which are relatively loud compared to background levels (such as pilling and seismic survey) are likely to result in a discrete behavioural response such as displacement from or avoidance of an area, although this is not to say that exposure to chronic background noise is without impact (e.g. Rolland *et al.* 2012). Animals could also be expected to respond differently to sudden (e.g. impulsive) sound and continuous noise, although there is potential for habituation in both situations. Equally, not all animals will respond in the same manner and there may be marked differences between responses to the same sound source even for individuals of the same species (e.g. Brandt *et al.* 2016).

7.2.11 Most threshold noise levels for marine mammals are based on impulsive noise and the reported levels cannot be used directly for continuous noise. Southall *et al.* (2007) discuss criteria for both impulsive and non-impulsive noise and based on a number of studies on harbour porpoise it is concluded that the species is quite sensitive to a wide range of human sounds. Recorded exposures exceeding 140 dB re 1 µPa induced clear avoidance behaviour in wild harbour porpoise; however, the studies related to acoustic mitigation devices (AMDs) which are specifically designed to emit sound in the frequency spectrum at which harbour porpoise are most sensitive and no threshold levels for lower frequency sounds such as ship noise were described or can be deduced from these studies.

7.2.12 There is likely to be variation in background noise levels and the hearing capacity of individuals within the auditory groups and impacts across the marine mammal species groups may vary from those tested by NMFS (2016).

7.2.13 Results indicate that studies into marine mammal disturbance by anthropogenic noise acknowledge a high degree of variation in results and even when information on equipment specifications is known it is still difficult to predict the level of disturbance for marine mammals accurately. It is widely recognised that further study and monitoring of marine mammal reactions and recoverability is required (NMFS 2016).

## 7.3 Potential Injury from Underwater Noise (UXO)

7.3.1 If any significant UXO are identified it is Best Practice to follow the below decision making process:

- Avoid by micro-routing the submarine cables.
- If it cannot be avoided, consider whether it is safe to move.
- If it cannot be moved, detonate on site.

7.3.2 If detonation is required, it is acknowledged there is potential for significant adverse impacts in the form of injury or death for marine mammals if present in relatively close proximity to underwater explosions.

7.3.3 Detonation, it is assumed, would result in a relatively large release of impulsive sound energy. Peak source levels would depend on the quantity and nature of explosive material, but would likely exceed the NMFS (2016) injury criteria thresholds detailed in Table 7-2. At close range there would be risk of mortality as relatively small quantities of explosive can result in significant sound pressure levels e.g. Richardson *et al.* (1995) reported that 0.5kg of TNT was associated with a peak SPL of 267dB re 1µPa @ 1m.

7.3.4 Without specific information on the UXO that might need to be detonated, a review of literature conducted by Genesis (2011) has been used to predict potential sound pressure levels. Genesis (2011) summarise information collected by Nedwell et al. (2001) during explosive operations in support of wellhead decommissioning (Table 7-3). Measurements of sound pressure levels were taken at two locations: the CSO Seawell in a standoff position 600-800m from the wellhead; and seabed mounted hydrophones at different ranges. For a 45kg charge the highest sound pressure level recorded by the seabed mounted hydrophones was 232 dB re: 1µPa (0-peak) at 300m from the source (91m water depth). Sound pressure levels were also recorded for charge sizes between 36kg and 81kg at varying shallower water depths.

**Table 7-3 :Sound pressure levels (0-Peak) recorded from the detonation of explosive charges measured from the CSO Seawell adapted from Nedwell et al. (2001)**

| Range (m) | Charge size kg | Depth of hydrophone | Received level (0-Peak) dB re1µPa @ range |
|---|---|---|---|
| 650 | 36 | 30 | 221 dB re1µPa @ 650m |
| 650 | 36 | 25 | 222 dB re1µPa @ 650m |
| 800 | 36 | 30 | 221 dB re1µPa @ 800m |
| 575 | 45 | 30 | 211 dB re1µPa @ 575m |
| 575 | 45 | 25 | 211 dB re1µPa @ 575m |
| 600 | 45 | 40 | 213 dB re1µPa @ 600m |
| 600 | 45 | 35 | 214 dB re1µPa @ 600m |
| 600 | 45 | 30 | 214 dB re1µPa @ 600m |
| 600 | 45 | 25 | 214 dB re1µPa @ 600m |
| 650 | 45 | 40 | 216 dB re1µPa @ 650m |
| 650 | 45 | 35 | 218 dB re1µPa @ 650m |
| 650 | 45 | 40 | 218 dB re1µPa @ 650m |
| 650 | 45 | 35 | 217 dB re1µPa @ 650m |
| 650 | 45 | 40 | 221 dB re1µPa @ 650m |
| 650 | 45 | 35 | 217 dB re1µPa @ 650m |
| 650 | 45 | 40 | 221 dB re1µPa @ 650m |
| 650 | 45 | 35 | 221 dB re1µPa @ 650m |
| 650 | 45 | 30 | 218 dB re1µPa @ 650m |
| 650 | 45 | 25 | 217 dB re1µPa @ 650m |
| 75 | 45 | 116 | 227 dB re1µPa @ 75m |
| 125 | 45 | 87 | 226 dB re1µPa @ 125m |
| 200 | 45 | 110 | 225 dB re1µPa @ 200m |
| 300 | 45 | 91 | 232 dB re1µPa @ 300m |
| 300 | 45 | 84 | 230 dB re1µPa @ 300m |
| 400 | 45 | 108 | 223 dB re1µPa @ 400m |
| 600 | 73 | 30 | 220 dB re1µPa @ 600m |

**Table 7-3 :Sound pressure levels (0-Peak) recorded from the detonation of explosive charges measured from the CSO Seawell adapted from Nedwell et al. (2001)**

| Range (m) | Charge size kg | Depth of hydrophone | Received level (0-Peak) dB re1µPa @ range |
|---|---|---|---|
| 650 | 73 | 25 | 226 dB re1µPa @ 650m |
| 600 | 81 | 30 | 220 dB re1µPa @ 600m |
| 600 | 81 | 25 | 226 dB re1µPa @ 600m |

Source: Genesis (2011)

7.3.5 The source level of explosives can be predicted if certain parameters are known, such as the weight of the charge (w) and depth of detonation. The SPL (0-peak) of the initial shock wave, the largest amplitude component, is given by the formulae:

SPL (0-peak) dB re1µPa @ 1m = 271 dB + 7.533(log)(w) (Ulrick 1975)

7.3.6 Once the initial SPL is calculated the standard sound propagation formula can be used to calculate the distance that sound will attenuate to at distance from source. For example, if a 36kg charge is assumed, the formula calculates the SPL (0-peak) as 283 dB re1µPa @ 1m. Assuming spherical spreading from the explosion i.e. N = 20, then the SPL will attenuate to 227 dB re1µPa @ 600m. This figure is 6dB higher than the measured SPL @ 650m recorded by Nedwell *et al.* (2001) presented in row 1 of Table 7-3, suggesting that the calculations are conservative.

7.3.7 The precise injury effect range (i.e. range to TTS) cannot be stated in advance of information on the nature and quantity of explosive material potentially involved. Standard mitigation for such events (e.g. JNCC 2010) recommends that a 1000m radius Mitigation Zone (MZ) be applied so that no detonation occurs until it is confirmed as far as reasonably practical that no animals are present within this range.

7.3.8 It is unknown how many, if any, UXO detonations are required. Any events would be limited in number and represent discrete, one-off occurrences.

## 7.4 Risk of disturbance from the presence of survey and installation vessels

7.4.1 Human disturbance of seals is only important if it affects survival or fecundity (Gill *et al.* 2001). Disturbance caused by visual disturbance can cause marine mammals to stop feeding, resting, travelling and socialising. Repeated disturbance may cause long term effects including loss of weight, condition and a reduction in reproductive success (JNCC 2008). Seals are most at risk from visual disturbance when they are hauled out on land resting or breeding.

7.4.2 Grey seal are highly sensitive to disturbance by humans hence their preference for remote haul out and breeding sites. Harbour seal often haul out onto tidally exposed sandbanks to rest, moult and suckle their young and are common along the East coast of Britain. Haul out locations in close proximity to the submarine cable route are located at The Wash and North Norfolk Coast

SAC (Britain) approximately 14.5km from the submarine cable corridor, Vadehavet National Park (Denmark) approximately 16km from the submarine cable corridor and the Sylter outer reef SAC approximately 58km from the submarine cable corridor.

7.4.3 Visual disturbance of seal is dependent on the background levels animals are habituated to. In general, ships more than 1,500m away from grey seal haul out areas are unlikely to evoke any reactions from grey seals. Between 900m and 1,500m, grey seals could be expected to detect the presence of vessels and at closer than 900m a flight reaction could be expected (Scottish Executive 2007). This is similar to the flight reaction observed in harbour seal. Studies in Alaska looking at reactions to cruise ships show that hauled-out harbour seal are alert to the presence of vessels at >800m with disturbance responses (e.g. flushing into the water) observed at distances of 500-800m (Blundell and Pendleton 2015). Other disturbances are caused by kayak and small boats.

7.4.4 The protected areas with identified haul outs are greater than 1.5km from the submarine cable corridor and therefore limited disturbance is expected.

7.4.5 Seals in the water within 2km of the survey activities and 3km of the installation activities may adapt their behaviour in response to disturbance from underwater noise and temporarily leave the area. Foraging distances and distribution data indicate that grey and harbour seal may be foraging or travelling through the vicinity of the submarine cable corridor particularly in relation to the Klaverbank SCI. Their distribution offshore is constrained by a need to return to land periodically, and is dependent on the availability and distribution of food, particularly preferred prey items such as sandeel, cod and sole.

## 7.5 Risk of Injury to Species from Collision

7.5.1 The survey and installation vessels will marginally increase the level of vessel activity in the marine environment; across an area that already contains predominantly low (0.1 ships per week) to moderate levels (50 ships per week) of shipping activity, with some sections of the cable within proximity to the coast having high levels of shipping activity of up to 100 ships per week (MMO 2014). Vessel transit speed will be restricted during survey and installation activities to below 16 knots. Therefore it is unlikely that any marine mammals will collide with the slow moving or stationary project vessels.

7.5.2 It is recognised that the results of a collision with project vessels could be very serious and possibly life threatening for marine mammals.

## 7.6 Risk of Exposure to Accidental Hydrocarbon or Chemical Spill

7.6.1 Any unplanned release of surface pollutants, such as mineral oils and chemicals from project vessels, has the potential to affect marine mammals which encounter the surface pollutant. Marine mammals must surface to breathe, and their vulnerability to surface pollutants is considered to be high, particularly in the near shore waters that are within foraging range of seal haul outs. Highest vulnerability is within the breeding season when seals remain within waters closer to their haul out locations and the density of seals in the water in these locations is higher. Marine diesel is likely to evaporate quickly, however any spill can spread across surface waters quickly and may have significant impacts to mammals within the area affected by the spill.

7.6.2 Data showing the probability of a hydrocarbon or chemical release from survey and installation vessels are not available. However, analysis of data from the Advisory Committee on Protection of the Sea (ACOPS) Annual Survey of Reported Discharges shows that during the period 2012-2013 there were a total of five reported marine pollution incidents within the Eastern English waters (ACOPS 2012, 2013). Figures are currently unavailable for other jurisdictions, however as shipping, oil and gas exploration and wind farm development is similar any unplanned discharges are likely to be similar in scale. Of these incidents the majority that occurred were related to oil and gas activities within ports and harbours. During 2012 - 2013, there were no reported discharges from offshore support vessels and such spills from vessels are unlikely.

## 7.7 Risk of Exposure to Potential Contaminant Release from Sediments

7.7.1 Sediments accumulate toxins and pollutants such as hydrocarbons and heavy metals. Disturbance to the seabed from cable installation and maintenance can release these contaminants into the water column which has the potential to change chemical properties of the sediment and reduce water quality.

7.7.2 Once suspended, contaminants can become available to marine mammals and can accumulate within the organism. Marine mammals are sensitive to bioaccumulation because they feed at high trophic levels, and have a large proportion of lipid-rich blubber which accumulates contaminants readily. High contaminant levels have been linked to immune system depression, disease breakouts, reproductive effects, developmental effects and endocrine disruption.

7.7.3 Marine mammals accumulate high levels of contaminant irrespective of whether disturbance from cable installation occurs and therefore linking bioaccumulation in marine mammals from this process is difficult. Lethal effects are highly unusual and likely to be confined spatially (Todd *et al.* 2014).

## 7.8 Potential Disturbance from Changes in Electromagnetic Fields

7.8.1 During operation of the submarine cables, emissions to the environment will consist of electric-induced and magnetic fields and heat. Some marine species are electrically and/or magnetically sensitive and have the ability, at least in principal, to detect emissions from operating HVDC cables. Cetaceans are known to be magnetically sensitive (and emissions of a magnetic field have the potential to cause temporary changes in swim direction or greater detours during migration in sensitive species (Gill *et al.* 2005). This may temporarily affect sensitive species crossing the submarine cables or passing along their length, and therefore temporarily reduce their navigational ability when within the immediate vicinity of the cable.

7.8.2 The implications for temporary loss of navigation for cetaceans are not fully understood. However, there have been no reported impacts to the migration of harbour porpoise or other cetacean over existing interconnector cables. There is no current evidence to suggest that pinnipeds are directly influenced by, sensitive to, or use magnetic fields (Gill *et al.* 2005).

7.8.3 The background geomagnetic field in the vicinity of cable system is anticipated to be approximately 49.5µT (NIRAS 2016). Submarine power cables generate magnetic fields owing to the electric current flowing along the cables. The magnitude of the magnetic fields produced is directly dependent upon the level of current flow. The design of the cables, including lead sheathing and armoured cores, prevents the propagation of electric (E) fields into the surrounding environment; however, these materials are permeable to magnetic (B) fields, which therefore emanate into the surrounding environment, effectively unimpeded. The B field attenuates with distance (both horizontally and vertically) from the cable conductor. Localised static electric fields may be induced as seawater (tidal flow) or other conductors such as marine organisms pass through the DC cable's magnetic field. Electric fields will attenuate with both horizontal and vertical distance from the cable conductor. Burial depth can reduce the effect range of EMFs but to a lesser extent than cable bundling, due to mutual cancellation of the positive and negative poles and currents travelling in opposite directions.

7.8.4 Within Dutch and German waters the submarine cables will be installed within the same trench with nominal separation of 0.2m. Within British and Danish waters, the cable will be installed within two separate trenches assumed to be approximately 50m apart.

7.8.5 Modelling has been conducted to estimate the EMF field strength produced by the Project. It has been assumed that, in line with Dutch legislation, the cable will have a DoL of 1m. Predictions of induced electrical field strengths were made for two tidal velocity scenarios: 0.5 m/s and 1.25 m/s, with the results from the faster current speed being used as the worst case scenario (Table 7-2).

Table 7-4 Expected Maximum Electric and Magnetic fields from the Viking Link Submarine Cable

| Cable configuration | Electric field strength (µV/m) | | | Magnetic field strength (µT) | | |
|---|---|---|---|---|---|---|
| | 0.5 m from cable | 1 m from cable | 5 m from cable | 0.5 m from cable | 1 m from cable | 5 m from cable |
| **Bundled (0.2 m separation)** | 238* | 105 | 63.1 | 190 | 83.9 | 50.5 |

*a theoretic value as the field is believed to be below the minimum burial depth

The Viking Link cable design eliminates direct electric field generation and, by minimizing the magnetic field generated by the Interconnector, the system configuration also minimizes electric fields induced in the marine environment. Given the approach to cable burial and bundling for the Viking project induced electric fields are only anticipated at very close range to the cable alignment, up to around 1m in UK and Danish waters (NIRAS 2016).

# 8 Significance of Effect

## 8.1 Potential Injury and Disturbance from Underwater Noise

8.1.1 The proposed operations for the Viking Link will cross two protected areas for marine mammals. The submarine cable corridor passes through the proposed SNS cSAC within British waters and through the Klaverbank SCI within Dutch waters.

8.1.2 The marine mammal risk assessment, presented in Appendix A1, has established zones of influence summarised in Table 8.1 for survey, installation, operation and maintenance activities.

**Table 8-1 : Worst Case Impact Zone of Influence**

| Project Phase | Project Activity | Aspect | Potential Impact | Receptor | Zone of Influence |
|---|---|---|---|---|---|
| Survey Activities | Pre-installation, post-installation and maintenance survey operations | Presence of Project Vessels | Injury from underwater noise | Cetacean | 200m |
| | | | | Pinniped | 50m |
| | | | Disturbance from underwater noise | Cetacean | 25km |
| | | | | Pinniped | 16km |
| Installation and Maintenance | Presence of DP vessel | Presence of Project Vessels | Injury from underwater noise | Cetacean | 1.5m |
| | | | | Pinniped | None |
| | | | Disturbance from underwater noise | Cetacean | 5.5km |
| | | | | Pinniped | 2.8km |
| | Rock or concrete mattress placement | Presence of Project Vessels | Injury from underwater noise | Cetacean | None |
| | | | | Pinniped | None |
| | | | Disturbance from underwater noise | Cetacean | 990m |
| | | | | Pinniped | 510m |
| | Cable ploughing & trenching | Presence of Project Vessels | Injury from underwater noise | Cetacean | None |
| | | | | Pinniped | None |
| | | | Disturbance from underwater noise | Cetacean | 230m |
| | | | | Pinniped | 170m |

| Table 8-1 : Worst Case Impact Zone of Influence | | | | | |
|---|---|---|---|---|---|
| **Project Phase** | **Project Activity** | **Aspect** | **Potential Impact** | **Receptor** | **Zone of Influence** |
| Installation and Maintenance | Removing Seabed Obstruction | UXO detonation | Disturbance from underwater noise | Cetacean | 1km |
| | | | | Pinniped | 1km |
| Operation | Operation of Cable | Magnetic Field (B fields) interfering with cetacean navigation | Disturbance to navigation | Cetacean | 150m (UK & Danish waters)<br><br>10m (Dutch & German waters) |
| Unplanned Event | Release of hydrocarbons or chemical spill | Accidental chemical or hydrocarbon release | Contamination of sea and foreshore leading to exposure to surface hydrocarbons or chemicals | Cetacean Pinniped | 10km from point of spill |

## 8.2 Potential Injury from Underwater Noise

Modelling results in Appendix A1 show that cetaceans and pinnipeds are at risk of temporary or permanent injury from the noise emitted from the SSS, MBES, and SBP, and temporary injury from dynamically positioned ships. The worst case zone of injury is produced by the MBES. Cetacean are only vulnerable to injury if they are present within 200m and pinniped 50m of the MBES. This equipment has the potential to cause PTS to harbour porpoise within 120m of the survey vessel, and within 15m for pinniped. High frequency cetaceans are also more sensitive to the SSS and SBP than other auditory groups, however the effects of this equipment is less than for the MBES.

8.2.1 The submarine cable corridor passes through the SNS cSAC and Klaverbank SCI. Both protected areas are designated for harbour porpoise and the Klaverbank also notes high numbers of pinniped species. Vessel operational speeds (approximately 3.5 knots) indicate that survey operations will be within the SNS cSAC and Klaverbank SCI for approximately 10 hours and 3 hours respectively. Impact areas and percentages of SNS cSAC and Klaverbank SCI affected have been calculated and are presented in Appendix A3.

8.2.2 While survey operations transit across the SNS cSAC it is possible that noise levels in up to 0.0001% of the protected site will be of a magnitude to cause permanent injury to harbour porpoise; 0.0003% of the protected site will be affected by noise levels sufficient to cause a temporary impact on marine mammal hearing (Appendix 3) for a duration of 10 hours.

8.2.3 For the Klaverbank up to 0.0036% of the site may be within the zone of permanent injury from the MBES; and 0.01% of the Klaverbank SCI within the zone of temporary injury; for approximately 3 hours duration.

8.2.4 The SBP has a reduced zone of injury compared to the MBES (Appendix A1), however due to the low frequency of the sound emitted it may cause disturbance over greater distances of up to 25km (Appendix A2).

8.2.5 If present, pinnipeds may be at risk of being permanently injured by the MBES in approximately <0.0001% of the site; and temporarily injured in present within approximately 0.0006% of the Klaverbank SCI. The zones of risk will be present for three hours.

8.2.6 Installation operations generally do not present a risk of injury (permanent or temporary) to cetacean or pinniped. The exception to this is the harbour porpoise which may receive temporary hearing injury if within 1.5m of the DP cable installation vessel, which is unlikely. This equates to approximately 7m$^2$ surrounding the vessel and <0.0001% of the SNS cSAC and 0.0005% of the Klaverbank protected areas as the survey progresses through these sites.

8.2.7 Sound produced by installation operations is unlikely to have a significant effect to marine mammal populations or the conservation objectives for the protected sites crossed by the submarine cable corridor.

8.2.8 Generally, the maximum sound pressure levels related to the installation of cables are considered moderate to low when compared with activities such as seismic surveys, military activities or construction work involving pile driving (OSPAR 2012).

8.2.9 It should be noted that the modelled results included in this assessment do not account for the directional quality of the survey noise source (marine survey equipment is designed to concentrate energy output downwards), seabed interactions, seabed type, and changes in salinity, bathymetry, water temperature or density, which influence the attenuation of underwater sound.

8.2.10 Accounting for these may reduce the suggested impact zone (typically, for example, lateral sound pressures will be around 20dB lower than directly under a directional sound source such as an airgun), thereby reducing the potential spatial extent of impact. In addition to cylindrical spreading loss for acoustic propagation in the water column, higher frequency acoustic energies are more quickly absorbed through the water column than sounds with lower frequencies. Due to these factors the operations emitting lower frequencies (MBES and DP vessels) have a greater disturbance zone.

## 8.3 Potential Disturbance from Underwater Noise

8.3.1 Modelling results (see Appendix A1) suggest that for survey activities a temporary avoidance response may be invoked by the project for species able to hear well at lower frequencies, such as the minke whale and harbour seal. Behavioural disturbance from underwater sound sources is more difficult to assess than injury and is dependent upon many factors related to the circumstances of the exposure (Southall *et al.* 2007). An animal's ability to detect sounds produced by anthropogenic activities depends on its hearing sensitivity and the magnitude of the noise compared to the amount of natural ambient and background anthropogenic sound. In simple terms a noise for a noise to be detected it must be louder than background and above the animal's hearing sensitivity at the relevant sound frequency.

8.3.2 Zones of disturbance have been modelled (Appendix A2) using internationally agreed values for harbour porpoise and pinniped in water (ASCOBANS 2011). A range of studies exist which suggest that a value of 140dB is a reasonable level at which to assume disturbance effects can be expected for harbour porpoise. A threshold of 145dB is used for pinnipeds in water (Kastelein 2011).

8.3.3 The modelled results indicate that the operations producing the lowest frequencies (SBP and DP vessels) have the greatest potential for disturbance. The SBP may disturb harbour porpoise up to 25km from the survey activity and 16km for seal species. Installation noise from the DP vessel may be audible up to 5.5km from the source for harbour porpoise and 2.8km for seal.

8.3.4 It is quite possible that minke whales detect low frequency noise at considerable distances over many tens of km, and it is possible that low frequency noise sources mask communication signals within the zone of audibility.

8.3.5 The SNS cSAC will be impacted by disturbance from operations for approximately 10 hours. Up to 0.03% of the SNS cSAC will be affected by noise levels sufficient to cause disturbance from the MBES. However, this increases to 5.3% of the cSAC if a SBP is used. Approximately 1% of the Klaverbank SCI is estimated to experience noise levels sufficient to cause disturbance from the MBES for approximately 3 hours while survey vessels pass through the area. However, a maximum of 61% of the Klaverbank SCI will be affected by noise levels sufficient to cause disturbance from operation of the SBP during this 3 hour period.

8.3.6 During installation the disturbance to marine mammals is likely to be far less than during survey operations, however DP vessels will disturb a zone up to 5.5km from the vessel which will effect up to 0.26% of the SNS cSAC and 7.69% of the Klaverbank SCI (Appendix 3).

8.3.7 Due to the disturbance zone, injury is unlikely, as animals are likely to avoid the area of disturbance. Cable installation is considered a non-pulse activity and therefore the disturbance distances stated for this activity are likely to be considerably more than actually experienced by species within the environment (Subacoustech 2012).

8.3.8 Marine mammals are highly mobile and range widely across the North Sea, and animals outside the protected sites may be affected by the moving operations.

8.3.9 Seals are not considered EPS; however, Annex II seals from protected sites within close proximity of the submarine cable corridor may be present. The sites designated for seal within the potential disturbance zone for pinniped are Klaverbank SCI, the Humber Estuary SAC, Sydige Nordsø, The Wash and North Norfolk Coast SAC and the Dutch & German Doggerbank SAC located within, 8.5km, 9km, 14.5km and 16km respectively from the submarine cable corridor.

8.3.10 Seal are most likely to be encountered within proximity to the coast and haul out locations and therefore less likely to be in offshore areas. However, based on data obtained from satellite trackers, density maps have been made which indicate that both grey and harbour seal can occur in the site (Jak *et al.* 2009). Harbour seal are most likely to be encountered in offshore waters between December – February (Geelhoed et al 2015). Grey seal are likely to be breeding and moulting over winter and are more likely to be offshore during the summer months although unlikely to be present in high numbers within the submarine cable corridor.

8.3.11 Harbour Porpoise have been found to have greater densities on the DCS and waters south of the submarine cable corridor over winter. From April they migrate north, following prey items towards the Dogger Bank (in particular the Botney Cut) and throughout the Central North Sea. Densities are greater in waters north of the submarine cable corridor over the summer months (Geelhoed et al 2015; JNCC 2016).

8.3.12 An animal's response to disturbance is dependent upon background noise levels, individual sensitivity to hearing and duration of the disturbance. Swimming speeds will allow mammals to move away from the zones of disturbance produced by the proposed operations and remain outside the area as it progresses across the North Sea. The zones of disturbance will move with the survey, installation or maintenance operation (progressing at approximately 3.5 knots) and it is unlikely that there will be a significant displacement of the wide ranging mobile populations of Annex II or Annex IV species within this area.

## 8.4 Potential Injury from Underwater Noise (UXO)

8.4.1 As discussed in Section 7.3, until it is known whether UXO is present, that requires in-situ detonation, it is not possible to determine the potential impact. The sound pressure levels generated by the detonation depend on the weight of charge found, but are likely to exceed to the injury thresholds proposed by NMFS (2016).

8.4.2 If detonation is required, it is acknowledged there is potential for significant adverse impacts in the form of injury or death for marine mammals if present in relatively close proximity to underwater explosions.

8.4.3 If any significant UXO are identified it is Best Practice to follow the below decision making process:

- Avoid by micro-routing the submarine cables.
- If it cannot be avoided, consider whether it is safe to move.
- If it cannot be moved, detonate on site.

8.4.4 Standard mitigation for detonation has been provided by UK regulators (JNCC 2010). No current guidance is available from Dutch authorities. The JNCC (2010) guidance recommends that a 1000m radius Mitigation Zone (MZ) be applied so that no detonation occurs until it is confirmed as far as reasonably practical that no animals are present within this range. Two trained marine mammal observers are required to undertake a pre-detonation search of the mitigation zone. Explosive detonations should only be conducted during day light hours and in good visibility. The guidelines also require the operator to demonstrate that the 1000m mitigation zone is sufficient for the weight of charge identified, typically by conducting underwater modelling. Within Dutch waters conditions within permits related to UXO detonation may include the use of an acoustic deterrent device to establish that no marine mammals are within the mitigation zone.

8.4.5 With mitigation in place, the impacts to marine mammals will be significantly reduced and it is unlikely that there will be a significant impact to the wide ranging mobile populations of Annex II or Annex IV species within the area.

## 8.5 Risk of disturbance from the presence of survey and installation vessels

No visual disturbance at seal haul out locations is expected. Some disturbance of preferred feeding provided by the Klaverbank SCI habitats may occur during installation for short durations. Activities will not exclude animals from the entire protected area and disturbance will be limited to approximately 1% of the Klaverbank SCI for approximately 3 hours while survey vessels pass through the area. Disturbance will be localised transient and temporary. It is unlikely that there will be a significant displacement of the wide ranging mobile populations of Annex II or Annex IV species during survey and installation operations.

## 8.6 Risk of Injury to Species from Collision

8.6.1 No impacts are predicted, as vessel speeds will be low and animals will be able to change course.

## 8.7 Risk of Exposure to Accidental Hydrocarbon or Chemical Spill

8.7.1 None expected as contractors are fully trained. The potential for exposure is low but possible.

## 8.8 Risk of Potential Contaminant Release from Sediments

8.8.1 Although physiological effects arising from the remobilisation of contaminants can be of great harm to marine mammals, it is considered that only small volumes of sediment are likely to be re-suspended from submarine cable installation, and that careful route planning can avoid any known contaminated sediments keeping any pollution to a minimum.

## 8.9 Potential Disturbance from Changes in Electromagnetic Fields

8.9.1 Electromagnetic fields reduce with distance from the cable core and any effect from magnetic or electric fields will be localised. The submarine cables will be buried to minimum target depths of 1m within Dutch waters and 1.5m within German and a minimum of 0.5m within UK and Danish waters. Where the cables are bundled (Dutch and German waters) the configuration eliminates the vast majority of direct EMF generation. Where the cables are not bundled (i.e. UK and Dutch waters) they will act more like single cables without significant magnetic field cancellation.

8.9.2 Given the approach to cable burial and bundling for the Project induced electric fields are anticipated to be above background geomagnetic fields up to 50m from the cable in UK and Danish waters. In German and Dutch waters the practical limit of magnetic field, and hence induced electric field effects (in terms of increase above background levels) is expected to be not more than 10m (NIRAS 2016).

8.9.3 Owing to their predominantly pelagic existence, the relatively rapid attenuation of the B field to background levels or below within tens of metres of the cables, combined with lack of evidence of effects upon cetaceans, it is expected that cetaceans will be unaffected by magnetic fields from Project. NIRAS (2016) concluded, with high confidence, that there will be no significant effects on migratory or orientation behaviours of cetaceans as a consequence of the magnetic field generated by the cables.

## 8.10 Cumulative Effect

8.10.1 Anthropogenic activity in the North Sea may give rise to impacts that individually would not give cause for concern, however when considered alongside other activities occurring within the same region may give rise to cumulative effects to marine mammals or conservation objectives of protected areas associated with Annex II and IV species.

8.10.2 Marine mammals are wide ranging across the North Sea and their range may be restricted by the effects of cumulative anthropogenic activities. Cumulative effects are likely to result where localised disturbance from more than one activity occurs simultaneously, restricting foraging, migratory or breeding behaviour. An animal may swim away from the zone of discomfort and be excluded until the activities have passed.

8.10.3 Cumulative effects have been assessed within the individual jurisdiction Environmental Statements / Reports. These conclude that the Project will either have no or a negligible cumulative effect with other projects, plans and licensed activities.

# 9 Mitigation Measures

9.1.1 As identified in Section 8 there are a number of potential effects that are considered to have the potential to cause temporary disturbance to marine mammals. Where any disturbance is considered likely, mitigation measures could be applied subject to requirement which will further reduce the likelihood of a significant effect.

9.1.2 Table 9-1 presents measures that the project should adhere to in order to ensure Best Practice and alignment with relevant international statute.

| Table 9-1: Best Practice | | |
|---|---|---|
| Risk of exposure to accidental chemical or fuel spill | Control measures and oil pollution emergency plans will be put in place and adhered to under MARPOL Annex I requirements. | International Convention |

9.1.3 In addition to the Best Practice, Table 9-2 presents measures based on British and German guidance relating to underwater sound that may be considered. German, Dutch and Danish guidance is largely related to piling and explosives and may not be relevant for survey and cable installation operations. The implementation of project specific mitigation measures as part of pre-installation survey works may require a marine mammal observer to operate on board and/or Passive Acoustic Monitoring to be undertaken during 24 hour operations/after dark – particularly for operations producing impulsive noise. It is not expected that mitigation measures will be required for installation activities.

| Table 9-2: Guidance proposing mitigation measures applicable to the proposed operations | | |
|---|---|---|
| | | Guidance |
| Disturbance/injury from underwater noise during survey works | Viking Link will require that the appointed installation contractor follows Sections 7 and 8 of the 'DRAFT JNCC guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys' (JNCC 2016a), appropriate to sub-bottom profiling and multi-beam and echo-sounder surveys respectively, unless the FINAL guidance is issued which will take precedence. In particular:<br>• Establishing a 500m mitigation zone for marine mammal observation.<br>• Provide marine mammal observers to implement the JNCC guidelines.<br>• Undertake pre-survey search - On-board MMO will scan the waters surrounding the vessel for 30 | JNCC (2016a) |

| Table 9-2: Guidance proposing mitigation measures applicable to the proposed operations | | |
|---|---|---|
| | | Guidance |
| | minutes before operations start to determine whether any marine mammals are within 500m of the survey equipment.<br>• Where possible, according to the operational parameters of the equipment concerned, its acoustic energy output shall commence from a lower energy start-up and thereafter be allowed to gradually build up to the necessary maximum output over a period of at least 15 minutes, with the duration from the start of the soft start until the start of the survey line being a maximum of 25 minutes.<br>• If the device cannot be ramped up then it shall be switched on and off in a consistent sequential manner over a period of 20 minutes prior to commencement of the full necessary output. | |
| Risk of injury/death from UXO detonations (if required) | Viking Link will require the appointed UXO contractor follows the JNCC guidelines for minimising the risk of injury to marine mammals from using explosives (JNCC 2010) including:<br>• Establishing a default 1km mitigation zone for marine mammal observation, measured from the explosive source and with a circular coverage of 360 degrees.<br>• Providing a trained Marine Mammal Observer to implement the guidelines outlined in Section 2 e.g. pre-detonation search of mitigation zone.<br>• Only commence explosive detonations during daylight hours and good visibility.<br>• Accurately determine the amount of explosive required for the operation, so that the amount is proportionate to the activity and not excessive. | JNCC (2010); BMU (2013); Heinis & De Jong, (2015); Energinet.dk |
| Risk of collision | All project vessels operating for survey, installation or maintenance will operate at low speeds of 14 knots or less. | |

# 10 Conclusions

10.1.1 Following assessment of the impacts to marine mammals, cetacean and pinniped species are most likely to be affected (through disturbance to normal behaviour) by the proposed survey activities (MBES, SSS and SBP) and operation of DP vessels during installation.

10.1.2 A 200m mitigation zone around the cable to minimise the injurious effects of underwater noise is recommended during survey activities. Within this zone mitigation measures should be considered to reduce the likelihood of a marine mammal entering the area to minimise the effect of a temporary or permanent change to an animal's auditory ability. The maximum distance of underwater noise propagation, resulting from geophysical surveying (SBP, SSE and MBES), has been calculated through noise modelling to be up to 25km from the vessel.

10.1.3 The species most sensitive are high frequency cetaceans such as harbour porpoise. The submarine cable corridor passes through the SNS cSAC and the Klaverbank SCI. Both sites are designated for Harbour porpoise, and the Klaverbank SCI is also noted for seal species.

10.1.4 The percentage of the SNS cSAC and Klaverbank SCI effected by noise levels sufficient to cause injury to marine mammals from MBES is <0.01%; for approximately 10 hours duration in the cSAC and 3 hours duration within the Klaverbank SCI.

10.1.5 The maximum distance in which a behavioural disturbance (Sound Pressure Levels above 140 dB re. 1µPa for cetaceans) may occur is across a radius of 25 km from the sound source. The maximum distance that a behavioural disturbance (Sound Pressure Levels above 145 dB re. 1µPa) for pinnipeds may occur is anticipated to be within a 16km radius of the sound source.

10.1.6 It is probable that if a behavioural response occurs, animals will leave the area minimising the risk of injury occurring. During installation, harbour porpoise may receive temporary hearing injury if within 1.5m of the DP vessel which is unlikely as disturbance may be up to 5.5km from the source for cetacean and 2.8km for pinniped.

10.1.7 No visual disturbance at haul out locations is expected due to the distance from the operations. Some disturbance of preferred offshore feeding areas such as the Klaverbank SCI may occur from the DP vessel during installation; however this will be localised, transient and temporary.

10.1.8 The submarine cable corridor will be optimised to avoid anomalies or UXO. Should UXOs require detonation; a separate risk assessment will be conducted. No impacts are anticipated from UXO during the operational phase as no disturbance to the seabed will occur.

All operations are transient and temporary. Following Best Practice and the application of project specific mitigation measures outlined in Table 9.1 and Table 9.2, no significant effects to marine mammal populations across the route are expected to arise from the proposed activities of the Viking Link Project.

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# Appendix: Noise Modelling Results

## Noise Modelling

11.1.1 Sound attenuates as it propagates through water and the local oceanographic conditions will affect both the path of the sound into the water column and how much sound is transmitted. Attenuation can be calculated using the equation SPL = SL – 15log (R). In this equation SPL = sound pressure level, R is the distance from a source level (SL) and 15 is attenuation value associated with spreading (MMO 2015).

11.1.2 The assessment considers the likely noise levels associated with the Project and using the equation above calculates the distance from the source that noise levels will diminish to below the NMFS (2016) injury criteria thresholds presented in Table 7-2. The criteria defined by NMFS (2016) have been used as they either match or are a lower threshold than those proposed by Southall et al. (2007). The results are presented in Table A1.

11.1.3 The same approach is taken to calculate the distance at which disturbance effects may be observed. A range of studies exist which suggest that a value of 140dB is a reasonable level at which to assume disturbance effects can be expected. This is also the figure used by ASCOBANS (2011) as the reference level for disturbance of harbour porpoise. A threshold of 145dB is used for pinnipeds in water based on research in Kastelein (2011). The results are presented in Table A2.

11.1.4 The calculation for PTS, TTS and disturbance does not account for the directional quality of the noise source; seabed interactions; seabed type; and change in salinity, bathymetry, temperature or density, which would reduce the zone of esonification. In addition to cylindrical spreading loss for acoustic propagation in the water column, higher frequency acoustic energies are more quickly absorbed through the water column than sounds with lower frequencies. Due to these factors, the distances for PTS and TTS are conservative and worst case.

11.1.5 As the Project vessels will progress along the submarine cable corridor (typically at 3.5 knots) the Zone of Influence will move. Table A3 presents calculations showing the maximum area over which noise levels could exceed the various thresholds at any one time i.e. not the entire area of the site that could be affected by the Project. It also presents calculations indicating the maximum area of the SNS cSAC and Klaverbank SCI which could be affected at any one time, noting that the submarine cable corridor does not pass through the centre of the sites and therefore part of the Zone of Influence could be outside of the site.

| Appendix A1: Table A1: Results from noise modelling indicating the potential worst case injury distances from sound source | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Auditory group | Threshold SPL dB re: 1µPa (peak) | | Distance from source (m), where threshold is exceeded | | | | | | |
| | | | SSS | MBES | SBP | DP Vessel | | Cable trenching | Rock placement |
| | | | SPL: 229 dB re: 1µPa @1m Frequency: 100 kHz | SPL: 235 dB re: 1µPa @1m Frequency: 70 kHz | SPL: 211 dB re: 1µPa @1m Frequency: 3.5 kHz | SPL: 177 dB re: 1µPa @1m Frequency: 3 kHz | SPL: 197 dB re: 1µPa @1m Frequency: 3 kHz | SPL: 185 dB re: 1µPa @1m Frequency: 160 kHz | SPL: 186 dB re: 1µPa @1m Frequency: 10kHz |
| Low frequency cetaceans | PTS | 219 | 5 | 15 | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded |
| | TTS | 213 | 15 | 40 | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded |
| Medium frequency cetaceans | PTS | 230 | Threshold not exceeded | 2.6 | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded |
| | TTS | 224 | 2.6 | 7 | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded |
| High frequency cetaceans | PTS | 202 | 60 | 120 | 4.6 | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded |
| | TTS | 196 | 110 | 200 | 11 | Threshold not exceeded | 1.5 | Threshold not exceeded | Threshold not exceeded |
| Pinnipeds in water | PTS | 218 | 7 | 15 | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded |
| | TTS | 212 | 15 | 50 | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded | Threshold not exceeded |

Notes: Source input noise characteristics: MMO (2016); DHAG (2014); OSPAR (2009); Nedwell *et al.* (2003); and Richardson *et al* (1995).

| Appendix A2: Table A2: Results from noise modelling indicating the potential worst case disturbance distances from sound source | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Auditory group | Threshold (dB re. 1µPa) | Distance from source (m) | | | | | | |
| | | SSS | MBES | SBP | DP Vessel | | Cable trenching | Rock placement |
| | | SPL: 229 dB re: 1µPa @1m Frequency: 100 kHz | SPL: 235 dB re: 1µPa @1m Frequency: 70 kHz | SPL: 211 dB re: 1µPa @1m Frequency: 3.5 kHz | SPL: 177 dB re: 1µPa @1m Frequency: 3 kHz | SPL: 197 dB re: 1µPa @1m Frequency: 3 kHz | SPL: 185 dB re: 1µPa @1m Frequency: 160 kHz | SPL: 186 dB re: 1µPa @1m Frequency: 10kHz |
| Cetacean | 140 | 1,400 | 2,000 | 25,000 | 310 | 5,500 | 230 | 990 |
| Pinnipeds in water | 145 | 1,200 | 1,800 | 16,000 | 150 | 2,800 | 170 | 510 |

Notes: Disturbance Threshold value source: Kastelein *et al*. (2011); Kastelein *et al.* (2013a and b); TNO (2015)

| Appendix A3: Table A3 Zones of Influence and Maximum Percentage of Protected Site Effected (at any one point in time) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Area surrounding source (km$^2$) | | | | | |
| | | SSS | MBES | SBP | DP Vessel | Cable trenching | Rock placement |
| PTS | | 0.011 | 0.045 | 0.000 | No effect | No effect | No effect |
| TTS | | 0.038 | 0.126 | 0.000 | 0.00707 | No effect | No effect |
| Disturbance | | 6.158 | 12.566 | 1963.45 | 95.033 | 0.166 | 3.079 |
| % of Klaverbank SCI | PTS | 0.0009% | 0.0037% | <0.0001% | No effect | No effect | No effect |
| | TTS | 0.0031% | 0.0102% | <0.0001% | No effect | No effect | No effect |
| | Disturbance | 0.5% | 1.02% | 61%* | 7.69474% | No effect | No effect |
| % of SNS cSAC | PTS | <0.0001% | 0.0001% | <0.0001% | No effect | No effect | No effect |
| | TTS | <0.0001% | 0.0003% | <0.0001% | <0.0001% | No effect | No effect |
| | Disturbance | 0.017% | 0.034% | 5.313% | 0.257% | 0.0005% | 0.008% |

*Note – as the submarine cable corridor does not pass directly through the centre of the site, the 25km radii disturbance zone only affects the northern portion of the Klaverbank SCI. The worst case area affected (at any one point) has been estimated (using a geographical information system) to be 750km$^2$.

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# Annex III

**VKL-07-30-J800-015**

**February 2017**

VikingLink

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# Electromagnetic Fields – Marine Ecological Report

## Viking Link

**Document Reference:VKL-07-30-J800-015**

**February 2017**

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Connecting Europe Facility

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# 1 Introduction

1.1.1 The proposed Project is a High Voltage Direct Current (HVDC) electrical interconnector with an approximate capacity of 1400MW, which will allow transfer of power between the electricity transmission systems of Denmark and Great Britain, crossing through the Exclusive Economic Zones (EEZ) of UK, the Netherlands, Germany and Denmark (see Figure 1).

1.1.2 The Project is configured so that power would be able to flow in either direction at different times, depending on the supply and demand in each country.

1.1.3 The proposed link has achieved Project of Common Interest (PCI) status under the Regulation for the trans-European energy infrastructure (EU 347/2013) (TEN-E Regulation).

1.1.4 In common with other submarine power cabling, magnetic and direct or induced electric fields may occur in the marine environment when the cable is operational. The Viking Link Interconnector is not expected to generate external electric fields directly (see Section 0) but induced electric (iE) fields may be generated by the movement of water and/or organisms through the electromagnetic field (EMF) produced by the cable. This is the same process by which movement through the natural geomagnetic field of the earth will induce an electric field.

1.1.5 A relatively large number of organisms in the marine environment are either known to be sensitive to EMF and/or iE fields or have the potential to detect them (Gill & Taylor, 2001; Gill *et al*., 2005) and fields of the magnitude anticipated from submarine power cabling have been demonstrated to lie within the sensitivity ranges of a variety of marine organisms (CMACS, 2003; Gill *et al*., 2009).

1.1.6 In view of this overlap there is concern that potential effects should be considered (Gill, 2005; Gill & Kimber, 2005; Ohman *et al*., 2007; Sutherland *et al*., 2008); especially bearing in mind that many electrically or magnetically sensitive species are also commercially exploited and/or of high conservation importance (e.g. salmon, thornback rays, cetaceans), with some having suffered severe population declines in recent decades (e.g. skates and rays: Baum *et al*., 2003; Myers & Worm, 2003).

1.1.7 This report has been prepared to inform the assessment of potential impacts of operation of the interconnector upon marine ecological receptors through effects associated with EMF generation.

# 2 Project Description

## 2.1 Project Overview

2.1.1 The proposed cable route would run form Bicker Fen in Lincolnshire in UK to Revsing in Jutland in Denmark (see Figure 1). The total length of the interconnector is 760km, with 630km of submarine cable and 55km and 75km of onshore cable in Great Britain and Denmark respectively.

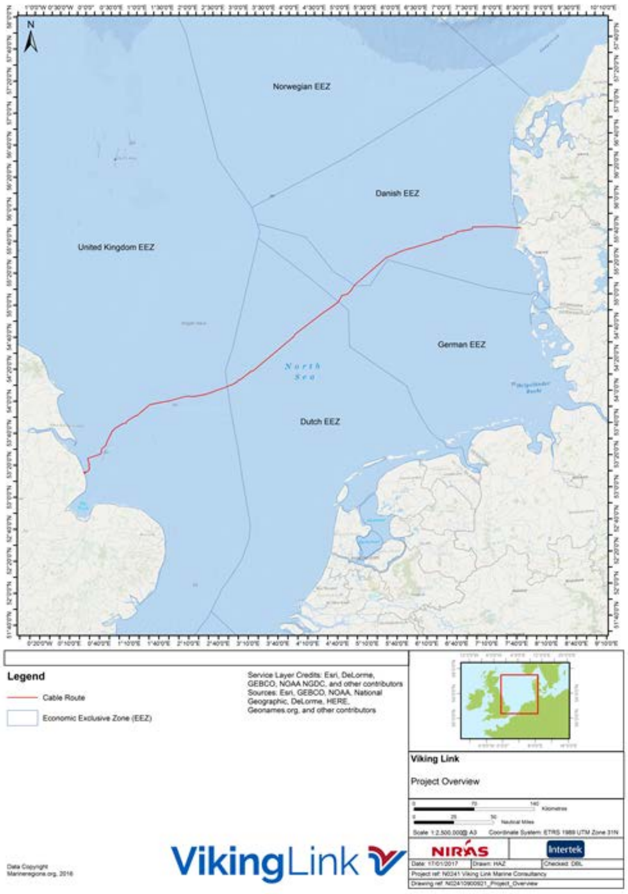


**Figure 1 : Viking Link Interconnector submarine cable corridor.**

2.1.2 The use of HVDC provides the most efficient and effective means to transport electricity over this distance. The high voltage grid systems in the UK and Denmark operate using high voltage alternating current (HVAC). To transport electricity from one country to the other first requires the HVAC to be converted to HVDC at the transmitting end and after traversing the seabeds of the UK, Netherlands, Germany and Denmark by means of HVDC cables then needs to be converted from HVDC to HVAC near to Bicker Fen, Lincolnshire, and Revsing in Denmark (see Figure 2).

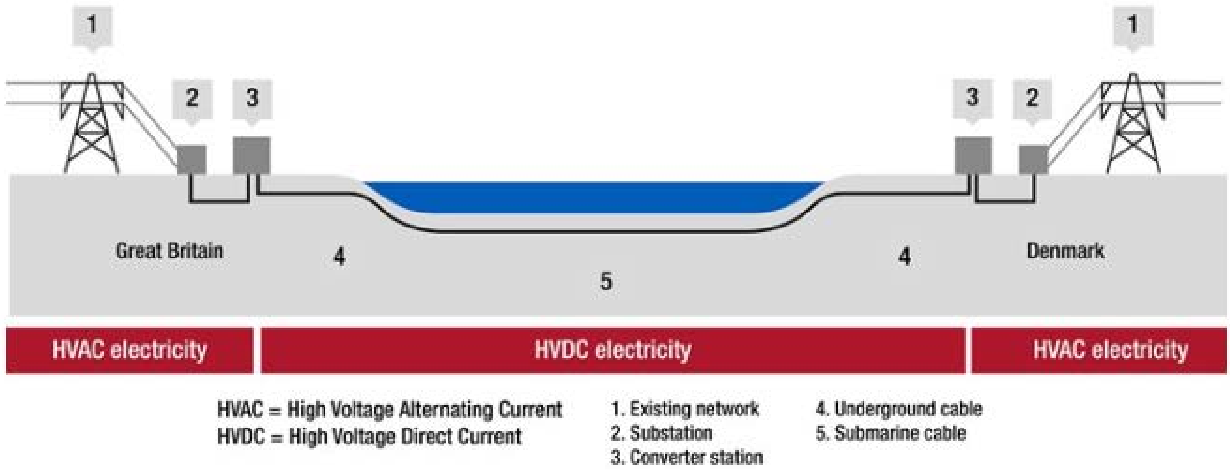


**Figure 2 : Connection of the high voltage grid systems via Viking Link Interconnector.**

## 2.2 The Cable System

2.2.1 The Viking Link cable system will be a bipole cable system. Bipole systems transmit power via a closed circuit of two HVDC submarine cables installed alongside each other. There are currently two types of HVDC cable available. These will be of either Extruded or Mass Impregnated Non-Draining (MIND) insulation technology. Typically, these cables are 150mm diameter and will operate at a voltage of 525kV.

2.2.2 The submarine cable lay configurations being considered for each jurisdiction are outlined in Table 1 below.

**Table 1. Cable configuration for each jurisdiction.**

| Term | UK Sector | NL Sector | DE Sector | DK Sector |
|---|---|---|---|---|
| HVDC Cable Installation | Assumed to be 'bundled' in same trench | In same trench ('bundled') | In same trench ('bundled') | Assumed to be 'bundled' in same trench |

## 2.3 Submarine Cable Installation

Overview

2.3.1 The submarine cables will be buried along its entire length, apart from where this is not feasible, for example at crossings with existing cables or pipelines, or where the seabed characteristics are inappropriate for cable burial.

### Submarine Cable protection

2.3.2 Once laid on the seabed the submarine cables need to either be buried or otherwise protected from the threat of external damage such as anchors or fishing activity. The nature of the seabed varies along the submarine cable corridor between sand, clay and gravel. The choice of burial technique or protection method will vary along the route depending upon the seabed conditions in each section. Where the seabed composition is not suitable for burial, external mechanical protection will be provided, e.g. through rock placement or application of concrete mattresses.

2.3.3 It is envisaged that a variety of installation and burial techniques may be required due to the variable nature of the seabed along the marine cable route. It is proposed to that the submarine cables will be installed as bundled pairs in the German and Dutch sections of the route (and possibly along the nearshore approach to the landfalls). Elsewhere along the UK and Danish sections of the route the two submarine cables will be laid separately up to a distance of 50m.

2.3.4 Rock placement is used to protect subsea cables by covering them in a continuous profiled berm of graded rock. The berm provides a strong protective cover to prevent potential impact and snagging, and also ensures stability by shielding the cable from the current flow. The size of the berm and grade of rock required will depend on the current and wave loading conditions.

2.3.5 The submarine cables will be buried into the seabed along as much of the offshore route as possible. The target burial depth varies along the route and at any given location is determined by the hazard profile and the geotechnical properties of the soil at that location.

## 2.4 Anticipated EMF and iE Fields

### Overview

2.4.1 Submarine power cables generate EMF owing to the electric current flowing along the cables. The magnitude of the magnetic fields produced is directly dependent upon the amount of current flow. The design of the cables, including lead sheathing and armoured cores, prevents the propagation of electric (E) fields into the surrounding environment; however, these materials are permeable to magnetic fields, and the EMF therefore emanate into the surrounding environment, effectively unimpeded. These magnetic fields attenuate with distance (both horizontally and vertically) from the cable conductor.

2.4.2 Three-core AC cables, commonly used in the offshore renewable energy industry, transmit three current flows that fluctuate between positive and negative polarity. The EMF generated by these cables are therefore constantly changing, which continuously induces varying electric (iE) fields (CMACS, 2003; Gill et al., 2009).

2.4.3 Contrastingly, the EMF generated by DC cables, such as the Viking Interconnector bipole system, is static and thus varying iE fields will not be induced in the same way as by AC cables. However, localised, static iE fields may be induced as seawater (tidal flow) or other conductors such as marine organisms pass through the DC cable's EMF. Owing to the dependence of iE field magnitude upon magnetic field magnitude, iE fields will attenuate with both horizontal and vertical distance from the cable conductor.

2.4.4 National Grid have provided a report (Tripp, 2016) which predicts magnetic and induced electric field strengths in the marine environment for different project design scenarios. Information from the National Grid report forms the basis of this evaluation in terms of anticipated field strengths and is summarised here.

### Summary of anticipated field strengths

2.4.5 German and Dutch authorities will require the cables to be bundled together in the same trench. This has implications for magnetic field generation since there will be a marked reduction in the resultant magnetic field due to a cancelling out effect out. There are no such requirements in UK and Danish waters and the modelling (Tripp, 2016) has assumed a separation distance of 50m as a worst-case scenario (greater separation would not increase EMF in the marine environment).

2.4.6 For the purpose of modelling, environmental field strengths assumptions were also made about the burial depth which will be achieved in each jurisdiction. In order to meet minimum design criteria in Germany and The Netherlands cable target burial depths of 1.5m and 1m respectively were assumed. In UK and Danish waters the minimum burial depth is assumed to be 0.5m. In all cases ‘burial’ could be achieved either by trenching within seabed sediments and/or covering with rock armour or matressing.

2.4.7 Further factors taken into account for the modelling were cable orientation (assumed to be North-South and so approximately at right angles to the geomagnetic field which would tend to maximise resultant effects) and the magnitude of the geomagnetic field (49.2 µT). Predictions of induced electrical field strengths were made for two tidal velocity scenarios: 0.5 m/s and 1.25 m/s. Results for the faster current speed are presented in Table 2 since these lead to higher induced electric fields. Where the modelled distance from the cable is less than the minimum burial depth there will be no current flow and hence no induced electric field; however, the theoretical induced electric field strength is indicated (italicised and in brackets).

2.4.8 The small separation distance between the bundled submarine cables will result in significant cancellation of the EMF in German and Dutch waters. Where the cables are not bundled (i.e. UK and Dutch waters) they will act more like single cables without significant magnetic field cancellation.

2.4.9 The EMF is predicted to remain slightly above the geomagnetic field at up to 50m distance (either (approximately) horizontally at the seabed surface or vertically in waters of ≥50 m depth) in UK and Danish waters. Since the iE field is directly related to the EMF it is also the case that there will be a slight elevation of the induced electric field at up to around 50m distance.

2.4.10 In German and Dutch waters the practical limit of electromagnetic field, and hence induced electric field, effects (in terms of increase above background levels) is expected to be not more than 10m.

2.4.11 As can be seen in Table 2, cable burial depth is rather less important than bundling in diminishing the resultant effect ranges.

2.4.12 A range of factors will influence resultant fields produced by the built system; for example, magnetic anomalies caused by iron-bearing magnetic rocks may complicate interactions between marine organisms and cable EMF, while organisms moving through the EMF at a velocity greater than 1.25 m/s could momentarily induce a larger electric field. However, for the purposes of this report and the dependent impact assessments these predictions are believed to represent realistic estimates of likely electromagnetic and induced electric field strengths.

**Table 2. Expected magnetic (B) and induced electric (iE) fields for Viking Link cable (see supporting text for assumptions). Brown shading, field is below seabed surface; blue shading, field at seabed surface or in water column. From Tripp (2016).**

| Distance from cable (m) | UK and Danish waters | | Dutch waters | | German waters | |
|---|---|---|---|---|---|---|
| | B (µT) | iE (µV/m) | B (µT) | iE (µV/m) | B (µT) | iE (µV/m) |
| Cable surface (within sediments or cable protection) | 3733 | 0 *(4666)* | 3741 | 0 *(4676)* | 3741 | 0 *(4676)* |
| 0.1 | 2801 | 0 *(3501)* | 2605 | 0 *(3256)* | 2605 | 0 *(3256)* |
| 0.2 | 1401 | 0 *(1751)* | 869 | 0 *(1086)* | 869 | 0 *(1086)* |
| 0.3 | 935 | 0 *(1169)* | 432 | 0 *(540)* | 432 | 0 *(540)* |
| 0.4 | 702 | 0 *(878)* | 268 | 0 *(335)* | 268 | 0 *(335)* |
| 0.5 | 563 | 704 | 190 | 0 *(238)* | 190 | 0 *(238)* |
| 1.0 | 290 | 363 | 83.9 | 105 | 83.9 | 0 *(105)* |
| 1.5 | 201 | 251 | 64.4 | 80.5 | 64.4 | 80.5 |
| 2.0 | 158 | 198 | 57.7 | 72.1 | 57.7 | 72.1 |
| 5.0 | 88.3 | 110 | 50.5 | 63.1 | 50.5 | 63.1 |
| 10 | 69.9 | 87.4 | 49.5 | 61.9 | 49.5 | 61.9 |
| 15 | 64.8 | 81.0 | 49.3 | 61.6 | 49.3 | 61.6 |
| 20 | 62.0 | 77.5 | 49.3 | 61.6 | 49.3 | 61.6 |
| 50 | 53.4 | 66.8 | 49.2 | 61.5 | 49.2 | 61.5 |

## Comparison with other HVDC Systems

2.4.13 Poleo *et al.* (2001) calculated an EMF of 5500 µT at the surface of a 1600 A HVDC cable, attenuating to 50 µT at a distance of 10m.

2.4.14 Modelling undertaken by Voet (2005) for the BritNed Inteconnector HVDC cable, rated at 450kV with a maximum current load of 1320A, predicted EMF and iE fields of 21 µT and 18 µV/m respectively at 5m distance for cables with 2m separation and 0.85 m/s tidal velocity. These fields were predicted to be around an order of magnitude lower if cables were bundled.

2.4.15 Tricas and Gill (2011) modelled electromagnetic field generation from nine subsea HVDC cables of varying designs and representing differing maximum current loads (Figure 3). Projects incorporated in calculations included Naikun Wind Energy Project, Juan de Fuca Transmission Project, Cross Sound Cable, EirGrid Irish Interconnector and Basslink Interconnector, among others. For comparison purposes it was assumed that all cables were buried to 1m depth. The modelling did not consider any combined effect resulting from cable EMF and the geomagnetic field. Current load is a key factor influencing resultant EMF and this study simply serves to illustrate the range of possible EMF strengths.

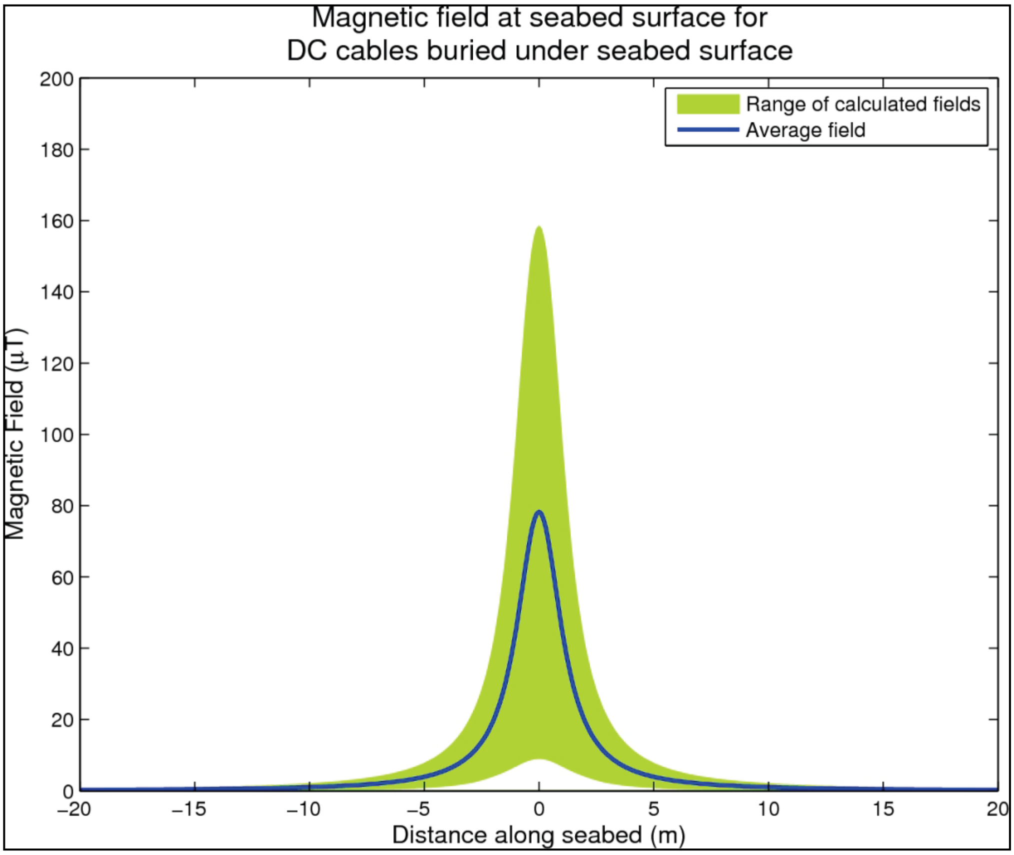


**Figure 3. Average and range of DC electromagnetic fields calculated at seabed surface for various projects assuming 1m burial (from Tricas & Gill 2011).**

2.4.16 The predicted external electromagnetic field for the Viking submarine cables lies within the range of values discussed above where the cables are bundled (German and Dutch waters) but is seen to represent a relatively large field if the cables are laid separately (worst case scenario for UK and Danish waters). However, it should be noted that modelling by Tricas and Gill (2011) did not factor in the geomagnetic field in the same manner as modelling by Tripp (2016) for the Viking Project. This is therefore a comparative statement only; whether the difference could be significant in ecological terms is considered in Section 4.

# 3 Electric and Magnetic Field Detection

## 3.1 Electric Field Detection

3.1.1 More detailed information on electric field detection is provided in Section 4.3. The following provides a broad overview, adapted mainly from Gill *et al*. (2005)

3.1.2 The predominant electroreceptive marine organisms are elasmobranchs (sharks, skates and rays) and holocephalans (chimaeras such as ratfish), which possess specialist electroreceptive organs, ampullae of Lorenzini, that are relatively well studied and described (see Tricas & Sisneros, 2004 for review). This extremely acute sense, which is sensitive to 5 to 20 nV/m (Kalmijn, 1982; Tricas & New, 1998), is used for detecting the bioelectric fields of prey, predators and conspecifics as well as for navigation.

3.1.3 Other species that are electrosensitive such as agnathans (jawless fishes; e.g. lampreys) do not possess specialized electroreceptors but are able to detect induced voltage gradients associated with water movement through the geomagnetic field. The actual sensory mechanism of detection is not yet properly understood but is thought they use the sense for similar behaviours as elasmobranchs (Normandeau *et al*., 2011).

3.1.4 Electroreception of AC fields has been demonstrated in a dolphin (Czech-Damal *et al.*, 2011) and suggests that the widely held belief that cetaceans are not sensitive to electric fields may be incorrect. However, the authors state that their perception system appears to be far less sensitive than those used by elasmobranchs (a 460 µV/m threshold of sensitivity was established, approximately three orders of magnitude lower than elasmobranchs). In addition to their predominantly pelagic life histories, cetaceans are therefore expected to be unaffected by electric fields induced by HVDC cables and the group is not considered further in this report in relation to potential effects of induced electric fields.

3.1.5 A summary of electrically sensitive marine species potentially occurring in the submarine cable corridor in all four jurisdictions, and those assumed to be so because of close physiological similarities, is provided in Table 3. The listing includes species present only rarely in addition to those commonly occurring. Distributions are taken from IUCN (2016).

**Table 3. Presumed and confirmed electrosensitive species potentially occurring in the UK/NL/DE/DK submarine cable corridor (adapted from Gill et al. 2005).**

| Species | Common name | Species | Common name |
|---|---|---|---|
| **Elasmobranchii** | **Sharks** | **Holocephali** | **Chimaeras** |
| *Cetorhinus maximus* | Basking shark | *Chimaera monstrosa* | Rabbit fish |
| *Galeorhinus galeus* | Tope | | |
| *Lamna nasus* | Porbeagle | **Agnatha** | **Jawless fish** |
| *Mustelus asterias* | Starry smooth-hound | *Lampetra fluviatilis* | European river lamprey |
| *Scyliorhinus canicula* | Small-spotted catshark | *Petromyzon marinus* | Sea lamprey |
| *Squalus acanthias* | Spurdog | **Teleostei** | Bony fish |
| *Alopias vulpinus* | Thintail thresher | *Anguilla anguilla* | European eel |
| *Dalatias licha* | Kitefin shark | *Gadus morhua* | Cod |
| *Isurus oxyrinchus* | Shortfin mako | *Pleuronectes platessa* | Plaice |
| *Mustelus mustelus* | Smooth-hound | *Salmo salar* | Atlantic salmon |
| *Prionace glauca* | Blue shark | | |
| *Scyliorhinus stellaris* | Nursehound | | |
| *Echinorhinus brucus* | Bramble shark | | |
| *Etmopterus spinax* | Velvet belly lantern shark | | |
| *Galeus melastomus* | Blackmouth catshark | | |
| *Hexanchus griseus* | Bluntnose sixgill shark | | |
| *Somniosus microcephalus* | Greenland shark | | |
| **Elasmobranchii** | **Skates & Rays** | | |
| *Amblyraja radiata* | Starry ray | | |
| *Raja clavata* | Thornback ray | | |
| *Leucoraja circularis* | Sandy ray | | |
| *Leucoraja naevus* | Cuckoo ray | | |
| *Raja brachyura* | Blonde ray | | |
| *Raja montagui* | Spotted ray | | |
| *Raja undulata* | Undulate ray | | |
| *Amblyraja hyperborea* | Arctic skate | | |
| *Dasyatis pastinaca* | Common stingray | | |
| *Dipturus batis* | Common skate | | |
| *Torpedo marmorata* | Spotted/marbled torpedo ray | | |
| *Torpedo nobiliana* | Atlantic torpedo ray | | |

## 3.2 Magnetic Field Detection

3.2.1 More detailed information on magnetic field detection is provided in Section 4.2. The following provides a broad overview, adapted from Gill *et al*. (2005).

3.2.2 Magnetically sensitive organisms can be categorised into two groups based on their mode of magnetic field detection: induced electric field detection; and direct magnetic field detection.

3.2.3 The first group relates to the electroreceptive species described above. These animals detect the presence of a magnetic field indirectly by detection of the electrical field induced by the movement of water through a magnetic field or by their own movement through that field. In natural scenarios induction of the electric field usually results from organisms positioning themselves in tidal currents and animals may time certain activities (e.g. foraging) by detecting diurnal cues resulting from varying tidal flows.

3.2.4 The second group is believed to use magnetic particles (magnetite) within their own tissues in magnetic field detection (Kirschvink, 1997). Whilst the mechanism of how these organisms detect magnetic fields is still unknown it is generally acknowledged that they are able to use magnetic cues, such as the earth's geomagnetic field, to orient in their environment during migration. In NW European waters such as the North Sea, such organisms include cetaceans (whales, dolphins and porpoises), chelonians (turtles), teleosts (bony fishes; e.g. salmon and eel), crustaceans (lobsters, crabs, prawns and shrimps) and molluscs (snails, bivalves and cephalopods).

3.2.5 A summary of magnetically sensitive marine species potentially occurring in the Project Area, and those assumed to be so because of close physiological similarities, is provided in (Table 4). The listing includes species present only rarely in addition to those commonly occurring. Distributions are taken from IUCN (2016).

**Table 4. Presumed and confirmed magnetoreceptive species potentially occurring in the Project Area (adapted from Gill *et al.* 2005).**

| Species | Common name | Species | Common name |
|---|---|---|---|
| **Cetacea** | **Whales, dolphins & porpoises** | **Chelonia** | **Turtles** |
| *Phocoena phocoena* | Harbour porpoise | *Chelonia mydas* | Green turtle |
| *Tursiops truncatus* | Bottlenose dolphin | **Teleostei** | **Bony fish** |
| *Delphinus delphis* | Short-beaked common dolphin | *Anguilla anguilla* | European eel |
| *Balaenoptera acutorostrata* | Minke whale | *Salmo salar* | Atlantic salmon |
| *Globicephala melas* | Long-finned pilot whale | **Scombridae †** | Tunas & mackerels |
| *Lagenorhynchus acutus* | Atlantic white-sided dolphin | *Pleuronectes platessa* | Plaice |
| *Orcinus orca* | Killer whale | *Salmo trutta* | Sea trout |
| *Lagenorhynchus albirostris* | White-beaked dolphin | **Elasmobranchii *** | **Sharks, skates & rays** |
| *Grampus griseus* | Risso's dolphin | **Holocephali *** | **Chimaeras** |
| *Physeter macrocephalus* | Sperm whale | **Agnatha *** | **Jawless fish** |
| *Megaptera novaengliae* | Humpback whale | **Crustacea †** | **Lobsters, crabs, shrimps & prawns** |
| *Balaenoptera physalus* | Fin whale | **Molluscs †** | **Snails, bivalves & squid** |
| *Stenella coeruleoalba* | Striped dolphin | | |
| *Pseudorca crassidens* | False killer whale | | |
| *Hyperdoon ampullatus* | Northern bottlenose whale | | |
| *Ziphius cavirostris* | Cuvier's beaked whale | | |
| *Mesoplodon bidens* | Sowerby's beaked whale | | |
| *Balaenoptera borealis* | Sei whale | | |
| *Balaenoptera musculus* | Blue whale | | |
| *Kogia breviceps* | Pygmy sperm whale | | |

† species within this group believed to be magnetically sensitive

* all species in these groups listed in Table 3 are also understood to be magnetically sensitive

# 4 Identification of Potential Effects

## 4.1 Introduction

4.1.1 Whilst it is established that a number of taxonomic groups potentially occurring in the Project Area are sensitive to electric and/or magnetic fields there is limited understanding of the response to anthropogenic magnetic and induced electrical fields and hence of any impact. Some evidence of effects such as altered swimming behaviour of certain fish species in the presence of artificial magnetic fields exists and this is detailed below; however, even if such behavioural effects can be attributed to artificial fields this does not necessarily imply an ecologically significant impact in terms of the population of any particular species.

4.1.2 A range of potential effects of EMF have been identified. In a recent review Thomsen *et al*. (2015) suggested that the most likely effects relate to attraction or avoidance of EMF (or rather the induced electrical field) associated with cables. This could lead to consequences for individuals, and potentially populations, if there was repulsion from an area or confusion between anthropogenic and bioelectric fields.

4.1.3 For those species utilising magnetic fields for navigation and/or orientation the potential exists for impacts to occur if anthropogenic electromagnetic fields interfere with natural behaviour (e.g. Gill *et al*., 2005). Furthermore, there is considered to be potential for artificial magnetic fields to have physiological effects on developing eggs, embryos or larvae (e.g. Zimmerman *et al.,* 1990; Cameron *et al*., 1993).

4.1.4 For the purposes of this report it is assumed, on a precautionary basis, that there is potential for EMF from submarine power cabling to have ecological effects. The range of potential effects considered in this report is summarised in Table 5.

| Table 5. Potential ecological effects of EMF emissions from Viking Link. | | |
|---|---|---|
| Project phase | Potential effect | Groups which may be affected |
| Operation | **Electromagnetic Fields**<br>Impairment of navigation or orientation | Fish (as listed in Table 4)<br>Invertebrates (as listed in Table 4)<br>Cetacea<br>Chelonia |
| | **Electromagnetic Fields**<br>Physiological effects on development | Fish<br>Crustacea<br>Mollusca |
| | **Induced Electric Fields**<br>Repulsion | Elasmobranch fishes |
| | **Induced Electric Fields**<br>Confusion with bioelectric fields | Elasmobranch fishes |
| | **Induced Electric Fields**<br>Physiological effects | Elasmobranch fishes |

## 4.2 Magnetic Fields

### Impairment of Navigation or Orientation

4.2.1 Compass orientation, demonstrated by migration in magnetic fields as weak as 50 µT, is evident even among bacteria (Kirschvink 1980) and algae (Lins de Barros *et al.*, 1982).

4.2.2 Despite many marine invertebrates being magnetically sensitive, there is little and contradicting evidence of interactions with anthropogenic sources of magnetic fields. The brown shrimp (*Crangon crangon*) has been recorded as being attracted to AC magnetic fields from submarine power cabling (ICES 2003). Contrastingly, Bochert & Zettler (2004) found no effects of exposure to static EMF upon the same species, nor upon the round crab (*Rhithropanopeus harrisii*), an isopod (*Saduria entomon*) or the mussel (*Mytilus edulis*).

4.2.3 A number of marine invertebrate species that inhabit the Project area are magnetically sensitive, including important commercially targeted taxa such as crabs, shrimps, and molluscs. Electromagnetic fields expected to be generated by the Viking link cables will attenuate to below geomagnetic field levels (around 49 µT) within approximately 50 m (UK and Danish waters) to 10 m (German and Dutch waters). Burial to a depth of at least 0.5m will prevent most invertebrates (except deep borrowing species such as certain Crustacea and bivalve molluscs) encountering the strongest fields present on the cable surfaces.

4.2.4 There is no strong evidence to suggest that significant effects on the movements of magnetically sensitive invertebrates will occur. The confidence in this assertion is moderate due to the relative lack of information from controlled scientific studies.

4.2.5 There is extensive evidence of teleost fishes possessing magnetic receptors (see Kirschvink 1997 for review), often supported by demonstrations of orientation behaviour, for example in species such as eels (*Anguilla rostata*; Souza *et al.*, 1988), plaice (*Pleuronectes platessa*; Metcalfe *et al.*, 1993), salmon (*Salmo salar*; Rommel & McCleave 1973; *Oncorhynchus tshawaytscha*; Kirschvink *et al.*, 1985) and trout (*Salmo gairdneri*; Chew & Brown 1989). Equally, chondrichthyans' ability to detect magnetic fields through the presence of induced electric fields (Kalmijn, 1984) is supported by demonstrations of orientation behaviour towards magnetic fields, including species such as round stingray, *Urobatis halleri*, leopard shark, *Triakis semifasciata* (Kalmijn 1978), sandbar, *Carcharhinus plumbeus*, and scalloped hammerhead, *Sphyrna lewini* (Meyer *et al.*, 2004). Whilst there is evidence that certain fish species orientate in relation to magnetic fields it is not known whether their natural behaviour would be affected by elecromagnetic fields from sub-sea cables.

4.2.6 Bochert & Zettler (2004) found no significant effects of static magnetic fields upon flounder, *Platichthys flesus*. Swedpower (2003) found no measurable impact of subjecting salmon and trout to magnetic fields twice the magnitude of the geomagnetic field. The European eel (*Anguilla anguilla*), has been suggested to deviate temporarily from its migration course in the presence of a 5 µT magnetic field 60m from a HVDC cable; however, the spatial resolution of the tracking was too low to draw any firm conclusions (Westerberg 2000; Ohman *et al.*, 2007). The temporary and small scale nature of such effects would suggest it is unlikely that key functions such as breeding or feeding success would be adversely affected. Subsequent laboratory experiments with weak magnetic AC fields of 9.6 µT found no effect on anguillid movement (although the experimental field was well below the level of the geomagnetic field, Orpwood *et al.* (2015).

4.2.7 Walker (2001) noted that Atlantic salmon migration in and out of the Baltic Sea, over a number of operating sub-sea HVDC cables, seems to continue unaffected.

4.2.8 Benthic species are more likely to encounter elevated magnetic fields, and are possibly able to detect them even at distances at which they fall below the geomagnetic field (Westerberg 2000; Meyer *et al.*, 2004).

4.2.9 It is concluded that any effects upon fish orientation or migratory behaviour are likely to be small and temporary, with normal movement/migration expected to resume beyond 50 m distance even in the worst-case scenario (UK and Danish waters), and less for NL and DE waters. The confidence in this statement is moderate due to the relative lack of information from controlled scientific studies.

4.2.10 Cetaceans are strongly linked with the use of geo-navigation by detection of variation in magnetic fields (e.g. Kirschvink *et al.*, 1986, who correlated strandings with local magnetic minima). However, the ability has not been demonstrated experimentally, and how the sense operates remains unconfirmed. There is no evidence of cetacean migration being affected by sub-sea cable electromagnetic fields. Harbour porpoise (*Phocoena phocoena*) migration across the Skagerrak and western Baltic Sea has been observed unhindered despite several crossings over operating sub-sea HVDC cables (Walker 2001).

4.2.11 Owing to their predominantly pelagic existence, the relatively rapid attenuation of the EMF to background levels or below within tens of metres of the cables, combined with lack of evidence of effects upon cetaceans, it is expected that cetaceans will be unaffected by magnetic fields from Project. The same is postulated for chelonians (turtles), which are also summer visitors to the area, for similar reasons.

4.2.12 No significant effects of magnetic field on migratory or orientation behaviours of cetaceans or chelonids are anticipated. The confidence in this statement is high because of the expectation that serious (population level) concerns for these high profile groups would have been apparent if the potential for significant effects existed.

### Physiological Effects

4.2.13 Demonstrations of B fields ranging between 1-100µT delaying embryonic development in sea urchins (Zimmerman *et al.*, 1990), and of high frequency AC EMF causing cell damage to barnacle larvae and interfering with their settlement (Leya *et al.*, 1999), contrasts with evidence of benthic invertebrates living directly upon DC electrodes (Nielsen 1986) with no apparent effects (Walker 2001; Swedpower 2003). It would seem, therefore, that DC magnetic fields cause fewer biological effects upon these taxa than AC magnetic fields, although this assumption is made tentatively owing to the lack of supporting studies.

4.2.14 Whether any physiological effects on demersal fish could result if animals approached cables, e.g. by inhabiting crevices in any rock armour used, is uncertain but considered unlikley. The only evidence relates to fish embryonic development, which has been shown to be delayed by AC magnetic fields of 1 to 100µT (Cameron *et al.*, 1985; Cameron *et al.*, 1993); however, AC fields are not comparable to static (DC) fields and such an effect should not be implied. Shallow sandy areas, in particular, are important nursery areas for many fish species (e.g. thornback rays, flatfish), but in areas of such substratum, the cables are likely to be buried. Burying the cables would obviously prevent fish (including eggs and juveniles) from encountering the stronger fields, including those present on cable surfaces.

4.2.15 It is concluded to be very unlikely that significant physiological effects will occur as a result of exposure to magnetic fields. The confidence in this statement is moderate-high. There is a lack of supporting scientific evidence but the spatial scale of possible effects is relatively small which limits the possibility of significant population level impact.

## 4.3 Induced Electric Fields

### Repulsion

4.3.1 In general, teleost fishes are not believed to be electrically sensitive (except weakly electric fish, such as electric catfishes or knifefishes, but these are almost entirely tropical freshwater species). Species such as salmon, tunas, plaice and cod have been postulated as being electrically sensitive in the past (Regnart 1931; Rommel & McCleave 1973; Kalmijn 1974), but more recent reviews have cast doubt on these abilities (Bullock 1986). Teleosts would probably only respond to strong DC electric fields of 6 to 15v/m or more, at which levels the fish would be repulsed (Uhlmann 1975; Poleo et al 2001). Sturgeons (Acipenseriform fish), for example, have been shown to veer away, or slow when approaching high voltage overhead lines (110kV AC) passing over the water (Poddubny 1967). However, even the maximum electric field induced from the Viking EMF will be orders magnitude less than these levels and static in nature.

4.3.2 One exception is the European eel (*Anguilla anguilla*), which has been demonstrated as being sensitive to weak electric AC and DC fields (Berge, 1979; Enger *et al.*, 1976), and which possesses some life history stages in marine and coastal waters. However, any effect of the bipolar HVDC induced electric field upon eels would likely be similar to that elicited by magnetic fields; and expected to be minimal and only temporary.

4.3.3 By far the most likely group of marine animals to be affected by any induced electric fields are the elasmobranchs, owing to their sensitivity to even minute electric fields (5-20nV/m: Kalmijn 1982; Tricas & New 1998). Elasmobranchs are known to be repelled by strong electric fields, which has previously raised concerns that cables inducing such electric fields may act as barriers to movement (e.g. between feeding, breeding and nursery areas). Theoretically, this was thought to have the potential to impair growth, health, reproductive success or survival of individual elasmobranchs, which might, in turn, affect population distribution and size.

4.3.4 Precisely what magnitude of electric field induces an avoidance response in elasmobranchs is uncertain. Other than the use of very strong electric fields (80V & 100A) to prevent large, pelagic sharks attacking divers and surfers, avoidance behaviour has only been documented in a few elasmobranchs; when small-spotted catsharks (*Scyliorhinus canicula*) were presented with DC electric fields of 1,000 µv/m (Gill & Taylor 2001), and when silky (*Carcharhinus falciformis*), white tip reef (*Traenodon obesus*) and zebra (*Stegostoma fasciatum*) sharks were presented with both DC and AC fields of 1,000µv/m (Yano *et al.*, 2000). Neither of these studies was designed to consider a range of field strengths and so it is difficult to be certain of an avoidance threshold. However, other research demonstrated repeated, unequivocal attraction behaviour to DC fields of approximately 60 µV/m (Kalmijn 1982; Kimber *et al.*, 2011), and whilst latter study recorded the majority of responses to DC fields of approximately 400 to 600 µVm as attraction, some occurrences of avoidance were observed. This suggests that the threshold electric field between attraction and avoidance lies somewhere between approximately 400 and 1,000 µv/m.

4.3.5 Given the approach to cable burial and bundling for the Viking project induced electric fields in excess of around 400 µv/m are only anticipated at very close range to the cable alignment, up to around 1m in UK and Danish waters only. The potential for repulsion effects to occur is theoretical; part of the issue being that monitoring has been limited to a relatively few offshore renewable energy projects where the maximum electric fields induced by AC cables associated with offshore wind farms have been demonstrated as being slightly weaker than the smallest fields shown to elicit avoidance behaviour in elasmobranchs (CMACS 2003; Gill & Taylor 2001).

4.3.6 It should be noted that these distances may extend further when considering electric fields induced by elasmobranchs swimming swiftly through the electromagnetic field, rather than tidal flow. However, uncertainty exists as to the swimming speed of the small, benthic elasmobranchs in question (large pelagic sharks are often cited as cruising at 0.7m/s and bursting up to 8 to 14m/s), and it is therefore difficult to predict the electric fields induced in this manner. There is considerable uncertainty as to whether laboratory demonstrated repulsion would translate into avoidance of the cable in the real world and, if so, whether such effects would be temporary or sustained. It is clear that any species capable of moving away from the seabed into the water column would be able to cross the cable; all elasmobranch species can do this although whether predominantly benthic species such as the rays would do so to pass by the cable is uncertain.

4.3.7 Overall it is concluded that significant population level effects due to repulsion are unlikely. The confidence in this statement is moderate due to the relative lack of supporting research.

### Confusion with bioelectric fields

4.3.8 Elasmobranchs are responsive to electric fields below those that elicit repulsive reactions, and utilise them for a number of behaviours; namely prey, predator, mate detection and navigation (Tricas & Sisneros 2004). There is concern that these fish will be confused by anthropogenic electric field sources that lie within similar ranges to natural bioelectric fields. Aquatic animals emit weak bioelectric fields of three types:

a) high frequency alternating currents caused by muscle action potentials (including heart, gill and motor function muscles);
b) direct currents associated with the difference in potential arising from membranous and epithelial proximity to water in body cavities (mouth, respiratory and anal); and,
c) low frequency alternating currents caused by the alternating expansions and contractions of body cavities modulating the direct currents.

4.3.9 The extent and strength of these bioelectric fields varies significantly among different taxa and in general each species' fields increase in strength with increasing body size (Kalmijn 1972; Haine *et al.*, 2001). Measurements of bioelectric fields are difficult and vary between the few studies attempting them, but in general they seem to range between 1 µV (small molluscs) to 500 µV (small fish). Larger organisms most likely emit bioelectric fields in excess of the latter figure.

4.3.10 Marra (1989) recorded details of four power transmission failures in an AT&T transatlantic fibre-optic cable in the mid-1980s. Upon raising the cable for repairs, bite marks and embedded teeth were found at the damaged sections. Further investigation revealed the damage was attributable to shark bites in all four instances. Attraction to electric fields induced around the cable (confusing them for prey) was considered the most likely reason for shark responses. Whether the sharks were harmed by biting the cables is unknown. Laboratory behavioural studies have demonstrated both AC and DC artificial electric fields stimulating similar feeding responses in elasmobranchs (Kalmijn 1982; Tricas & Sisneros 2004; Kimber *et al.*, 2011). Recent work using small-spotted catsharks (*Scyliorhinus canicula*) as a model benthic elasmobranch has demonstrated that despite the ability to distinguish certain induced electric fields (strong versus weak; DC versus AC), the shark seemed either unable to distinguish, or showed no preference between similar strength, anthropogenic (dipole) and natural (live crab) DC induced electric fields (Kimber *et al.*, 2011). In turn, this raises the question of whether these predators might effectively waste time and energy "hunting" electric fields such as those associated with subsea electrical cables whilst searching for bioelectric fields associated with their prey.

4.3.11 An experiment which involved enclosing a section of sub-sea cable within a suitable area of seabed, using an approach known as 'mesocosm studies', allowed the response of elasmobranch test species to controlled electromagnetic fields (of similar intensity as those expected around submarine power cabling, and therefore more likely to elicit attraction, rather than avoidance behaviour) to be assessed within a semi-natural setting (Gill *et al.*, 2009). The investigation demonstrated that benthic elasmobranch species did respond to the presence of AC EMF emitted by the sub-sea cable. One species, *S. canicula*, was more likely to be found within the zone of EMF emissions when the cable was switched on. Another species, the thornback ray (*Raja clavata*), showed increased movement around the cable when it was switched on. This was the first clear experimental confirmation that elasmobranchs are influenced by sub-sea cable EMF. What ecological implications such interactions might have upon the fish, however, is still unclear.

4.3.12 *S. canicula* have been demonstrated as being able to rapidly adapt (learn) to concentrate upon profitable electric sources (associated with food), and habituate (ignore) non-profitable electric sources, although their memory of these adaptations seemed limited. Such traits would be expected for an opportunistic predator in a variable, coastal environment. This suggests these fish might initially be attracted to anthropogenic electric field sources (should they resemble prey species' bioelectric fields), but be able to learn to ignore them relatively quickly during localised, short foraging bouts (as long as they could decipher them, possibly utilising senses other than electroreception). However, over longer time periods and greater distances, the fish may well respond to the fields as if encountering them for the first time should they encounter them in the future.

4.3.13 Pelagic species such as the basking shark are unlikely to be affected due to their habits leading them to be distant from the seabed and strongest E fields. Benthic species, which are more likely to encounter the electric fields induced around the HVDC cable, include several commercially important species that have also suffered significant population declines, such as skates, rays and spurdogs. Induced E fields are expected to attenuate to levels approximately comparable to background levels within around 10 m (German and Dutch waters) to 50 m (UK and Danish waters). Confusion effects could potentially occur within these distances, but the significance of such effects is unknown. Again, these distances might be increased when considering fast-moving organisms, should their velocity be greater than tidal flow.

4.3.14 On balance it is concluded that the potential for ecologically significant effects due to elasmobranch attraction to induced electric fields are low. The confidence in this statement is high for Dutch and German waters but low-moderate for Danish and UK waters where the potential range of effect is greater.

### Physiological Effects

4.3.15 Physiological effects upon elasmobranchs are unlikely due to the relatively weak electric fields involved. However, Sisneros *et al.*, (1998) and Ball (2007) have demonstrated embryonic thornback rays ceasing body movement that facilitates critical ventilatory movement of water upon sensing artificial electical fields. This suggested the developing rays were employing detection minimisation behaviour as the electric fields were similar to those of predatory animals (such as small, adult elasmobranchs, and larger teleosts and cephalopds). There is potential for HVDC iE fields to affect this behaviour, but there is no evidence to confirm this scenario. The potential for an ecologically significant proportion of a ray breeding ground to be affected by a linear cable project of this nature appears limited.

4.3.16 There is considered to be no likelihood of significant physiological effects occurring due to exposure to induced electric fields. The confidence in this statement is moderate-high.

# 5 Summary

5.1.1 The conclusions reached in Section 4 are summarised in Table 6. A comparative scale of impact magnitude, ranging from negligible/absent, through moderate to high has been applied.

5.1.2 The confidence of each evaluation is given as low, moderate or high.

**Table 6. Summary conclusions of potential ecological effects of EMF emissions from Viking Link.**

| Potential effect | Groups (magnitude of effect) (confidence) |
|---|---|
| **Electromagnetic Fields**<br>Impairment of navigation or orientation | Fish (low) (moderate)<br>Invertebrates (negligible-low) (moderate)<br>Cetacea (negligible) (high)<br>Chelonia (negligible) (high) |
| **Electromagnetic Fields**<br>Physiological effects on development | Fish, Crustacea and Mollusca (negligible-low) (moderate-high) |
| **Induced Electric Fields**<br>Repulsion | Elasmobranch fishes (negligible-low) (moderate) |
| **Induced Electric Fields**<br>Confusion with bioelectric fields | Elasmobranch fishes (negligible-low) (high, NDL & DE; low-moderate, DK & UK) |
| **Induced Electric Fields**<br>Physiological effects | Elasmobranch fishes (negligible) (moderate-high) |

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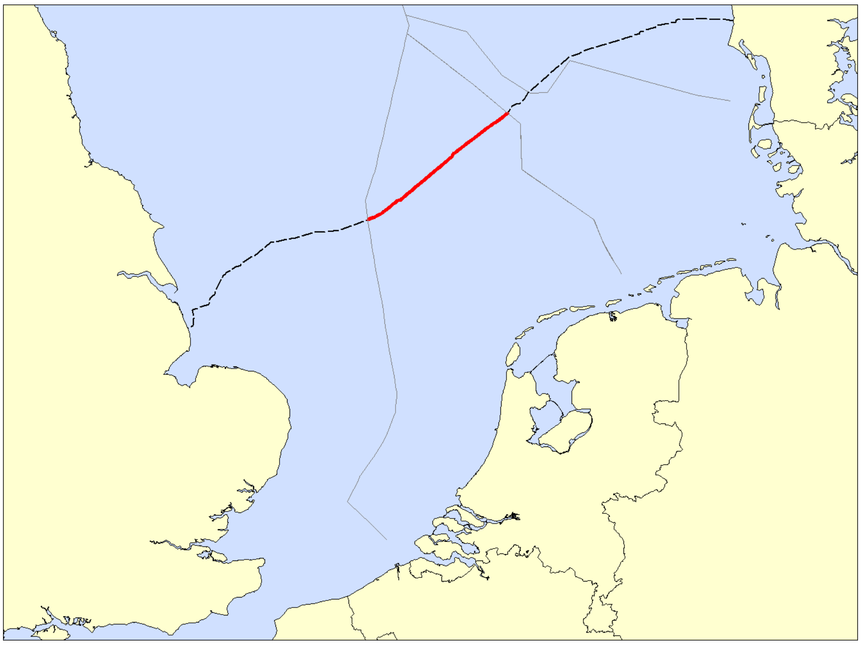
# Annex IV

VKL-07-30-J800-033

March 2017

# Viking Link Interconnector

An archaeological assessment of
geophysical survey results
in the Dutch exclusive economic Zone



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Viking Link Interconnector – An archaeological assessment of geophysical survey results

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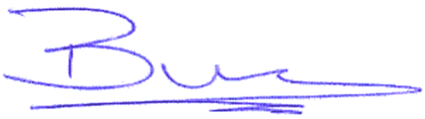

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# Contents

*Table 1. Dutch archeological periods*

| Period | Time in Years | | | | |
|---|---|---|---|---|---|
| Post-medieval / Modern Times | 1500 | A.D. | - | Present | |
| Late medieval period | 1050 | A.D. | - | 1500 | A.D. |
| Early medieval period | 450 | A.D. | - | 1050 | A.D. |
| Roman Times | 12 | B.C. | - | 450 | A.D. |
| Iron Age | 800 | B.C. | - | 12 | B.C. |
| Bronze Age | 2000 | B.C. | - | 800 | B.C. |
| Neolithic (New Stone Age) | 5300 | B.C. | - | 2000 | B.C. |
| Mesolithic (Stone Age) | 8800 | B.C. | - | 4900 | B.C. |
| Paleolithic (Early Stone Age) | 300.000 | B.C. | - | 8800 | B.C. |

*Table 2. Administrative details*

| | | |
|---|---|---|
| Location: | North Sea | |
| Toponiem Dutch: | Viking Interconnector Link | |
| Chart: | BA 2182A North Sea southern sheet | |
| Coordinates<br>Geodetic datum: ETRS89<br>Projection: UTM31N | Centre | E 545954, N 6050014 |
| | NW | E 486662, N 6010852 |
| | NE | E 608907, N 6112297 |
| | SW | E 489898, N 5988195 |
| | SE | E 623414, N 6100225 |
| Depth (LAT): | 30 to 60 meter, average 44.7 meter | |
| Surface area | 3096 square km | |
| Environment: | Tidal currents, salt water | |
| Area use: | Shipping lane, fishing area | |
| Area administrator: | Rijkswaterstaat Zee en Delta | |
| Advisor authorities: | Dutch Cultural Heritage Agency | |
| ARCHIS-research report (CIS-code): | 4010433100 | |
| Periplus-project reference: | 16A006-02 | |
| Period | July - November 2016 | |

# Samenvatting (Abstract in Dutch)

In opdracht van Witteveen + Bos heeft Periplus Archeomare een archeologische analyse gemaakt van geofysische onderzoeksresultaten voor de geplande route voor de Viking Link Interconnector cable. Het onderzoeksgebied van ongeveer 99 vierkante kilometer wordt begrenst door een gebied met een breedte van 450 meter door het Nederlandse deel van de exclusieve economische zone.

De Viking Link Interconnector bestaat uit twee ondergrondse elektriciteitskabels tussen Denemarken en Groot Britannië. Beide kabels zullen in één sleuf op een diepte van ongeveer één meter onder de zeebodem worden gelegd.

Een grote hoeveelheid geofysische data (*side scan sonar, magnetometer en multibeam echosounder*) is geanalyseerd op het voorkomen van archeologische objecten. Dit onderzoek vormt de toets van de archeologische verwachting voortgekomen uit het eerder uitgevoerde archeologisch bureauonderzoek.

Uit het bureauonderzoek was naar voren gekomen dat het slechts één scheepswrak bekend was binnen het onderzoeksgebied. Het gaat om het wrak van de *Windfjord,* gezonken in 1981 en heeft geen archeologische waarde.

In totaal zijn 128 objecten aangetroffen met side scan sonar. Na analyse zijn twee objecten op basis van vorm en afmetingen geclassificeerd als objecten met een mogelijk archeologische waarde. Een samenvatting van deze objecten is weergegeven in de onderstaande tabel.

| Nr | KP | Offset | ETRS_E | ETRS_N | L (m) | W (m) | H (m) | interpretation |
|---|---|---|---|---|---|---|---|---|
| B10_065 | 394.120 | -151 | 495436 | 6011324 | 21.3 | 12.6 | 0.4 | unknown object |
| B10_067/B10_068 | 403.423 | -107 | 487170 | 6007710 | 36.4 | 3.0 | 0.3 | possible wreck |

*Table 3. Beschrijving van de aangetroffen objecten met een mogelijke archeologische waarde*

Zo lang niet is vastgesteld of de objecten werkelijk een archeologische waarde hebben wordt geadviseerd om deze locaties inclusief een bufferzone van 100 meter te mijden bij de voorgenomen werkzaamheden. Dit advise geldt voor alle bodemroerende activiteiten zoals het aanleggen van kabelsleuven en verankeringen van werkschepen.

De bufferzone van 100 meter is standaard in Nederland om het cultureel erfgoed te beschermen. De reden om deze bufferzone in acht te nemen ligt in het feit dat tijdens offshore constructiewerk de omliggende zeebodem kan worden verstoord, bijvoorbeeld door het gebruik van ankers. De afstand kan eventueel worden verkleind als aangetoond kan worden dat de locatie zelf niet wordt verstoord. Dit dient in overleg te gebeuren met het bevoegd gezag (Rijkswaterstaat) en hun adviseur (de Rijksdienst voor het Cultureel Erfgoed).

In totaal zijn 142 magnetische anomalieën waargenomen. 57 van deze anomalieën kunnen worden gerelateerd aan bekende pijpleidingen en kabels in het gebied. Drie van de anomalieën zijn gerelateerd aan contacten waargenomen met side scan sonar.

85 magnetische anomalieën kunnen niet worden gerelateerd aan bekende of zichtbare objecten. Deze worden veroorzaakt door afgedekte ijzerhoudende objecten in de bodem. Tien van deze objecten hebben een magnetische uitslag van 50 nano Tesla of meer. Drie van deze objecten liggen binnen 100 meter van de voorgestelde kabelroute. Geadviseerd wordt, om deze locaties te mijden bij de voorgenomen werkzaamheden. Het kan hier gaan om (archeologische) obstakels, maar ook om niet-gesprongen explosieven.

Als het niet mogelijk is om de locaties met een archeologische verwachting te mijden is aanvullend onderzoek nodig om de werkelijke archeologische waarde vast te stellen.

Zodra de seismische gegevens geïnterpreteerd zijn, en gridmodellen zijn opgesteld van de lithostratigrafische eenheden aangetroffen langs de route, wordt geadviseerd om deze modellen te gebruiken voor het identificeren en in kaart brengen van gebieden waarin prehistorische nederzettingsresten verwacht kunnen worden. Het resultaat kan worden gebruikt om locaties voor boorbemonsteringen te selecteren. Deze monsters kunnen worden gebruikt voor nader onderzoek: de formatie ontwikkeling, de integriteit van de laaggrenzen, de aanwezigheid van palaeosols en archeologische resten (vuurstenen artefacten, verbrande zaden, botresten en houtskoolconcentraties) en pollen en 14C-analyse. Aanvullend onderzoek voor de prehistorische resten in relatie met het Pleistoceen landschap kan in overleg worden uitgevoerd met de Britse en Deense onderzoekers die betrokken zijn bij het project.

Tijdens de geplande werkzaamheden kunnen archeologische resten aan het licht komen die volledig afgedekt waren of niet als een archeologisch object zijn herkend tijdens het geofysisch onderzoek. Daarom wordt een passieve archeologische begeleiding geadviseerd op basis van een goedgekeurd Programma van Eisen. Passieve archeologische begeleiding betekent dat een archeoloog niet tijdens de uitvoering van het werk aanwezig is, maar altijd op afroep beschikbaar. Hiermee kunnen vertragingen tijdens de werkzaamheden voorkomen worden wanneer onverwacht archeologische resten worden aangetroffen. Conform de Nederlandse wetgeving (Erfgoedwet 2016) is het verplicht om toevalsvondsten te melden aan de bevoegde autoriteit. Deze kennisgeving moet ook worden opgenomen in het bestek van de geplande werkzaamheden.

# 1 Summary

Periplus Archeomare was appointed by Witteveen + Bos to conduct an archaeological assessment of the geophysical survey data of the proposed corridor of the Viking Link Interconnector cable. The research area of 99 square kilometers is limited to a corridor of 450 meters crossing the northern part of the Dutch EEZ.

The Viking Link interconnector will consist of two high voltage cables running underground and under the sea. It will connect into a converter station and an electricity substation in Denmark and Great Britain, which will allow electricity to flow in either direction between the two countries. The cables will be installed in the same trench. The expected burial depth is approximately 1 meter below the seabed.

A large quantity of survey data (*side scan sonar, magnetometer* and *multibeam* echosounder) recorded in the survey corridor covering a total area of 99 km$^2$ was analyzed for an archaeological assessment. The current analysis of the geophysical survey data is the second step of the archaeological assessment, following the desk study.

The desk study has shown that only one object, the ship wreck *Windfjord* is known within the boundaries of the proposed marine cable corridor. This ship sunk in 1981 and is not considered to be of archaeological importance.

Apart from the Windfjord wreck, 128 contacts were reported with side scan sonar. The analysis of these contacts resulted in a final selection of two unknown objects and structures which, based on their shapes and dimensions, may be of archaeological value. A summary of these objects with a possible archaeological expectation is listed in the table below.

| Nr | KP | Offset | ETRS_E | ETRS_N | L (m) | W (m) | H (m) | interpretation |
|---|---|---|---|---|---|---|---|---|
| B10_065 | 394.120 | -151 | 495436 | 6011324 | 21.3 | 12.6 | 0.4 | unknown object |
| B10_067/B10_068 | 403.423 | -107 | 487170 | 6007710 | 36.4 | 3.0 | 0.3 | possible wreck |

*Table 4. Summary of objects from side scan sonar and multibeam with a possible archaeological value*

As long as the archaeological value of the objects is undetermined, it is advised to stay clear of the possible archaeological objects and the 100 m-buffer zones around the objects. This advise concerns all soil disturbing activities, such as cable laying and anchorages of the work vessels.

The buffer zone of 100 meters is a standard in the Netherlands that applies to the protection of cultural heritage. The reason to keep this distance is the fact that during offshore construction works the surrounding seabed can be disturbed by for instance the use of anchors. This distance of 100 meters may be reduced if it can be substantiated that the applied disturbance has no effect on the archaeological object. For example, when no anchoring is used during cable lay operations the buffer zone can be decreased. Consent may be obtained after consultation with Rijkswaterstaat (authority) and their advisor the Cultural Heritage Agency.

A total of 142 magnetic anomalies have been observed. 57 of these anomalies can be related to known pipelines and cables. Three of the magnetometer anomalies can be related to the side scan sonar contacts.

A total of 85 magnetic anomalies cannot be related to known pipelines and cables, or visible objects at the seabed surface. They are related to unknown ferrous objects buried in the seabed, covered by sediments. Ten of these anomalies have an amplitude of 50 nT or more. Three of the anomalies lie within 100 meters of the proposed marine cable corridor.

Concerning these buried ferrous objects, it is advised to avoid such areas whilst laying the cables. It should be stressed that the origin of the magnetic anomalies is unknown and apart from possible archaeological remains any type of man-made objects can be encountered including unexploded ammunition, anchors, pieces of chains and cables, debris, etcetera.

.
If it is not feasible to avoid the reported contacts with a possible archaeological expectation, additional research is required in order to determine the actual archaeological value of the reported locations.

When the seismic data recorded in the survey corridor have been processed into grids of the lithostratigraphic units encountered along the cable route, it is advised to use these grids to identify and map areas in which remains of prehistoric camp sites are expected. This map can be used to select locations for bore hole sampling. These samples can be used for further research: formation evaluation, integrity of layer boundaries, the presence of palaeosols and archaeological remains (flint artifacts, burnt seeds, bone remains and charcoal concentrations), pollen and 14C-analysis. Additional research for prehistoric remains of camp site and their position in the Pleistocene landscape can be carried out in consultation with British and Danish researchers who are involved in the project.

During the cable lay operations archaeological objects may be discovered which were completely buried or not recognized as an archaeological object during the geophysical survey. We recommend passive archaeological supervision based on an approved Program of Requirements. Passive archaeological supervision means that an archaeologist is not present during the execution of the work but always available on call. Following this recommendation would prevent delays during the work when unexpectedly archaeological remains are found. In accordance with the Dutch legislation (Erfgoedwet 2016), it is required to report those findings to the competent authority. This notification must also be included in the scope of work for the cable installation work.

# 2 Introduction

Periplus Archeomare was appointed by Witteveen + Bos to conduct an archaeological assesment of the geophysical survey data of the route corridor of the Viking Link Interconnector cable. The research area of 99 square kilometers is limited to a corridor of 500 meters crossing the northern part of the Dutch EEZ.

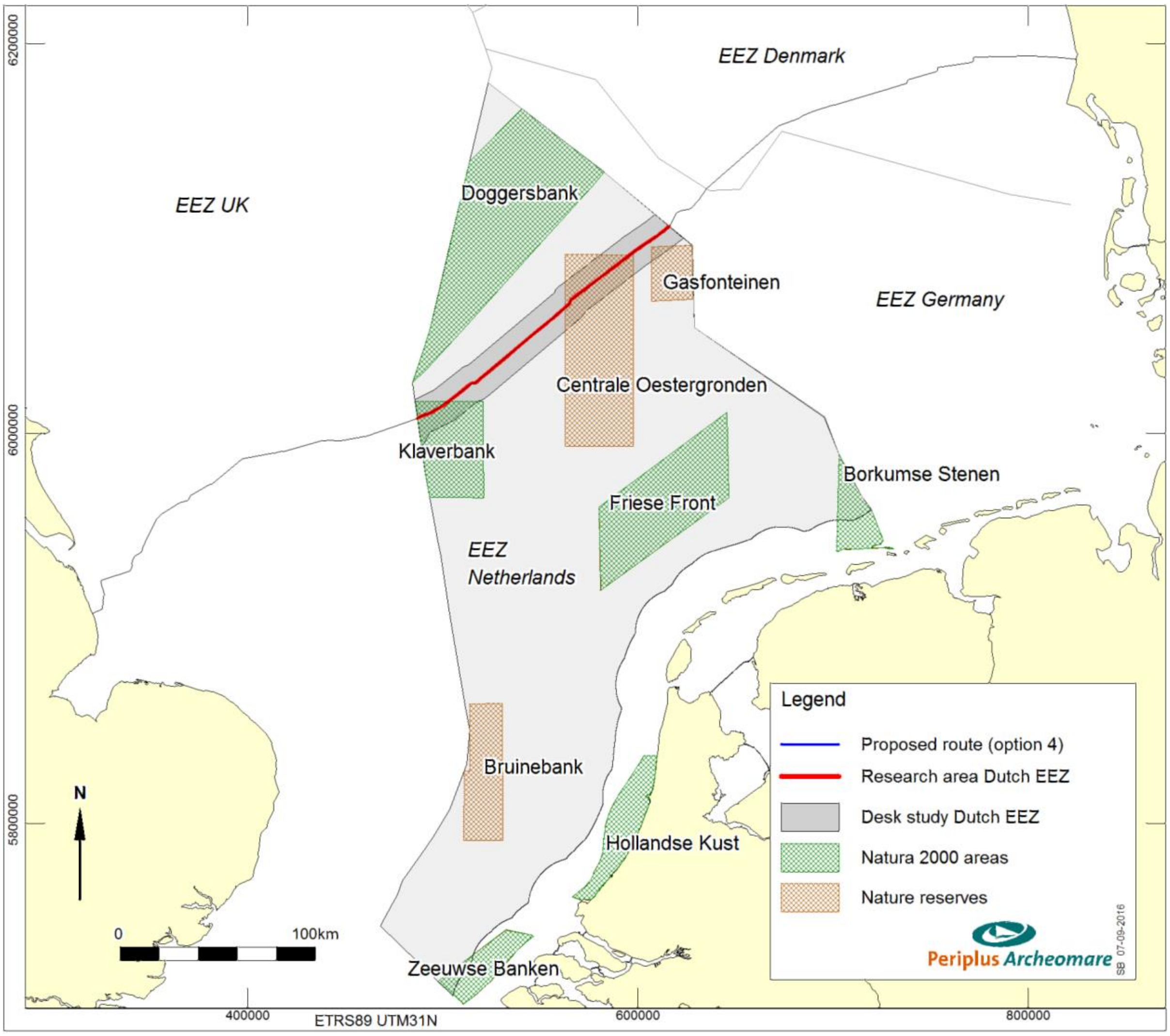


*Figure 1. Overview of the research area*

The inventory field study was carried out in accordance with the Dutch quality standards for archaeological research.[1]

[1] Kwaliteitsnorm Nederlandse Archeologie (KNA waterbodems 4.0).

## 2.1 Introduction

Viking Link is a proposal to build a high voltage direct current (HVDC) electricity interconnector between Bicker Fen in Lincolnshire, Great Britain and a substation at Revsing in southern Jutland, Denmark. It is expected to be operational by the end of 2022. Viking Link is being jointly developed by National Grid through National Grid Viking Link Limited and its other subsidiaries, and Energinet.dk which owns, operates and develops the Danish electricity and gas transmission systems[2].

The Viking Link interconnector will consist of two high voltage cables running underground and under the sea. It will connect into a converter station and an electricity substation in each country, which will allow electricity to flow in either direction between the two countries. The cables will be installed in the same trench. The expected burial depth is approximately 1 meter below the seabed.

## 2.2 Motive

The protection of the Dutch archaeological heritage is incorporated in the Dutch Erfgoedwet (2016). Planned activities, such as the installation cables in the North Sea, may affect the archaeological values if present. If the remains are threatened, there is a statutory obligation to conduct archaeological research. In line with this obligation an archaeological desk study has been carried out for the proposed marine cable corridor.

An archaeological desk study is the first step in the so-called *AMZ* cycle (Archeologische Monumenten Zorg).[3] The *AMZ* cycle includes a description of procedures for subsequent phases of archaeological research to be performed in order to ensure the protection of archaeological heritage in the Netherlands. The separate phases of the AMZ-cycle are embedded in the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.0). This standard dictates a mandatory workflow for archaeologists. A detailed description of the different phases of archaeological research is included in appendix 3.

This report contains the results of the second phase of the *AMZ* cycle: the inventory archaeological field study.

## 2.3 Objective

The purpose of the inventory field study is to test the desk study based predictive model for the likelihood of finding archaeological remains in the research area.

## 2.4 Results desk study[3]

In January 2016 Periplus Archeomare BV conducted an archaeological desk study for the proposed corridor of the Viking Link Interconnector cable. The research area included a 10 nautical mile buffer zone on both sides of the cable route and was limited to the Dutch part of the Continental Shelf. The outcome of the desk study is summarized below.

The investigated corridor inhabits a high potential for the presence of (remains of) ship wrecks from all periods and WWII plane wrecks. Locally *in situ* remains of Late Paleolithic and Early Mesolithic camp sites might be present.

**Shipwrecks**

A total of six shipwrecks and two possible obstructions is known in the area, and fishermen reported the find of a submarine just north- or possibly in the area. Details like names, types and date of sinking are not

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[2] Viking-link.com

[3] Van den Brenk 2016.

known, nor are the exact locations. Additional research is needed to determine the cultural-historical value of these objects.

**Plane wrecks**

During World War II, many airplanes crashed into the North Sea. Several sources are ambiguous about the number of aircraft still missing, but it must be at least several hundreds. Remains are found regularly by fishermen or during sand extraction. In the vicinity of the research area, no locations of plane wrecks are known, but it is likely that plane wrecks will be present within the proposed marine cable corridor.

**Prehistory**

Remains of camp sites are to be expected in the top of Pleistocene formations and at the base of Early Holocene deposits: the Velsen Bed and Basal Peat Bed. Considering the clayey context and rapid drowning of the area, the physical quality of potential archaeological remains is expected to be high.

Archaeological markers comprise flint and bone artifacts, burnt nuts and seeds and charcoal. The size of sites can vary from a few square meter to one hundred square meter or more in the case of repeated use or if settlements were used for a longer period of time. Apart from isolated concentrations of flint artifacts, bone remains, charcoal and burnt seeds, the possible presence of archaeological layers within the clayey context cannot be excluded.

It should be noted however, that little is known about remains from this period that are currently at 40 to 60 meters below the sea level. Information on the Pleistocene landscape and the prehistoric settlements expected within the context of this landscape is of great value. The prospect of well-preserved archaeological remains of human settlements of which our knowledge is limited is important and challenging.

## 2.5 Research questions

For the inventory archaeological field study, the following research questions have been drawn up:

<u>with respect to side scan sonar, magnetometer and multibeam survey:</u>

*Are there any phenomena visible on the seabed?*

If so:

*What is the description of these phenomena?*

*Do these phenomena have a man-made or natural origin?*

If these phenomena can be designated to be man-made:

*What classification can be attached?*

If these phenomena can be classified as archaeological:

*Is it possible to attach an interpretation to the nature of the archaeological objects and to prioritise importance?*

If these phenomena can be identified as natural:

*What is the nature of these natural phenomena?*

*Based on the acoustic image is it possible to designate zones of high, middle or low marine activity on the seabed?*

If so:

*How can these zones be interpreted?*

General:

*What is the relation between the observed objects and the topography of the seabed? Based on this relationship can risk-prone areas be marked selectively?*

If no acoustic phenomena can be observed:

*Are there any clues that this is a consequence of either natural erosion, sedimentation or human interference?*

with respect to subbottom profiler- and sampling:

*Based on seismic profiles and geotechnical data is it possible to map the Pleistocene landscape?*

If so:

*What is the depth of the Pleistocene landscape compared to the present seabed?*

*From Pleistocene to Holocene deposits is the transition gradual or instantaneous (erosive)?*

*Can zones be identified where prehistoric settlement remains can be expected?*

If so:

*Could these expected settlement remains be endangered by the installation of the cables based on their vertical position related to the seabed?*

*Are there any indications observed on the seismic profiles for the presence of buried (man-made) objects?*

If so:

*Based on the presence of buried objects and its correlation with side scan sonar, magnetometer and multibeam data can something be said about the nature of these buried objects?*

*Are there any mitigating measures necessary to avoid disturbance of possible archaeological remains?*

# 3 Methodology

As part of the planned installation of the Viking Link Cable a pre-lay survey has been carried out by survey company FUGRO.

The following methods have been deployed:

- sidescan sonar (SSS)
- magnetometer (MAG)
- multibeam echo sounder (MBES)
- sub-bottom profiler (SBP)
- cone penetration testing (CPT)
- vibrocore sampling
- remotely operated vehicle investigation (ROV)
- grab sampling

The objectives and the general outcome of the survey activities including the minimum technical, functional and procedural requirements are described in a Scope of Services.

The results of the survey and geotechnical activities have been recorded in reports, listings, drawings and images. The input for the archaeological assessment consists of the deliverables listed in table 5.

| | |
|---|---|
| SSS | - XTF-files of all side scan records<br>- event listings containing all contacts observed |
| MAG | - event listings containing all anomalies observed |
| MBES | - validated multibeam XYZ point cloud dataset |
| SBP/UHR | - representative subbottom profiles |
| VC | - descriptions of the bore samples (if applicable) |
| Report | - survey report |

*Table 5. Data used for the archaeological assessment*

The field study has been conducted in accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.0, Protocol 4103).

## 3.1 Survey program

The investigation areas were surveyed in the period 18 March to 21 May 2016.

The Route 4 survey plan is sub-divided into 15 survey blocks. The figure below shows the survey blocks for the selected survey route. The Dutch sector is divided into blocks 7 to 10, running from KP 239.239 (border German sector) to KP 403.451 (border UK sector).

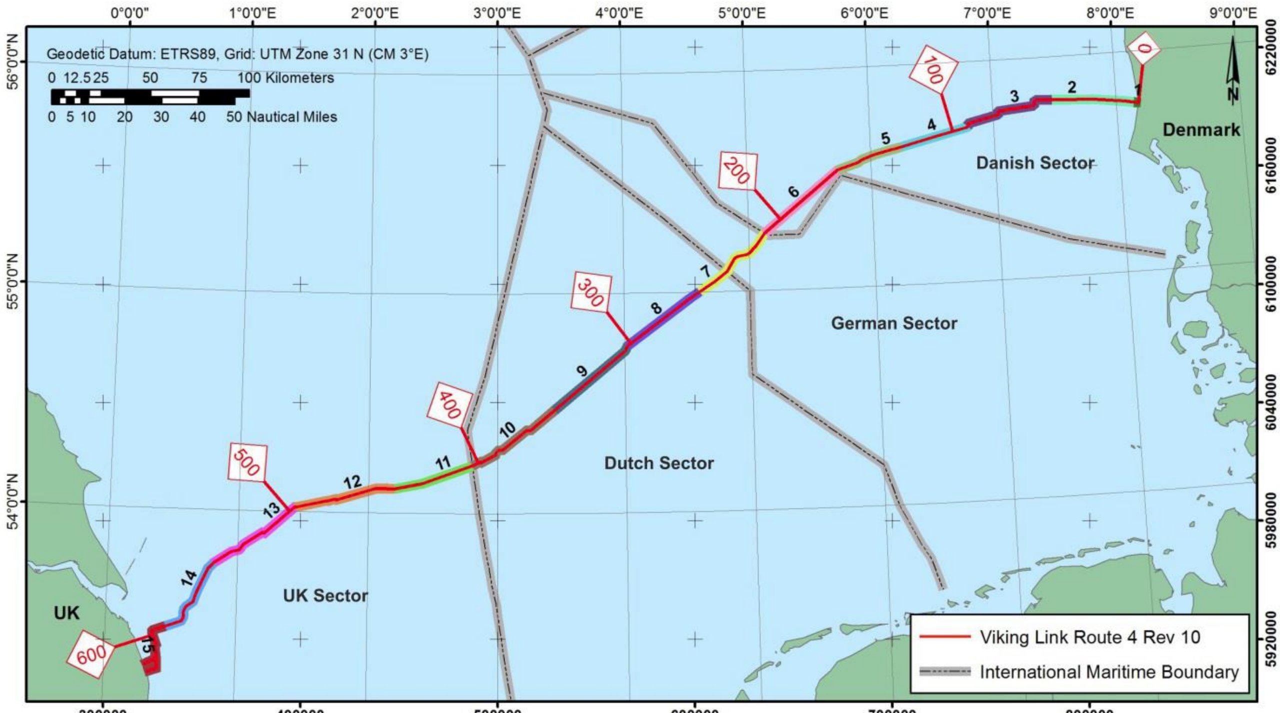


*Figure 2. Viking Link Cable route overview (Fugro report J35045-R_RESB)*

The survey was carried out utilising the survey vessels Fugro Frontier and Fugro Pioneer. Survey operations were conducted on a 24 hour basis. The survey vessels were equipped with both hull-mounted and towed equipment in order to meet the scope of work, as described in the table below.

| **Survey Operations** | |
|---|---|
| Multibeam Bathymetry | 450 m data corridor for all route<br>Multibeam only infill lines as and when required to achieve the required data resolution and specification of IHO Order 1a (S-44);<br>Full seabed coverage of the survey corridor |
| Side Scan Sonar | 450 m data corridor for all route<br>Resultant coverage of 200% minimum insonification (100% overlap) of the seabed;<br>High and low frequency sonar coverage with range set to 125 m and 100 m |
| Sub-Bottom Profiler | At least one seismic source acquired along all survey lines;<br>Fugro Frontier is equipped with a hull mounted pinger and additionally carried a towed sparker system |
| Magnetometer | Data acquired along all survey lines |
| Grab Sampling | As and when required for aiding side scan sonar interpretation |

*Table 6. Offshore Survey Operations Requirements*

## 3.2 Known objects

The desk study[4] contains a listing of the known objects in the vicinity of the research area. An overview is presented in the figure below.

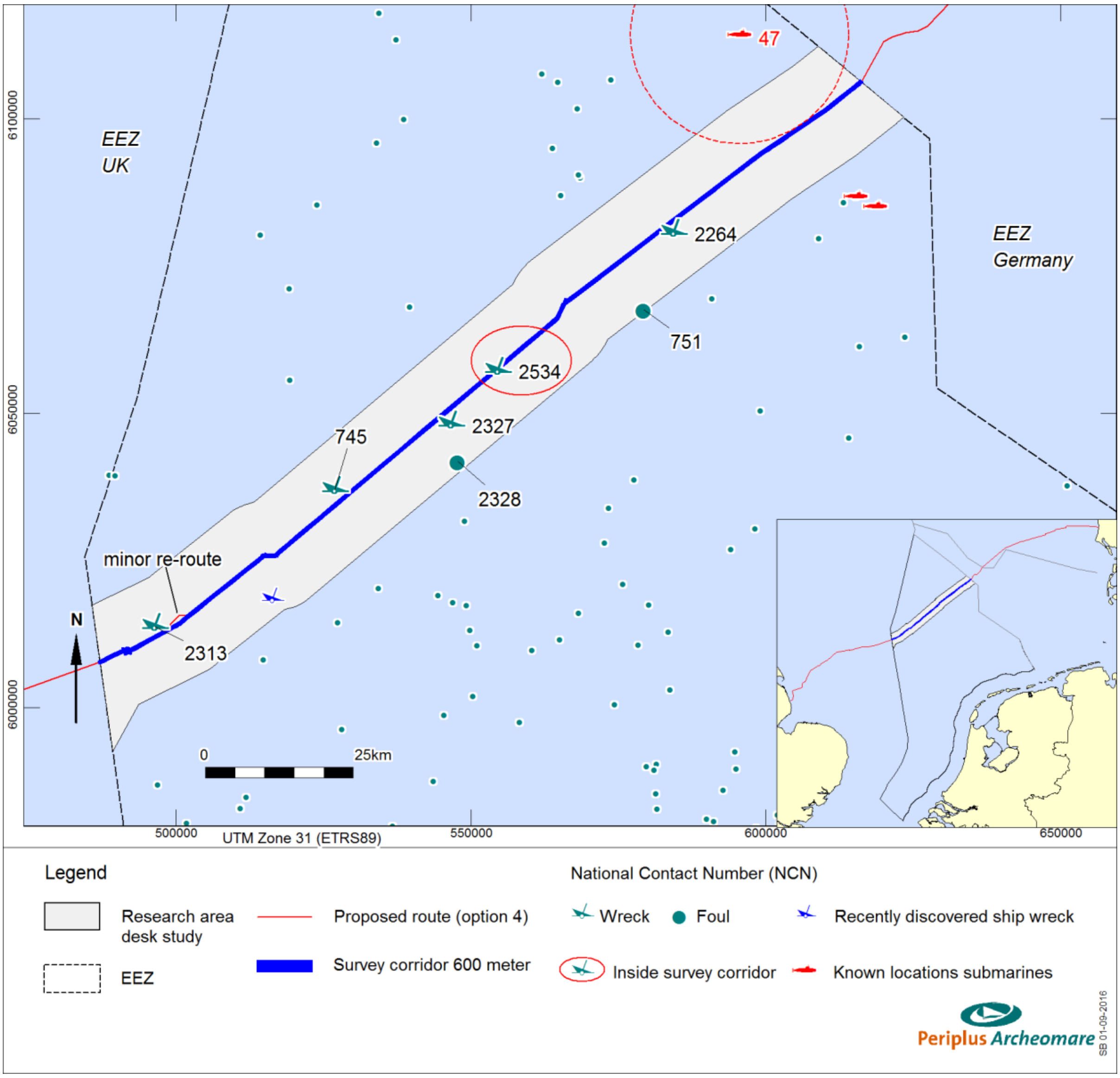


*Figure 3. Known objects within the vicinity of the survey corridor from the desk study.*

Only one object falls within the surveyed corridor.

| NCN | SR92 | DHY | Easting | Northing | R95 | Description |
|---|---|---|---|---|---|---|
| 2534 | - | 2967 | 554484 | 6057225 | 5 | Ship wreck Windfjord MV, a Norwegian motor cargo vessel of 1,678grt which sunk on the 17th September 2001 after engine failure. |

The remains of this (recent) ship wreck have been found during the geophysical survey. The results are presented in chapter 4.

[4] Van den Brenk and van Lil, 2016.

## 3.3 Archaeological assessment of the survey data

The geophysical and hydrographic survey techniques employed include *side scan sonar* (SSS), *magnetometer* (MAG), *multibeam* (MBES) and subbottom profiling (SBP). With *side scan sonar* all objects and structures on the seabed can be made visible. Seabed sediment of different composition can be distinguished by their characteristic reflection. *Multibeam* images reveal the morphology of the seabed. Large objects and *scouring* can be mapped. Smaller objects, like thin cables, or flat objects lying on the seabed often are impossible to identify in *multibeam* images.

*Magnetometer* contacts are identified by the presence of ferro-metalic objects which induce an anomaly in the earth magnetic field. These objects can be buried in or lying on the seabed. Unlike *side scan sonar* and *multibeam* no exact positions can be given. The actual object can be located at both sides of the survey line. Given the 100 meter spacing of the run lines the accuracy perpendicular to the line is in the order of 50 meter.

Fugro Survey, further referred to as Fugro Survey processed their survey data and produced detailed event listings of the *side scan sonar* and *magnetometer* contacts encountered within the survey areas. Like the known objects the locations of the contacts are plotted in a geographic information system (GIS).

During this archaeological assessment a selection was made based on the dimensions of the reported contacts. The fraction of contacts larger than or equal to four meter was looked into in more detail. Purpose of this analysis was to identify contacts that could reflect potential archaeological sites.

This is done by analyses of:

- *side scan sonar* images included in the survey reports;
- raw *side scan sonar* data (XTF-files) in SonarWiz;
- raw *multibeam*-data (xyz-files) in Autoclean, Qloud and Global Mapper;
- values of magnetic anomalies reported in the survey reports;
- comparison of *side scan sonar* and *magnetometer* contacts;

Also the geological formation and seabed morphology of the area are taken into account as outcrops of geological strata and sedimentary structures can lead to (apparent) anomalies in the *side scan sonar* record.

The *side scan sonar* images and classification were reviewed in order to define potential archaeological sites. A selection of contacts equal to or larger than four meters was made to be studied in detail. The further interpretation of *side scan sonar* contacts was based on best professional judgement. Additional research is needed to identify the exact nature of the contacts with certainty. This can be done by means of a *ROV* or divers.

Fugro Survey has acquired and processed shallow seismic data using a sub-bottom profiler (SBP), a single channel sparker (SPK) and an ultra-high resolution multi-channel sparker (UHR). The resulting seismic profiles were analyzed. Observed seismic strata were digitized and - based on known geological data from the area - lithostratigraphic units have been identified. The base of each lithostratigraphic unit was interpolated into a grid. In addition to the identification and occurrence of lithostratigraphic units, seismic anomalies that are expected to reflect potential hazardous phenomena were identified.

## 3.4 Data Analysis

The first step in the data analysis is to cross-reference known objects with the survey data. For the comparison the results of the desk study and the survey datasets were used. All the known objects were projected in a geographic information system (GIS) together with the survey data.

For the cross-reference the assumption is made that all contacts and anomalies present have been reported and described by the survey contractor. Raw data - if available - is used only to verify the description of found objects and anomalies as reported.

The positions of the interpreted contacts from the different surveys were compared with the positions of the known objects collected from the databases. Besides that, all the positions of both the survey contacts and the known objects were plotted on the high resolution *multibeam* grid to visualize the morphological influence of the presence of these objects. This assisted in the determination of possible archaeological value of the present remains. If an object had a potential archaeological value, the description of the object was finalized.

Besides the objects detected from the *side scan sonar* survey, the *magnetometer* contacts were plotted on the high resolution *multibeam* grid. *Magnetometer* contacts and *side scan sonar* contacts which are located within 50 meters of each other were considered to be related. An extra check of this relationship was made visually by judging their mutual positions in relation to the survey lines sailed.

When at the position of the *magnetometer* anomaly no visible object was recognized, the size of the anomaly was leading in the assessment of its archaeological potential. If the magnetic anomaly of a contact is more than 50 nT (nano-Tesla) it is stated that the contact could possibly be of archaeological value. All the *magnetometer* contacts above 50 nT, but within 25 meter of the existing cable and pipeline routes, were exempted for further investigation. It has to be stressed that within this assessment no distinction can be made between anomalies related to possible archaeological objects or anomalies related to (for example) unexploded ordinance (UXO's).

An archaeological assessment has been undertaken for all visible contacts. This interpretation is based on best professional judgment.

The interpreted seismic data were assessed in order to test the archaeological expectation with respect to remains of prehistoric settlements in the area. The archaeological desk study resulted in the identification of lithostratigraphic units that could contain archaeological levels. Grids produced by Fugro Survey could have been used to get an insight in both the lateral and vertical distribution of the lithostratigraphic units and the expected archeological levels herein in order to test the predictive model. Unfortunately these grids were not available yet during the execution of this assessment. Because of the absence of detailed information on the distribution and depth of the occurrence of lithostratigraphical units it was difficult to judge the effects of the installation of the cable on archaeological remains over the full length of the route.

The integrity of layer boundaries is important, because erosion by natural processes poses a significant threat to archaeological levels. Based on the assessment, zones within the proposed marine cable corridor which are expected to contain archaeological remains were mapped. The results were put in the context of the activities planned in order to predict whether the activities might damage potential archaeological remains.

The analysis was executed in August 2016 by R. van Lil and S. van den Brenk (both senior KNA senior prospector). The investigation is carried out according to specifications set up within the Dutch Quality Standard for Archaeology (*KNA Waterbodems 4.0; protocol 4103*).

## 3.5 Used Sources

The following sources were used for the analysis:

- Survey data Fugro Survey, original survey data and reported interpretations;
- Archaeological desk study Periplus (15A038-01);
- ARCHIS database Cultural Heritage Agency;
- Archeomare Database;
- NLhono database Hydrographic Service of the Royal Netherlands Navy;
- Wrecksite.eu;
- Database, Nationaal Contact Nummer (NCN).

For a complete list of used sources and literature see the reference list at page 51.

*Italic* written words are explained in the glossary at page 50.

# 4 Results

## 4.1 Seabed bathymetry and morphology

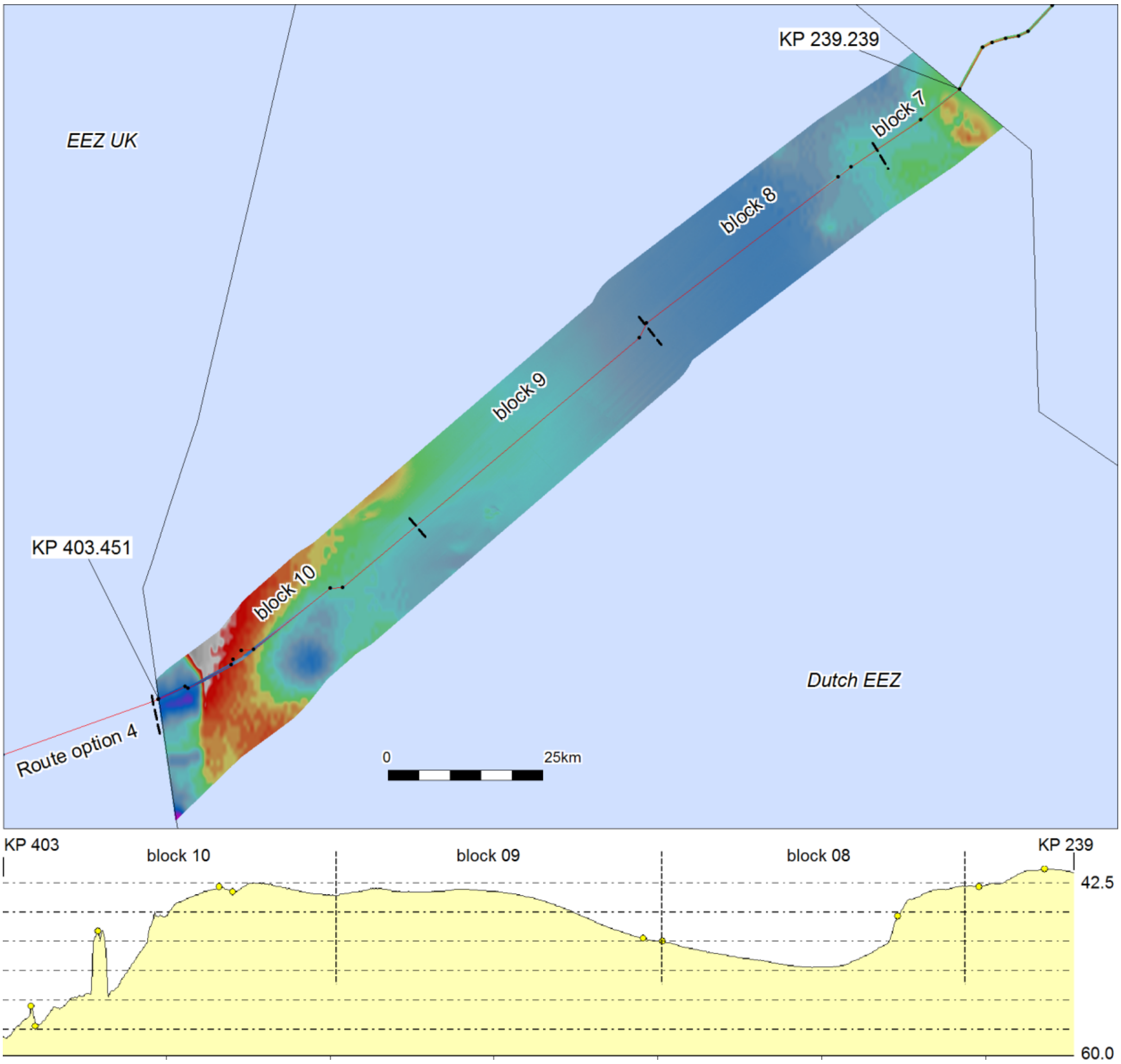


*Figure 4. Bathymetry and profile along the proposed route based on the multibeam recordings*

The water depth along the route varies from LAT -56m in the west to LAT -41m in the east. The general bathymetry and morphology will be discussed per survey block in the following paragraphs.

**Block 10**

Block 10 is located within the Dutch sector between approximately KP 351.615 and KP 403.406 (border EEZ UK). The proposed cable route is aligned north-east to south-west.
The water depths range from 42.3 m to 56.8 m below LAT. The water depths at KP 351.615 and KP 403.406 are 43.5 m and 55.6 m below LAT respectively. From KP 351.615 to KP 381.500 the seabed is fairly featureless. Beyond KP 381.500 the seabed dips towards the south-west.

Little to no variation in acoustic reflectivity was observed indicating a smooth homogenous seabed. The side scan sonar records indicate a low to medium reflectivity seabed with low reflectivity patches. Numerous trawl marks were observed which indicates widespread trawling in the block

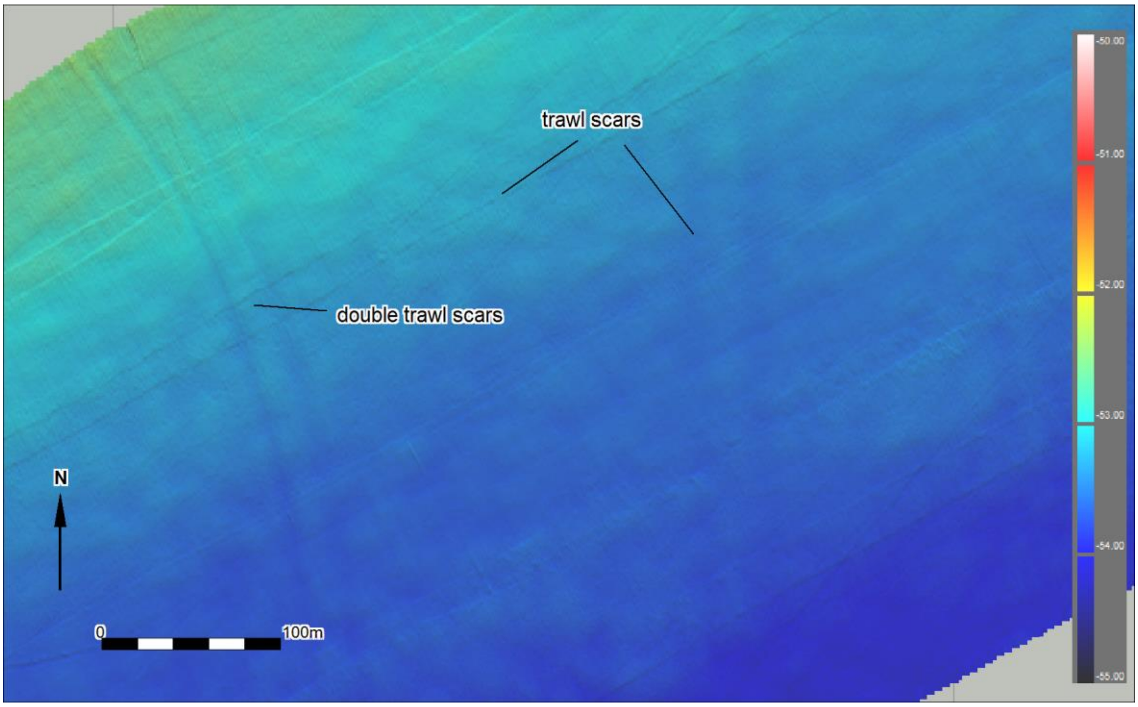


*Figure 5. Example of trawl scars within block 10*

The figure below shows the mound of outcropping strata which resulted in a reroute between KP 385.354 and KP 390.190.

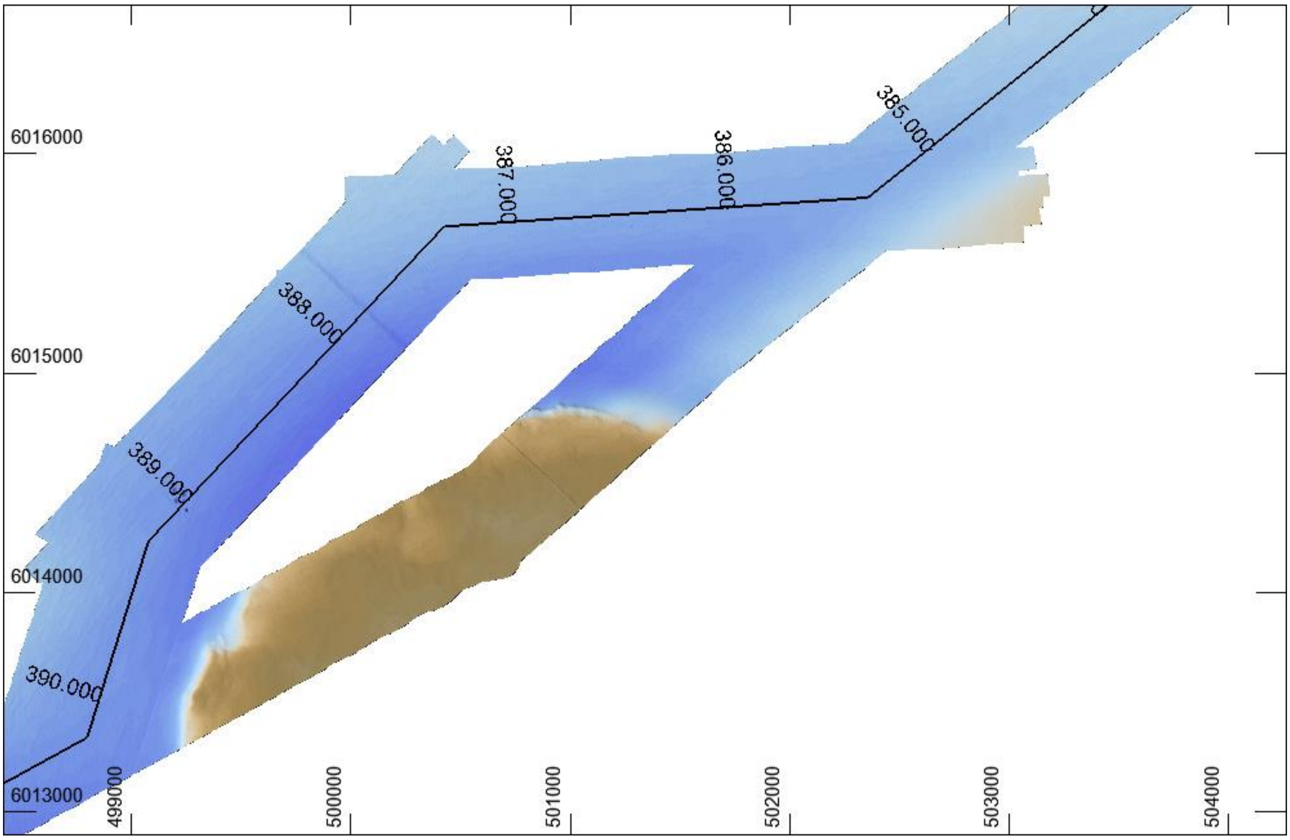


*Figure 6. Reroute around the mound of outcropping strata (refer to: Dyers 2016, figure 3.51)*

**Block 9**

Block 9 is located within the Dutch sector between approximately KP302.226 and KP 351.615. The proposed cable route is aligned north-east to south-west. The water depths range from 39.0 m to 43.5 m below LAT. The water depths at KP 302.226 and KP 351.615 are 42.8 m and 47.5 m below LAT respectively. The seabed between KP 302.226 and KP 351.615 is relatively featureless. The seabed dip gently increases with water depths decreasing to approximately KP 323.000. Beyond KP 323.000 the seabed is virtually flat.

Little to no variation in acoustic reflectivity was observed. The side scan sonar records indicate a low to medium reflectivity seabed with low reflectivity patches. Numerous trawl marks were observed which indicates widespread trawling in the block.

Grab samples acquired at different locations describe the sediments as sandy silt with occasional shell fragments. Samples acquired toward the west of the block all describe the sediments as silty sand.

**Block 8**

Block 8 is located within the Dutch sector approximately between KP 256.300 and KP 302.226. The proposed cable route is aligned north-east to south-west. The water depths within Block 8 range from 42.7 m to 49.9 m below LAT. The water depths at KP 256.300 and KP 302.226 are 42.8 m and 47.5 m below LAT respectively. The seabed within Block 8 is relatively featureless. The seabed gently slopes towards the south-west. Beyond KP 267.700 the seabed dip increases, with a commensurate increase in water depth.
The side scan sonar data showed little variation in acoustic reflectivity which indicates homogenous seabed sediments. The side scan sonar records indicate a low to medium reflectivity seabed with high reflectivity patches.

Grab samples describe the sediments as silty sand with occasional shell fragments.

**Block 7**

Block 7 is located between KP 210.795 and KP 256.300. The block is located within the German sector from KP 210.795 to KP 239.009 and in the Dutch sector to KP 256.300. The proposed cable route is aligned north-east to south-west with a bend in the route between KP 223.500 and KP 239.000. The water depths range from 38.3 m to 43.0 m below LAT. The water depths at KP 210.795 and KP 256.300 are 42.3 m and 42.8 m below LAT respectively.

Between KP 210.795 to KP 216.500 water depths seabed gradually increase and decrease, with less than 0.5m variation. Between KP 216.500 and KP 231.443 water depths decrease towards the south-west. Water depths increase between KP 231.443 and KP 256.300.

Between KP 210.795 and KP 256.300 there is little to no variation in acoustic reflectivity indicating a uniform seabed with homogenous sediments. The side scan sonar records generally indicate a low to medium reflectivity seabed. Grab samples describe the sediments in block 7 as silty organic sand.

## 4.2 Known objects: As Found positions versus database positions

Based on the desk study a total of six shipwrecks and two possible obstructions are known in the area, and fishermen reported the find of a submarine just north- or possibly in the area. Details like names, types and date of sinking are not known, nor are the exact locations.

The SSS contacts and MAG anomalies encountered during this survey have been stored in event listings. The positions of the contacts and anomalies in these listings are compared with the theoretical positions of objects in the NCN database. In order to conduct this comparison all SSS contacts and MAG anomalies found within a range of 50 meters around the database locations are selected.

The outcome of this comparison can be:

- The As Found position of a ship wreck is in agreement with the database position of a known wreck;
- The As Found position of a contact is in agreement with the position of a contact listed in the database, but the interpretations do not match;
- The As Found position of ship wreck is not in agreement with the database position of a known wreck;
- A wreck listed in the database has not been found.

The results of the comparison are presented in the next figure.

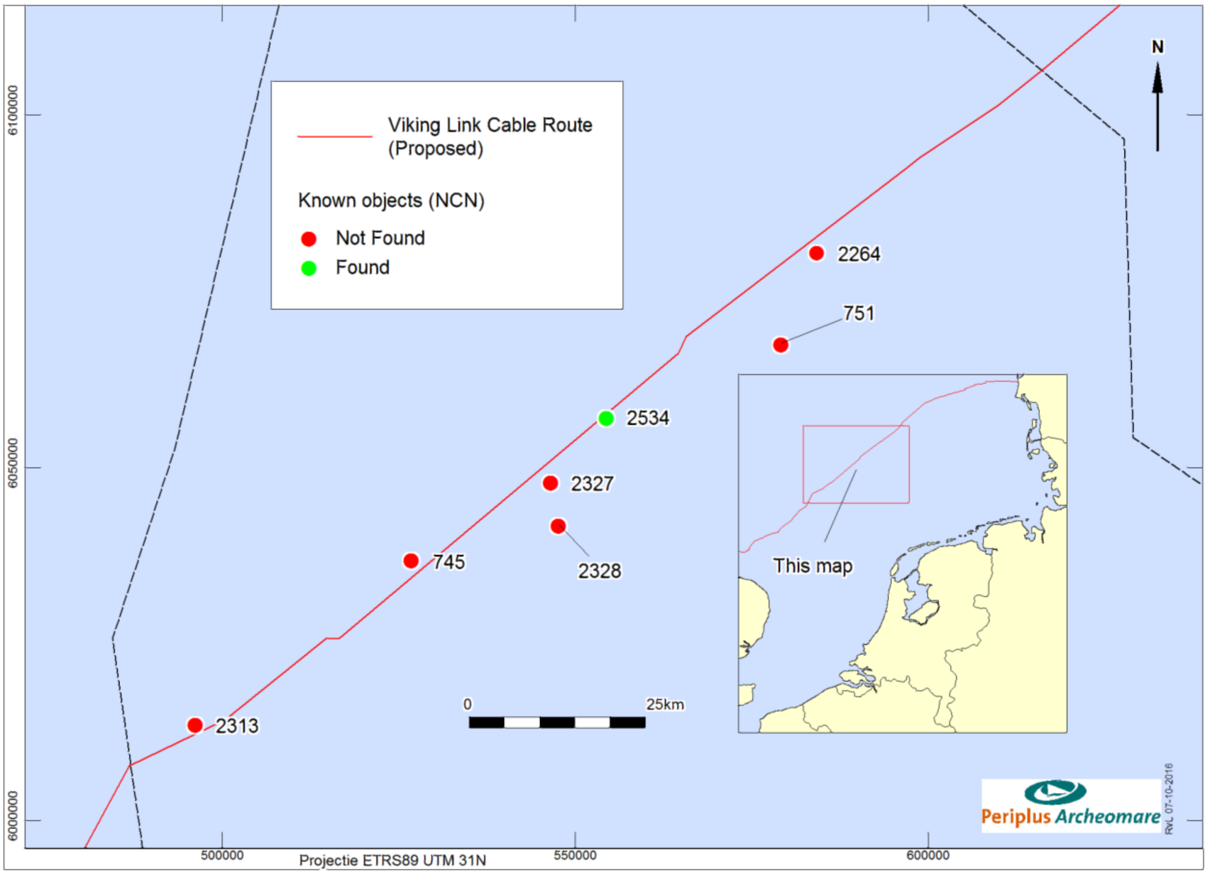


*Figure 7. Known objects found or not found during the survey*

In table 7 a listing is presented of the objects which have come forward from the archaeological desk study to be present within 10 nM on both sides of the proposed cable route. The corridor surveyed with side scan sonar is 500 meters wide. So a much smaller part has been surveyed than the area investigated during the desk study. With the exception of the wreck of the *Windfjord* (NCN 2534) none of the known objects are, given the accuracy of their position, expected to actually be located within the surveyed area.

| NCN | Easting | Northing | R95 | Description | Found |
|---|---|---|---|---|---|
| 745 | 526900 | 6036989 | 5 | Ship wreck fishing Vessel King William, a British registered fishing vessel of 162grt that was mined 125 miles E by N of Spurn Light Vessel, Humber on the 5th November 1915. | Outside the surveyed area |
| 751 | 579292 | 6067589 | 5 | Foul, no additional information | Outside the surveyed area |
| 2264 | 584354 | 6080616 | 5 | Ship wreck fishing vessel Inger Cristina from Denmark, sunk 21-03-1990 | Outside the surveyed area |
| 2313 | 496330 | 6013744 | 20 | Wreck, no additional information | Outside the surveyed area |
| 2327 | 546625 | 6048072 | 5 | Ship wreck fishing vessel Liza Olesen from UK, sunk 05-12-1985 | Outside the surveyed area |
| 2328 | 547715 | 6041920 | 5 | Foul, no additional information | Outside the surveyed area |
| 2534 | 554484 | 6057225 | 5 | Ship wreck Windfjord MV, a Norwegian motor cargo vessel of 1,678grt which foundered on the 17th September 2001 after engine failure. | Found by side scan sonar: contact B09_0016; not found by magnetometer. |
| - | 516309 | 6018468 | 5 | Unknown wreck, discovered by RWS during survey Klaverbank in 2013. Dimensions 32x7.5x1.5m | Outside the surveyed area |

*Table 7. Listing of known objects and survey results*

The *Windfjord* ship wreck which sank in 2001 was found at the edge of the surveyed area. This wreck has no archaeological value, but might form an obstacle.

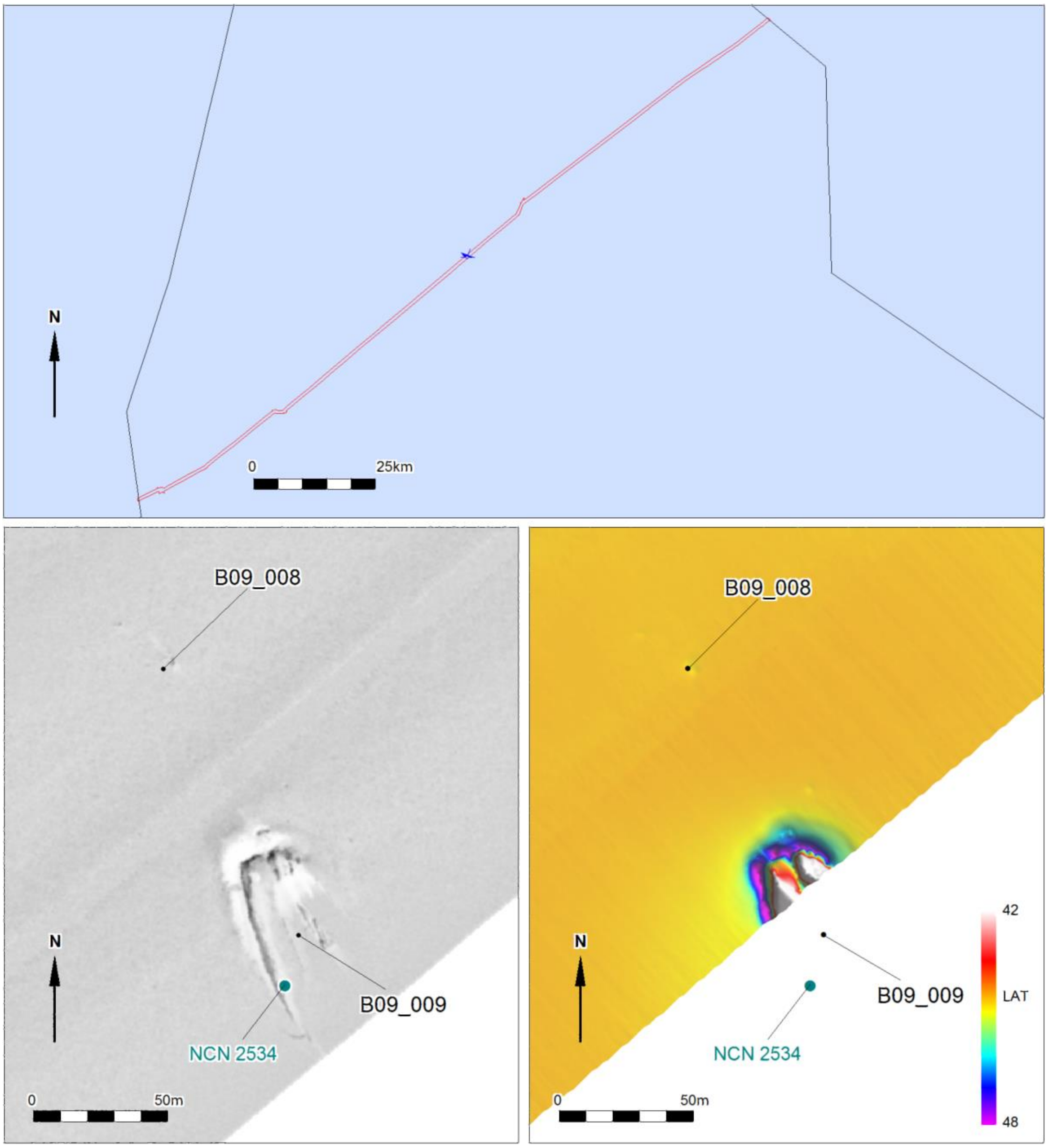


*Figure 8. Side scan sonar mosaic and multibeam image of the Windfjord ship wreck.*

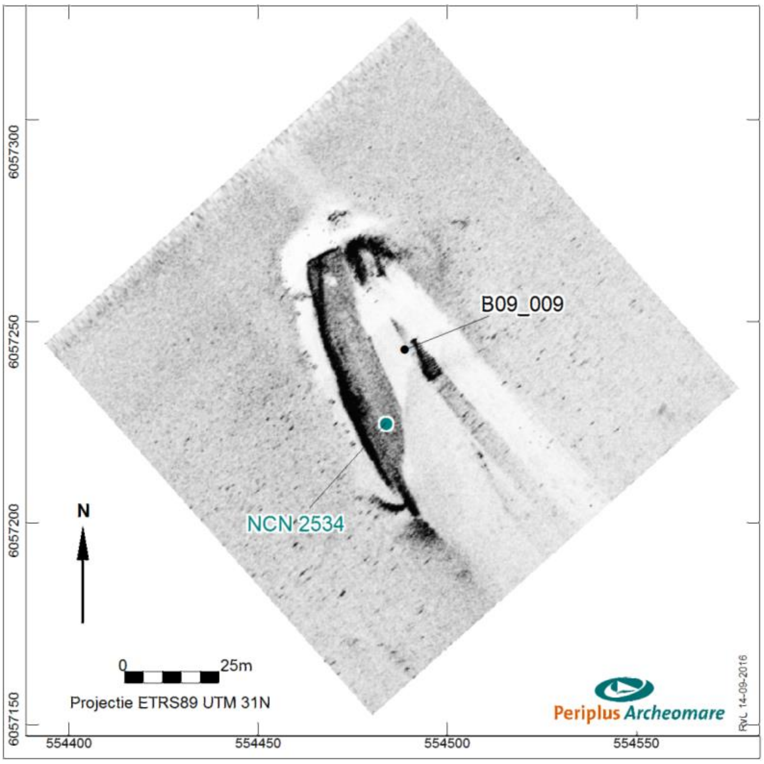


*Figure 9. Raw side scan sonar image of the Windfjord ship wreck.*

## 4.3 Sidescan sonar

Fugro Survey has identified 129 side scan sonar contacts within the survey corridor. In the table below an overview of the Fugro Survey interpretation of these contacts is presented.

| **Classification** | **Total** |
|---|---:|
| Anchor Pullout Pit | 1 |
| Boulder | 62 |
| Debris | 50 |
| Depression | 2 |
| Existing well | 1 |
| Possible anchor | 1 |
| Scour Marks | 2 |
| Spudcan Depression | 3 |
| Unknown | 6 |
| Wreck | 1 |
| **Total** | **129** |

*Table 8. Side scan sonar contacts identified*

At total of 62 contacts has been identified as boulders or boulder area. The majority of these boulders (37) have been found within a confined outcrop of moraine which shows a marked plateau-like relief both on multibeam and side scan sonar images. Along with two other boulders these boulders and boulder areas (39 in total) have been found within the Klaverbank area.

Three of the contacts that have been classified as items of debris could represent exposures of the active 36-Inch gas pipeline from D15-FA1 to L10-AC. This pipeline has been crossed perpendicularly during the survey, possibly to obtain an accurate identification on magnetometer and subbottom profiler data.

This orientation can however lead to the absence of an acoustic shadow behind exposed sections of the pipeline on side scan sonar images. Exposures of the pipeline could and probably will exhibit of a stronger than the surrounding seabed, but identification of pipeline exposures could be troublesome due to the absence of shadows.

The *side scan sonar* contact and images have been scanned and checked for the presence of potential archaeological contacts. This is done by analyses of:

- *Side scan sonar* images included in the survey reports;
- Raw *side scan sonar* data (XTF-files) in SonarWiz;
- Raw *multibeam*-data (xyz-files) in Autoclean, Qlloud and Global Mapper;
- Comparison of *side scan sonar* and magnetometer contacts.

Apart from the survey data studied the geological formation and seabed morphology of the area are taken into account as outcrops of geological strata and sedimentary structures can lead to (apparent) anomalies in the *side scan sonar* record.

The interpretation of *side scan sonar* contacts is based on best professional judgment. Additional research by means of a ROV or divers could be employed to identify the nature of the contacts observed with certainty.

A selection of 25 contacts has been examined in detail. This selection includes:

- all contacts larger than or equal to four meter ;
- side scan sonar contacts less than four meters which coincide with morphological phenomena on multibeam images (4);
- locations at which on the multibeam images bulges or depressions have been observed which did not coincide with side scan sonar contacts (3).

Fugro Survey has classified these contacts as 'debris', 'boulder', 'boulder area', 'wreck' and 'other' (see table 9) .

| **Fugro Survey Classification** | **Number** |
|---|---|
| debris | 13 |
| boulder / boulder area | 7 |
| other | 1 |
| wreck | 1 |
| n/a*[1] | 3 |
| **Total** | **25** |

*Table 9. Classification by Fugro Survey*

*[1] multibeamcontacts

Periplus Archeomare reexamined the 25 contacts and assessed the archaeological potential of these contacts. A summary of the outcome of the detailed inspection and assessment of selected contacts is presented in table 10.

| **Archaeology** | **Periplus Classification** | **Method** | **Number** | **Remark** |
|---|---|---|---|---|
| NO | anchor | sss | 1 | Common finds in North Sea |
| | beam | sss | 1 | |
| | cable | sss | 1 | |
| | boulder / boulder area | sss | 3 | Natural deposits |
| | outcrop of natural sediments | sss | 4 | |
| | shells or reef | sss | 2 | |
| | spike | mbes | 2 | Small multibeam contacts without scour, not found on side scan sonar |
| | unknown object | sss | 7 | |
| | wreck | sss | 1 | NCN 2534 wreck Windfjord MV, Norwegian motor cargo vessel foundered on the 17th September 2001 |
| POSSIBLE | unknown object | sss/mbes | 1 | |
| | possible wreck | sss/mbes | 1 | two proximate coherent side scan sonar contacts are considered to belong to one possible wreck; partly buried; |
| **Total** | | | **24*** | |

*Table 10. Periplus Archeomare interpretation*

* At one of these 24 locations a possible wreck has been found which has been tagged with two side scan sonar contacts resulting in a total of 25 Fugro Survey contacts.

Nine contacts have been classified as natural phenomena. Natural phenomena are defined as outcrops of contrasting sediments, boulders/boulder areas, shells or reefs.

Eight contacts have been classified as unknown object. One of these inferred unknown objects has been identified in the multibeam data only; this contact is located amidst a scour and therefore obscured in the side scan data.

The other two apparent morphological structures identified in the multibeam data have been abstained as these 'structures' are presumably the result of spikes in the data.

Three contacts were interpreted as finds which are very common in the North Sea: a possible anchor, a beam and piece of cable.

At two locations three contacts were encountered which have been interpreted as objects with a possible archaeological value.

Two contacts (B10-067 and B10-068) represent a possible wreck. It is thought that the contact is intermitted because part object is covered with sand. The contact is accompanied by two depressions which presumably are caused by scouring. Near contact B10_068 two point contacts are visible on the side scan sonar image. Behind these point contacts very thin long shadows can be distinguished. These point contacts and shadows are not observed on the raw sonar data. The point contacts could e.g. reflect two vertical beams. The dimensions of the contact, including the presumed buried parts, are: L=36.4m; W=3.0m; H=unknown.

The second potential archaeological object is found at the location of contact B10_065. The contact is round with a hard reflection and a clear shadow. The contact occurs amidst a drop-shaped area with moderate reflection and coherent depression. This depression is also thought to be the result of scouring near a partly covered object.

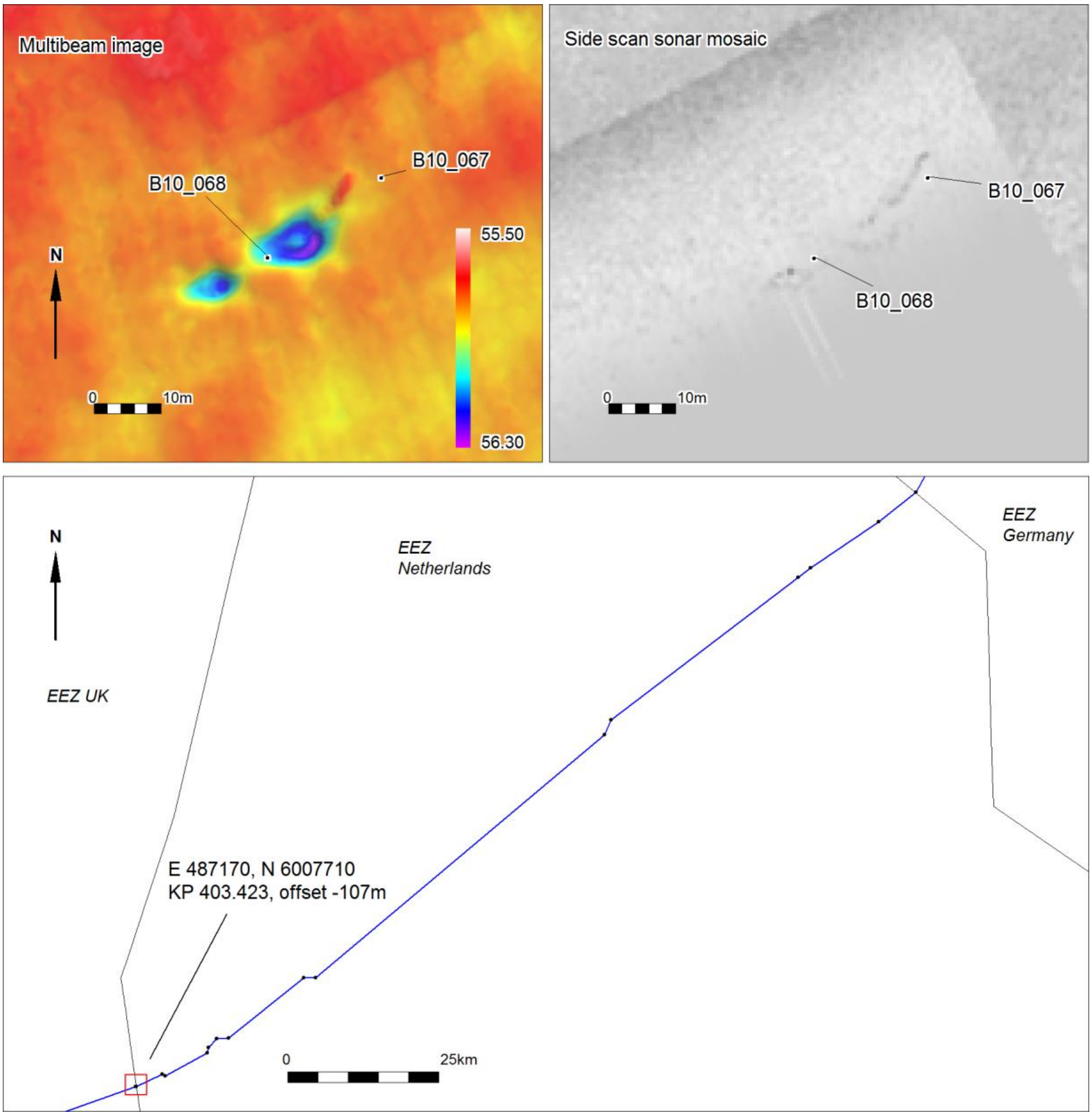


*Figure 10. Multibeam and side scan sonar image of contacts B10 067 and 068*

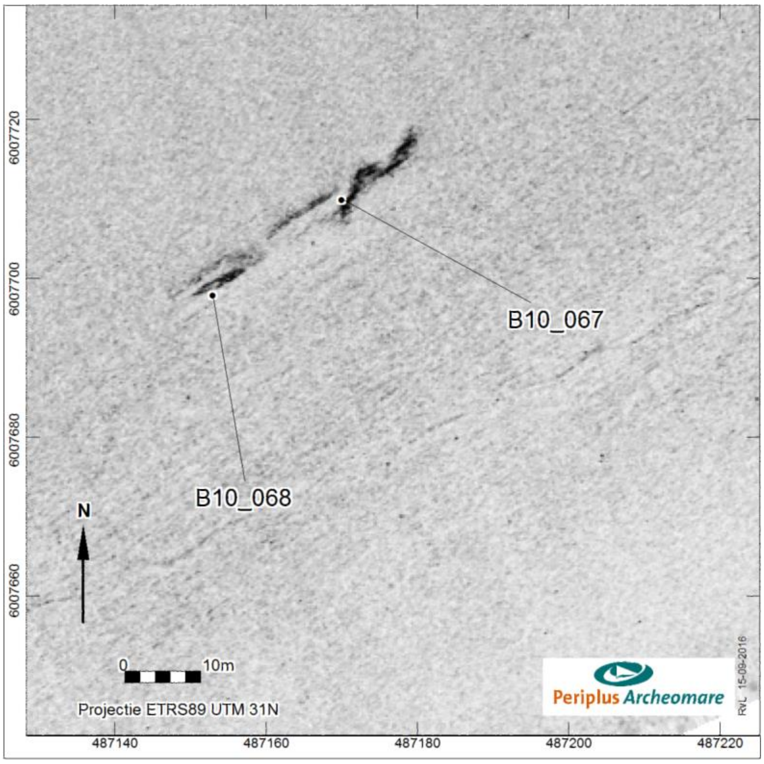


*Figure 11. Raw side scan sonar image of contacts B10_067 and B10_068*

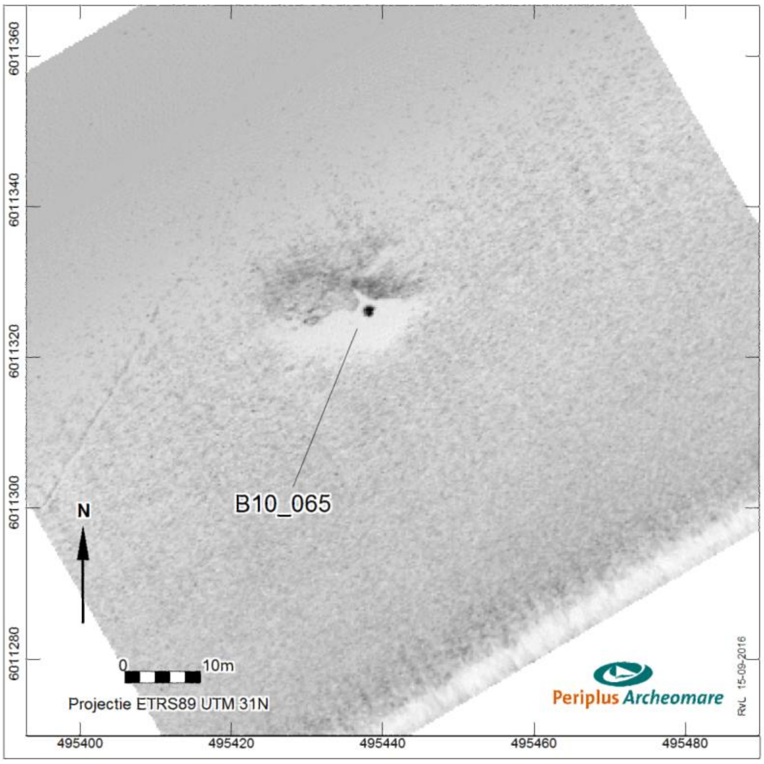


*Figure 12. Raw side scan sonar image of contacts B10_065*

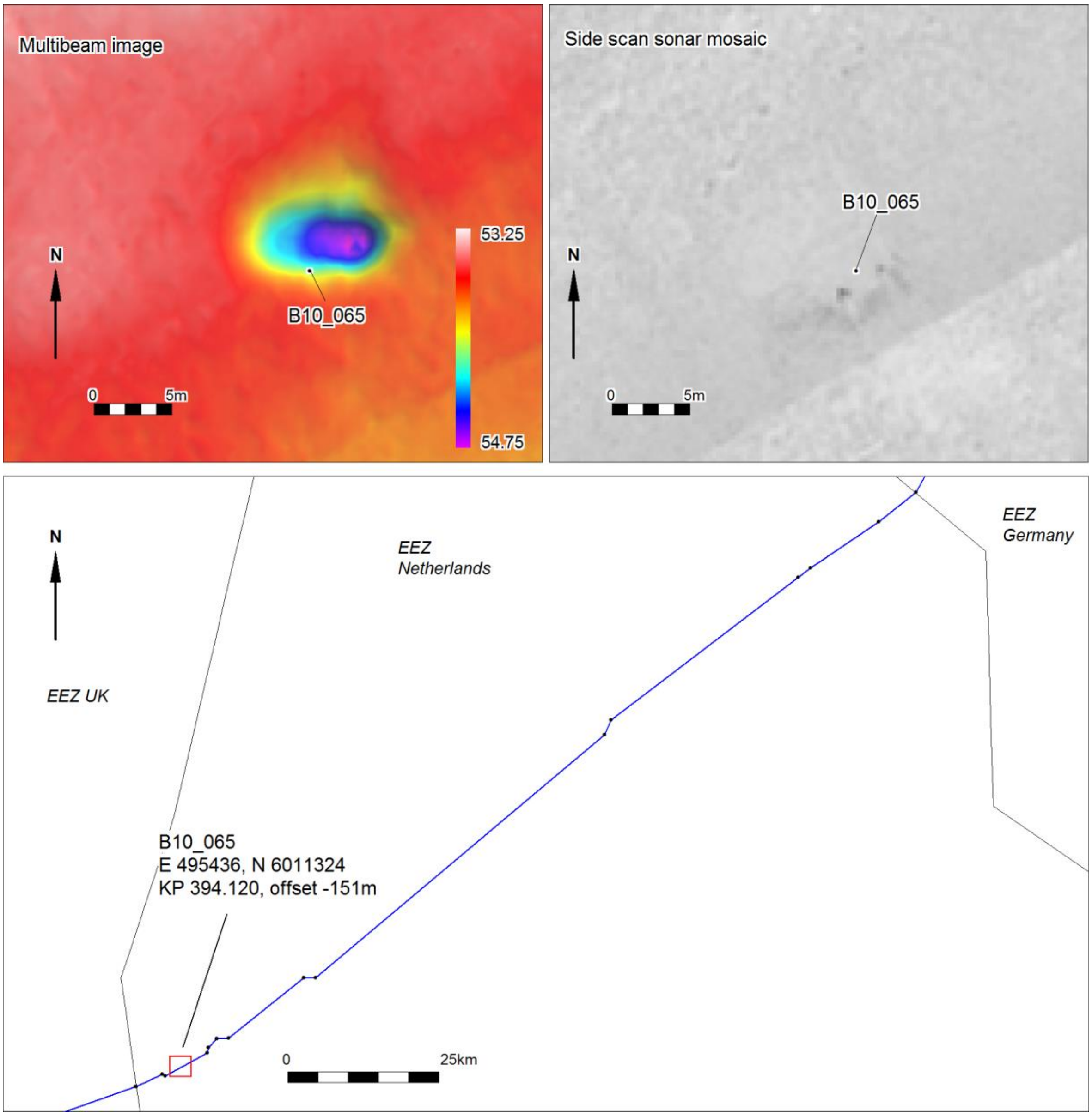


*Figure 13. Multibeam and side scan sonar image of contact B10 065*

## 4.4 Multibeam

Within the multibeam recordings, one object was found which did not show on the side scan sonar records. This is a small object with dimensions 2 x 2 x 0.5m at KP 353.118, 185 meter south of the route 4.

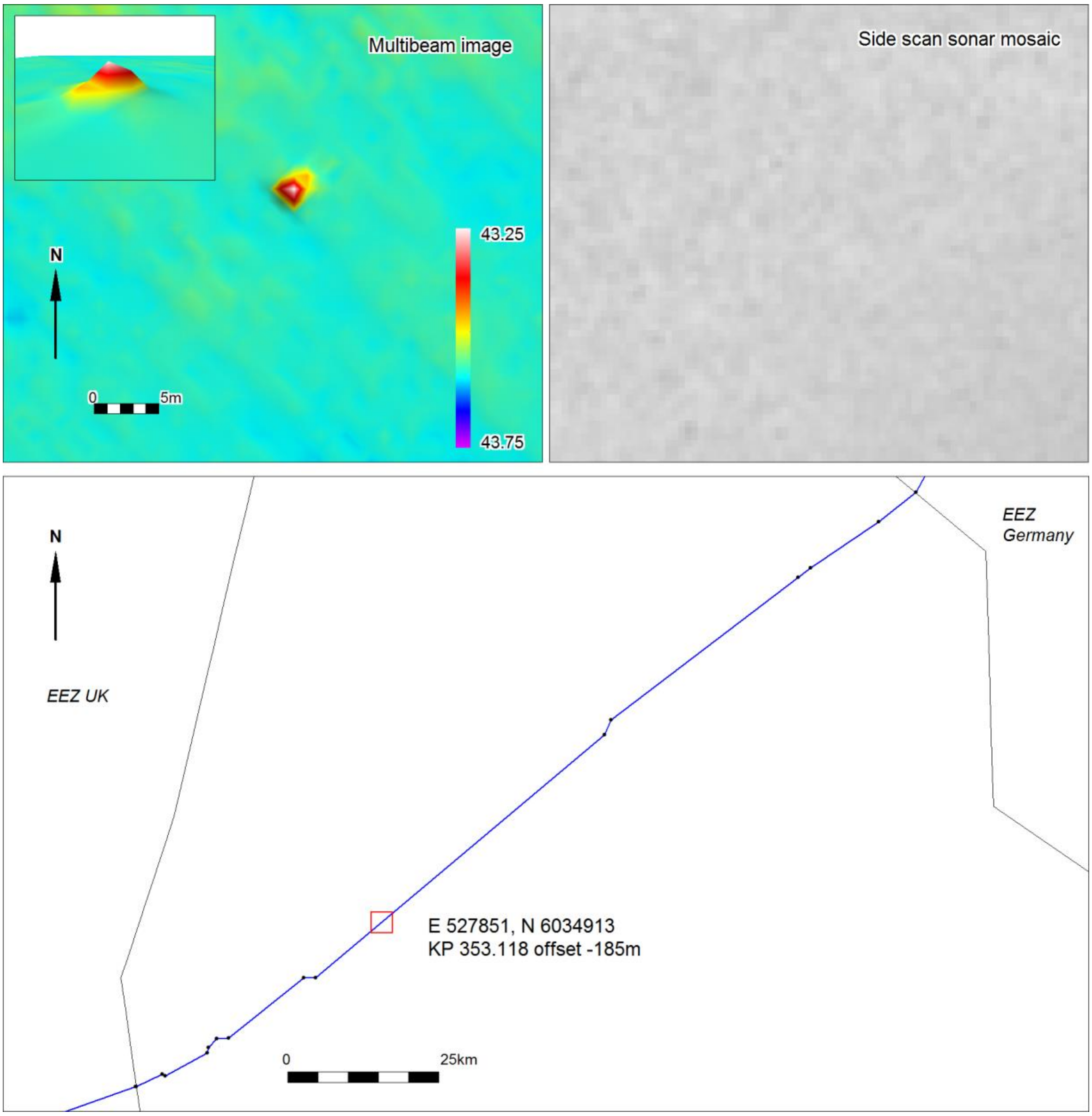


*Figure 14. Multibeam image of an object not detected with side scan sonar.*

## 4.5 Magnetometer

Besides the objects that are visible on the geophysical data and are considered to be of possible archaeological value there also are large *magnetometer* anomalies which are not observed on the *side scan sonar* or *multibeam* data. Although the nature of these objects is not known it is possible that the anomalies represent archaeological remains buried in the seabed, and therefore have to be taken into account within this assessment.

A total of 142 magnetic anomalies have been observed. 57 of these anomalies can be related to known pipelines and cables. Three of the magnetometer anomalies can be related to side scan sonar contacts.

A total of 85 magnetic anomalies cannot be related to known pipelines and cables, or visible objects at the seabed surface. They are related to unknown ferrous objects buried in the seabed, covered by sediments. Ten of these anomalies have an amplitude of 50 nT or more. An overview is presented in the figure below.

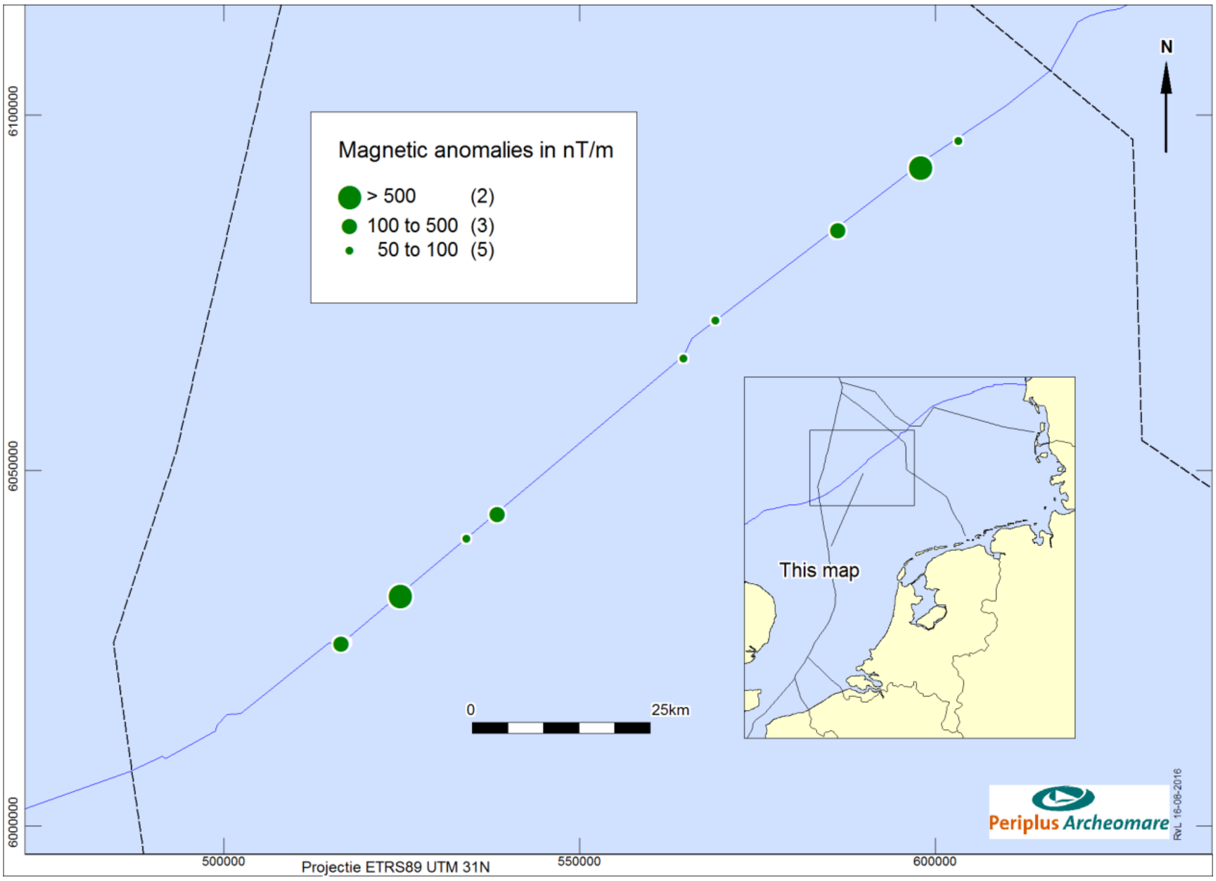


*Figure 15. Unidentified magnetic anomalies larger than 50 nT*

Concerning these buried ferrous objects, it is advised to avoid such areas whilst laying the cables. It should be stressed that the origin of the magnetic anomalies is unknown and apart from possible archaeological remains any type of man-made objects can be encountered including unexploded ammunition, anchors, pieces of chains and cables, debris, etcetera.

Three of the anomalies lie within 100 meters of the proposed marine cable corridor.

| Contact_ID | KP | Offset | Easting | Northing | nT/m | Comments |
|---|---|---|---|---|---|---|
| B07_MAG_092 | 255.304 | -203 | 603336 | 6096596 | 72 | Unknown anomaly |
| B08_MAG_007 | 261.823 | -198 | 597984 | 6092899 | 723 | Unknown anomaly |
| B08_MAG_017 | 276.459 | -199 | 586357 | 6084008 | 173 | Unknown anomaly |
| B08_MAG_028 | 297.772 | 197 | 569181 | 6071383 | 59 | Unknown anomaly |
| B09_MAG_007 | 304.889 | -127 | 564706 | 6066021 | 54 | Unknown anomaly |
| B09_MAG_020 | 339.069 | -11 | 538484 | 6044095 | 112 | Unknown anomaly |
| B09_MAG_031 | 344.598 | 121 | 534171 | 6040635 | 64 | Unknown anomaly |
| B10_MAG_003 | 356.924 | 12 | 524812 | 6032611 | 17341 | Unknown anomaly |
| B10_MAG_008 | 366.868 | -126 | 517295 | 6026102 | 63 | Unknown anomaly |
| B10_MAG_009 | 367.639 | 6 | 516586 | 6025805 | 162 | Unknown anomaly |

*Table 11. Listing of unknown magnetic anomalies larger than 50 nT/m*

## 4.6 Subbottom data

### Desk study results

Before discussing the survey results, a summary is presented of the lithostratigraphic sequence which, based on the desk study, is to be expected. The desk study results are displayed in the tables below.

| Unit | Expected Occurrence | Lithology | Depositional environment | Date |
|---|---|---|---|---|
| Southern Bight Formation | | | | |
| Terschellingerbank Member | total area | mobile sand layer, seabed | marine | Holocene |
| Velsen Bed | western and central part of the area | humic clay | lagonal | Early Holocene |
| Basal Peat Bed | total area | peat | coastal marine | Early Holocene |
| Boxtel Formation | northeast (block 7) | well sorted fine sand with wood remains | aeolian and fluvioperiglacial | Late Weichselien |
| Dogger Bight Formation | | | | |
| Botney Cut Member | dominant in western part | soft silty clay | channel infill | Late Weichselien |
| Bolders Bank Member | western part | gravelly poorly sorted clay, loam and sand | moraine | Late Weichselien |
| Dogger Bank Member | dominant in eastern part | stiff laminated clay with laminae of silt and fine sand | pro-glacial fluvial | Late Weichselien |
| Eem Formation | isolated patch at western border | very fine to medium sand | marine | Eemien |
| Drente Formation | | | | |
| Uitdam member | northeast (block 7) | laminated clay (varves) | lacustrine | Saalien |

*Table 12. Lithostratigraphic units expected in the area*

| Unit | Archaeological remains | In situ |
|---|---|---|
| Terschellingerbank Member | reworked flint and bone artifacts | no |
| Basal Peat Bed / Velsen Bed | lost objects (hunting gear), dumps | yes |
| Boxtel Formation (Wierden Member) | camps sites of hunters and gatherers; flint and bone artifacts; burnt nuts and seeds; charcoal; hunting gear | yes |
| Botney Cut Member | lost objects (hunting gear), dumps; possible camp sites at transitions to Bolders Bank Member | possibly |
| Bolders Bank Member | camps sites of hunters and gatherers; flint and bone artifacts; burnt nuts and seeds; charcoal; hunting gear | yes |
| Dogger Bank Member | lost objects (hunting gear), dumps; possible camp sites at transitions to Bolders Bank Member | possibly |

*Table 13. Archaeological levels within the lithostratigraphic units*

### Survey results

Based on the survey results Fugro Survey has defined six geological zones (A – F) along the Viking Link cable route. Within the Dutch part of the Continental Shelf the cable route crosses the geological zones defined as B and C. Zone B ranges from KP 239.237 (east side) to KP 266.000; zone and C ranges from KP 266.000 to KP 403.450 (west side).

An overview of the zones within the Dutch part of the Continental Shelf is shown in figure 16.

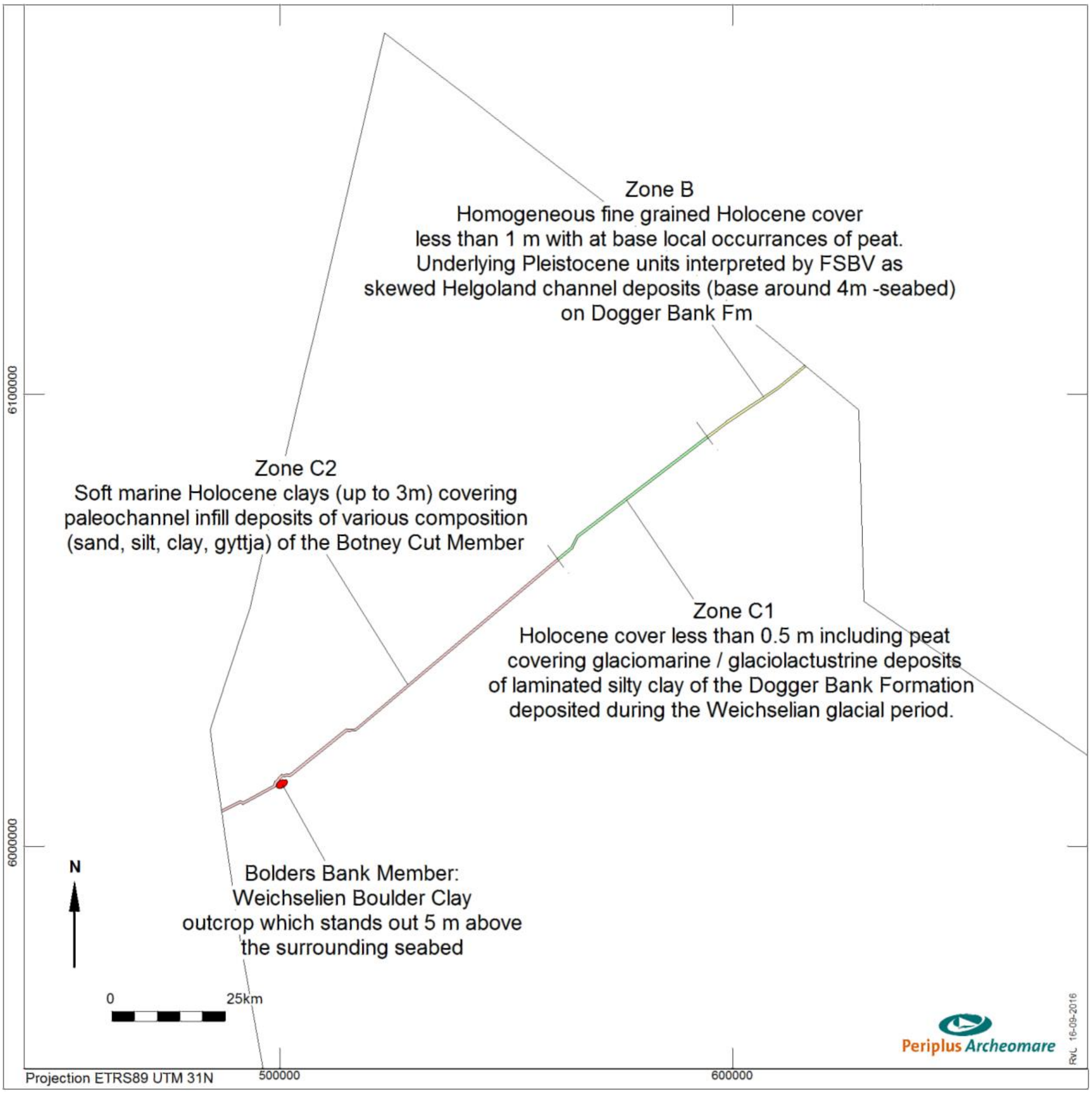


*Figure 16. Geological sections defined by Fugro Survey*

The deposits in Zone B are reported by Fugro Survey as follows:

***'Zone B – Estuarine to Marine Sediments***

*Towards the western limits of Zone B between KP 216.0 and KP 266.0, SBP data display inclined reflectors which are interpreted to represent the migration of palaeochannels within the estuary. Vibrocore data from these sections suggest little change from the silty or sandy material elsewhere in Zone B. SBP data suggest that this material was deposited overlying the Dogger Bank Formation at this location, a geological formation which is interpreted to dominate Zone C. Figure 6.4 shows sandy sediments and peat. Therefore, although the axis of the channel has migrated over time, based on the sampling soil, conditions can be considered ubiquitous.'*

Based on the desk study Pleistocene deposits in this part of the route were expected to consist of Late Weichselien fine perifluvioglacial sand and loam and cover sand of the Boxtel Formation and Saalien lacustrine clay of the Uitdam Member in the area that has been designated as Zone B by Fugro Survey.

In Zone B Pleistocene units are covered by a thin layer (0.5 meter) of mobile deposits of the Terschellingerbank Member. This layer appears to contain reworked remnants of peat which has eroded from local occurrences of peat. As shown in figure 17 vibrocore sample B08-10-VC contains a peat layer ranging from 0.50 to 1.05 meter below the seabed. Fugro Survey interpreted the subcropping Pleistocene unit to consist of estuarine channel deposits. Within the geological framework this interpretation seems plausible. However, due to an often incomplete recovery of the vibrocore samples in Zone B the presence of the Boxtel Formation or the Uitdam Member can in our view not be excluded. Covers sands of the Wierden Member, river dunes of the Delwijnen Member and small scale fluvial deposits of the Singraven Member, all subunits within the Boxtel Formation, can occur as layers separating the channel deposits related to the Palaeo Elbe Estuary from the covering Holocene deposits.

Whatever the actual composition of subcropping Pleistocene deposits is, the occurrence of peat, which is inferred to represent the Basal Peat Member, does indicate that the top of the Pleistocene landscape at least at a number of locations can be expected to be intact.

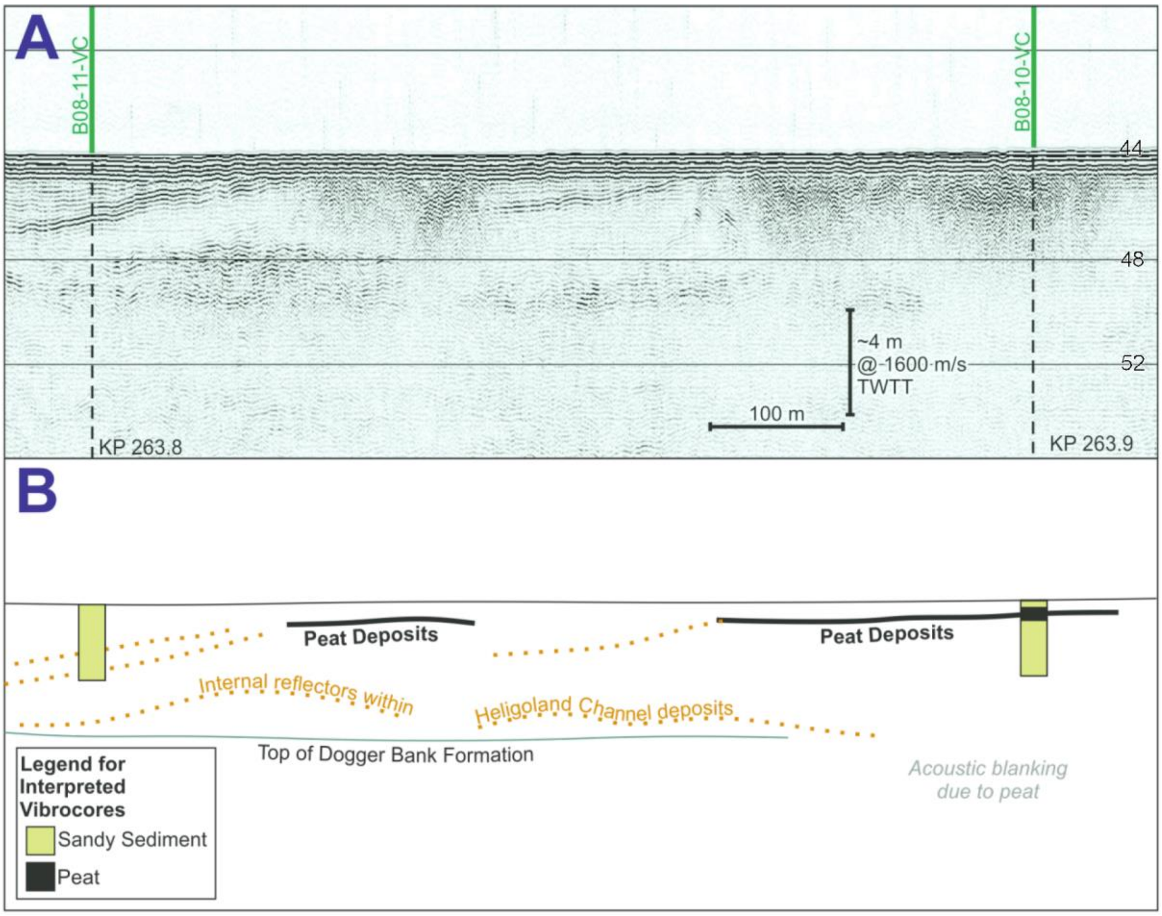


*Figure 17. Block 8: Sub-bottom profiler data (A) and interpreted sub-bottom profiler and vibrocore data (B) displaying inferred channel deposits under a Holocene cover of the Basal Peat Bed and the mobile Terschellingerbank Member; depth in m LAT*

Zone C consists of 'Variable Glacially Derived Sediments'. This zone is subdivided in Subzone C1 and Subzone C2. The deposits in Subzone C1 are reported by Fugro Survey as follows:

*'Between KP 266.0 and KP 309.0, the geology in the top 3 m is characterised by a thin (less than 0.5 m) layer of Holocene material (including peat) overlying glacial deposits comprising medium to high strength silty clay (Figure 6.5). At some geotechnical locations laminae of clayey silt were identified. It is interpreted that these sediments are the Dogger Bank Formation, glaciomarine sediments deposited during the Weichselian glacial period.'*

Based on the archaeological desk study the pro-glacial glaciolacustrine/glaciomarine sediments of the Dogger Bank Member were expected to be the dominant Pleistocene deposits in the eastern part of the route. This expectation was confirmed by the sub-bottom profiler and vibrocore data analysis and interpretation by Fugro Survey. This conclusion also applies to the glacial valley infill deposits of the Botney Cut Member found to be widespread in the southern part of the route surveyed.

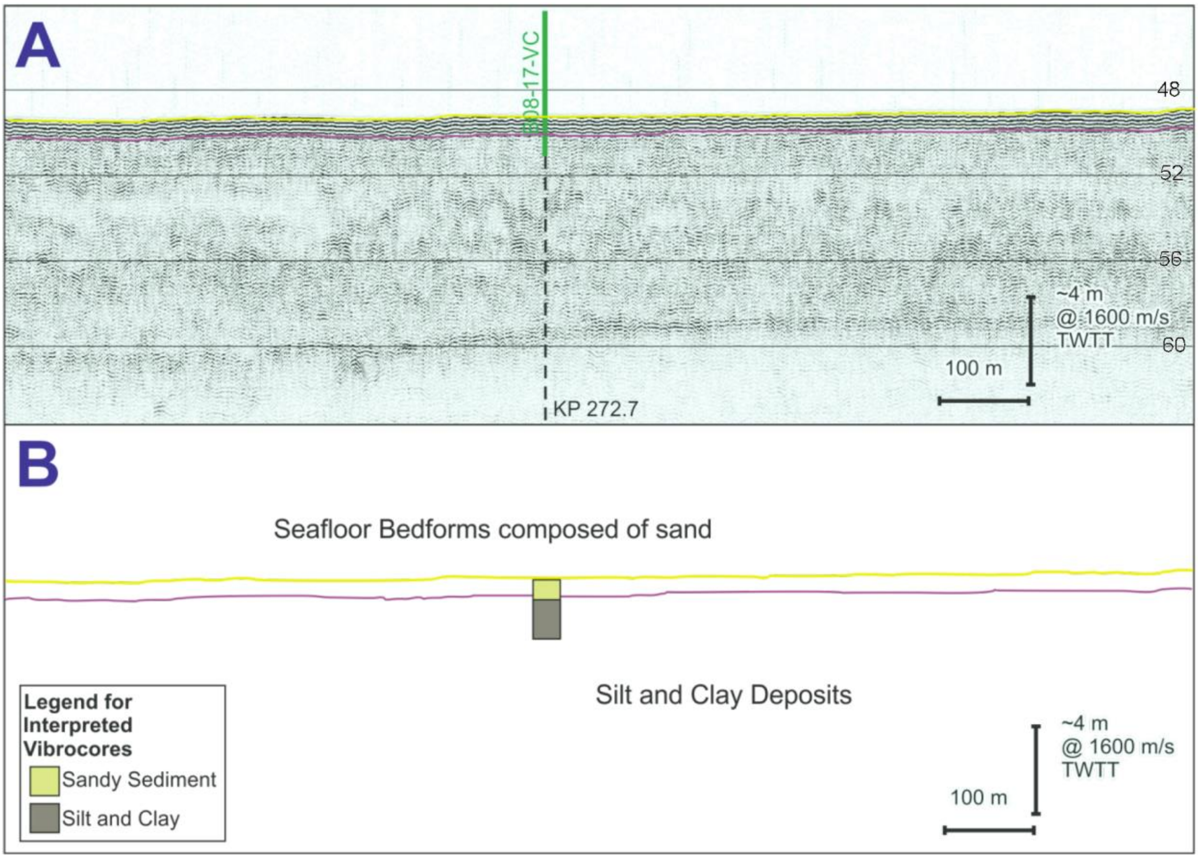


*Figure 18. Block 8: Sub-bottom profiler data (A) and interpreted sub-bottom profiler and vibrocore data (B) displaying Holocene deposits (including peat) overlying glaciolacustrine/glaciomarine silt and clay of the Dogger Bank Member; depth scale = m LAT*

The deposits in Subzone C1 are reported by Fugro Survey as follows:

*'Much of the remainder of Zone C is characterised as Subzone C2 which comprises extensive palaeochannels, up to 8 km width, which contain variable fill materials to variable depths of incision. These are thought to have been originally incised at the end of the LGM when ice had retreated and subsequently filled with Botney Cut Formation and more recent sediment. Preliminary geotechnical data suggest that the channels are often covered by Holocene marine sediments up to 3 m thick and comprise low strength clay. Due to the environment of deposition of these channels, it is possible that fill sediments may contain organic matter such as peat or gyttja, although this was not sampled during the geotechnical campaign.'*

The cross-bedded palaeochannel infill deposits of the Botney Cut Member clearly displayed in figure 19. The thickness of the Holocene deposits covering the Botney Cut Member is some two meter. At the base of the cross/bedded infill a continuous slightly undulating reflector reflects what appears to be a discordant contact with underlying sub-parallel deposits. Fugro Survey interpreted these deposits also to be part of the Botney Cut Member.

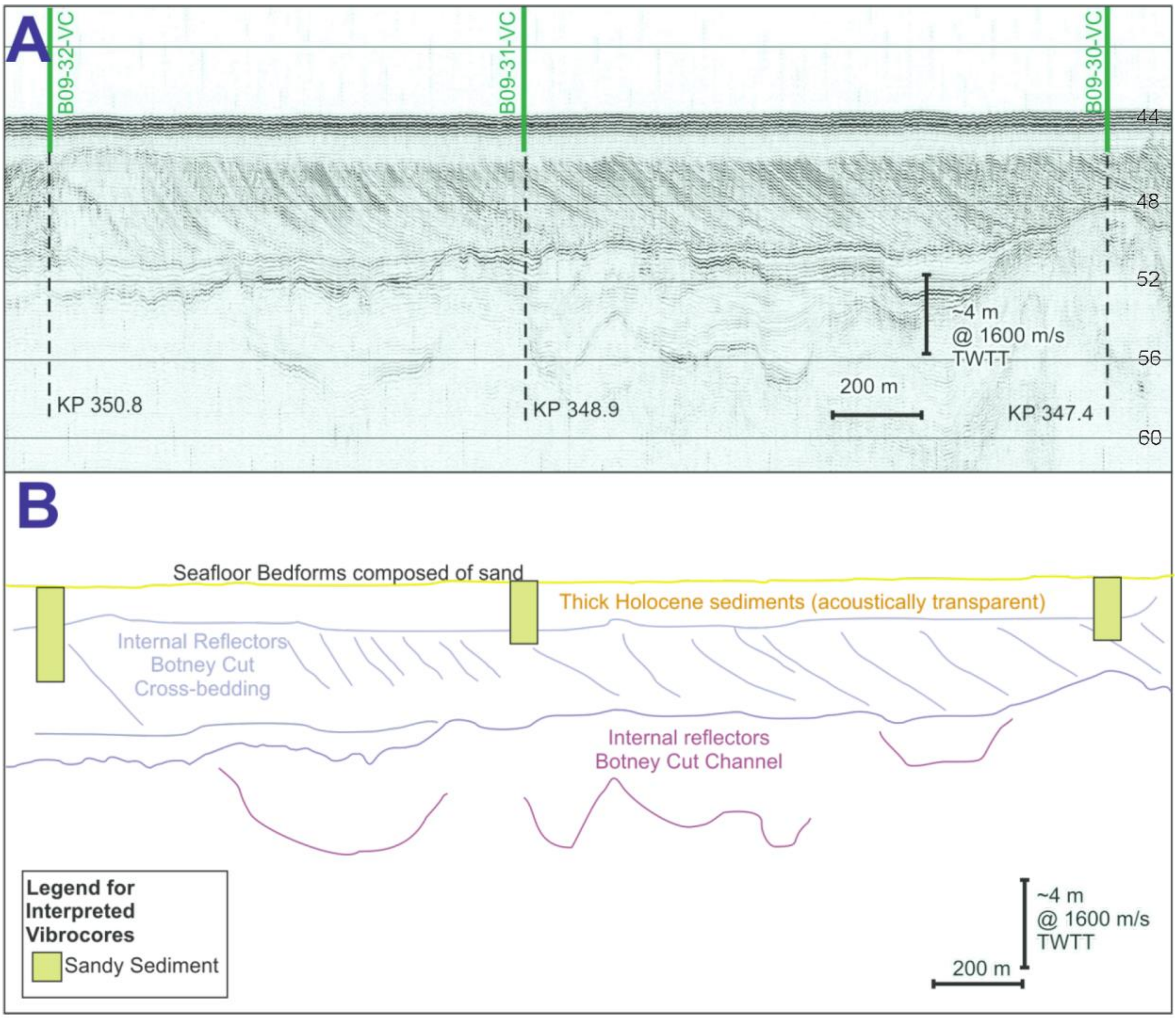


*Figure 19. Block 9: Sub-bottom profiler data (A) and interpreted sub-bottom profiler and vibrocore data (B) displaying Holocene material (including peat) overlying glacial valley infill deposits of the Botney Cut Member; depth scale = m LAT*

Further on the deposits in Subzone C2 Fugro Survey reports:

*'Sub to outcrops of Bolders Bank Formation and Dogger Bank Formation are present in Zone C. These areas are characterised by extremely high strength gravel-rich clays and are thought to have been resistant to erosion, potentially due to subtle differences in subglacial depositional history. Locations where glacial till is present at or close to seabed are a potential constraint to installation of the cable and are discussed in greater detail in Section 7.*

*Interpretation of SBP data between KP 322.0 and KP 347.0 highlights an area of glacially-derived clay close to seabed that is potentially highly variable. It is possible that this area was an area of interfingering between the Dogger Bank Formation and Bolders Bank Formation units. Preliminary geotechnical logs suggest differences in clay origin between grey and olive grey clays often associated with the Dogger Bank Formation and the brown and reddish brown of the Bolders Bank Formation.'*

The initial cable route crosses a plateau-like outcrop of glacial till of the Bolders Bank Member. These glacial tills consist of stiff gravelly clay. The plateau is at least 2500 meters in diameter and stands out 5 meters above the surrounding seabed, thus forming a pronounced morphological phenomenon. At the fringes of the plateau on-lapping 'well stratified sub parallel reflectors; Low to medium reflective sediment' occur. These sediments could comprise glaciolacustrine/glaciomarine clay, silt and fine sand of the Dogger

Bank Member, though based on Laban's Top Pleistocene Formations map channel infill deposits of the Botney Cut Member are to be expected.

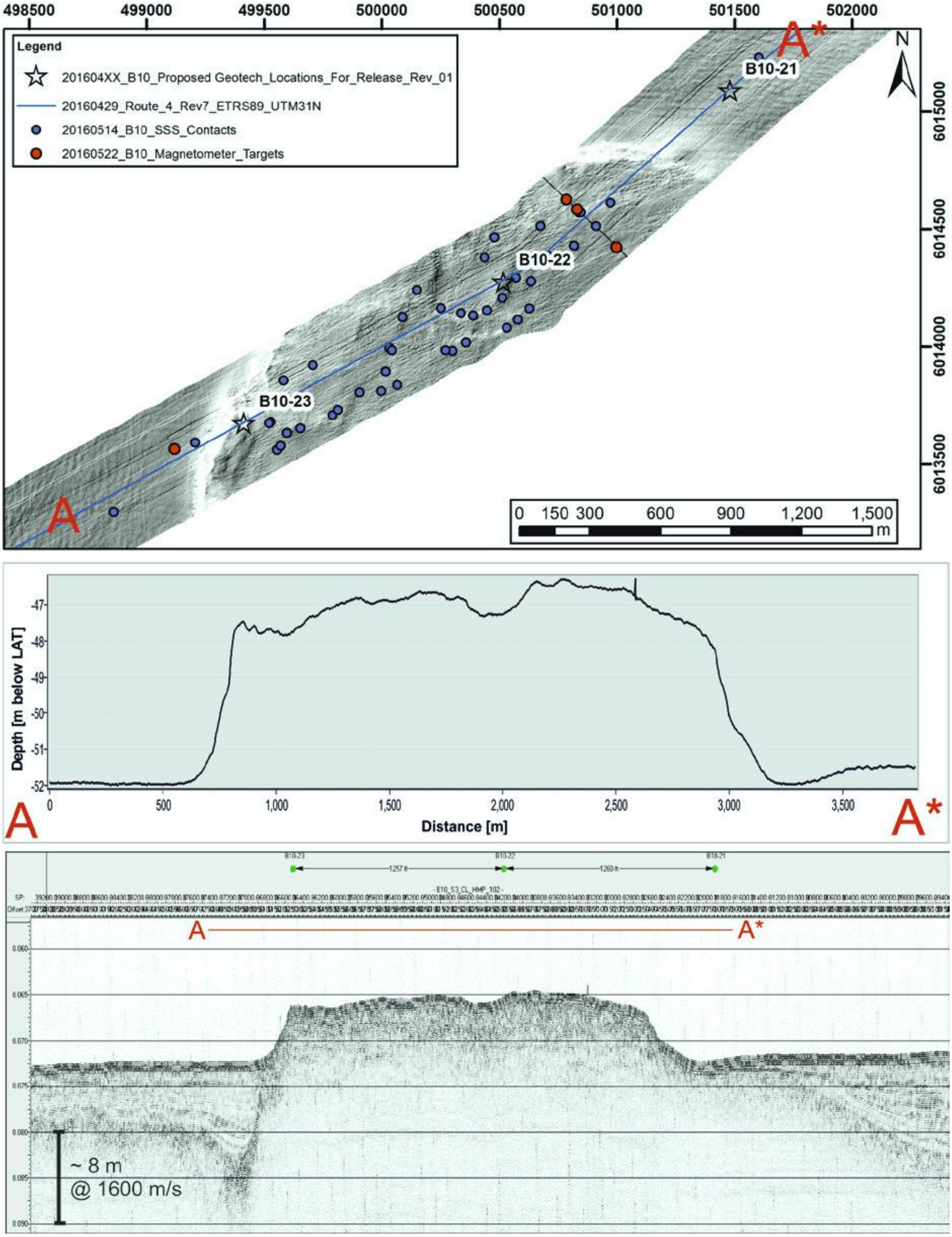


*Figure 20. Plateau-like outcrop of glacial till of the Bolders Bank Member fringed by on-lapping glaciolacustrine/glaciomarine silt and clay of the Dogger Bank Member; depth scale = m LAT*

Given their stratigraphical position it can be concluded that these layers of clay and silt are younger than the bordering and underlying glacial till of the Bolders Bank Member, regardless if they are part of the Dogger Bank member or Botney Cut Member. Supposedly the Bolders Bank Member has been deposited during Late Glacial Maximum, 20.000 years ago. The moment of retreat of the ice sheets from the North Sea area is not exactly known. It is thought by the end of the Allerød interstadial, approximately 13.000 years ago that glaciers had largely if not fully melted. Available sea level curves indicate that because of the marine transgression the landscape along the cable route drowned in Early Holocene times, between 12.000 and 10.000 years ago.

The glacial till left behind by the retreating glaciers must have formed a 2.5 kilometer wide inselberg which stood out in the landscape. The current height of this structure with respect to the surrounding seabed is five meter. Prior to the onset of the sedimentation in the surrounding areas the surface level of these surrounding areas even lay up to some fifteen meter lower than the top of the inselberg.

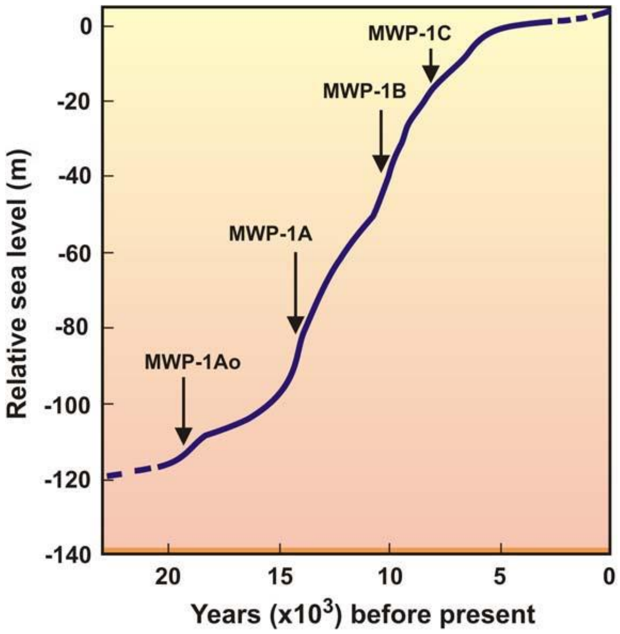


*Figure 21. Sea level rise over the past 20.000 years (Gornitz 2009)*

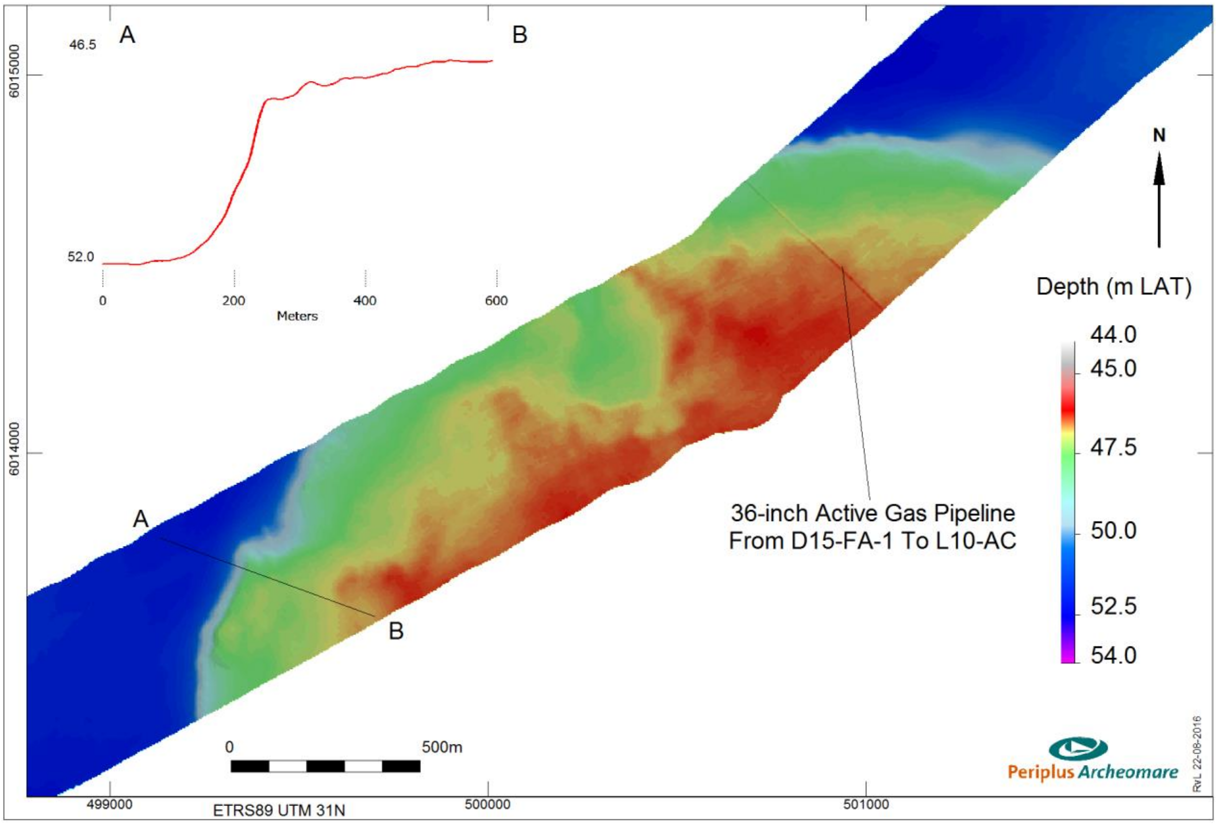


*Figure 22. Morphology of the seabed related to an outcrop of glacial till*

Another outcrop of glacial till is only slightly elevated with respect to the surrounding seabed. This structure consists of and admixture of gravel, sand, silt and clay and is 1500 meter wide. Fugro Survey has inferred bordering sediments as clay and silt which have resulted in 'well stratified sub parallel reflectors' in the seismic data. Large boulders have not been observed in the side scan sonar images.

# 5 Synthesis

Based on the results of de data analysis the research questions are answered.

with respect to side scan sonar, magnetometer and multibeam survey:

*Are there any phenomena visible on the seabed?*

Yes, the analysis of side scan sonar data resulted in the detection of 129 phenomena on the seabed.

Apart from the visible phenomena 142 magnetic anomalies have been observed.

If so:

*What is the description of these phenomena?*

The Fugro Survey classification of these phenomena is listed below.

| **Classification** | **Total** |
|---|---|
| Anchor Pullout Pit | 1 |
| Boulder | 62 |
| Debris | 50 |
| Depression | 2 |
| Existing well | 1 |
| Possible anchor | 1 |
| Scour Marks | 2 |
| Spudcan Depression | 3 |
| Unknown | 6 |
| Wreck | 1 |
| **Total** | **129** |

*Do these phenomena have a man-made or natural origin?*

The boulders 62 are considered to be of natural origin. The 2 depressions can be both man-made and natural. The remainder if the contacts (65) are considered to be man-made objects or morphological phenomena induced by man.

If these phenomena can be designated to be man-made:

*What classification can be attached?*

The wreck found by Fugro Survey is that of the *Windfjord* MV, a Norwegian motor cargo vessel foundered on the 17th September 2001. This wreck is known and registered in the NCN-database as number 2534 and is not considered to be of archaeological value.

Two contacts close to one another (B10_067 and B10_068) were annotated as debris by Fugro Survey and were interpreted by Periplus Archeomare as a possible wreck site. The possible wreck occurs as an object which appears to be partly covered with sediment which has resulted in scouring of the seabed. Along with another contact (B10_065) which was interpreted by Periplus as an unknown man-made object, these contacts are considered to be of potential archaeological value.

If these phenomena can be classified as archaeological:

*Is it possible to attach an interpretation to the nature of the archaeological objects and to prioritise importance?*

One of the archaeological objects is interpreted as possible wreck. The other contact is classified as unknown object. As very little is known about objects and related scouring observed is not advisable to prioritize between those objects in terms of archaeological value.

If these phenomena can be identified as natural:

*What is the nature of these natural phenomena?*

The contacts interpreted as natural phenomena are boulders, boulder areas, and natural deposits of boulder clay of Bolders Bank Member outcropping amidst a homogeneous sandy, silty or clayey flat seabed. Also acoustic phenomena have been observed which have been interpreted as shell ridges and/or reefs.

*Based on the acoustic image is it possible to designate zones of high, middle or low marine activity on the seabed?*

No, a distinction cannot be made. Water depth ranges from 42 to 57 meter LAT. The changes in water depths along the route are, with the exception of the outcrop of glacial till, gradual. In sections 7 and 8 the seabed is flat due to the absence of sedimentary structures with some sparsely scars of fishing trawlers. Towards the southwest of section 9 the amount trawling scars increases. An abundant occurrence of criss-cross trawler scars in a random direction in section 10 indicates that the morphology of the seabed is primarily shaped by trawling activities rather than by natural causes.

If so:

*How can these zones be interpreted?*

The natural sedimentary regime shows too little variation to define separate zones.

General:

*What is the relation between the observed objects and the topography of the seabed? Based on this relationship can risk-prone areas be marked selectively?*

The boulders identified are all related to a confined outcrop of glacial till which manifests itself as a pronounced geomorphic structure. This elevated plateau-like structure is 2500 meters wide and lies five meters higher than the surrounding seabed. Fugro Survey has proposed a rerouting of the cable in order to bypass the outcrop of glacial till, because boulder clay can potentially hamper the installation of the cable.

The seabed adjacent to the remainder of the contacts observed displays little or no scouring.

If no acoustic phenomena can be observed:

*Are there any clues that this is a consequence of either natural erosion, sedimentation or human interference?*

This question is not applicable.

<u>with respect to subbottom profiler- and sampling:</u>

*Based on seismic profiles and geotechnical data is it possible to map the Pleistocene landscape?*

Grids of seismostratigraphic / lithostratigraphic units which could be used to reconstruct and map the Pleistocene landscape were not available prior to the execution of this study. Examples presented in the Fugro Survey report do however give an impression of the stratigraphic units encountered and their genesis.

If so:

*What is the depth of the Pleistocene landscape compared to the present seabed?*

Along the Viking Link cable route the Pleistocene landscape is covered by a thin layer of Holocene deposits ranging in thickness from 0 - 3 meter. In the zones referred to by Fugro Survey as 'zone B' and 'zone C1' the thickness of the Holocene cover is fairly constant; on average less than 1 meter. In 'zone C2' variations are somewhat larger ranging from 0 to 3 meter.

*From Pleistocene to Holocene deposits is the transition gradual or instantaneous (erosive)?*

The Holocene cover consists of fine grained laminated soft deposits. The transition between Pleistocene and Holocene units appears instantaneous, but it is inferred that the Holocene sediments have gradually been deposited overtime in a calm non-erosive sedimentary regime. The presence of peat at the base of the Holocene cover in zone B supports this idea.

*Can zones be identified where prehistoric settlement remains can be expected?*

As was concluded in the desk study, strong varieties in the morphology of the landscape have proven attractive to prehistoric man. In this respect the elevated outcrop of boulder clay amidst the surrounding low-lying landscape would have provided preferred locations for the installation of camp sites. It is expected that from the boulder clay plateau (centre coordinate ETRS89 UTM31N: E500425, N6013845) Late Palaeolithic and Early Mesolithic hunters could oversee there hunting grounds and avail of cobbles and boulders from the clay for the production of their tools.

Skewed subcropping strata in zone B have been interpreted by Fugro Survey as Heligoland channel deposits, whereas Laban predominantly mapped the Boxtel Formation in this zone. In places the Pleistocene units have been covered by the Basal Peat Bed. Based on the desk study also humic clays of the Velsen Bed can be present at the base of the Holocene sequence. The data provided thus far do not suffice to pinpoint areas where deposits occur, like the Wierden Member, in which *in situ* remains of camp sites are to be expected. Up till now little is known of anthropogenic activities in this part of the Dutch Sector.

If so:

*Could these expected settlement remains be endangered by the installation of the cables based on their vertical position related to the seabed?*

The Viking Link cable has been rerouted north of the boulder clay plateau in the western part of zone C2. Remains related with the boulder clay outcrop and transition to surrounding low-lying areas are therefore not expected to be endangered by the installation of the cable. However, it is not known if subcropping boulder clays are present which occur near to the seabed surface. A grid of the top of the Bolders Bank Formation referenced to the current seabed would provide the information needed.

*Are there any indications observed on the seismic profiles for the presence of buried (man-made) objects?*

No phenomena were observed in the seismic data that indicate the presence of buried man-made objects.

If so:

*Based on the presence of buried objects and its correlation with side scan sonar, magnetometer and multibeam data can something be said about the nature of these buried objects?*

This question is not applicable.

*Are there any mitigating measures necessary to avoid disturbance of possible archaeological remains?*

Disturbance of possible archaeological remains have already been realized by rerouting the cable north of the boulder clay plateau. Information on shallow subcropping occurrences of the Bolders Bank and possible occurrences of the Boxtel Formation in section 7 is insufficient to exclude the presence of remains and concluding on the mitigating measures to be taken.

# 6 Recommendations

A large quantity of survey data (*side scan sonar, magnetometer* and *multibeam* echosounder) recorded within the survey corridor covering a total area of 99 $km^2$ were analyzed in order to conduct an archaeological assessment.

The current analysis of geophysical survey results is the second step in the archaeological assessment, following the desk study. The desk study has shown that only one object, the ship wreck *Windfjord* is known within the boundaries of the route corridor. This ship sunk in 1981 and is not considered to be of archaeological importance.

Apart from the ship wreck found, 128 other contacts were reported with side scan sonar. The analysis of these contacts resulted in a final selection of two unknown objects and structures which, based on their shapes and dimensions, may be of archaeological value. A summary of all objects with a possible archaeological expectation is listed in the table below.

| Nr | KP | Offset | ETRS_E | ETRS_N | L (m) | W (m) | H (m) | interpretation |
|---|---|---|---|---|---|---|---|---|
| B10_065 | 394.120 | -151 | 495436 | 6011324 | 21.3 | 12.6 | 0.4 | unknown object |
| B10_067/B10_068 | 403.423 | -107 | 487170 | 6007710 | 36.4 | 3.0 | 0.3 | possible wreck |

*Table 14. Summary of objects from sonar and multibeam with a possible archaeological value*

A map showing the distribution of the objects is presented in figure 23.

As long as the archaeological value of the objects is not determined, it is advised not to conduct cable lay operations which could affect the locations with possible archaeological objects including a buffer zone of 100 meters around. This also applies to anchorages of work vessels.

The buffer zone of 100 meters is a standard in the Netherlands that applies to the protection of cultural heritage. The reason to keep this distance is the fact that during offshore construction works the surrounding seabed can be disturbed by the use of anchors etcetera. This distance of 100 meters may be reduced if it can be substantiated that the applied disturbance has no effect on the archaeological object. For example, when no anchoring is used during cable lay operations the buffer zone can be decreased. Consent may be obtained after consultation with Rijkswaterstaat (authority) and their advisor the Cultural Heritage Agency.

A total of 142 magnetic anomalies have been observed. 57 of these anomalies can be related to known pipelines and cables. Three of the magnetometer anomalies can be related to side scan sonar contacts.

A total of 85 magnetic anomalies cannot be related to known pipelines and cables, or visible objects at the seabed surface. They are related to unknown ferrous objects buried in the seabed, covered by sediments. Ten of these anomalies have an amplitude of 50 nT or more and are presented in figure 23. Three of the anomalies lie within 100 meters of the proposed cable route.

Concerning these buried ferrous objects, it is advised to avoid such areas whilst laying the cables. It should be stressed that the origin of the magnetic anomalies is unknown and apart from possible archaeological remains any type of man-made objects can be encountered including unexploded ammunition, anchors, pieces of chains and cables, debris, etcetera.

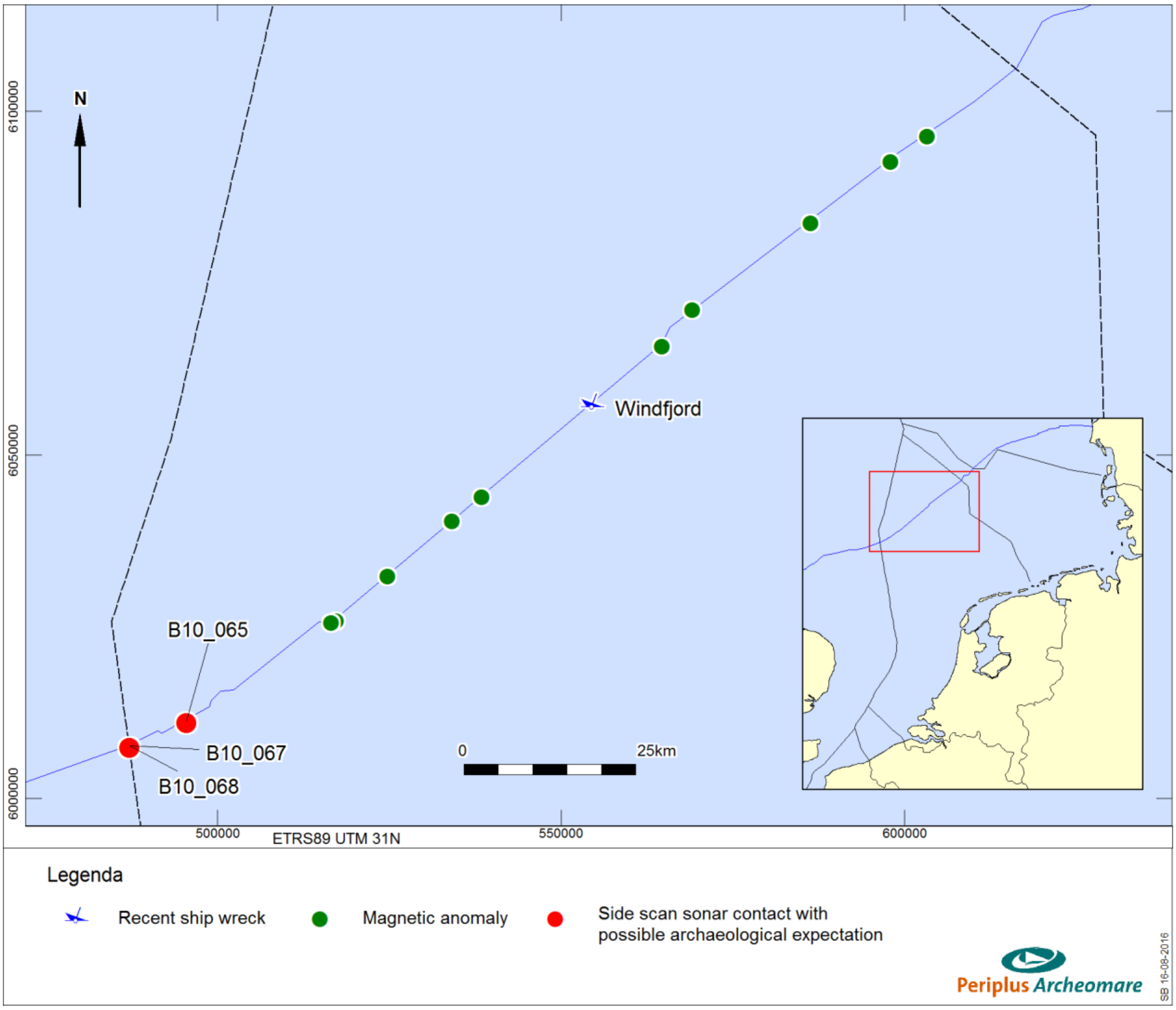


*Figure 23. Overview of the potential archaeological objects found with side scan sonar and magnetometer*

If it is not feasible to avoid the reported contacts with a possible archaeological expectation, additional research is required in order to determine the actual archaeological value of the reported locations.

When the seismic data have been processed into grids of the lithostratigraphic units encountered along the cable route it is advised to use these grids to identify and map areas in which remains of prehistoric camp sites are expected. This map can be used to select locations for bore hole sampling. These samples can be used for further research: formation evaluation, integrity of layer boundaries, the presence of palaeosols and archaeological remains (flint artifacts, burnt seeds, bone remains and charcoal concentrations), pollen and 14C-analysis. Additional research for prehistoric remains of camp site and their position in the Pleistocene landscape will be carried out in consultation with British and Danish researchers.

The risk of the cable intersecting units containing *in situ* prehistoric remains is assessed in Figure 24. As stated above when lithostratigraphic grids become available additional research of these data is needed to conclude on the areas in which prehistoric archaeological remains could be jeopardized by the installation of the Viking Link Interconnector cable. The assessment presented is therefore to be considered preliminary.

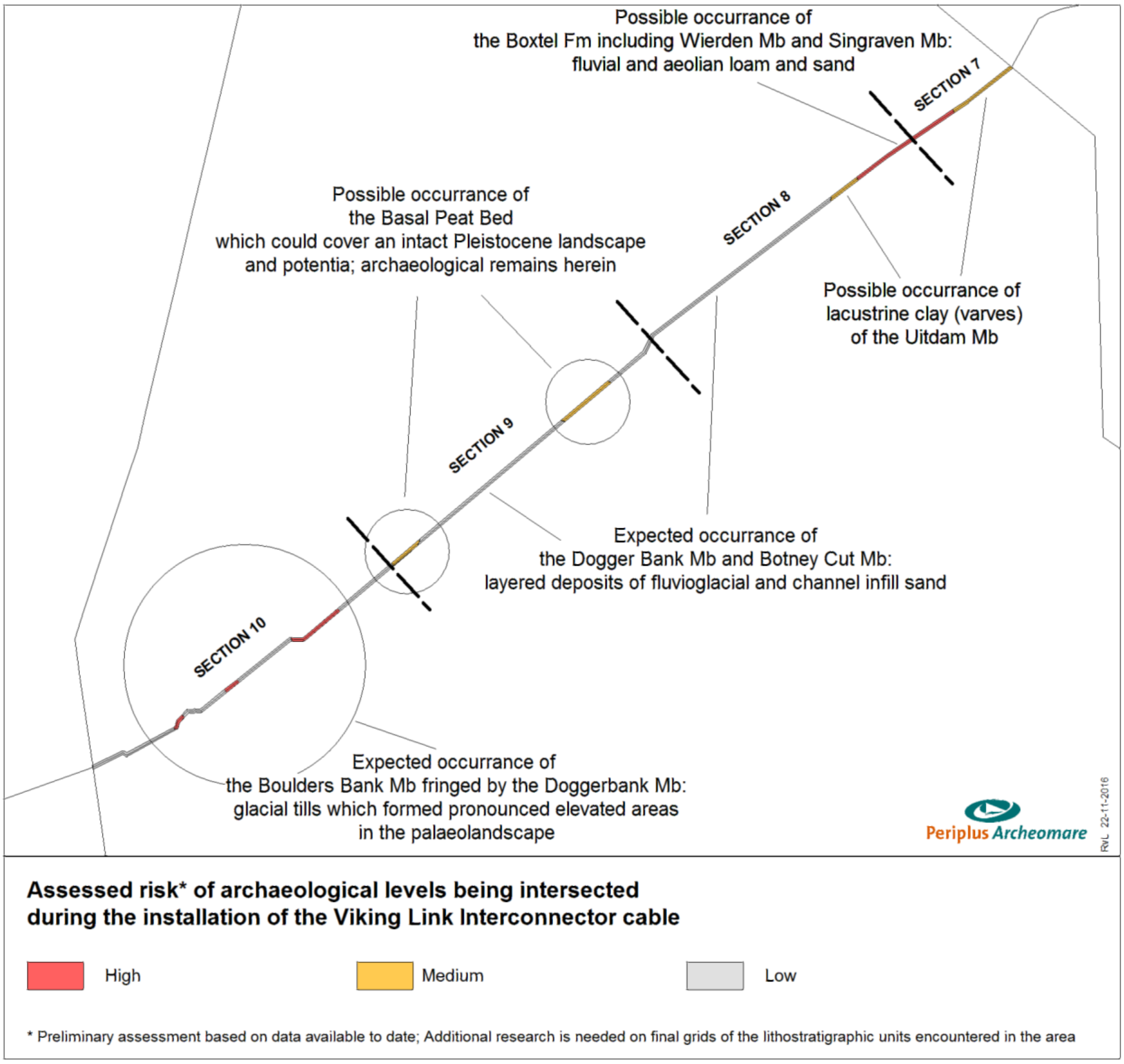


*Figure 24. Preliminary assessment for prehistoric remains to be jeopardized by the installation of the Vikiing Link Interconnector cable*

During the cable lay operations archaeological objects may be discovered which were completely buried or not recognized as an archaeological object during the geophysical survey. We recommend passive archaeological supervision based on an approved Program of Requirements. Passive archaeological supervision means that an archaeologist is not present during the execution of the work but always available on call. Following this recommendation would prevent delays during the work when unexpectedly archaeological remains are found. In accordance with the Dutch legislation (Erfgoedwet 2016), it is required to report those findings to the competent authority. This notification must also be included in the scope of work.

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# Glossary and abbreviations

| Terminology | Description |
| --- | --- |
| *AMZ* | Archeologische Monumenten Zorg, a description of procedures to ensure the protection of National archaeological Cultural Heritage |
| *CPT* | Cone penetration test |
| *Erratic* | An (glacial) erratic is a piece of rock that differs from the size and type of rock native to the area in which it rests. These rocks are carried by glacial ice, often over distances of hundreds of kilometres. Erratics can range in size from pebbles to large boulders. |
| *Ferreous* | Material which is magnetic or can be magnetized, and well known types are iron and nickel |
| *Holocene* | Youngest geological epoch (from the last Ice Age, around 10,000 BC. To the present) |
| *In situ* | At the original location in the original condition |
| *KNA* | Kwaliteitsnorm Nederlandse Archeologie |
| *Magnetometer* | Methodology to measure deviations from the earth's magnetic field (caused by the presence of ferro-magnetic = ferrous objects) |
| *Multibeam* | Acoustic instrument that uses different bundles or beams to measure the depth in order to create a detailed topographic model |
| *Pleistocene* | Geological era that began about 2 million years ago. The era of the ice ages but also moderately warm periods. The Pleistocene ends with the beginning of the Holocene |
| *PvE* | Programma van Eisen |
| *RCE* | Rijksdienst voor het Cultureel Erfgoed |
| *ROV* | Remotely Operated Vehicle |
| *Side scan sonar* | Acoustic instrument that registers the strength of reflections of the seabed. The resulting images are similar to a black / white photograph. The technique is used to detect objects and to classify the morphology and type of soil |
| *Current ripples* | Asymmetrical wave pattern at the seabed caused by currents. The steep sides of the ripples are always on the downstream side. |
| *Subbottom profiler* | Acoustic system used to create seismic profiles of the subsurface. |
| *Trenching* | Construction of a trench for the purpose of burying a cable or pipeline |
| *Vibrocore* | Vibrocore bore is a special drilling technique where a core tube is driven by means of vibration energy in the seabed. In addition, the core tube is provided with a piston so that the bottom material in the core tube remains in place. |

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**Atlases and Maps**

- GeoTOP-model Laag van Wijchen en Hollandveen Laagpakket
- Globale Archeologische Kaart van het Continentale Plat
- Noordzee atlas

**Sources from the Internet**

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- Dutch Federation of Aviation Archaeology (www.nfla.nl)
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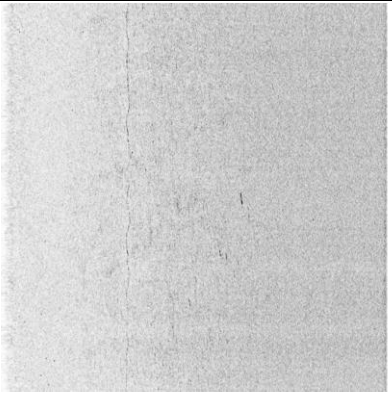
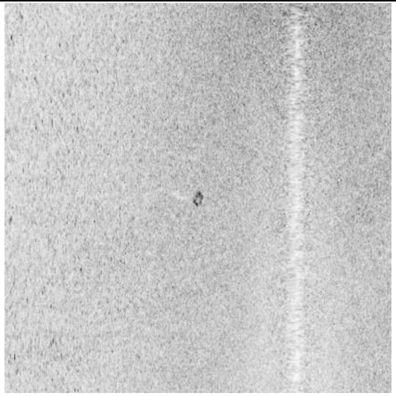
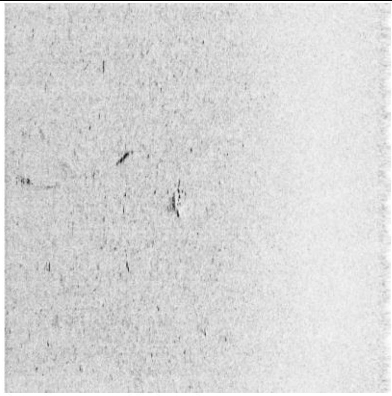
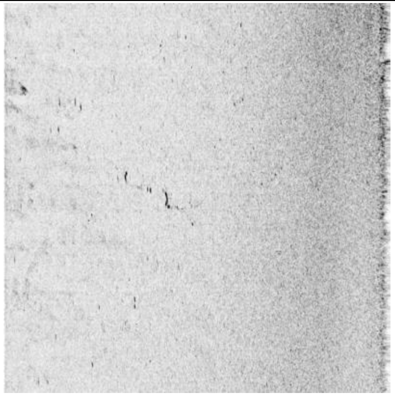
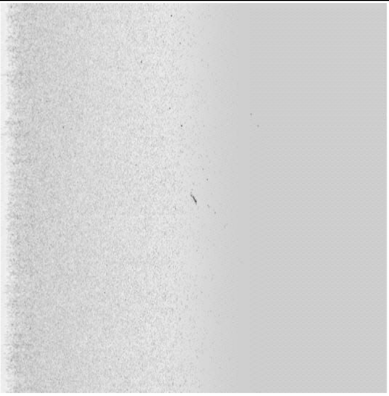
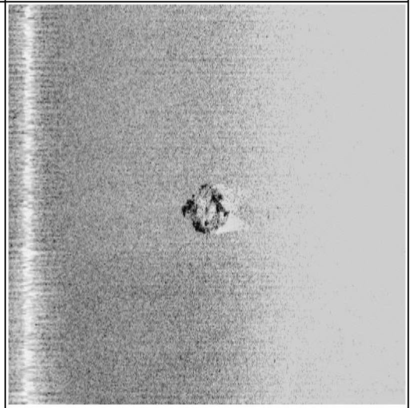
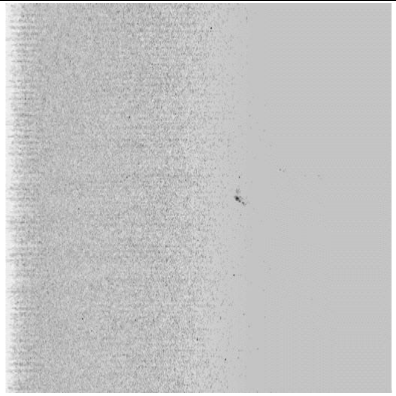
- Nationaal Contactnummer Nederland (NCN)
- Royal Dutch Navy, KLTZT J. Spoelstra
- SonarReg92, objectendatabase Rijkswaterstaat Noordzee en Delta

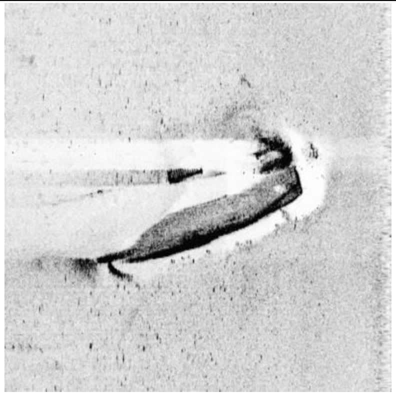
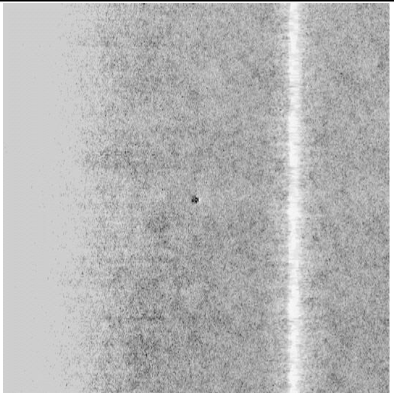
# Appendix 1. Listing of selected side scan sonar contacts

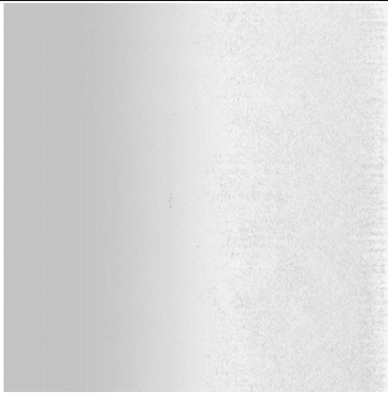
| Contact_ID | KP | Offset | Easting | Northing | Dimensions | Original description | Description after additional analysis | Final Interpretation | Side scan sonar image |
|---|---|---|---|---|---|---|---|---|---|
| B08_013 | 270.690 | 139 | 590735 | 6087780 | 4.3 x 0.6 x nmh | Debris | linear contact, hard reflection, no clear shadow | cable |  |
| B08_014 | 273.488 | 97 | 588538 | 6086047 | 4.8 x 3.9 x 0.4 | Debris | rectangular contact, moderate to hard reflection, amidst flat seabed, no clear shadow | unknown object |  |

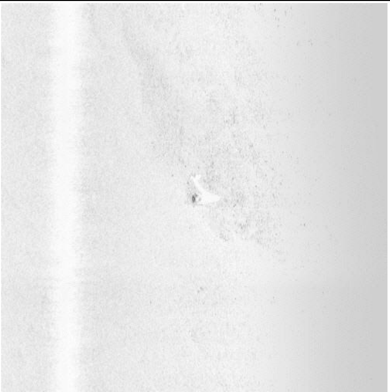
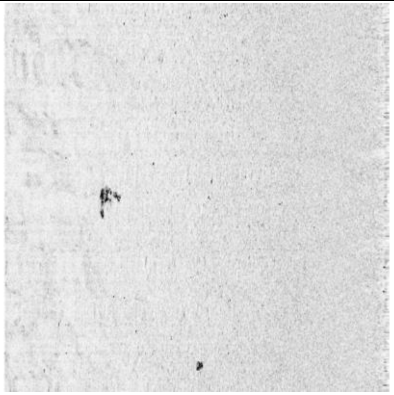
| Contact_ID | KP | Offset | Easting | Northing | Dimensions | Original description | Description after additional analysis | Final Interpretation | Side scan sonar image |
|---|---|---|---|---|---|---|---|---|---|
| B08_017 | 277.544 | 111 | 585307 | 6083595 | 6.2 x 4.9 x 0.5 | Boulder area | irregular contact within trawler mark, moderate reflection, no shadow | outcrop of natural sediments |  |
| B08_035 | 298.679 | -67 | 568621 | 6070622 | 11.6 x 4.7 x 0.3 | Debris | elongated contact amidst flat seabed, moderate reflection, no clear shadow | unknown object |  |

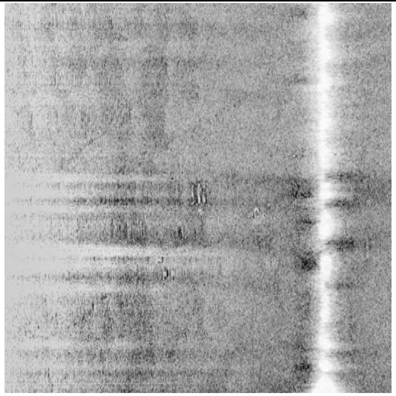
| Contact_ID | KP | Offset | Easting | Northing | Dimensions | Original description | Description after additional analysis | Final Interpretation | Side scan sonar image |
|---|---|---|---|---|---|---|---|---|---|
| B08_039 | 301.896 | -114 | 566093 | 6068632 | 16.1 x 2.7 x nmh | Debris | point and linear contacts, hard reflective amidst flat seabed | outcrop of natural sediments |  |
| B09_005 | 305.221 | 39 | 564344 | 6065934 | 7.3 x 1.0 x 0.2 | Debris | elongated contact, strong reflection, no clear shadow | unknown object |  |

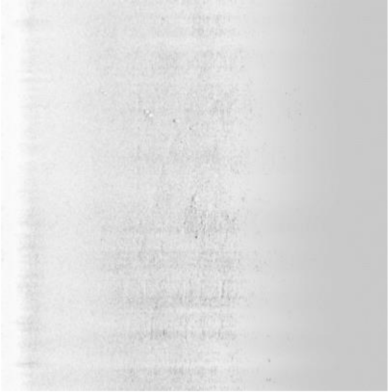
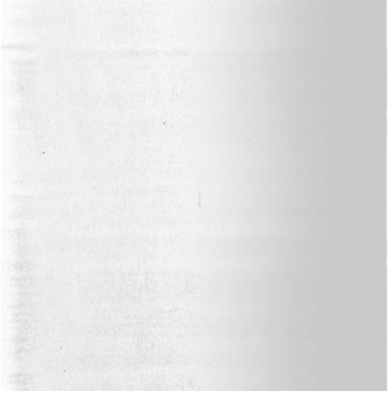
| Contact_ID | KP | Offset | Easting | Northing | Dimensions | Original description | Description after additional analysis | Final Interpretation | Side scan sonar image |
|---|---|---|---|---|---|---|---|---|---|
| B09_006 | 309.145 | -194 | 561494 | 6063228 | 18.7 x 11.0 x nmh | Debris | eye shaped contact with internal reflections; within a poor gain range of the sonar image | outcrop of natural sediments |  |
| B09_007 | 309.467 | -188 | 561243 | 6063025 | 5.4 x 8.5 x nmh | Debris | granular contact; moderate reflection | outcrop of natural sediments |  |

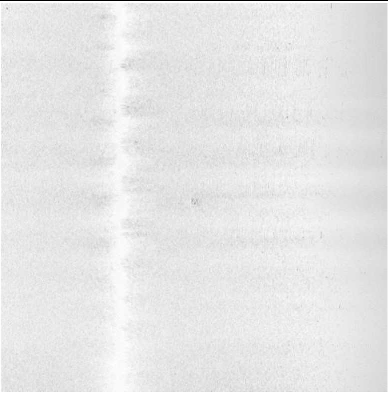
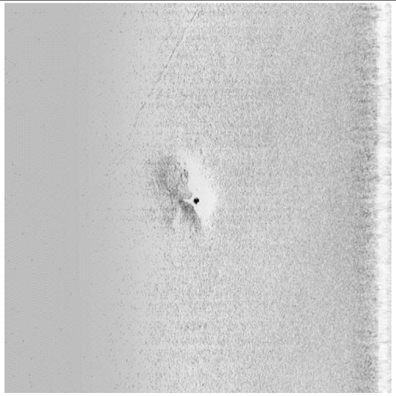
| Contact_ID | KP | Offset | Easting | Northing | Dimensions | Original description | Description after additional analysis | Final Interpretation | Side scan sonar image |
|---|---|---|---|---|---|---|---|---|---|
| B09_009 | 318.358 | -261 | 554489 | 6057243 | 74.9 x 36.5 x 2.2 | Wreck | pointed elongated contact, hard reflections, moederately hard homogeneous internal reflector, clear shadow, some scour | wreck |  |
| B09_012 | 338.262 | -34 | 539118 | 6044596 | 1.6 x 1.5 x 0.2 | Debris | round contact, hard reflection, no clear shadow | unknown object |  |

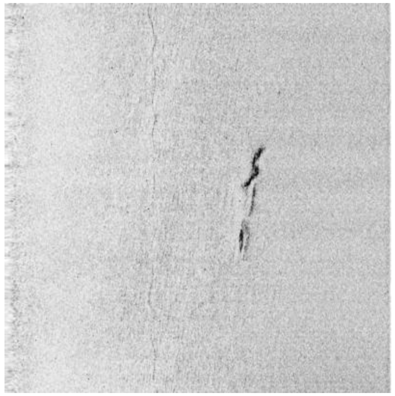
| Contact_ID | KP | Offset | Easting | Northing | Dimensions | Original description | Description after additional analysis | Final Interpretation | Side scan sonar image |
|---|---|---|---|---|---|---|---|---|---|
| B10_005 | 377.426 | -54 | 508585 | 6020718 | 4.7 x 1.5 x 0.2 | Other | elongated contact, weak to moderate intermitted reflection, no clear shadow | unknown object |  |
| B10_006 | 377.659 | -94 | 508428 | 6020540 | 8.4 x 2.0 x 0.2 | Debris | elongated contact, very hard reflection, comparable with seabed phenomena in the surrounding area | shells or reef |  |

| Contact_ID | KP | Offset | Easting | Northing | Dimensions | Original description | Description after additional analysis | Final Interpretation | Side scan sonar image |
|---|---|---|---|---|---|---|---|---|---|
| B10_007 | 379.753 | 147 | 506643 | 6019420 | 6.5 x 2.4 x 1.3 | Boulder area | spherical contact, moderate to hard reflection, clear shadow, part of seabed disturbance and outcrop of harder reflective sediments | boulder / boulder area |  |
| B10_008 | 382.95 | -275 | 504410 | 6017092 | 6.1 x 4.2 x 0.2 | Boulder area | patch of hard reflective material amidst flat weak reflective seabed | shells or reef |  |

| Contact_ID | KP | Offset | Easting | Northing | Dimensions | Original description | Description after additional analysis | Final Interpretation | Side scan sonar image |
|---|---|---|---|---|---|---|---|---|---|
| B10_020 | 387.933 | -1135 | 500816 | 6014429 | 2.4 x 1.5 x 0.7 | Boulder | spherical contact, moderate reflection, clear shadow, some scour | boulder / boulder area |  |
| B10_040 | 388.786 | -859 | 500031 | 6013995 | 5.5 x 4.5 x 0.2 | Boulder area | three elongated parallel contacts; clear short shadows | unknown object |  |

| Contact_ID | KP | Offset | Easting | Northing | Dimensions | Original description | Description after additional analysis | Final Interpretation | Side scan sonar image |
|---|---|---|---|---|---|---|---|---|---|
| B10_044 | 388.943 | -960 | 499997 | 6013812 | 6.0 x 4.7 x 0.2 | Boulder area | cluster of point contacts and small spherical contacts, partly with clear shadows | boulder / boulder area |  |
| B10_060 | 389.746 | -665 | 499569 | 6013578 | 4.3 x 0.5 x 0.1 | Debris | straight elongated contact, clear hard reflection, no shadow | beam |  |

| Contact_ID | KP | Offset | Easting | Northing | Dimensions | Original description | Description after additional analysis | Final Interpretation | Side scan sonar image |
|---|---|---|---|---|---|---|---|---|---|
| B10_063 | 390.202 | -68 | 498858 | 6013296 | 1.2 x 1.4 x 0.2 | Debris | U-shaped contact, clear reflection, weak shadows | anchor |  |
| B10_065 | 394.12 | -151 | 495436 | 6011324 | 1.9 x 1.5 x 0.3 | Boulder | round contact with hard reflection and clear shadow amidst drop-shaped area with moderate reflection, behind depression | unknown object |  |

| Contact_ID | KP | Offset | Easting | Northing | Dimensions | Original description | Description after additional analysis | Final Interpretation | Side scan sonar image |
|---|---|---|---|---|---|---|---|---|---|
| B10_067 | 403.423 | -107 | 487170 | 6007710 | 13.9 x 3.3 x 0.3 | Debris | intermitted elongated contact; clear reflections, no shadow, comprising B10_0067 and B10_0068 | wreck |  |
| B10_068 | 403.443 | -111 | 487153 | 6007698 | 9.0 x 3.3 x 0.2 | Debris | intermitted elongated contact; clear reflections, no shadow, comprising B10_0067 and B10_0068 | wreck | See B10_067 |

# Appendix 2. Listing of selected magnetometer contacts > 50 nT

| Contact_ID | KP | Offset | Easting | Northing | nT/m | Comments |
|---|---|---|---|---|---|---|
| B07_MAG_092 | 255.304 | -203 | 603336 | 6096596 | 72 | Unknown anomaly |
| B08_MAG_007 | 261.823 | -198 | 597984 | 6092899 | 723 | Unknown anomaly |
| B08_MAG_017 | 276.459 | -199 | 586357 | 6084008 | 173 | Unknown anomaly |
| B08_MAG_028 | 297.772 | 197 | 569181 | 6071383 | 59 | Unknown anomaly |
| B09_MAG_007 | 304.889 | -127 | 564706 | 6066021 | 54 | Unknown anomaly |
| B09_MAG_020 | 339.069 | -11 | 538484 | 6044095 | 112 | Unknown anomaly |
| B09_MAG_031 | 344.598 | 121 | 534171 | 6040635 | 64 | Unknown anomaly |
| B10_MAG_003 | 356.924 | 12 | 524812 | 6032611 | 17341 | Unknown anomaly |
| B10_MAG_008 | 366.868 | -126 | 517295 | 6026102 | 63 | Unknown anomaly |
| B10_MAG_009 | 367.639 | 6 | 516586 | 6025805 | 162 | Unknown anomaly |

# Appendix 3. Phases of maritime archaeological research

The care for cultural heritage is legally required according to Dutch law. In order to comply with the requirements, all procedures and requirements for the archaeological research process haven been incorporated in the Dutch Quality Standard for Archaeology (KNA waterbodems, version 3.2). Below a brief description of the steps involved:

1. **Desk study**
   The purpose of a desk study is to collect and report all available historical data, geological information and information about disturbances in the past. The result is an archaeological expectation map or model.
   The desk study may be expanded with an analysis of sonar and multibeam data, if available.

   **IF** the outcome of the desk study shows that there is a risk of occurrence of archeology, then the next phase must be carried out:

2. **Exploratory field research (opwaterfase)**
   In order to test the archaeological expectation, a geophysical survey is carried out. The type of survey depends on the type of expected objects, local geology and expected depth of the objects below the seafloor. In practice, the research usually consists of a side scan sonar survey, if necessary, supplemented with multibeam echosounder recordings, subbottom profiling and magnetometer measurements. The requirements of the survey are based on the desk study and should be included in a program of requirements which must be approved by the competent authorities.

   **IF** potential archeological objects are found, then the next phase must be carried out:

3. **Exploratory field research (onderwaterfase verkennend)**
   The suspected sites are investigated by specialized divers in order to identify the objects. The requirements of the underwater research are included in a program of requirements which must be approved by the competent authorities.

   **IF** as site is identified as an archaeological object or structure then the next phase must be carried out:

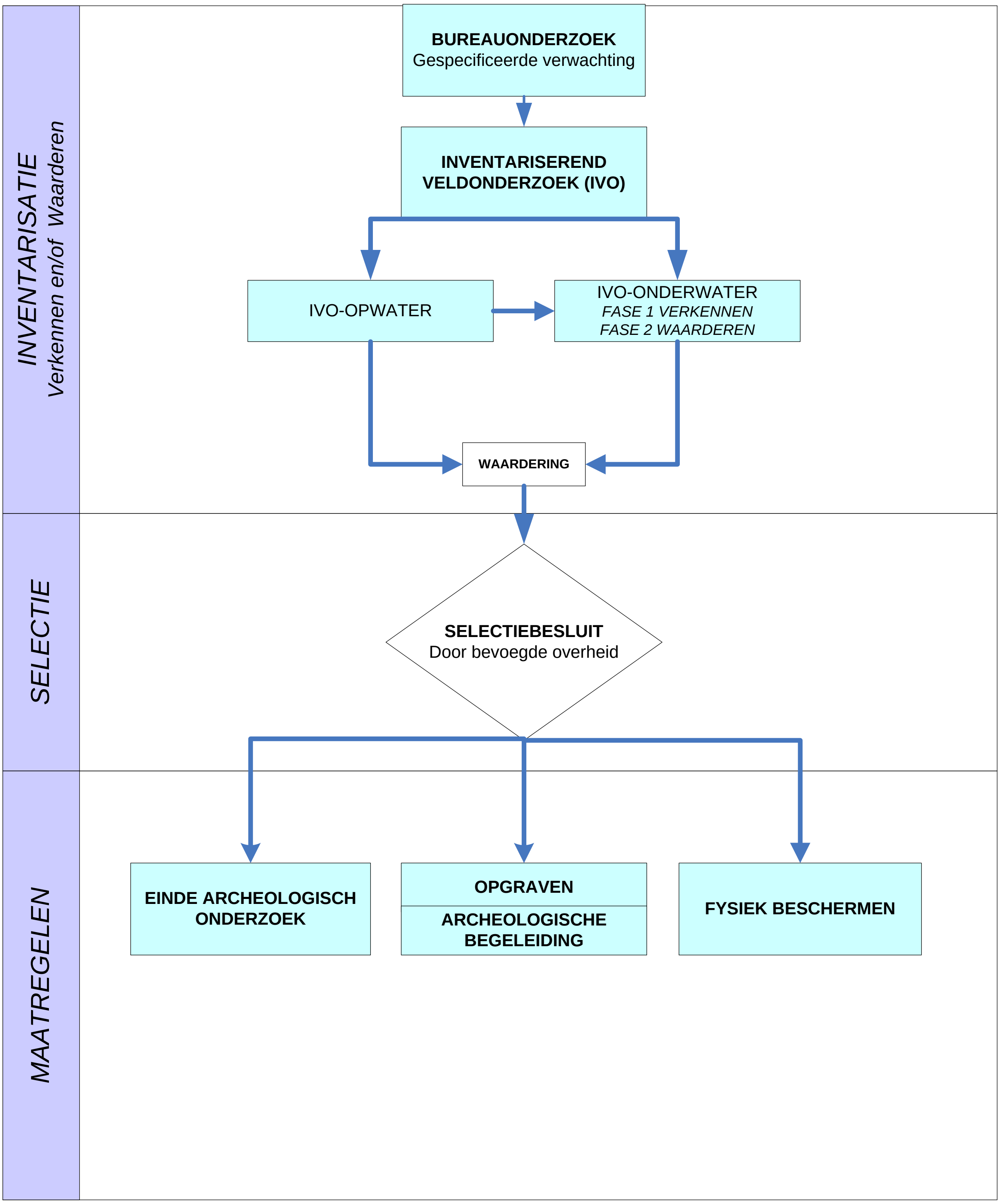
4. **Appreciative field research (onderwaterfase waarderend)**
   The archaeological remains at the site are thoroughly investigated and mapped by a specialized archaeological diving team and samples are collected for additional research. Then a decision will be made whether the archaeological remains are worth preserving. If the latter is the case, then there are two possibilities: either the remains can be preserved in situ (adjustment of plans) or the next phase will be conducted:

5. **Archaeological excavation**
   The archaeological remains are excavated under supervision of a senior maritime archaeologist. All remains need to be documented, registered and conserved. The requirements of the underwater research are included in a program of requirements which must be approved by the competent authorities.

The phases described above contain a number of decision points that are dependent on the detected archeological objects. The figure on the next page shows these moments schematically.

## Schematic overview KNA Waterbodems version 3.2

(AMZ cycle in Dutch)



# Viking Link – Advice National Committee Environmental impact Assesment (NCEA)

VKL-07-30-J800-028

March 2017

Co-financed by the European Union
Connecting Europe Facility

# Appendix 5: Addressing comments NCEA in EIA

The Viking Link project decided to request advice from the EIA Commission at the scoping stage of the EIA. The table below presents the advice from the EIA Commission received in September 2016, and where such advice has been included within the Environmental Impact Report.

| Aspect | Guideline / Advice | EIA Reference |
|---|---|---|
| 1. Essential information in the EIA | A clear description and motivation of the different installation alternatives with special attention to the legal constraints based on the four jurisdictions. | Chapter 3 |
| | Insight into the risks of exposing and damaging of the cable, possible mitigation measures and a description of the impact of these mitigation measures. | Section 5.4.69 and Chapter 6.7.3 and 13.7.10 |
| | A description of the impact on Nature 2000 areas ''Doggersbank'' and ''Klaverbank'', the central Oyster Grounds and protected species. | Chapter 9 |
| | A summary of the EIA. The summary needs to be an independent document with an accurate reflection of the content of the EIA. | "Summary" |
| 2. Background information, policy/framework and decision making process | Describe the importance of the Viking Link interconnector. Elaborate on expected economic and environmental benefits (such as reduction of CO2 emissions). Also describe the potential contribution of the Viking Link interconnector to the growth of sustainable energy in general and specifically to the development of offshore wind farms. | Section 1.2 |
| | Describe in the EIA the legal and policy constraints from these three jurisdictions that are applicable to the Dutch route. | Section 2.1.4 in table 2.2 the required consents and permits in the four jurisdictions are listed |
| | Pay attention to the following frameworks in relation to the initiative: | |
| | The European Marine Strategy Framework Directive (KRM), which provides a legal framework for the protection and restoration of the European seas and oceans by 2020. | Section 2.2 |
| | The OSPAR Convention for the protection of the marine environment of the North-Eastern part of the Atlantic Ocean. | Section 2.2 |

| | | |
|---|---|---|
| | The ASCOBANS agreement for the conservation of small whales in the Baltic and North Sea. | Section 2.2 |
| | The Act Nature Conservancy, which replaces on the first of January 2017 among others: the Nature Conservancy Act 1998 and the Flora and Fauna Act. | Chapter 2.3 |
| | Describe the procedural coordination, in relation to the applicable permits in the Netherlands and for the total route of the Viking Link interconnector, specify: | Chapter 1 and 2 procedure for the Netherlands mentioned in Section 1.3. Coordination for total route is described in Chapter 2 |
| | What decisions should be taken in the four jurisdictions, what is their relation with the EIA- procedure and how is coordination arranged between them. | See table 2.2 with an overview of the required consents and permits<br>See also table 2.1 with an overview of the competent authorities |
| | Which uncertainties occur in the decision making process. | Chapter 2<br>See Sections below table 2.2 |
| | Who is the competent authority for the different decisions and what is the global time schedule? | Chapter 1<br>See Section 1.4.16 on initiators, competent authorities and stakeholders<br>Global timeline is included in Section 4.10.2 in Figure 4.7 |
| 3. Intended activities and alternatives | Summarize the following on route alternatives: | |
| | How have the different route alternatives been developed? | Section 3.3 |

| | | |
|---|---|---|
| | Which criteria are used to assess the route options? | Section 3.3 |
| | What considerations have led to the selection of the preferred alternative for which a project-EIA is currently being drafted. | Section 3.3 |
| | The installation alternatives for the Viking Link Interconnector need to be described in the EIA when these are relevant for the assessment of environmental impacts. Installation alternatives should focus on: | |
| | The possible installation methods as described in table 3 of the SD. | Chapter 4 |
| | The technical considerations in relation to the burial depth of the cable and the distance between the two cables. | Chapter 4 |
| | Elaborate on the following aspects: | |
| | The risks associated with cable- and pipeline crossings. How to deal with those risks for the Viking Link Interconnector. | Section 5.4.69 and Chapter 6.7.3 and 13.7.10<br>**The design of the crossings are overtrawlable** |
| | What are the possible measures to prevent (the chance of) cable damage through trawling or emergency anchors or exposure by erosion. | Section 5.4.69 and Chapter 6.7.3 and 13.7.10 |
| | Temporary and permanent facilities for installation and maintenance of the cable. | Chapter 4 |
| | What are the opportunities to optimize the Viking Link Interconnector from an environmental point of view. Try to use experiences of other cable projects and refer in the EIA to used data of experience. | Chapter 3 and 4<br>Section 3.3.17 and 4.8.3 |
| 4. Environmental impacts | Describe the  seriousness of impacts in terms of  character, extent, duration, scope, reversibility, possibilities for mitigation and/or for compensation. | Chapters 6 and 9 till 13 |
| | Describe the uncertainties and inaccuracies of the used data and of methods used to determine effects. Elaborate on their consequences for the assessment of effects and for the distinction between alternatives. Particularly focus on environmental impacts which strongly influence the decision making process on the proposed project. | Sections 7.1 |
| | Make the scoring process of environmental impacts verifiable by adding used data to the appendix or by referencing to available background material. | appendix<br>references are include in the Chapters in last Section |

| | | |
|---|---|---|
| | Particularly elaborate on the effects that differ for each of the alternatives and/or effects (almost) exceeding target values. | part B EIA |
| | A chapter should be added on the cumulative effects of the entire proposed project. | cumulative effects mentioned for ecology in Section 5.4.72 and in 9.3.26 |
| | The installation of the marine cable will cause disturbance of the seabed through anchoring, burial of the cable and an increase of floating particles. Indicate whether it is possible to rule out such a situation from occurring. If this situation cannot be ruled out, elaborate on the duration and extent of the changes and on the amount of floating particles. | Section 5.4, Chapter 8 and 9 |
| | Describe the effects on nature that may occur during the installation and exploitation phases. | Chapter 5 and 9 |
| | If applicable, include the appropriate assessment (on Natura 2000 protected areas) specifically in the EIA. | Chapter 9 appropriate assessment is not required (14.1.5) |
| | Based on external effects, (cumulative) effects may occur in nearby protected areas in the British and German EEZ and for Natura2000 protected area 'Friese Front', these areas should also be considered. | cumulative effects mentioned for ecology in Section 5.4.72 and in 9.3.26 |
| | Pay special attention to the consequences for the structure and function of habitat type H1170 (riffs at open sea)[1], one of the conservation objectives of the Natura2000 protected area 'Klaverbank'. Particularly on the 'Klaverbank', the impacts of turbidity should be taken into account, because it is one of the clearest areas in the Dutch North Sea. Include the consequences for typical species in the impact assessment as part of the qualitative assessment. | Section 9.3.7, 14.2.2 |
| | The Viking Link cable crosses the Klaverbank, the EIA should indicate what this means for the conservation objectives of the area and for the cable route. | Chapter 9 |
| | Indicate the impact of the proposed project on the diversity, density and biomass of seabed species in the Central Oyster Grounds. Also elaborate on the presence of vulnerable, rare and long living species | Chapter 9 |

[1] See www.rijksoverheid.nl/documenten/besluiten/2015/09/21/aanwijzingsbesluit-natura-2000-gebied-klaverbank

| | | |
|---|---|---|
| | Elaborate on the consequences of the proposed project on the ocean quahog (*Artica islandica* ) living the area northwest of the Central Oystergrounds and south of the Doggersbank. | Chapter 9.7.32 the ocean quahog is mentioned and sensitivities are mentioned |
| | When relevant, elaborate on the impact of the proposed project on the status of conservation for marine mammals, birds and fish. Thereby, specify the stage of life wherein each species is most vulnerable to the effects of the installation of the cable in particular. Examples include the period of birth among Harbour porpoises and the molting period of the Common murre and other seabirds. Describe also measures to minimize these impacts. | Chapter 9 All stages of life are included in the assess-ment |
| | Elaborate on the consequences of changes in the electromagnetic fields caused by the presence of the cables. This implies both changes in the local magnetic field and changes of electric fields induced by water currents through the magnetic field. Quantify the extent of the fields. Describe possible impact on species who are sensitive to changes in the electromagnetic field and identify potential measures to prevent this. | Chapter 3 and 4<br>Section 3.3.17 and 4.8.3 |
| 5. evaluation, monitoring and presentation | Recommends to include an initial evaluation programme in the EIA enabling a coupling between (the reduction of) uncertainties in expected effects and the evaluation research that will be conducted at a later time. | Section 7.2 |
| | The Commission recommends to elaborate on the possibilities and desirability to set up a monitoring programme during the exploitation phase in case of damage due to the release of the cable. If changes in electric and magnetic fields are expected to have an impact on the migration of maritime organisms, a monitoring programme on these effects is also recommended. | Section 7.2 |
| | The EIA should be brief, for example by excluding background details from the main Chapters, but adding this information to the appendix. | all Chapters |
| | A glossary of terms, a list of abbreviations and a reference list are included | included |
| | Recent and legible maps are used, with a clear legend and readable topographic names. | all Chapters |

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# Samenvatting MER

VKL-07-30-J800-072

Maart 2017

Medegefinancierd door de Europese Unie
De financieringsfaciliteit voor Europese verbindingen

# Inhoud



## Overzicht van tabellen

## Overzicht van figuren

# 1 Inleiding

## 1.1 Overzicht

1.1.1 Het voorgenomen Viking Link-project betreft een hoogspanningsgelijkstroomverbinding (High Voltage Direct Current, HVDC) met een capaciteit van ca. 1400 megawatt (MW) waarmee elektriciteit zal worden getransporteerd tussen de transmissiesystemen van Denemarken en het Verenigd Koninkrijk. Deze verbinding doorkruist de Exclusieve Economische Zones (EEZ) van het Verenigd Koninkrijk, Nederland, Duitsland en Denemarken.

1.1.2 Het project is zodanig geconfigureerd dat elektriciteit afwisselend in beide richtingen kan stromen, afhankelijk van vraag en aanbod in beide landen.

1.1.3 De voorgestelde verbindingspunten van het project zijn Bicker Fen in het graafschap Lincolnshire (Verenigd Koninkrijk) en Revsing in Jutland (Denemarken). De totale tracélengte van het offshore-deel van de interconnector bedraagt ca. 635 km. De kabellengte in de Nederlandse Exclusieve Economische Zone (EEZ) is ca. 170 km; het project omvat twee onderzeese HVDC-kabels, een optionele glasvezelkabel voor beheerdoeleinden, optionele steenbestorting, kabelmoffen en diverse materialen om kruisingen met andere onderzeese pijpleidingen/kabels te realiseren.

1.1.4 Het Project wordt gezamenlijk ontwikkeld door National Grid door middel van National Grid Viking Link limited (NGVL) en Energinet.dk (ENDK), de Deense hoogspanningsnetbeheerder.

1.1.5 Nadat alle vergunningsaanvragen zijn ingediend, zal het Viking Link Bridging Document worden gepubliceerd. In dit onafhankelijke document zijn alle milieueffecten van het volledige 'end-to-end'-project en de vereiste vergunningen samengevat.

### Nut en noodzaak van het project

1.1.6 Het Project sluit aan bij de doelstelling van de Europese Commissie om een geïntegreerde energiemarkt te realiseren die een optimale prijs-kwaliteitverhouding biedt voor consumenten. De Viking Link-verbinding maakt efficiënter gebruik van hernieuwbare energiebronnen mogelijk en verbetert de leveringszekerheid van elektriciteit en de toegang tot hernieuwbare energiebronnen (duurzaam opgewekte elektriciteit). Daarmee komt het project de sociaal-economische situatie in zowel Denemarken als het Verenigd Koninkrijk ten goede.

1.1.7 De voorgestelde verbinding heeft de status van 'project van gemeenschappelijk belang' (Project of Common Interest, PCI) gekregen. Voor een PCI-project zijn de richtsnoeren voor de trans-Europese energie-infrastructuur (TEN-E), Verordening (EU) Nr. 347/2013 van toepassing. Hiermee wordt het erkend als een belangrijk project, dat van essentieel belang is voor de versterking van de Europese interne energiemarkt en voor het realiseren van de doelstellingen van het energiebeleid van de EU, te weten betaalbare, betrouwbare en duurzame energie. Het

Ministerie van Economische Zaken is het nationale bevoegde gezag voor de TEN-E-verordening in Nederland.

1.1.8 Het project zal bijdragen aan het Klimaat- en Energiekader 2030 van de EU, dat de volgende doelen omvat:

- Een afname van 40% in de uitstoot van broeikasgassen ten opzichte van het niveau van 1990.
- Hernieuwbare energiebronnen hebben een aandeel van ten minste 27% in het totale energieverbruik.
- Een energiebesparing van ten minste 27% ten opzichte van het 'Business as Usual'-scenario.

Voordelen

1.1.9 De voordelen van de Viking Link-verbinding kunnen als volgt worden samengevat:

- **Energiezekerheid:** Door elektriciteitshandel tussen het Verenigd Koninkrijk en Denemarken mogelijk te maken, draagt de Viking Link-interconnector bij aan de leveringszekerheid en de diversiteit van het elektriciteitsaanbod in beide landen.
- **Elektriciteitsprijzen:** De grotere mogelijkheden voor het Verenigd Koninkrijk en Denemarken om handel te drijven op de Europese energiemarkten zullen bijdragen aan een drukkend effect op de groothandelsprijzen voor elektriciteit.
- **Ondersteuning voor hernieuwbare energiebronnen:** Om de nationale en internationale doelstellingen op het gebied van duurzame energie en klimaatverandering te behalen, wekken het Verenigd Koninkrijk en Denemarken meer energie op uit hernieuwbare energiebronnen, waaronder offshore-windenergie. De opwekking van windenergie is van nature wisselend, en interconnectoren bieden een effectieve manier om met deze vraag- en aanbodschommelingen om te gaan.

## 1.2 Vergunningsprocedure

1.2.1 Voor de aanleg en exploitatie (inclusief onderhoud en reparaties) van de Viking Link-verbinding zijn in Nederland twee vergunningen vereist: een watervergunning en een vergunning op grond van de Wet natuurbescherming (in werking getreden op 1 januari 2017, en heeft de Flora- en faunawet en de Natuurbeschermingswet 1998 vervangen). Voor beide vergunningen is een m.e.r.-procedure verplicht. De procedures voor de watervergunning en de vergunning op grond van de Wet natuurbescherming, evenals de PCI-procedure, worden gecoördineerd door het Ministerie van Economische Zaken.

M.e.r.-procedure

1.2.2 Het milieueffectrapport biedt informatie over de mogelijke milieueffecten waarmee rekening moet worden gehouden in het besluitvormingsproces over de toepasselijke vergunningen. De Wet milieubeheer en het Besluit milieueffectrapportage onderscheiden m.e.r.-plichtige activiteiten en m.e.r.-beoordelingsplichtige activiteiten (in het laatste geval zullen de beoogde activiteiten naar verwachting niet leiden tot significante effecten). Bijlage C bevat een overzicht van m.e.r.-plichtige activiteiten en Bijlage D bevat een overzicht van m.e.r.-beoordelingsplichtige activiteiten. Een m.e.r.-beoordeling is een procedure om te bepalen of er al dan niet een volledig milieueffectrapport moet worden opgesteld voor het project.

1.2.3 Aangezien de Viking Link-verbinding een gevoelig Natura 2000-gebied (Klaverbank) over een lengte van meer dan 5 kilometer doorkruist, is het project m.e.r.-beoordelingsplichtig. Om te voorkomen dat in een later stadium een volledige m.e.r.-procedure moet worden uitgevoerd, is voor het project echter een volledig milieueffectrapport opgesteld. Het milieueffectrapport is opgesteld als integraal onderdeel van de aanvraag van de watervergunning.

### Voortoets en beoordeling van eventuele verslechteringseffecten

1.2.4 Een voortoets is uitgevoerd om te bepalen of het Viking Link-project significante effecten heeft op het aangewezen Natura 2000-gebied Klaverbank (dat door het voorkeurstracé wordt doorkruist) en de Doggersbank (extern effect). Aangezien hierin is geconcludeerd dat er geen significant negatieve effecten worden verwacht, heeft het bevoegd gezag bevestigd dat er geen passende beoordeling (PB) vereist is. Ter ondersteuning van de voortoets is echter tevens een verslechteringstoets uitgevoerd en is een vergunning aangevraagd in het kader van de Wet natuurbescherming.

### Inspraak en advies

1.2.5 Conform de vereisten van de TEN-E-verordening en de PCI-status van het project heeft van 1 juli tot en met 18 augustus 2016 een inspraakperiode plaatsgevonden. Op 6 juli 2016 was er een openbare bijeenkomst in Den Haag.

1.2.6 In het kader van de m.e.r.-procedure is een Notitie Reikwijdte en Detailniveau gepubliceerd; deze heeft ter inzage voor het publiek gelegen van 2 september tot en met 13 oktober 2016. Ook de Nederlandse Commissie voor de m.e.r. (‘Commissie m.e.r.’) heeft advies gegeven over de Notitie Reikwijdte en Detailniveau.

1.2.7 Belanghebbenden en burgers hebben de gelegenheid gehad om te reageren op het voorgenomen project evenals de reikwijdte en het detailniveau van de milieueffectrapportage, en om eventuele zorgen te uiten die zij van belang achten voor de m.e.r.-procedure.

1.2.8 Het milieueffectrapport is onderdeel van de aanvraag van de watervergunning en de vergunning op grond van de Wet natuurbescherming en wordt voor een periode van zes weken ter inzage en feedback van het publiek gelegd. Kijk voor meer informatie over het Viking Link-project op de volgende websites: www.bureau-energieprojecten.nl en www.viking-link.nl.

## 1.3 Doel van milieueffectrapport

1.3.1 Het doel van een milieueffectrapport is om ervoor te zorgen dat er rekening wordt gehouden met milieubelangen in het besluitvormingsproces rond plannen en projecten. Het milieueffectrapport biedt daarom informatie over de milieueffecten van een project of activiteit, evenals de redelijke alternatieven[1]. Deze worden op een systematische, transparante en objectieve manier weergegeven; waar nodig worden maatregelen beschreven om de risico's te beperken of eventuele negatieve gevolgen van het project te compenseren. De beoordelingen omvatten tevens cumulatieve effecten met andere projecten evenals grensoverschrijdende effecten.

1.3.2 Het Ministerie van Infrastructuur en Milieu en het Ministerie van Economische Zaken hebben de milieu-informatie in het milieueffectrapport nodig om officiële beslissingen in de vergunningsprocedure te nemen.

[1] Bron: http://www.infomil.nl/onderwerpen/ruimte/mer/procedurehandleiding/index/doel/

# 2 Wettelijk en beleidskader

## 2.1 Inleiding

2.1.1 Verordening (EU) Nr. 347/2013 van het Europees Parlement en de Raad betreffende richtsnoeren voor de trans-Europese energie-infrastructuur ("de TEN-E-verordening") geldt als overkoepelend wetgevend kader voor het project. De TEN-E-verordening is van toepassing in alle vier de rechtsgebieden. Ieder land beschikt over een eigen bevoegd gezag, dat de toepasselijke vergunningsprocedures voor elk rechtsgebied coördineert.

2.1.2 Het deel van de onderzeese kabel in de Nederlandse EEZ kan tevens worden beïnvloed door aspecten van het wettelijk en beleidskader van de andere drie rechtsgebieden waar het kabeltracé doorheen loopt. Zo kunnen bepaalde vereisten in de andere rechtsgebieden van invloed zijn op de configuratie van de kabel in de Nederlandse sector waarbij het gaat om de aanleg, exploitatie en buitenbedrijfstelling. In de milieueffectrapportage wordt rekening gehouden met dergelijke aspecten.

## 2.2 Beleidskader

2.2.1 Tabel 2.1 beschrijft het beleidskader voor het Nederlandse rechtsgebied en de overige drie rechtsgebieden (Denemarken, Duitsland en het Verenigd Koninkrijk) voor zover deze relevant zijn voor het Nederlandse deel van het kabeltracé. Dit omvat:

Europees beleid

- De Kaderrichtlijn Mariene Strategie (Marine Strategy Framework Directive, MSFD).
- De Europese Kaderrichtlijn Water (Water Framework Directive, WFD).
- Het OSPAR-verdrag inzake de bescherming van het mariene milieu in het noordoostelijk deel van de Atlantische Oceaan.
- Het ASCOBANS-verdrag inzake de bescherming van kleine walvisachtigen in de Oostzee, het noordoostelijk deel van de Atlantische Oceaan, de Ierse Zee en de Noordzee.

Nederlands beleid

- Nationaal Waterplan 2016-2021 (NWP2) en de Beleidsnota Noordzee 2016-2021.

| Tabel 2-1 Beleidskader | |
|---|---|
| **Europees beleid** | |
| De Kaderrichtlijn Mariene Strategie (Marine Strategy Framework Directive, MSFD). | Op grond van artikel 13.4 van de Europese Kaderrichtlijn mariene strategie, 2008/56/EG (Marine Strategy Framework Directive, 2008/56/EC) zijn de EU-lidstaten verplicht tot de ontwikkeling van een samenhangend en representatief netwerk van beschermde mariene gebieden die bijdragen aan de instandhouding van mariene ecosystemen. Dit geldt ook voor speciale beschermingszones op grond van de Habitatrichtlijn, speciale beschermingszones op grond van de Vogelrichtlijn, en voor beschermde mariene gebieden.<br>Op grond van de Kaderrichtlijn mariene strategie zijn de EU-lidstaten verplicht om de nodige maatregelen te nemen om een 'goede milieutoestand' van het mariene milieu te bereiken of te behouden. De kaderrichtlijn omvat elf descriptoren voor een goede milieutoestand van de mariene omgeving. |
| Europese Kaderrichtlijn Water (Water Framework Directive, WFD). | Het doel van de Europese Kaderrichtlijn Water is het beschermen van aquatische ecosystemen, het faciliteren van duurzaam gebruik van water en het voorkomen van achteruitgang van de chemische of ecologische situatie van het water. |
| Het OSPAR-verdrag | Het Verdrag inzake de bescherming van het mariene milieu in het noordoostelijk deel van de Atlantische Oceaan (Convention for the Protection of the Marine Environment of the North-East Atlantic) of OSPAR-verdrag heeft als doel het beschermen van het noordoostelijk deel van de Atlantische Oceaan tegen de nadelige effecten van menselijke activiteiten met uitzondering van<br>visserij en scheepvaart. In het bijzonder de Bijlagen 4 en 5 van het OSPAR-verdrag zijn relevant voor het Viking Link- project en zijn meegenomen in de milieueffectrapportage. |
| Het ASCOBANS-verdrag | Het ASCOBANS-verdrag (inzake de instandhouding van kleine walvisachtigen in de Noord- en Oostzee en het noordoostelijk deel van de Atlantische Oceaan en de Ierse Zee) dient ter bescherming van zeezoogdieren als bruinvissen en hun habitats. |
| **Nederlands beleid** | |
| Nationaal Waterplan 2016-2021 | Het Nationaal Waterplan (NWP2) schept de kaders en richtlijnen voor onderwerpen van nationaal belang, zoals zandwinning en kabels en pijpleidingen. Het plan schetst ook de strategische routekaart voor de Noordzee, in combinatie met andere functies, binnen de Nederlandse EEZ. Het wordt gebruikt als ruimtelijk toetsingsinstrument voor het Viking Link-project. |

## 2.3 Wettelijk kader

2.3.1 De Wet milieubeheer, de Waterwet en de Wet Natuurbescherming vormen de vigerende wetgeving voor het project binnen de Nederlandse jurisdictie.

### Wet milieubeheer

2.3.2 De Wet milieubeheer bevat regelgeving voor de bescherming van het milieu. Hoofdstuk 7 van deze wet is van toepassing op Viking Link. Dit hoofdstuk geeft een overzicht van de vereisten voor de verschillende m.e.r.-procedures. Tevens zijn activiteiten vastgelegd waarvoor een MER gemaakt moet worden, of waarin moet worden onderzocht of een m.e.r. procedure noodzakelijk is.

### Waterwet

2.3.3 De Waterwet bevat regelgeving over het beheer en gebruik van het watersysteem en valt onder de verantwoordelijkheid van het Ministerie van Infrastructuur en Milieu. De Waterwet is uitgewerkt in een aantal besluiten en verordeningen; de belangrijkste daarvan zijn het Waterbesluit en de Waterregeling. De hoofddoelen van de Waterwet zijn:

- het voorkomen en waar nodig beperken van overstromingen, waterverontreiniging en waterschaarste;
- beschermen en verbeteren van de chemische en ecologische kwaliteit van watersystemen;
- voldoen aan maatschappelijke functies die zijn toegekend aan watersystemen.

2.3.4 Om bovenstaande doelstellingen te verwezenlijken, legt de Waterwet een aantal voorwaarden aan aanvragers op. Voor Viking Link is een watervergunning vereist. Deze vergunning is noodzakelijk voor de aanleg, exploitatie (inclusief onderhoud en reparatie) en buitenbedrijfstelling van kabels in de Noordzee (onderdeel van de Nederlandse EEZ). De ontgraving van de zeebodem en de effecten op grondwater op zee maken ook deel uit van deze procedure.

### Wet Natuurbescherming

2.3.5 De Wet natuurbescherming is in werking getreden op 1 januari 2017. Deze wet vervangt 3 wetten: de Natuurbeschermingswet 1998, de Boswet en de Flora- en faunawet. Het Ministerie van Economische Zaken is het bevoegde gezag voor deze wetgeving. Ten aanzien van habitats en soorten die bescherming genieten in het kader van de Wet natuurbescherming moeten milieustudies worden uitgevoerd. Ecologisch onderzoek (in dit geval als onderdeel van de m.e.r.-procedure) moet uitwijzen of een vergunning op grond van de nieuwe Wet natuurbescherming vereist is. Bij de uitvoering van de soortenbeschermingstoets is rekening gehouden met de soorten die onder de Wet natuurbescherming vallen.

2.3.6 De Wet natuurbescherming bevat regels voor bescherming van de natuur en het landschap. Onder deze wet is een vergunning noodzakelijk voor activiteiten die significante negatieve effecten hebben voor Natura 2000-gebieden en/of natuurmonumenten. Het project kruist in Nederlandse wateren de Klaverbank. Aangezien dit een Natura 2000-gebied is, zijn de effecten op de beschermde kenmerken ervan in kaart gebracht in een voortoets. In de voortoets is geconcludeerd dat het project geen significant negatieve effecten heeft op Natura 2000-gebieden.

# 3 Ontwikkeling van het project en van alternatieven

## 3.1 Inleiding

3.1.1 Bij de ontwikkeling van het tracé van de Viking Link-interconnector is gekozen voor een integrale benadering. Het tracé is dus niet slechts de optelsom van de uitkomsten voor elk van de vier rechtsgebieden. Het voorgestelde tracé van de zeekabel is vastgesteld aan de hand van diverse voorbereidende tracéstudies, waarbij op basis van de mogelijke aansluitlocaties in het Verenigd Koninkrijk en Denemarken alternatieve opties zijn onderzocht. Door de zorgvuldig vastgestelde tracékeuze worden gevoelige gebieden vermeden. Hierdoor kunnen mogelijke milieueffecten door de aanleg en exploitatie van de kabels worden gemitigeerd. Bij de vaststelling van het Nederlandse tracédeel is rekening gehouden met milieukundige en technische randvoorwaarden, de uitkomsten van gedetailleerd locatieonderzoek en de feedback die werd ontvangen in het consultatieproces.

3.1.2 Het project is zodanig geconfigureerd dat elektriciteit afwisselend in de richting van het Verenigd Koninkrijk en Denemarken kan stromen, afhankelijk van vraag en aanbod in beide landen. Een HVDC-kabelverbinding vormt de meest efficiënte en effectieve manier om elektriciteit over lange afstanden te transporteren, zoals bij het Viking Link-project. De hoogspanningsgelijkstroom (High Voltage Alternating Current, HVAC) moet worden geconverteerd naar hoogspanningswisselstroom (High Voltage Alternating Current, HVAC) door converterstations in het Verenigd Koninkrijk en Denemarken.

## 3.2 Tracé- en locatiestudies

3.2.1 Het hoofddoel van de tracéstudies is om technisch en economisch haalbare alternatieven en varianten in kaart te brengen, waarbij verstoringen voor mens en milieu wordt geminimaliseerd. Om te komen tot een optimale oplossing voor het project zijn er een aantal studies uitgevoerd. Hierbij is gekeken naar diverse milieukundige, technische en economische randvoorwaarden die van invloed zijn op de ontwikkeling van het project. Dit betreft onder meer de volgende studies:

- Viking Link Offshore Desktop Route study (Rambøll, 2014);
- Viking HVDC Link Submarine Cable Route Development Final Report (Red Penguin, 2015);
- Route Review Report (Intertek, 2016).

Viking Link Offshore Desktop Route study (Rambøll, 2014)

3.2.2 In 2014 is een pre-haalbaarheidsbureaustudie verricht om mogelijke tracés in het studiegebied en de geschiktheid ervan in kaart te brengen. Op basis van algemeen beschikbare gegevens werden in het rapport een aantal mogelijke kabeltracés voorgesteld.

3.2.3 De randvoorwaarden werden in kaart gebracht aan de hand van landspecifieke gegevens, waarbij rekening is gehouden met de vier EEZ. Hierbij is onderscheid gemaakt tussen milieukundige, fysieke en menselijke beperkingen, waarbij deze als volgt werden gecategoriseerd: alle (‘either’), geen (‘none’), gering (‘minor’), beperkt (‘medium’) of ernstig (‘major’). De als beperkt of ernstig aangemerkte beperkingen zijn meegenomen in het tracéonderzoek, waarbij adequate bufferzones werden ingesteld om nadelige effecten te voorkomen (Tabel 3-1).

3.2.4 In totaal zijn er 48 mogelijke zeekabelcorridors (elk 500 meter breed) in kaart gebracht voor het project. Deze opties zijn nader beoordeeld; hierbij zijn een economische analyse van de tracécorridors en risicofactoren meegewogen.

3.2.5 In het Rambøll-rapport zijn twee mogelijke hoofdtracés aangewezen: een zuidelijke variant en een noordelijke variant. De zuidelijke variant doorkruist bestaande Duitse zeekabelcorridors en heeft een grotere tracélengte in de Nederlandse sector; bij de noordelijke variant wordt gestreefd naar een zo gering mogelijke tracélengte in de Duitse wateren en de Nederlandse sector doordat het smalle noordwestelijke deel van de Duitse EEZ wordt doorkruist.

### Viking HVDC Link Submarine Cable Route Development (Red Penguin, 2015)

3.2.6 In het kader van de tracéontwikkeling zijn de resultaten van de bureaustudie uitgewerkt tot specifiekere tracévarianten. Het kortst mogelijke tracé is in kaart gebracht, waarbij rekening gehouden is met milieuaspecten, belemmeringen, beschermde gebieden, installaties van derden, activiteiten en exclusieve zones. In het hoofdrapport van Red Penguin zijn deze aspecten nader beschreven.

3.2.7 In 2015 is met de Nederlandse en Duitse overheidsinstanties overleg gevoerd over de tracéopties. Hierna werd de noordelijke variant aangewezen als het voorkeurstracé. Uit de ontvangen reacties bleek dat de noordelijke variant de voorkeur heeft boven de zuidelijke tracéoptie. Het noordelijke kabeltracé bevindt zich ten noorden van de Duitse bestemmingszone voor offshore windparken en is verder afgelegen van de Nederlandse kust, van gebieden die zijn aangemerkt voor mogelijke olie- en gaswinning en van gebieden met concurrerende belangen, waaronder commerciële scheepvaart. Vervolgens werden vier varianten voor het noordelijke tracé vastgesteld, met daarbinnen alleen alternatieven voor de sector van resp. het Verenigd Koninkrijk en Denemarken.

3.2.8 Bij de bestudering van deze tracéopties voor de zeekabel moest rekening worden gehouden met aspecten als mogelijke olie- en gaswinning en de ontwikkeling van windparken in de Britse EEZ. Vervolgens werden twee van de noordelijke tracés aangewezen als tracés waarbij de meeste belemmeringen bij de aanlanding in het Verenigd Koninkrijk worden vermeden. Beide tracés maken gebruik van dezelfde route in de Nederlandse EEZ.

Route Review Report (Intertek, 2016)

3.2.9 De beide voorkeurstracés die zijn aangegeven in het Red Penguin-rapport (2015) verschillen alleen in de Britse sector van elkaar. Deze twee opties zijn bestudeerd en nader uitgewerkt tot een aantal varianten die zowel technisch uitvoerbaar als economisch haalbaar zijn, terwijl de verstoring voor de mens en het milieu wordt beperkt. Bij de ontwikkeling van het tracé richtte de aandacht zich vooral op de aanlanding van het Verenigd Koninkrijk, waarvoor vijf varianten werden opgesteld.

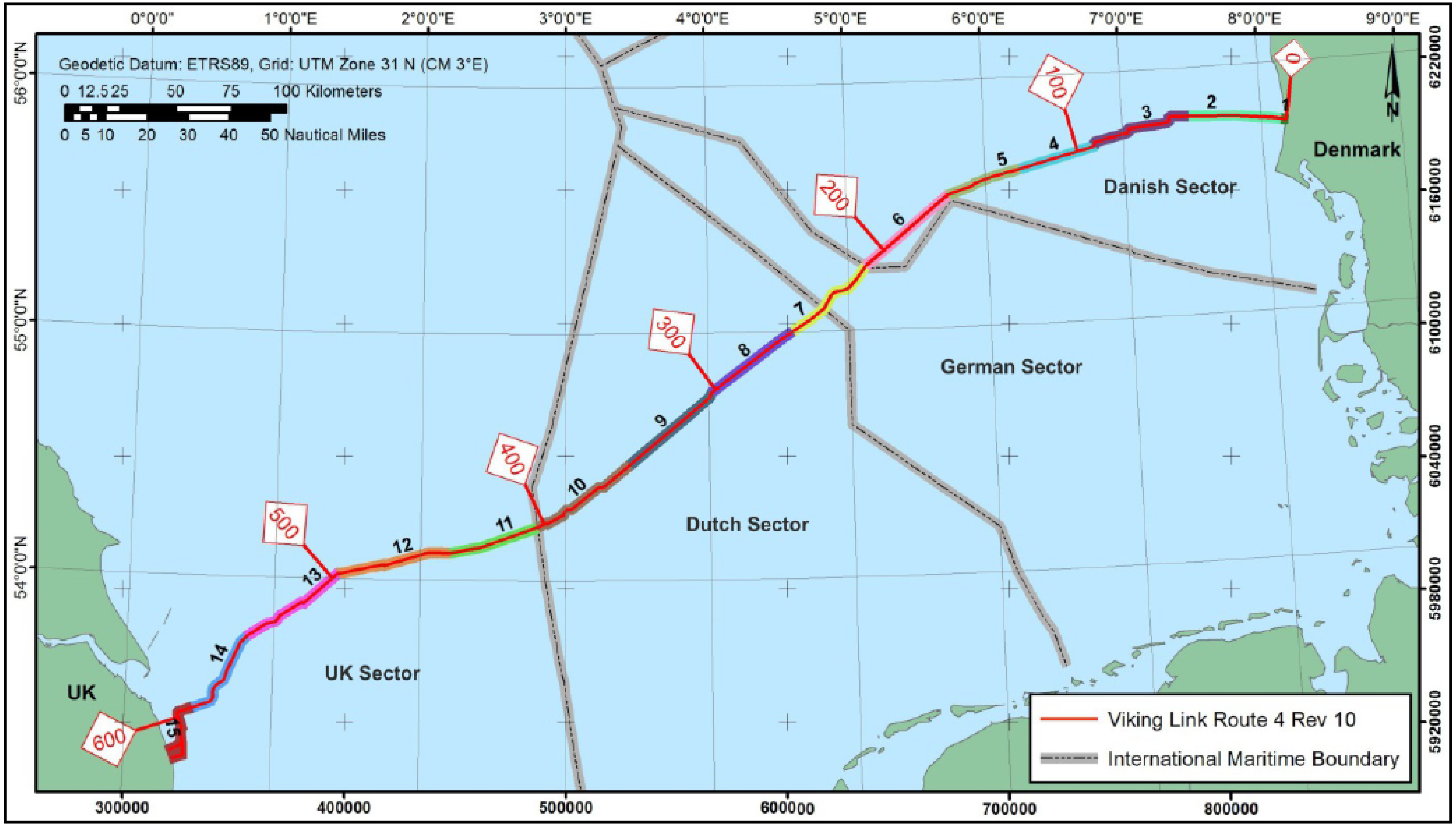
3.2.10 Na nadere beschouwing werden nog een aantal tracéafwijkingen doorgevoerd, geen daarvan in Nederlandse wateren. Aanbevolen werd om voor de noordelijke variant van beide tracéopties een zeebodemonderzoek uit te voeren, evenals een volledige risico-inventarisatie ten aanzien van de kabel en de gestelde eisen aan het ingraven daarvan. Ten aanzien van kosten werden beide opties als vergelijkbaar beschouwd.

3.2.11 Op grond van mariene onderzoeken (Fugro 2016) werden een aantal aanpassingen aan de kabelcorridor uitgevoerd: enerzijds om problematische gebieden te vermijden, anderzijds om meer mogelijkheden te hebben voor micro-routing. Binnen de Nederlandse EEZ werd het tracé op één plaats aangepast. Dit werd gedaan om een verhoogd gebied te vermijden met een harde zeebodem, waardoor problemen bij de aanleg zouden ontstaan.

## 3.3 Voorkeurstracé

3.3.1 De zeekabel komt aan land bij Blåbjerg aan de westkust van Jutland (Denemarken) en bij Boygrift in het graafschap Lincolnshire (Verenigd Koninkrijk). Het totale tracé van de zeekabel is ca. 635 km lang, waarbij in de Nederlandse EEZ een afstand van ca. 170 km wordt afgelegd.

3.3.2 In het Natura 2000-gebied Klaverbank hebben een aantal tracéaanpassingen plaatsgevonden om een gebied met een harde substraat te vermijden. Er is geconcludeerd dat het niet noodzakelijk is om nog andere tracéwijzigingen door te voeren.




**Figuur 3.1 : Voorkeurstracé Viking Link kabelcorridor**

# 4 Projectbeschrijving

## 4.1 Inleiding

4.1.1 Dit hoofdstuk biedt een beschrijving van de aanleg, exploitatie (inclusief onderhoud en reparaties) en buitenbedrijfstelling van de mariene elementen van het voorgenomen project binnen de Nederlandse EEZ, van de mediaan Verenigd Koninkrijk/Nederland tot de mediaan Nederland/Duitsland. Het beschrijft de aspecten van het project met betrekking tot de aanleg, exploitatie (inclusief onderhoud en reparatie) en buitenbedrijfstelling van de zeekabels, waaronder:

- opties voor het aanlegproces van de zeekabel, waaronder de aan de aanleg voorafgaande onderzoeken;
- de diverse in te zetten schepen;
- verschillende aanlegtechnieken die zouden kunnen worden toegepast bij het leggen, lassen en ingraven van de kabels, en
- gangbare technieken die kunnen worden toegepast bij de exploitatie van de kabels.

### Projectoverzicht

4.1.2 Tabel 4.1 biedt een overzicht van de specificaties van de Viking Link-kabel

| Tabel 4.1: Specificaties Viking Link-kabel | |
|---|---|
| Totale tracé lengte offshore-gedeelte (circa) | 635 km |
| Tracé lengte in Nederlandse EEZ (circa) | 170 km |
| Zeekabelcorridor (breedte) | 450 m |
| Sleuf (breedte) | 1 m |
| Voetafdruk installatie op zeebodem (breedte) | 5-15 m |
| Voetafdruk kabelkruisingen (breedte) | 50-100 m |
| Diepte kabels in zeebodem | 1m bedekking tot bovenzijde kabels |

### Globale beschrijving van het kabelsysteem

4.1.3 Het zeekabelsysteem is een zogenaamd tweefasekabelsysteem. Tweefasesystemen transporteren elektriciteit door een gesloten circuit van twee naast elkaar gelegen HVDC-zeekabels. Op dit moment worden er twee typen HVDC-kabel voor het project overwogen:

massageïmpregneerde kabels (Mass Impregnated Non-Draining, MIND) en geëxtrudeerde kabels (Extruded). Het basisontwerp van de kabels is vergelijkbaar, met als voornaamste verschil de gebruikte isolatie. Deze kabels hebben doorgaans een diameter van 150 mm en een maximale bedrijfsspanning van ca. 525 kV.

Kabellegconfiguratie

4.1.4 In de Nederlandse EEZ zullen de zeekabels in dezelfde sleuf worden gelegd, hetzij apart of als gebundeld kabelpaar. Ook kan een glasvezelkabel voor besturings- en communicatiedoeleinden worden gelegd.

4.1.5 Er moet worden opgemerkt dat hoewel de zeekabelcorridor 450 m breed is, er slechts een klein deel van deze breedte (1 m) nodig is voor de aanleg van de kabels. Nadat de vergunningen zijn toegekend zal een gedetailleerd kabel corridor onderzoek en optimalisatie plaatsvinden.

## 4.2 Aan de aanleg voorafgaande werkzaamheden

Onderzoeken

4.2.1 Langs de kabelcorridor zijn mariene onderzoeken verricht ten behoeve van het technisch ontwerp en de uitgangskarakterisering van de kabel. Waarschijnlijk zal meer onderzoek vereist zijn om het kabeltracé binnen de brede corridor te optimaliseren. Daartoe zullen waarschijnlijk behoren bathymetrie:, SSS, ondiepe ondergrondprofilering en magnetometer. Het primaire doel van deze onderzoeken is te bevestigen dat er sinds de uitvoering van de zeeonderzoeken geen nieuwe belemmeringen zijn ontstaan, om de zeebodemcondities van het voorgestelde zeekabeltracé te bevestigen en om mogelijk onderzoek te verrichten naar NGE (Niet-Gesprongen Explosieven). Daarnaast kunnen geotechnische onderzoeken worden verricht om de bodemcondities te verifiëren.

Tracévoorbereiding

4.2.2 De volgende tracévoorbereidingswerkzaamheden kunnen eventueel worden uitgevoerd voor aanvang van de aanleg van het zeekabelsysteem:

- Vrijmaken van het kabeltracé
- Vrijmaken van NGE (waarschijnlijk niet nodig)

Vrijmaken van het kabeltracé

4.2.3 Voor aanvang van de zeekabelinstallatie is het essentieel te waarborgen dat het kabeltracé vrij is van belemmeringen die de installatiewerkzaamheden kunnen hinderen. Afval op de zeebodem, zoals afgedankte werptrossen en netten of scheepskraandraden die mogelijk in zee zijn afgeworpen, communicatiekabels die niet meer in gebruik zijn en ander afval kunnen schadelijk zijn voor de graafmachine. Voor aanvang van de aanlegwerkzaamheden kan het kabeltracé worden onderzocht met een magnetometer om te bepalen of er draden en kabels liggen die kunnen worden verwijderd.

## 4.3 Kabelaanleg

4.3.1 De kabels zullen over de gehele lengte worden ingegraven, behalve op plekken waar dit onmogelijk is, bijvoorbeeld bij kruisingen met bestaande kabels of pijpleidingen, of waar de gesteldheid van de zeebodem dit niet toelaat.

4.3.2 Binnen de Nederlandse EEZ bedraagt de voorgenomen aanlegdiepte (de afstand tussen de bovenzijde van de kabels en het onberoerde zeebodemoppervlak) van het kabelsysteem minimaal 1,0 m. Een eerste interpretatie van de gegevens uit zeebodemonderzoek voor de zeekabelcorridor wijst erop dat deze aanlegdiepte haalbaar lijkt met de momenteel verkrijgbare graafwerktuigen. De bedekkingshoogte van het kabelsysteem is 1 m.

4.3.3 Het kabelaanlegproces omvat de volgende elementen:

- kabelbescherming d.m.v. ingraven en eventueel aanbrengen van steenbestorting; en
- kruisingen van andere zeekabels en pijpleidingen.

4.3.4 Alle werkzaamheden worden uitgevoerd op 24-uursbasis om de overige scheepvaart zo min mogelijk te hinderen en om de efficiënte benutting van gunstige weersomstandigheden en tijd van ingezette schepen en werktuigen te maximaliseren. Met het oog op de scheepvaart- en operationele veiligheid zullen meldingen worden uitgebracht conform de wettelijk voorgeschreven procedures.

### Kabelleggers

4.3.5 Het gebruik van specifieke hulpmiddelen, zoals kabelleggers, is afhankelijk van de onderneming waaraan het kabellegcontract wordt gegund en vervolgens van de beschikbaarheid van het betreffende vaartuig.

4.3.6 De bij het leggen van de kabel betrokken schepen zijn waarschijnlijk:

- Kabellegger: een kabellegger is een gespecialiseerd schip dat is ontworpen voor het transporteren en verwerken van lange lengtes zware elektriciteitskabels.
- Wachtschip: waar dit nodig wordt geacht, zal de kabellegger worden vergezeld van één of meer wachtschepen. Één of meer wachtschepen zullen rond de kabellegger de wacht houden.
- Steenstortschip: er zal steenbestorting worden aangebracht ter bescherming van delen van de zeekabels en voor kruisingen met bestaande kabels en pijpleidingen.

### Kabelleggen

4.3.7 Het tijdseffect van de formatie is afhankelijk van het element met de laagste snelheid, doorgaans de ingraafformatie. Vanuit het perspectief van de overige scheepvaart zal deze stil lijken te liggen. Het kabelleggen verloopt met snelheden tussen de 100 en 300 m per uur.

### Kabellassen

4.3.8 Viking Link waarborgt dat eventuele kabellassen voor zover mogelijk niet zullen komen te liggen in gevoelige gebieden, zoals vaarwegen en ankergronden, waar langdurige ligging van de installatieformatie onwenselijk is. Op dit moment wordt verwacht dat er geen kabellassen zullen voorkomen binnen het Natura 2000-gebied Klaverbank.

### Kabelbescherming

4.3.9 Er zijn drie generieke typen werktuigen voor het leggen van kabels in de zeebodem:

- Ploegen (gesleept): maken een open, V-vormige sleuf waarin de kabel wordt gelegd, en zijn geschikt voor de meeste soorten sediment, waaronder gesteente.
- Inspuitingsmachines: Inspuitingsmachines maken gebruik van waterstralen om de zeebodem onder de kabel los te maken, waardoor een sleuf gevuld met vloeibaar materiaal ontstaat. De kabel zakt door het eigen gewicht door het vloeibare materiaal heen in de sleuf of wordt in de sleuf geleid door een ‘stinger’ of ‘depressor’.
- Mechanische trenchers: zijn meestal gemonteerd op rupsbandvoertuigen en gebruiken kettingzagen of wielen gewapend met tanden uit wolfraam-koolstofstaal om een strakke sleuf te creëren.

4.3.10 Verwacht wordt dat langs het Nederlandse deel van de kabelcorridor de inspuitings- of ploegmethode zal worden gebruikt. Het aanbrengen van steenbestorting wordt toegepast om zeekabels te beschermen door deze af te dekken in een geprofileerde berm van breukstenen.

### Kruisingen van kabels en pijpleidingen

4.3.11 Viking Link kruist twee soorten infrastructuur van derden: buiten gebruik en in bedrijf. Kabels die buiten gebruik zijn worden meestal doorgesneden met toestemming van de eigenaar en worden beveiligd conform richtlijnen van het International Cable Protection Committee (ICPC).

4.3.12 Met eigenaren van in bedrijf zijnde kabels en pijpleidingen die door het project worden gekruist, worden kruisingsovereenkomsten gesloten. Alle partijen zijn geïnformeerd over de mogelijkheid van een kabelkruising. Deze overeenkomsten zetten het fysieke ontwerp van de kruising uiteen en beschrijven de rechten en verantwoordelijkheden van beide partijen om integriteitsbehoud van de kabels/leidingen te waarborgen.

## 4.4 Kabelonderhoud en -reparatie

4.4.1 Regelmatig onderhoudswerk aan de zeekabels na het leggen wordt niet verwacht. Er kan echter enig werk nodig zijn om de kabels ingegraven te houden ter bescherming tegen ongewenste interacties met andere zeegebruikers en mariene processen die schade zouden kunnen veroorzaken. De kabels en het leggen ervan worden ontworpen om eventuele onderhoudseisen zo beperkt mogelijk te houden.

## 4.5 Emissies

Elektromagnetische (EM-)velden

4.5.1 De kabelconfiguratie van Viking Link elimineert directe opwekking van een elektrisch veld; door minimalisatie van het opgewekte magnetische veld minimaliseert de systeemconfiguratie ook de in het mariene milieu opgewekte elektrische velden.

Warmte-emissies

4.5.2 Het transport van gelijkstroom gaat gepaard met verliezen als gevolg van de interne weerstand in de geleider. Deze weerstand is evenredig aan de lengte van de kabels en is omgekeerd evenredig aan het oppervlak van de dwarsdoorsnede van de geleider (in dit geval de koperen of aluminium kabelkern). De weerstand is ook afhankelijk van de omgevingstemperatuur: de weerstand (en daarmee het warmteverlies) neemt toe naarmate de omgevingstemperatuur stijgt. De verloren energie wordt hoofdzakelijk omgezet in warmte, waardoor de temperatuur van de kabel en de omliggende zeebodem stijgt. De seizoensgerelateerde omgevingswatertemperatuur verandert langzaam, zodat de omliggende zeebodem dezelfde temperatuur heeft. Hierdoor is de temperatuur van het water en van het zeebodemoppervlak in de winter minimaal 3°C en in de zomer maximaal 17°C. Doordat de verliezen minder zijn bij lagere temperaturen, is het warmteverlies in de winter geringer dan in de zomer. Hoewel de gemiddelde omgevingstemperatuur ca. 10°C2 bedraagt, zijn de simulaties van de warmteafgifte uitgevoerd voor een behoudende temperatuur van 15°C (Brakelmann & Stammen, 2017).

## 4.6 Buitenbedrijfstelling

4.6.1 National Grid Viking Link (NGVL) en Energinet.dk erkennen het belang van het tijdig in aanmerking nemen van het buitenbedrijfstellingsproces. Mocht buitenbedrijfstelling aan de orde komen, dan zal deze operatie ook worden uitgevoerd conform het op dat moment geldende standaardprotocol binnen de industrie. Aan het eind van de levensduur van de kabel zullen de opties voor buitenbedrijfstelling worden geëvalueerd. In bepaalde gevallen kan de milieuvriendelijkste optie inhouden dat de kabels blijven liggen. Indien wordt besloten om de kabels te verwijderen, zal de Viking Link- kabel corridor worden onderzocht op eventueel achtergebleven kabeldelen.

# 5 Overzicht van effecten

## 5.1 Overzicht van effecten

5.1.1 Deze paragraaf biedt een samenvatting van de mogelijke milieueffecten van het project langs de zeekabel corridor in de Nederlandse EEZ, per milieuthema en projectfase.

5.1.2 De effecten worden uitgebreid beoordeeld in het hoofdstuk over het betreffende onderwerp, waarbij elk hoofdstuk informatie biedt over het beoordelingskader, het toepasselijke beleid, de referentiesituatie en de beoordeling van de effecten.

- Hoofdstuk 8 – Fysieke omgeving en hydro-morfologie
- Hoofdstuk 9 – Ecologie
- Hoofdstuk 10 – Archeologie
- Hoofdstuk 11 – Scheepvaartveiligheid
- Hoofdstuk 12 – Niet-Gesprongen Explosieven
- Hoofdstuk 13 – Overige zeegebruikers

### Scoringssysteem

5.1.3 Er worden scores toegekend aan de vastgestelde mogelijke effecten volgens een vijfpuntsschaal (zie Tabel 5.1). De uiteindelijke beoordeling van het effect kan positief (+), neutraal (0) of negatief (-) zijn, en wordt vermeld in de paragraaf over het betreffende effect. Bij deze benadering wordt de definitieve score bepaald aan de hand van een deskundig oordeel, de toepasselijke wettelijke normen, overheidsbeleid, gebruikelijke optimale werkwijzen en de gezichtspunten van belanghebbenden.

5.1.4 Ten behoeve van dit Milieueffectrapport wordt een sterk negatief effect of een grote normoverschrijding beschouwd als 'significant'. Mitigerende maatregelen zijn in dat geval vereist om een dergelijk significant effect waar mogelijk te beperken. Lichte negatieve effecten, kleine normoverschrijdingen of effecten die niet leiden tot een verandering in de referentiesituatie worden niet beschouwd als significant; in een dergelijk geval zullen in principe geen mitigerende maatregelen worden voorgesteld.

| Tabel 5.1: Scoringssysteem | |
|---|---|
| Score | Beoordeling in vergelijking met referentiesituatie* |
| -- | Het Viking Link-project leidt tot een sterk negatief effect of tot een grote normoverschrijding. |
| - | Het Viking Link-project leidt tot een licht negatief effect of tot een kleine normoverschrijding. |
| 0 | Het Viking Link-project leidt niet tot een verandering in de referentiesituatie. |
| + | Het Viking Link-project leidt tot een licht positief effect. |
| ++ | Het Viking Link-project leidt tot een sterk positief effect. |

5.1.5 Tabel 5.2 biedt een overzicht van de effectenbeoordeling.

| Tabel 5.2: Samenvatting van effectenbeoordeling | | |
|---|---|---|
| Milieuthema | Mogelijk effect | Score (--, -, 0, +, ++) |
| Fysieke omgeving en hydro-morfologie | | |
| Aanleg en buitenbedrijfstelling | Verhoogde concentratie zwevende deeltjes | 0 |
| | Verstoring van verontreinigd sediment | 0 |
| | Verstoring van of schade aan morfologische kenmerken van de zeebodem | 0 |
| | Schade aan beschermde geologische kenmerken | 0 |
| | Veranderingen in sedimenttransportpatronen | 0 |
| Exploitatie (inclusief onderhouds- en reparatiewerkzaamheden) | Veranderingen in sedimenttransportpatronen | 0 |
| | Secundaire erosie in de buurt van kabelbeschermingsvoorzieningen | 0 |
| Natura 2000-gebieden en nationaal aangewezen gebieden | | |
| Natura 2000-gebieden en nationaal aangewezen gebieden | | |
| Natura 2000-gebied Klaverbank | Bijlage I Habitat - riffen | - |
| | Bijlage II Zeezoogdieren - bruinvis, grijze zeehond, gewone zeehond | - |
| Natura 2000-gebied Doggersbank | Bijlage I Habitat - zandbanken | - |
| | Bijlage II Zeezoogdieren - bruinvis, grijze zeehond, gewone zeehond | - |

| Tabel 5.2: Samenvatting van effectenbeoordeling | | |
|---|---|---|
| **Milieuthema** | **Mogelijk effect** | **Score<br>(--, -, 0, +, ++)** |
| Centrale Oestergronden | Ecosysteem van de zeebodem | - |
| **Ecologie van zeebodemdieren** | | |
| Aanleg en buitenbedrijfstelling | Permanent verlies van habitat | 0 |
| | Tijdelijke verstoring van habitat | - |
| | Tijdelijke fysieke verstoring, slijtage en/of pletten | - |
| | Tijdelijke stijging van concentratie zwevende deeltjes en verstikking | 0 |
| | Tijdelijke verstoring van verontreinigd sediment | 0 |
| | Tijdelijke indirecte effecten op prooibeschikbaarheid | 0 |
| | Lekkages van koolwaterstoffen of chemische stoffen | 0 |
| Exploitatie (inclusief onderhouds- en reparatiewerkzaamheden) | Permanente verstoring veroorzaakt door elektromagnetische velden | 0 |
| | Permanente verstoring veroorzaakt door warmteafgifte | 0 |
| | Effecten van tijdelijke onderhouds- en reparatiewerkzaamheden | 0 |
| **Vis- en schaaldier- en schelpdierecologie** | | |
| Aanleg (en buitenbedrijfstelling) | Permanent verlies van habitat | 0 |
| | Tijdelijke verstoring van habitat | 0 |
| | Tijdelijke fysieke verstoring, slijtage en/of pletten | 0 |
| | Tijdelijke stijging van concentratie zwevende deeltjes en verstikking | 0 |
| | Verstoring van verontreinigd sediment | 0 |
| | Tijdelijk onderwatergeluid | 0 |
| | Tijdelijke indirecte effecten op prooibeschikbaarheid | 0 |
| | Lekkages van koolwaterstoffen of chemische stoffen | 0 |
| Exploitatie (inclusief onderhouds- en reparatiewerkzaamheden) | Permanente verstoring veroorzaakt door elektromagnetische velden | 0 |
| | Permanente verstoring veroorzaakt door warmteafgifte | 0 |
| | Effecten van tijdelijke onderhouds- en reparatiewerkzaamheden | 0 |

**Tabel 5.2: Samenvatting van effectenbeoordeling**

| Milieuthema | Mogelijk effect | | Score (--, -, 0, +, ++) |
|---|---|---|---|
| **Zeezoogdieren** | | | |
| Aanleg en buitenbedrijfstelling | Tijdelijk onderwatergeluid | Aanlegwerkzaamheden | 0 |
| | | Geofysische onderzoeken – Verstoring | - |
| | | Geofysische onderzoeken – Letsel | 0 |
| | | Opruimen van Niet-Gesprongen Explosieven – Letsel | - |
| | Tijdelijk risico op aanvaringen | | 0 |
| | Tijdelijke indirecte effecten op prooibeschikbaarheid | | 0 |
| | Tijdelijk risico op lekkages van koolwaterstoffen of chemische stoffen | | 0 |
| | Tijdelijke verstoring van verontreinigd sediment | | 0 |
| Exploitatie (inclusief onderhouds- en reparatiewerkzaamheden) | Permanente verstoring veroorzaakt door elektromagnetische velden | | 0 |
| | Effecten van tijdelijke onderhouds- en reparatiewerkzaamheden | | 0 |
| **Zeevogels** | | | |
| Aanleg (en buitenbedrijfstelling) | Direct tijdelijk verlies / directe tijdelijke verstoring van habitat | | 0 |
| | Indirect tijdelijk verlies / indirecte tijdelijke verstoring van habitat | | 0 |
| | Onopzettelijke verontreiniging | | 0 |
| | Permanent(e) verlies of verstoring van habitat | | 0 |
| Exploitatie (inclusief onderhouds- en reparatiewerkzaamheden) | Effecten van tijdelijke onderhouds- en reparatiewerkzaamheden | | 0 |
| **Archeologie** | | | |
| Aanleg (en buitenbedrijfstelling) | Schade aan en/of vernietiging van locaties en/of voorwerpen | | 0 |
| | Transport van sediment | | 0 |
| Exploitatie (inclusief onderhouds- en | Transport van sediment | | 0 |

| Tabel 5.2: Samenvatting van effectenbeoordeling | | |
|---|---|---|
| **Milieuthema** | **Mogelijk effect** | **Score (--, -, 0, +, ++)** |
| reparatiewerkzaamheden) | | |
| **Scheepvaartveiligheid** | | |
| Aanleg (en buitenbedrijfstelling) | Verplaatsing van vaartuigen | 0 |
| | Aanvaringen tussen schepen | 0 |
| Exploitatie (inclusief onderhouds- en reparatiewerkzaamheden) | Risico's in verband met schepen die met een anker de kabel haken | 0 |
| **Niet-Gesprongen Explosieven** | | |
| Aanleg (en buitenbedrijfstelling) | Opruimen van Niet-Gesprongen Explosieven en mogelijke schade aan receptoren in de omgeving | 0 |
| Exploitatie (inclusief onderhouds- en reparatiewerkzaamheden) | Opruimen van verplaatste Niet-Gesprongen Explosieven en mogelijke schade aan receptoren in de omgeving | 0 |
| **Overige zeegebruikers** | | |
| Aanleg (en buitenbedrijfstelling) | Beperkte toegang tot visgronden | 0 |
| | Verlies van of schade aan habitats van vissen | 0 |
| | Aanvaringen tussen schepen | 0 |
| | Directe schade aan bestaande kabels en pijpleidingen | 0 |
| | Beperkte toegang tot bestaande infrastructuur | 0 |
| Exploitatie (inclusief onderhouds- en reparatiewerkzaamheden) | Verlies van of schade aan vistuig door kabelbeschermingsvoorzieningen | 0 |

## 5.2 Overzicht van resultaten

5.2.1 De belangrijkste conclusies van de beoordeling van de effecten op de fysieke, biologische en leefomgeving zijn als volgt:

- De belangrijkste effecten van het project betreffen naar verwachting kleine en tijdelijke negatieve effecten op zeebodemdieren tijdens de aanlegfase.
- De zeekabelcorridor loopt door het Natura 2000-gebied Klaverbank, dat is aangemerkt als habitattype H1170 (Riffen van open zee) en wordt gekenmerkt door delen met een hardere zeebodem en concentraties van rotsblokken. De bevindingen van het voor het Viking Link-project uitgevoerde zeebodemonderzoek sluiten nauw aan bij eerdere kenschetsende

onderzoeken van de Klaverbank. De verstoringen van de zeebodem zijn kleinschalig en alle gebieden met een harde ondergrond worden vermeden door optimalisering van het tracé. Hierdoor worden eventuele rechtstreekse effecten op gebieden met onderscheidende kenmerken beperkt. De toename van troebelheid is beperkt en heeft alleen betrekking op een klein gebied rond de zeekabelcorridor, waardoor er een verwaarloosbaar effect is op rifkenmerken. Er worden daarom geen negatieve effecten verwacht op de instandhoudingsdoelstellingen van het Klaverbank-gebied.

- De twee kabels worden in dezelfde sleuf aangelegd en vervolgens in de zeebodem begraven, waardoor de verstorende effecten van elektromagnetische velden aanzienlijk worden verminderd. Er worden daarom slechts beperkte en lokale elektromagnetische emissies verwacht, die geen verstorende effecten zullen hebben op soorten die gevoelig zijn voor elektriciteit en/of magnetische velden.
- Het transporteren van stroom door de kabels zal warmte opwekken, maar dit zal slechts beperkt effect hebben op het sediment aan de oppervlakte. Dit opwarmeffect zou zeer lokaal en alleen in het sediment in de directe nabijheid van de begraven kabels optreden, en de omgevingstemperatuur van het zeewater zou bovendien dicht bij die van het zeebodemoppervlak blijven. Warmte-emissies worden tegengegaan door de kabel voldoende diep te begraven. Vanwege de begraafdiepte zullen verwarmingseffecten van de kabels waarschijnlijk geen gevolgen hebben voor infauna. Verstoring veroorzaakt door verwarmingseffecten afkomstig van kabels in verband met het project wordt daarom geacht niet te leiden tot een wijziging van de referentiesituatie voor zeebodemdieren.
- Eventuele negatieve effecten op de scheepvaartveiligheid of overige zeegebruikers zullen kortdurend, lokaal en niet significant zijn. Er is een risicobeoordeling uitgevoerd op de bedekking van de kabels, waarbij de bedekking van de kabels is bepaald op basis van een aanvaardbaar minimaal risiconiveau om blootlegging van de kabel te voorkomen en effecten op de scheepvaart en visserij te beperken.
- Er worden geen significante negatieve effecten verwacht op archeologische kenmerken of als gevolg van Niet-Gesprongen Explosieven. Er worden mitigerende maatregelen toegepast als er beschermde kenmerken worden ontdekt binnen de zeekabelcorridor tijdens aanleg- of onderhoudswerkzaamheden (zie paragraaf 5.4)
- Er zijn geen andere projecten bekend binnen de Nederlandse, Britse of Duitse EEZ die interacties kunnen aangaan met het Viking Link-project, en er worden daarom geen cumulatieve effecten verwacht.
- De werkzaamheden tijdens de buitenbedrijfstellingsfase zullen grotendeels vergelijkbaar zijn met de aanlegfase, en er worden daarom geen sterke negatieve effecten verwacht als gevolg van het project.

## 5.3 Overzicht van leemten in kennis

5.3.1 Dit Milieueffectrapport is gebaseerd op recente en relevante informatie, die is aangevuld met locatiespecifieke onderzoeken om te komen tot een goed onderbouwde beoordeling. Eventuele leemten in kennis en de mogelijke effecten daarvan op de uitkomsten van de beoordeling zijn beschouwd per onderwerp.

5.3.2 Er zijn geen leemten in kennis vastgesteld die hebben geleid tot een slecht onderbouwde beoordeling of die naar verwachting effect zullen hebben op de beoordelingsscores. Onderzoeken vóór de aanlegfase zullen meer informatie opleveren over de referentiesituatie door de aanwezigheid van eventuele Niet-Gesprongen Explosieven en nog niet in kaart gebrachte archeologische overblijfselen of voorwerpen binnen de zeekabelcorridor te bevestigen.

## 5.4 Overzicht van mitigerende maatregelen

5.4.1 Als er mogelijke sterke negatieve effecten zijn vastgesteld moeten mitigerende maatregelen in overweging worden genomen om eventuele effecten te vermijden of tot een aanvaardbaar niveau te beperken. Als de beoordelingsscores niet als significant worden beschouwd, zijn mitigerende maatregelen niet vereist in de m.e.r.-procedure.

5.4.2 De volgende mitigerende maatregelen zijn als onderdeel van het project voorgesteld om de effecten van het project te verminderen:

- Door de risico’s van Niet-Gesprongen Explosieven goed te beheersen, kunnen deze risico’s worden beperkt tot een zo laag als redelijkerwijs mogelijk niveau. Vóór de aanlegfase zullen onderzoeken worden verricht om eventuele Niet-Gesprongen Explosieven in de zeekabelcorridor te lokaliseren en zo nodig op te ruimen. Eventuele Niet-Gesprongen Explosieven die worden aangetroffen in de zeekabelcorridor en waarvoor kleine lokale tracé-aanpassingen niet volstaan, zullen worden opgeruimd door een gespecialiseerde onderaannemer. Er wordt een onderhouds-, exploitatie- en controleplan opgesteld dat voorziet in protocollen voor de veilige uitvoering van exploitatie- en onderhoudswerkzaamheden, inclusief bepalingen over veiligheidsvoorschriften als Niet-Gesprongen Explosieven worden aangetroffen. Vóór eventuele werkzaamheden ter verwijdering van de kabel zullen onderzoeken vereist zijn om Niet-Gesprongen Explosieven te lokaliseren die mogelijk moeten worden verplaatst.
- Er wordt een bufferzone ingesteld binnen een straal van 100 meter rondom voorwerpen van mogelijk archeologisch belang. Er wordt voorzien in passieve archeologische begeleiding om vertragingen tijdens de aanlegwerkzaamheden te voorkomen als er onverwacht archeologische overblijfselen worden aangetroffen. Eventuele vondsten zullen worden gemeld aan het bevoegde gezag. (Rijkswaterstaat Zee en Delta).
- De kabelaanlegwerkzaamheden zullen dag en nacht worden uitgevoerd om verstoring van het scheepvaartverkeer en de beroepsvisserij zoveel mogelijk te beperken en om de toegang tot overige voorzieningen te waarborgen. Kennisgevingen zullen worden verstuurd conform de toepasselijke wettelijke procedures om de operationele en scheepvaartveiligheid te waarborgen (zoals Berichten aan Zeevarenden).
- Er zullen effectieve communicatiekanalen worden ingesteld en in stand worden gehouden tussen de aannemer die de kabel aanlegt en overige zeegebruikers. De ingezette

vaartuigen beschikken over passageprocedures, stationaire posities, verkeersmonitoringsystemen en noodplannen.

- Er worden kruisingsovereenkomsten gesloten met andere kabeleigenaren. Hierin wordt het fysieke ontwerp van de kruising beschreven, evenals de rechten en verantwoordelijkheden van de betrokken partijen conform NEN 3656 ('Stalen buisleidingsystemen op zee').

## 5.5 Conclusies

Het Milieueffectrapport is het resultaat van een uitgebreide m.e.r.-procedure op basis van uitvoerig overleg. De conclusie van dit rapport is dat de voorgestelde Viking Link-kabelverbinding niet zal leiden tot sterke negatieve effecten of tot significante effecten zoals gedefinieerd in de m.e.r.-procedure. In veel gevallen is dit te danken aan de zorgvuldige tracébepaling, waardoor negatieve effecten over de gehele linie worden voorkomen. Deze effectenbeoordeling is uitgevoerd op basis van de beste beschikbare kennis en er zijn geen leemten in kennis vastgesteld die naar verwachting effect zullen hebben op de conclusies. Als mogelijke significante negatieve effecten zijn vastgesteld, zijn mitigerende maatregelen voorgesteld om deze effecten te beperken.

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