Field development A/B blocks, North Sea

Archaeological desk study

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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	
Description	Field development A/B blocks	
Chart:	BA 267	
Coordinates Geodetic datum: ETRS89 Projection: UTM31N	Centre	E 563 611 - -N 6 122 847
	NW	E 542 022 – N 6 150 779
	NE	E 585 199 – N 6 150 779
	SW	E 542 022 – N 6 094 915
	SE	E 585 199 – N 6 094 915
Depth (LAT):	27.1 to 48.5 meter, average 40.6 meter	
Surface area	2142 km2	
Environment:	Tidal currents, salt water	
Area use:	Shipping lane, fishing	
Area administrator:	Rijkswaterstaat Zee en Delta	
ARCHIS-research report (CIS-code):	4625581100	
Periplus-project reference:	18A021-01	
Period	August 2018	

Samenvatting (Summary in Dutch)

Petrogas is voornemens nieuwe velden te ontwikkelen in de A/B-blokken in het noordelijke deel van het Nederlands Continentaal Plat. In het kader van deze ontwikkelingen zullen eind 2018 en begin 2019 evaluatieputten worden geboord.

De geplande activiteiten kunnen een bedreiging vormen voor potentiele archeologische resten. Daarom heeft Petrogas Periplus Archeomare opdracht verleend om een archeologisch bureauonderzoek uit te voeren. Het doel van dit onderzoek is het specificeren van de archeologische verwachting voor het onderzoeksgebied. De resultaten, conclusies en aanbevelingen van de studie zullen worden gebruikt voor de vergunningsprocedure.

Het bureauonderzoek heeft uitgewezen dat in het onderzoeksgebied scheepswrakken, wrakresten van gevechtsvliegtuigen uit de Tweede Wereldoorlog en, als het pleistocene landschap intact is, *in situ* resten uit de Prehistorie verwacht kunnen worden. In het onderzochte gebied zijn twaalf scheepswrakken bekend. De archeologische waarde van deze wrakken is nog niet vastgesteld. Naast de bekende wrakken kunnen nog onontdekte wrakken in het gebied aanwezig zijn.

Op basis van de uitkomsten van het onderzoek wordt geadviseerd om een inventariserend veldonderzoek (opwater) uit te voeren om de archeologische verwachting te toetsen. Voorafgaand aan de installatie van platforms en pijpleidingen op zee zal een geofysische en geotechnische *pre-lay route survey* en/of *site survey* worden uitgevoerd. De ingewonnen data van deze surveys kunnen worden gebruikt voor het toetsen van de archeologische verwachting (zie tabel onder).

Archeologische verwachting	**Methode**	**Doel**	**Opmerkingen**
Scheeps- en vliegtuigwrakken	Side Scan Sonar	Opsporen en karteren van wrakken	Volledig begraven wrakken kunnen niet worden opgespoord
	Multibeam	Opsporen van gedeeltelijk begraven wrakken aan de hand van slijpgeulen; karakterisering morfologie van de zeebodem rond wrakken	In aanvulling op side scan sonar
	Sub-bottom Profiler	Opsporen van begraven objecten waaronder mogelijke scheepswrakken en resten van WOII gevechtsvliegtuigen	de aard van het begraven object kan niet direct worden vastgesteld
	Magnetometer		
Prehistorische nederzekkingen (kampplaatsen)	Sub-bottom Profiler	Karteren van het begraven Pleistocene landschap; aanscherpen van de verwachting voor prehistorische resten	supported by, and validated with drill data
	Boringen	Vaststellen lithostratigrafie, aard laaggrenzen (erosief of niet-erosief) en aanwijzingen voor bodemvorming en rijping; specificeren van de verwachting	boorbeschrijvingen moeten voldoen aan de archeologische doelstelling; correlatie met subbottom profiler data
	Sonderingen	Vaststellen lithostratigrafie	correlatie met boorgegevens en subbottom profiler data

Als de bovenstaande onderzoeksmethoden worden ingezet tijdens de survey en de ingewonnen data van voldoende kwaliteit is, kan de toets en nadere specificering van de archeologische verwachting worden uitgevoerd. Het wordt aanbevolen om de technische Scope of Work af te stemmen met het archeologische team voorafgaand aan de survey. De eisen die het archeologische onderzoek stelt aan de geofysische opnamen dient te worden vastgelegd in een archeologisch Programma van Eisen.

Summary

Petrogas intends to develop new fields in the northern part of the Dutch North sea, in the A/B blocks. In the course of these developments Petrogas plans to drill appraisal wells at the end of 2018 or early 2019.

The planned activities could jeopardize potential archaeological remains. Therefore Petrogas assigned Periplus Archeomare to perform an archaeological desk study. The objective of this study is to compile the archaeological expectation for the area of interest. The results, conclusions and recommendations of this assessment will be included in the licensing procedure.

The desk study has shown that within the research area ship and aircraft wrecks and, if the *Pleistocene* landscape is intact*, in situ prehistoric* remains can be expected. Within the area studied, remains of twelve shipwrecks are known whose archaeological value has not yet been determined. Apart from the known wrecks, wrecks which have not been discovered jet, can be present.

Based on the outcome of the research, it is recommended to carry out an inventory geophysical survey to test the archaeological expectation. Prior to the installation of platforms and pipelines at sea, a geophysical and geotechnical *pre-lay route survey* is carried out as standard. The data from this survey can be used for the test (see table below).

Archaeological Expectancy	**Method**	**Goal**	**Remarks**
Ship and aircraft wrecks	Side Scan Sonar	detect and map wreck sites	wrecks exposed at, or protruding from the seabed
	Multibeam	characterize wreck sites morphologically; detect (partially) buried wrecks by the occurrence of scours	in addition to side scan sonar
	Sub-bottom Profiler	detect buried objects including possible ship wrecks and remains of aircraft	nature of the buried object cannot be determined directly
	Magnetometer		
Prehistoric settlements (camp sites)	Sub-bottom Profiler	map the Pleistocene landscape; specify expectancy	supported by, and validated with drill data
	Geological Drilling	determine lithostratigraphy, soil layer boundaries (erosive or gradual) and characteristics of soil formation and maturation; specify expectancy	bore hole descriptions must meet the objective
	Cone Penetration test	determine lithostratigraphy	correlate with drilling data

If the research methods described in the table are applied during the route survey and when the data obtained is of sufficient quality, the necessary archaeological assessment of the cable route can be carried out. It is advisable to coordinate the technical Scope of Work with the archaeological team before starting the survey activities. The requirements for the geophysical recordings must be laid down in an archaeological Program of Requirements.

1 Introduction

Periplus Archeomare was assigned by Petrogas Netherlands B.V. to conduct an archaeological desk study of the field development in the A/B blocks in the North Sea. The research area of 2142 km2 is located in the northern part of the Dutch Economical Zone, 240 km north of the island of Texel.

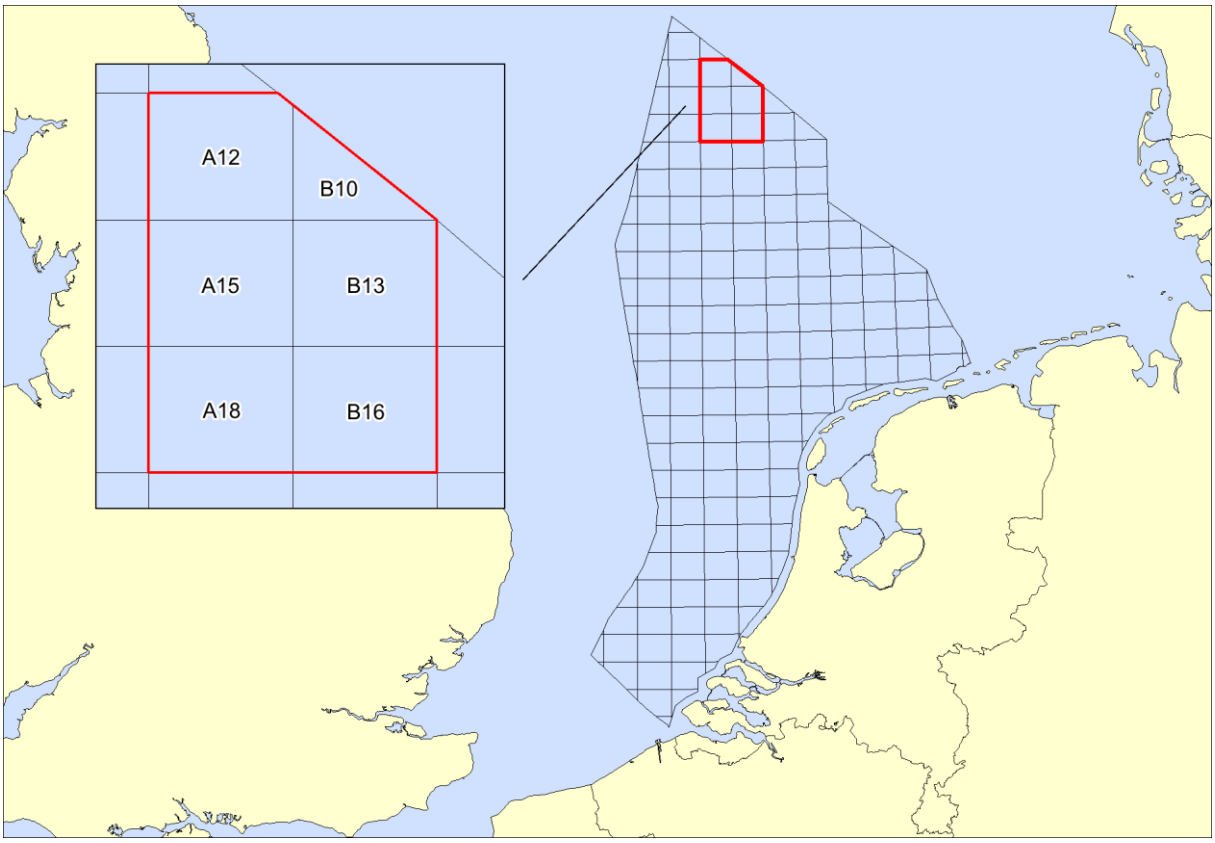

Figure 1. Location map

1.1 Motive

Petrogas intends to develop new fields in the northern part of the Dutch North sea, in the A/B blocks. Three fields in the same area are already developed. Petrogas plans to drill appraisal wells at the end of 2018 or early 2019.

The protection of the archaeological and historical heritage is anchored in the Dutch Heritage Act (July 2016).[1] The installation of platforms, wells and coherent infrastructure might affect archaeological remains, if indeed present. As the planned activities might jeopardize archaeological remains, Economic Affairs considers a research effort is needed to assess the archaeological potential of the area. The results, conclusions and recommendations of this assessment will be included in the licensing procedure.

1.2 Objective

The objective of this desk study is to compile the archaeological expectation for the area of interest.

[1] Dutch: Erfgoedwet.

1.3 Research questions

For an archaeological desk study the following research questions have been defined:

Are archaeological values known in the research area?

If so:

What is the nature, size, and location, depth of occurrence and age of the site?
What is the integrity and conservation of the site?

Are - apart from any known sites - archaeological values to be expected in the research area?

If so:

What is the expected nature, size, and location, depth of occurrence and age of the archaeological remains?
What is the expected integrity and conservation of the anticipated archaeological remains?

Are the known or expected archaeological remains affected by the installation of platforms and pipeline?

2 Methodology

The desk study was conducted in accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1, Protocol 4002). This concerns in particular the specifications LS01wb, LS02wb, LS03wb, LS04wb and LS05wb. The study is reported in accordance with specification LS06wb.

In order to comply with the main objectives and answer the research questions, the archeological desk study includes the following steps:

- Description of the Area of Interest and determination of the consequences for future use (LS01wb);
- Description of the current usage of the area of Interest (LS02wb);
- Description of the historical situation and possible disturbances (LS03wb);
- Description of the known archaeological features and objects (LS04wb);
- Description of the geological setting within which the archaeological objects are to be found (LS04wb);
- Definition of a specified archaeological expectation (LS05wb).

Based on these components the archaeological expectation is specified. It is expressed whether, and if so, which archaeological values are to be expected. The properties of these values will be indicated in as much detail as possible.

The results of the study are summarized in chapter three. Based on the results the research questions are answered in chapter 4. The study concludes with a summary and recommendation in chapter 5.

The desk study and reporting have been conducted by R. van Lil (senior prospector WB), S. van den Brenk (senior archaeologist WB) and authorized by B. van Mierlo (senior prospectorWB).

2.1 Sources

The following sources were consulted for the study:

- National Contact Number (NCN)
- The Hydrographic Service of the Royal Netherlands Navy
- Rijkswaterstaat Zee en Delta
- *TNO-NITG*; geological borehole data and maps
- Archis III, archaeological database of the Dutch Cultural Heritage Agency
- Databases of Periplus Archeomare
- Dutch Federation for Aviation Archaeology (NFLA)
- Various sources from the Internet

For a complete overview of the sources and literature see references on page 27. Words in *italics* and abbreviations are explained in the glossary on page 29.

3 Results – archaeological desk study

3.1 Definition of the plan area and determination of the consequences of future use

The research area comprises six offshore blocks (A12, A15, A18, B10, B13 and B16).

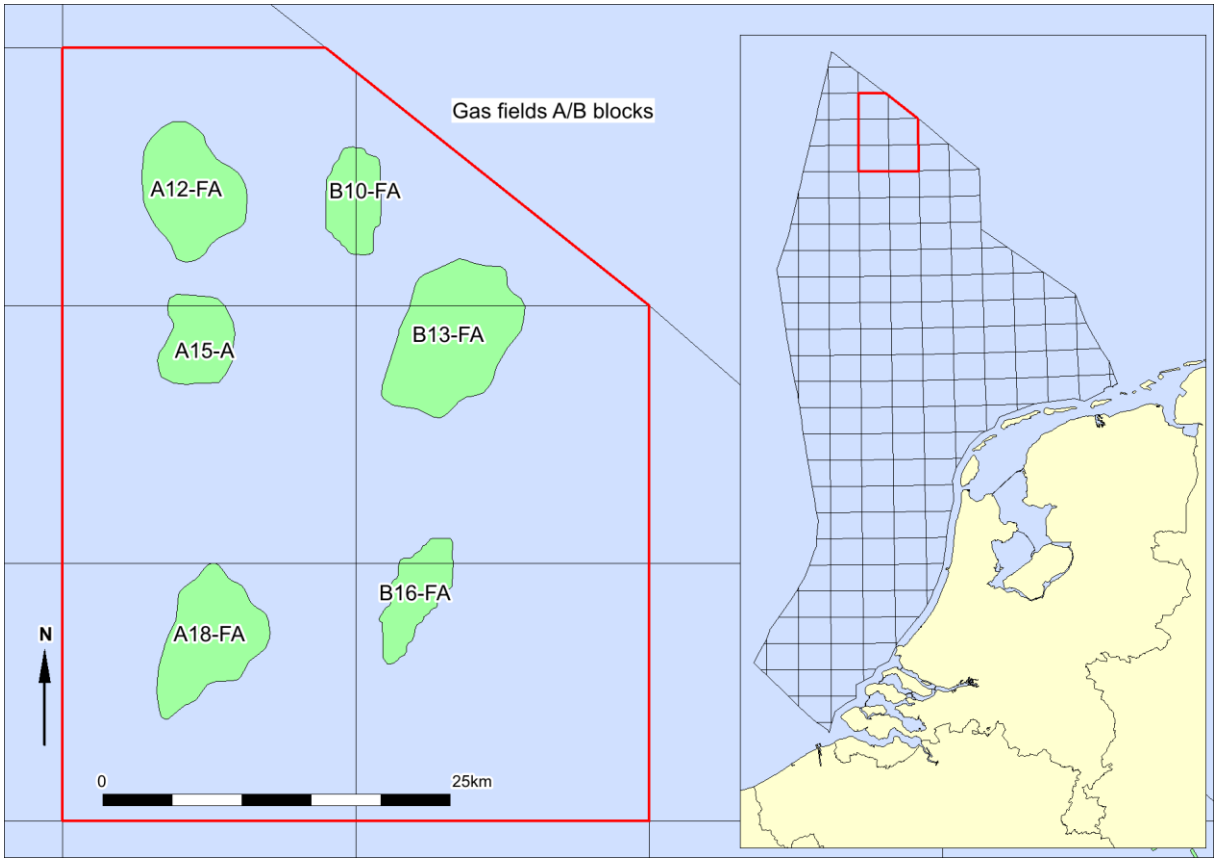

Figure 2. Definition of the research area; known gas fields shown in green

3.2 Current constellation

The figure below shows the water depth in the research area based on the data of the Hydrographic service (2009) complemented by the data from Emodnet (2018) [2]. The depth within the research area varies from 27.1 to 48.5 mLAT, with an average of 40.6 meter.

[2] Hydrographic survey, 2009.

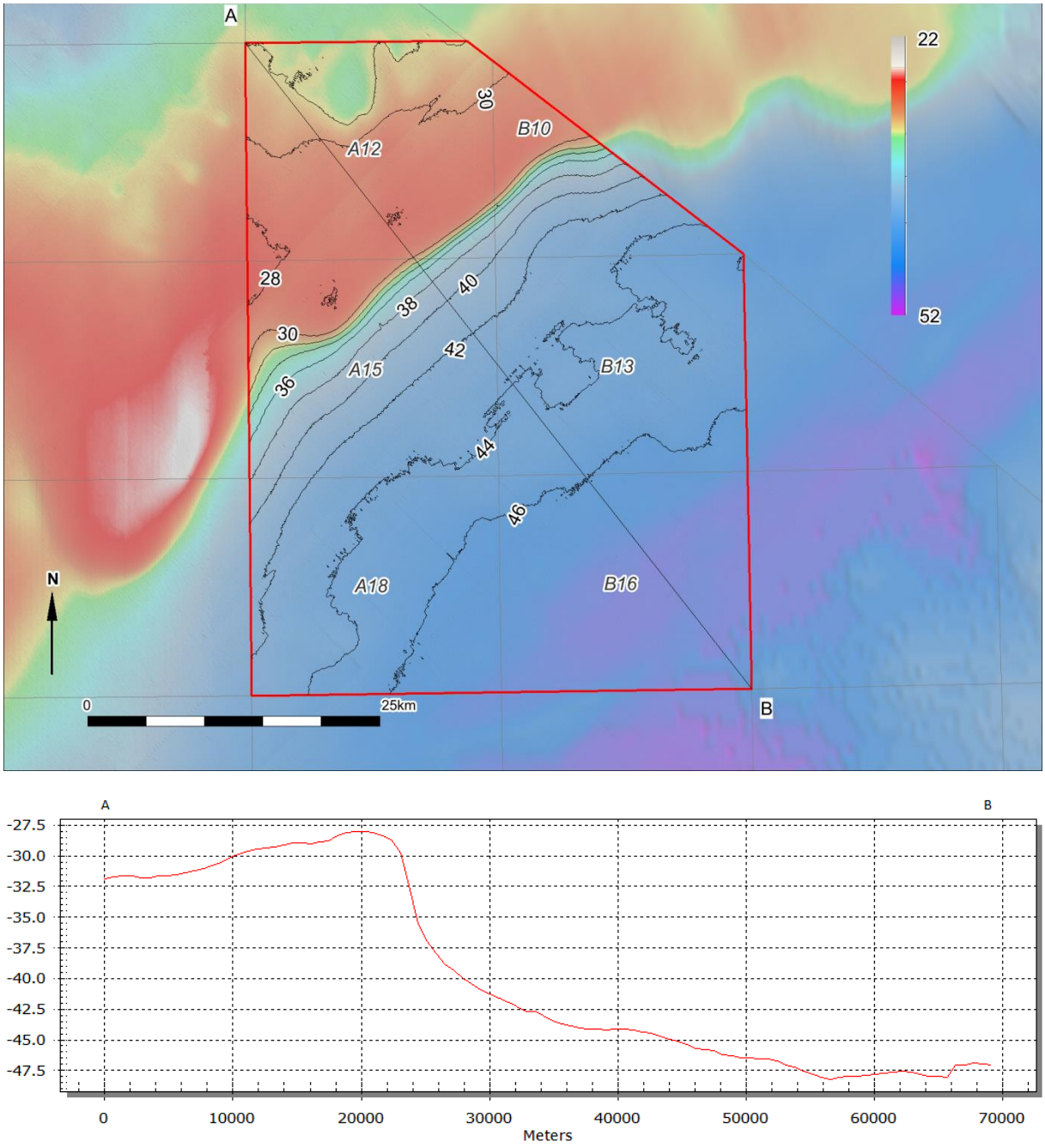

Figure 3. Bathymetry (source DTM: Hydrographic Service 2009 and Emodnet 2018)

The northern part of the research area is defined by the topographic high of the Dogger Bank with a minimum depth of 27m. To the south, the seabed drops quickly to a depth of more than 40m, with a maximum of 48.5m in the southeastern corner.

Pipelines and cables

Four pipelines cross the research area.[3] The labeled pipelines are displayed in figure 4.

[3] Rijkswaterstaat cables and pipelines, November 2017.

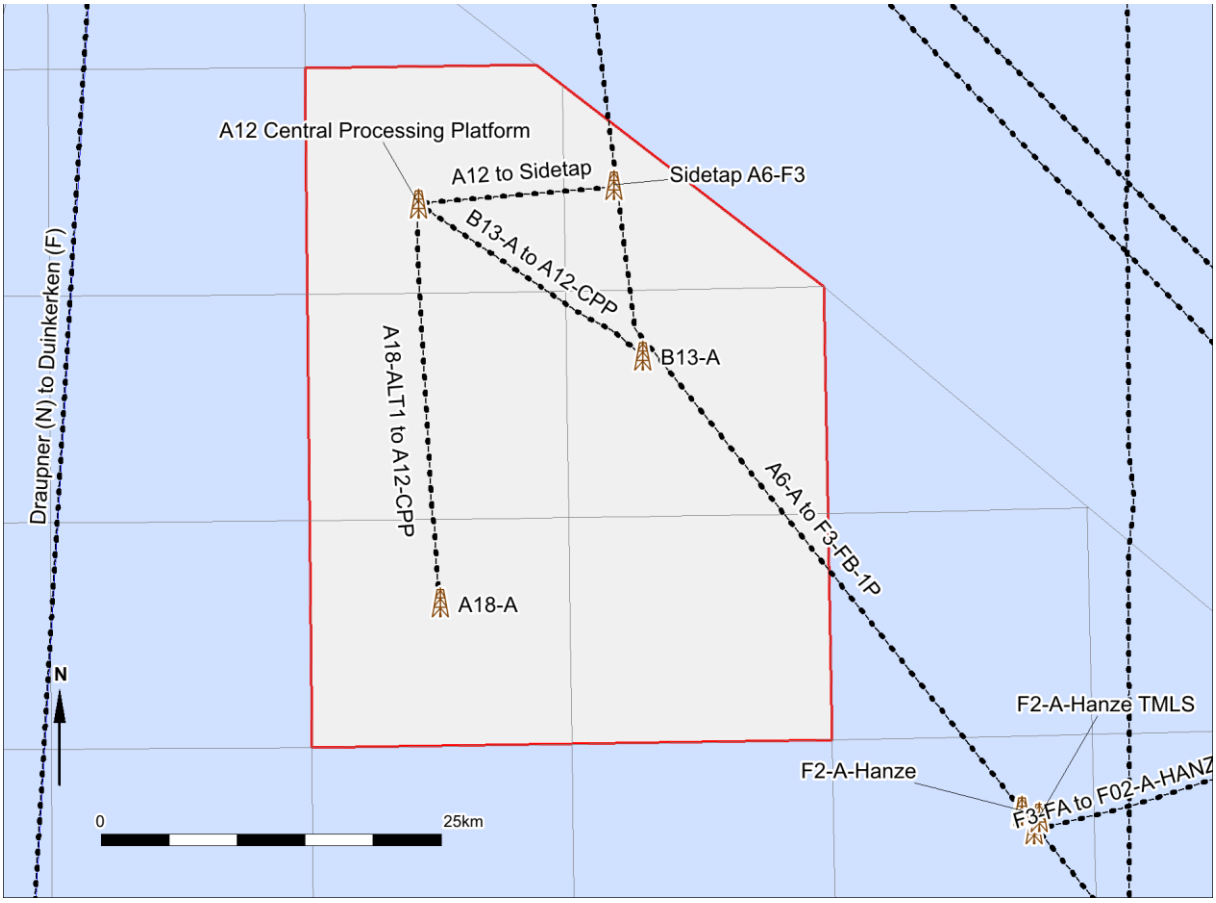

Figure 4. Pipelines and cables

Operator	From	To	Status	Type	Diameter
Petrogas E&P Netherlands B.V.	A18_ALT1	A12-CCP	Active	Gas	12 inch
Petrogas E&P Netherlands B.V.	A12-CCP	Sidetap A6-F3	Active	Gas	16 inch
Petrogas E&P Netherlands B.V.	B13-A	A12-CCP	Active	Gas	16 inch
Wintershall Noordzee B.V.	A6-A	F3-FB-1P	Active	Condensate/Gas	4/20 inch

Table 3 Pipelines crossing the research area

No cables cross the research area.

3.3 Historic situation and known disturbances

The North Sea basin formed about 12,000 years ago as an extensive aeolian sand landscape with a tundra climate. At the end of the last Ice Age (ca 11,500 years ago) the temperature rose, and as a result the northern glaciers melted. The sea level rose and the North Sea basin was gradually filled. The residents of the area had to leave for higher ground.[4]

The Dogger Bank in the North of the Dutch Continental Shelf is an example of an elevated area. Remnants of the tundra landscape and its inhabitants are regularly found in the nets of fishermen. Best known are the many fossils that have been caught in the Dogger Bank. Human artefacts (flints and spearheads) and mammal remains (mammoth and rhinoceros teeth) have been dredged from the Dogger Bank and it has been assumed that the finds have been retrieved from the seabed[5] (2002). More to the south artifacts of bone and antler were found.[6]

Due to the sea level rise the ancient landscapes drowned. These landscapes are depicted through geophysical and geotechnical engineering. In the last decade, for example, on the basis of seismic data from the oil industry a prehistoric landscape was reconstructed near the east coast of England. [7]

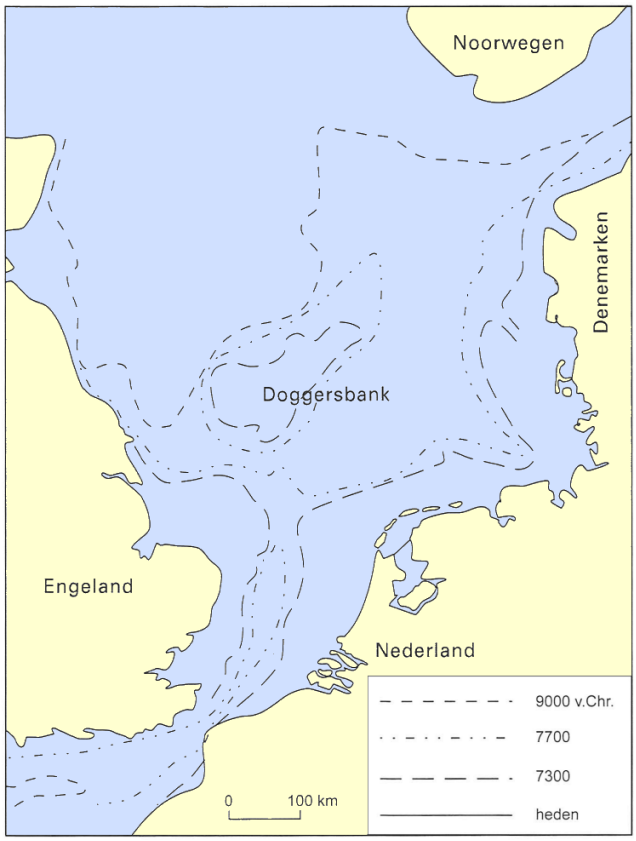

Figure 5. Reconstruction of the historical coast lines in the North Sea basin

[4] Gaffney e.a. 2005.

[5] Fleming 2002.

[6] Louwe Kooijmans 1970.

[7] Project 'North sea paleo-landscapes' of the University of Birmingham.

The archaeological prehistoric findings from the North Sea known in the Netherlands consist of individual finds in sand extraction areas or by fisher men. For example during the construction of Maasvlakte I en II varoius bone artefacts from the early *Paleolithicum and Mesolithicum* were discovered.[8]

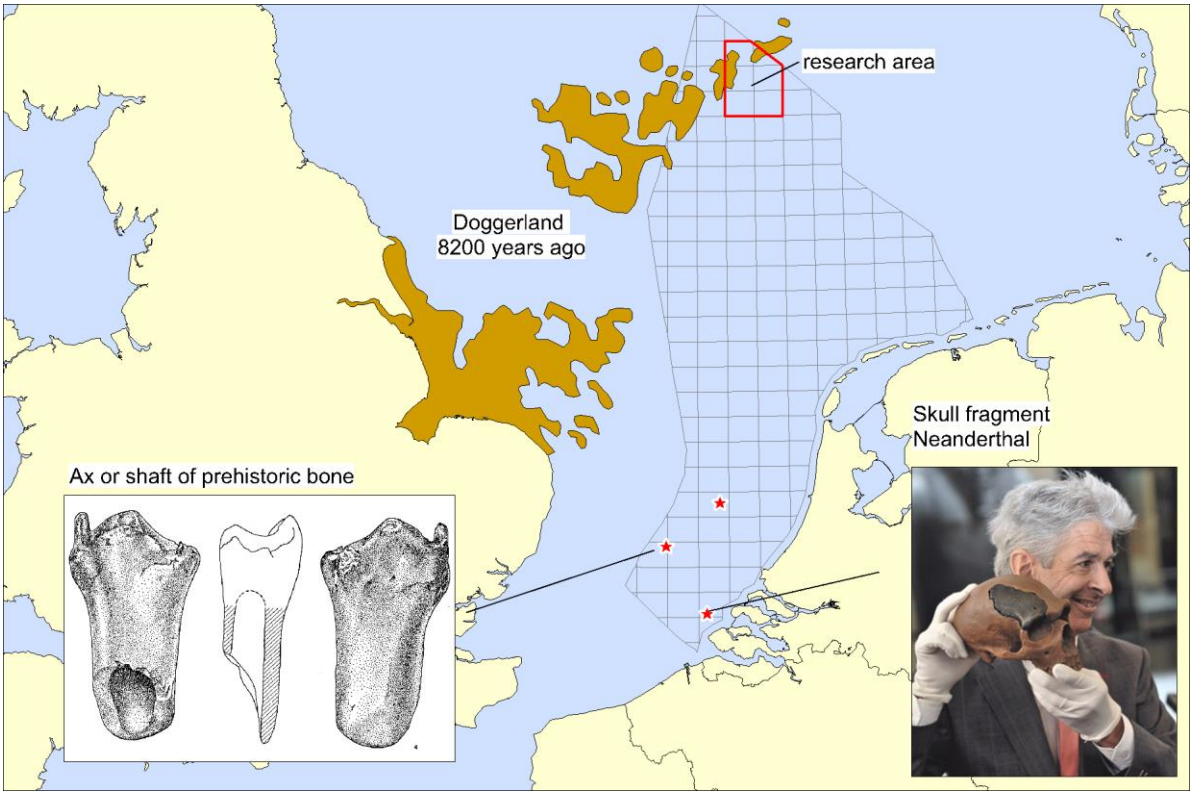

Figure 6. Example of prehistoric artefacts from the North Sea (artefacts from Kooijmans 1970)

Shipping

The earliest evidence of shipping in the North Sea dates from the Bronze Age. Since then, there is an increase of shipping in the North Sea with a few well-documented historical peaks. During Roman times, the North Sea and in particular the Channel served as connecting bridge for the empire. From the Early and High Middle Ages new centers of power arose along the North Sea coast. Furthermore, the raids of the Vikings should also be mentioned in this context. From the late Middle Ages, the international trade and the shipbuilding industry developed so that the North Sea was a stepping stone for global shipping routes. In all periods, ships were lost at sea. Shipwrecks are the traces of the maritime past and this can be preserved under favorable storage conditions in sediment.

[8] Verhart 2005 159.

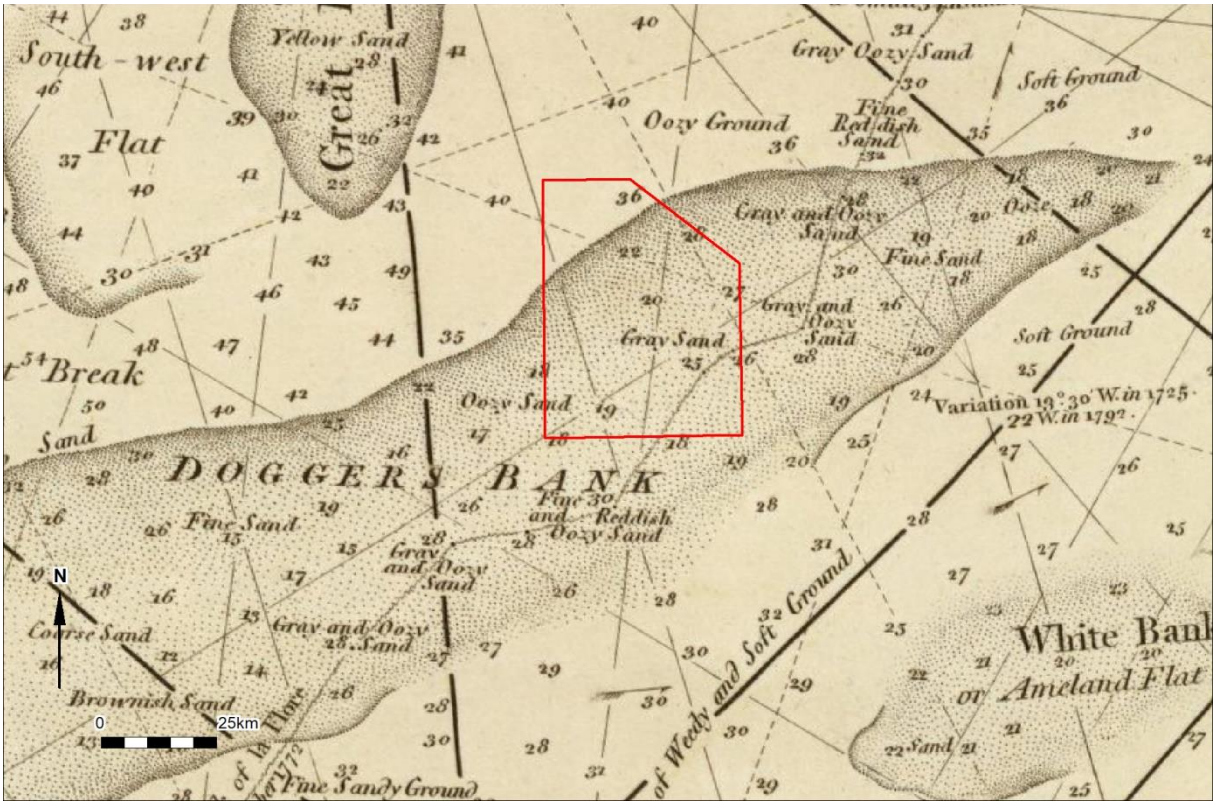

Figure 7. The research area on a historical map of 1777 (William Faden).

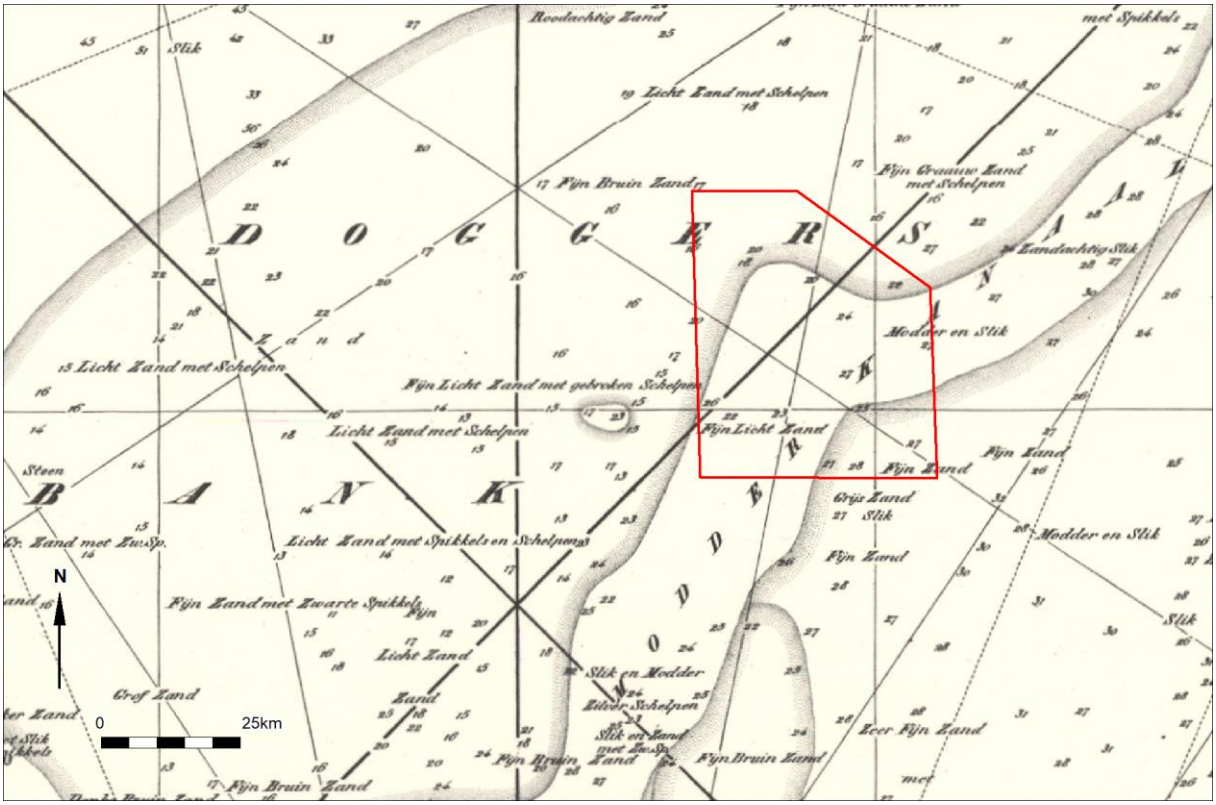

Figure 8. The research area on a historical map of 1852 (Jacob Swart).

Known disturbances of the seabed in the research area

In general, parts of the area may have been disturbed by fishing nets. The pipelines crossing the area have been laid in a trench by ploughing or jetting (see also paragraph 3.2). The initial depth of burial of the pipelines is known and varies between 0.7-1.5m.[9] Depth of burial is measured on an annual basis.

3.4 Description of geological data (LS04wb)

The seabed consists of sand. Locally outcrops of gravelly sand and peat occur (figure 9). The sandy seabed sediments form a mobile top layer in which slowly migrating sand dunes and rapidly migrating current ripples can develop.

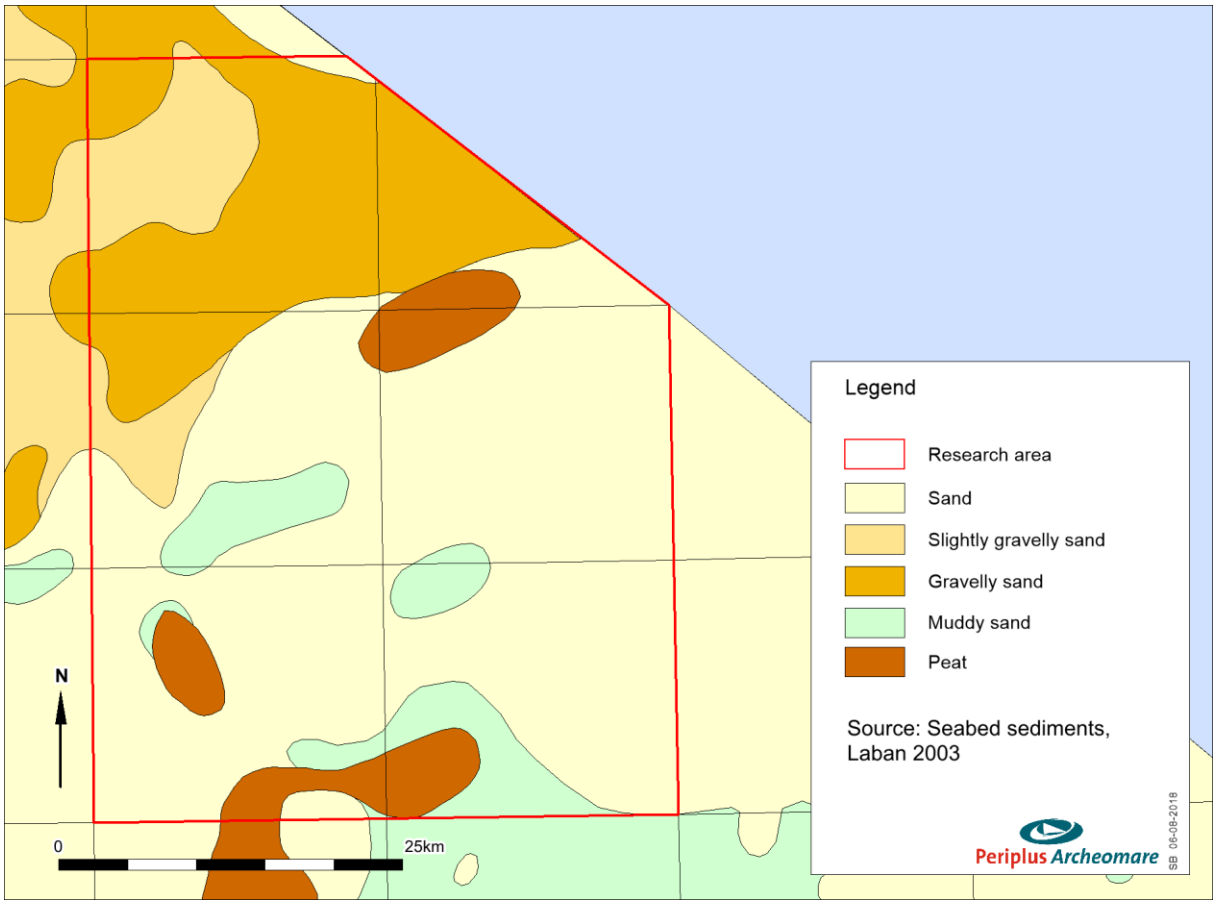

Figure 9. Seabed sediments (source: Laban 2003)

This mobile top layer has been classified as the Nieuw Zeeland Gronden Formation. The thickness Nieuw Zeeland Gronden Formation varies within the research area from less than 1 meter in the western part to 20 meters in the center.

The Geological Survey of the Netherlands (Dutch: Rijks Geologische Dienst) and the British Geological Survey have mapped the quaternary geological units in the area.[10] The names of those units have since changed.[11] In this report we will use the current names of the lithostratigraphic units.

[9] Information supplied by client.

[10] Jeffery et al, 1991.

[11] Rijsdijk 2005.

Current name		Old name
Boxtel Formation	Local terrestrial	Twente Formation
Dogger Bank Member part of the Dogger Bight Formation	Glaciolacustrine clay	Dogger Bank Formation
Uitdam Member Part of the Drente Formation	Glaciolacustrine clay, silt and fine sand	Cleaver Bank Formation

Table 4. Old and new names of lithostratigraphic units in the area

Local occurrences of Early Holocene deposits of the Wormer Member and Basal Peat Bed can be encountered underneath the Nieuwzeeland Ground Formation.

Pleistocene units in the area date from the Late Weichselian and consist of the Dogger Bank Member and the Boxtel Formation. In places where the sequence of Holocene units is thin local outcrops of Pleistocene deposits can occur at the seabed.

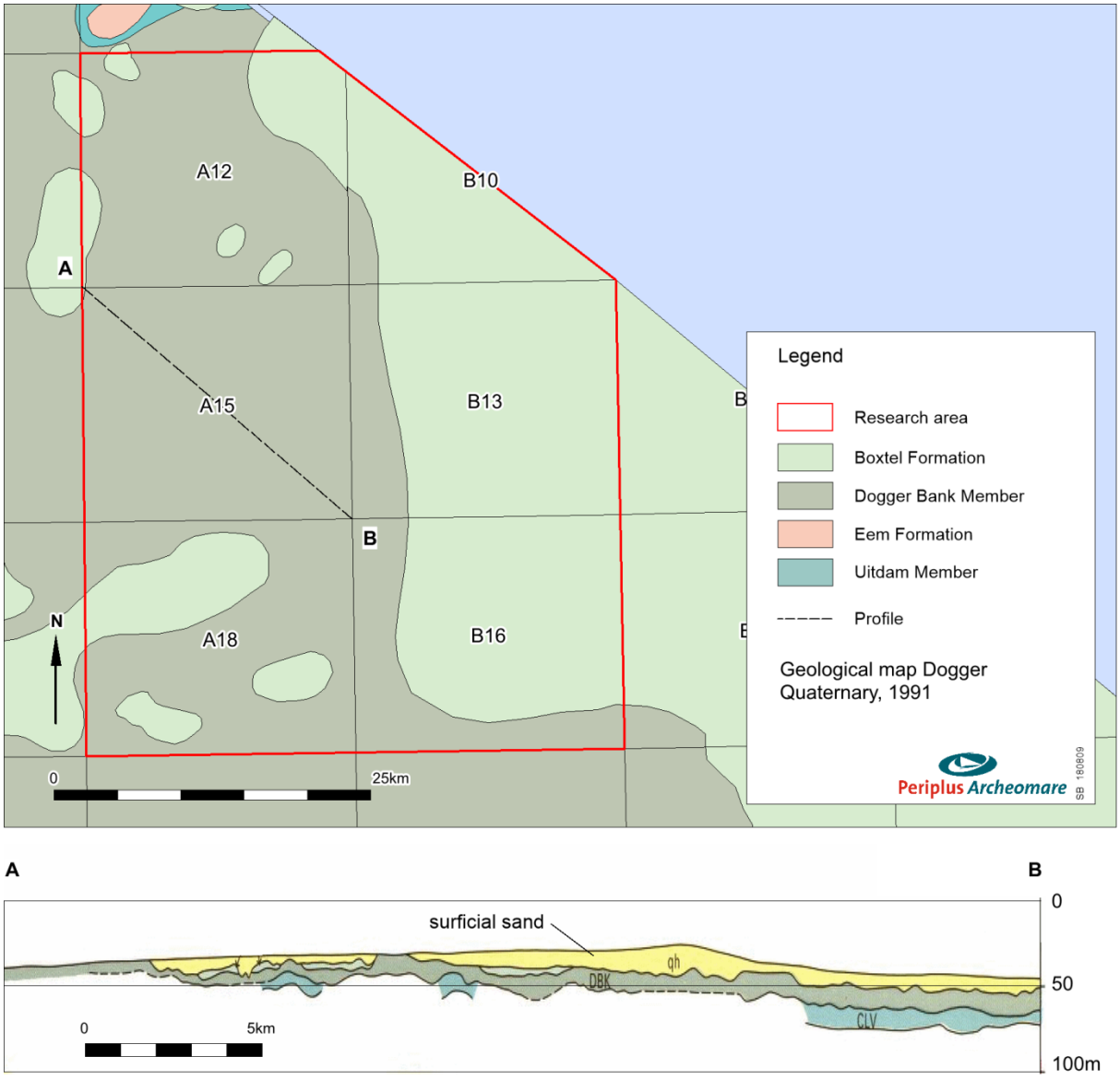

Figure 10. Quaternary geology with profile

The Boxtel Formation consists of very fine to fine sand with peat detritus. The sediments are partly aeolian, partly fluvial. The total thickness of the sequence ranges from 1 to 8m. The Dogger Bank Member consists of glaciomarine and glaciolacustrine clays from the Late Weichselian, and has a thickness of several meters.

The Eem Formation is found north of the research area, where samples were obtained from boreholes. The formation consists of very fine silty marine sands with clay laminae. The Eemian deposits date from the warm interglacial Eemian period, 128.000 – 116.000 years ago, and are preserved in the remnants of tidal channels.

The Uitdam Member consists of stiff clay with silt laminae. The clay is deposited in lakes which are fed by melting glaciers at the end of the Saalian glacial period (238.000 - 128.000 years ago). The sediments can display a typical varve layering comprising an rhythmic alternation of clay deposited during the winter periods (little melting water) and silt and fine sand during summer periods (relatively much melting water). Each layer represents one year of deposition. In the research area, parallel bedding occurs with possible drop stones. At the base of the formation coarse grained deposits have been observed.

The morphology of the seabed is dictated by the geological constellation of the area. The southwest-northeast trending ridge in the northwestern part of the research area is a thrust moraine complex.[12] This idea is not only supported by the morphology of the area but also on the occurrence of fast outcrops of gravelly deposits. The thrust moraine complex developed at the front of glaciers which came from the north to northeast and moved southward during the Late Glacial maximum, some 20.000 years ago. The current seabed morphology does not reflect the original landscape. After the Late Glacial Maximum an overall trend of rising global temperatures is observed, but with distinct alternating warmer interstadials (Bølling / Allerød) and colder stadials. Glaciers melted, which resulted in the development of melt water streams and lakes in which the above described glaciolacustrine clays of the Dogerbank Member are deposited. During the Dryas stadials the area is covered with layers of aeolian sand ('cover sand') of the Boxtel Formation.

Due to the changing climate vegetation developed. Pollen analysis on a borehole sample located 27 kilometer north of the research area displays a record of the flora occupying the area.[13] The sample was taken from a depth of 38.8m (seabed). The lithology found is listed in the table 5.

The pollen diagram spans the chronozones of the Younger Dryas, Preboreal and Boreal. During the Younger Dryas, around 9500 BC, the landscape was characterized by a tundra vegetation with different grass species, pine trees and birch and heather increasing. This pollen assemblage was found in the fine grained cover sand.

During the Preboreal, around 9000 BC, peat developed. The lower 8cm of the peat section shows birch was common, along with heather and increasing hazel and peat moss (*Sphagnum*). The upper part of the peat dates from the Boreal, around 8300 BC. In this period birch becomes scarce; hazel becomes abundant and scrubs increase. Alder, elm and oak pollen is found in small quantities.

[12] Phillips 2018.

[13] Krüger 2017.

The overlying clayey peat shows an increase in fresh water organisms indicating the development of a fresh water lake. The calcareous clay deposited on top of those fresh water clay and peat contains a gradual increase in foraminifera indicate an increase in the marine influx.

Depth (cm)	Lithology	Lithostratigraphy (interpreted)
0–12	Medium to coarse grained sand, interspersed with shells and many small stones, calcareous, 7.5YR N7 olive-grey	Nieuw Zeeland Gronden FM
12–58	Clayey sediments, calcareous, 5Y 4.1 dark grey	Velsen Bed (Wormer MB; Naaldijk FM)
58–62	Clayey sediments and peat, gradual transition to peat below, 10YR 3.1–4.1 very dark grey	Velsen Bed (Wormer MB; Naaldijk FM) Basal Peat Bed (Nieuwkoop FM)
62–73	Peat, highly compressed, no organic macro-remains visible, partly sand lenses, 10 YR 2.1 black	Basal Peat Bed (Nieuwkoop FM)
73–86	Fine to medium grained sand, sharp transition, 2.5Y 4.2 dark grey-brown	Wierden MB (Boxtel FM); paleosol?
86–100	Fine to medium grained sand, 2.5Y 5.3 light olive-brown	Wierden MB (Boxtel FM)

Table 5. Lithological description of borehole sample used for pollen analysis (from: Krüger 2017); lithostratigraphic interpretation by Periplus Archeomare

In figure 11 an indication is given of the drowning history of the research area. The figure is based on a sealevel curve for the Southern North Sea[14] and current depth data from Hydrographic Service 2009 and Emodnet 2018. The figure does not take into account erosion and sedimentation, which means that areas which have eroded could have drowned at a later stage, while areas in which sedimentation has taken place could have drowned at an earlier stage as indicated in the figure. In other words, this figure does not reflect the exact coastline in the Early Holocene.

There are signs that erosion indeed has taken place. Around 8200 calBP (=6250 BC) Doggerland is believed to be struck by a major tsunami.[15] This Storegga Slide tsunami was generated on the Norwegian coastal margin by a submarine landslide. Sealevel had at that time risen to -16m. Possibly the top of the Doggerland landscape in the northwestern part of the research area has been washed away by the tsunami. It is however hard to say if, and if so, to what extent the catastrophic event has affected the area.

[14] Behre 2007.

[15] Weninger 2008.

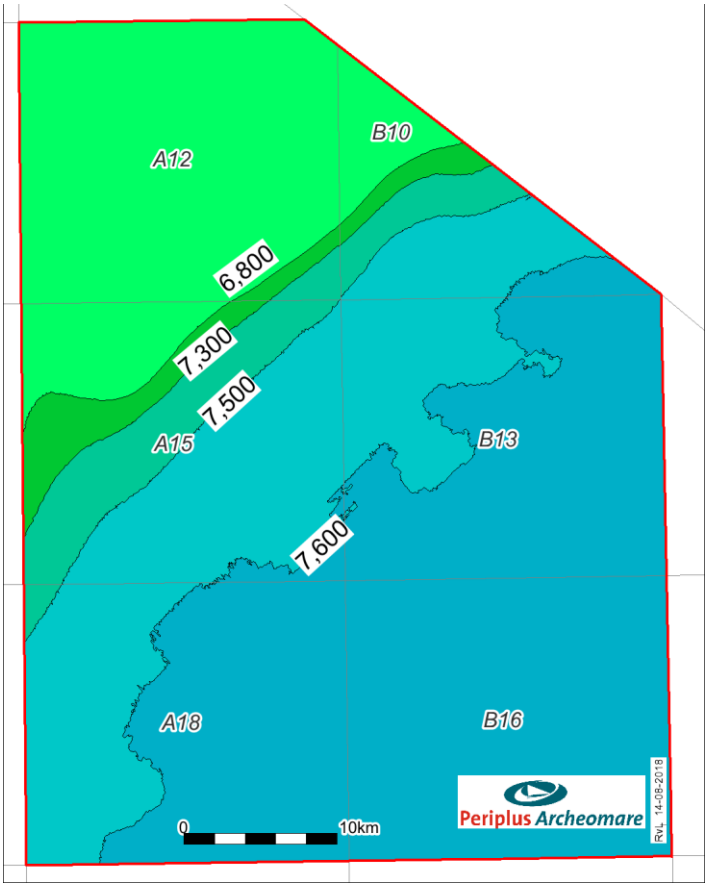

Figure 11. Possible date of drowning in cal. years BC interpreted from bathymetry

3.5 Description of known archaeological values (LS04wb)

The former National Service for Archaeological Heritage (ROB, now Dutch Cultural Heritage Agency or RCE) in collaboration with Rijkswaterstaat and TNO NITG have developed a comprehensive archaeological map of the continental shelf based on geological and archaeological observations (see figure 12).[16]

This global map will give the chance of presence of well-preserved shipwrecks (and often a ship's discovery of high archaeological value) for the Dutch part of the Continental Shelf. However, this map has a very limited use, partly due to the large scale of 1: 500,000. In addition, the degree of conservation is closely related to geology and morphology.

The idea here is that in channel deposits or regions with soft sediment, a wreck quickly sinks into the seabed and therefore remains in good condition. In other areas with harder top sediments the chance of a find is not necessarily lower, but the chance to find a well-preserved ship with the cargo and equipment still intact is considerably less.

[16] IKAW 3rd generation, RCE 2008.

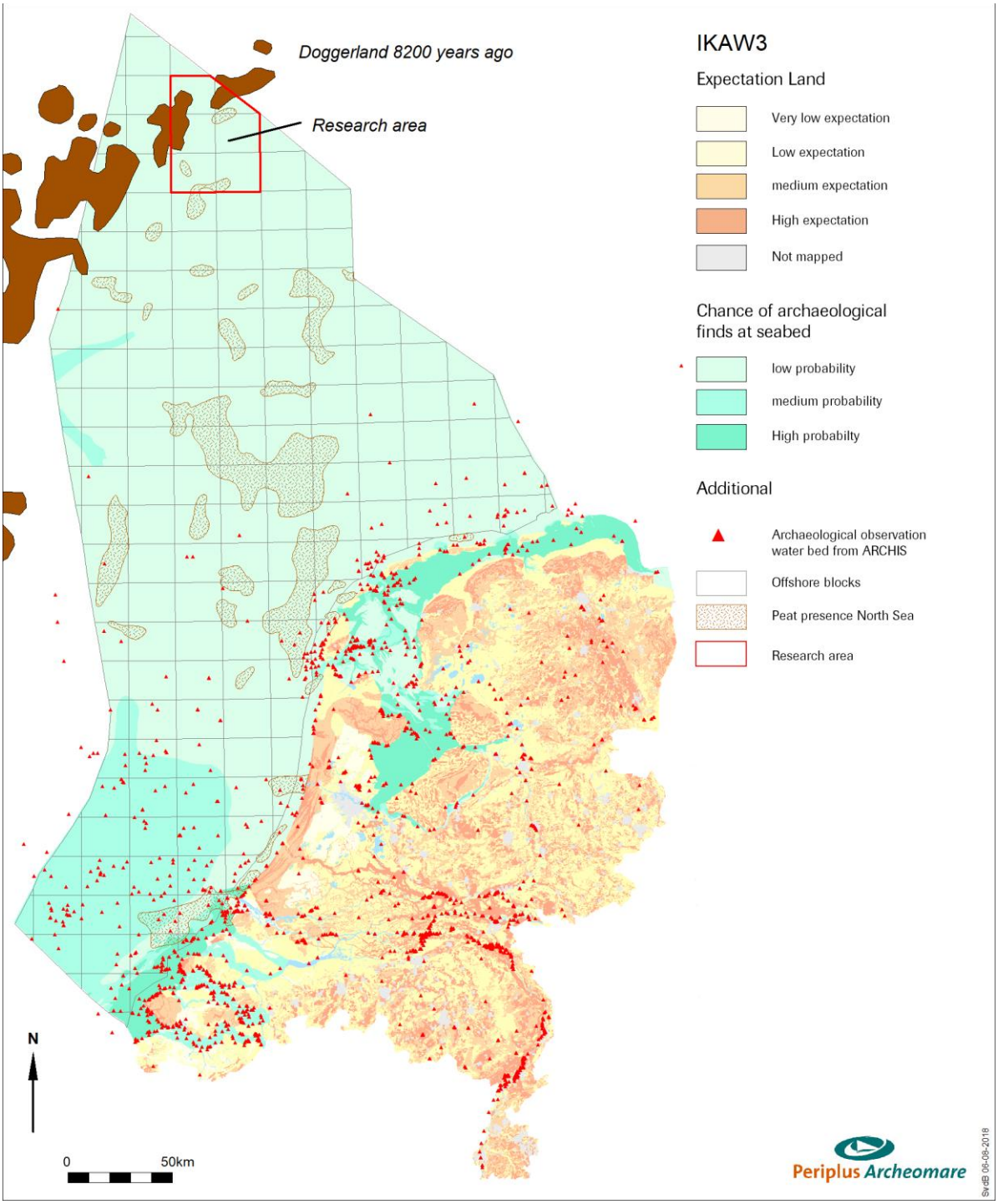

Figure 12. Overview of archaeological expectation in the Netherlands including the Dutch Continental Shelf

The map also indicated areas where peat and clay are preserved. This cover with clay / peat only refers to the possible location of Pleistocene deposits on / near the seabed. Where Holocene clay or peat is eroded Pleistocene layers with artifacts and fauna fossils may be present. The presence of early Holocene sediments could indicate the presence of a well preserved prehistoric landscape.

Research in the last decade has shown that the probability of encountering prehistoric residues in the North Sea, is much greater than originally thought. The archaeological map for the Dutch continental shelf will therefore need to be revised.[17]

Prehistory

In 2016 Deltares has started with the production of a chart on which the expectation for archaeological remains from prehistoric times is mapped.[18] For the realization of this map an indicative archaeological model for the Dutch part of the Continental Shelf has been generated. The upper part of the sedimentary sequence (30m) has been translated into an archaeological model of the terrestrial prehistoric remains which are to be expected in the North Sea area. A distinction was made between remains from 'Early and Middle Paleolithic', 'Late Paleolithic' and 'Mesolithic' times. For each of the time frames a distinction was made between areas where remains are expected to occur *in situ* or little disturbed and areas where remains are expected to be disturbed (referred to as residuary). Also a class 'no prehistoric remains intact' has been defined.

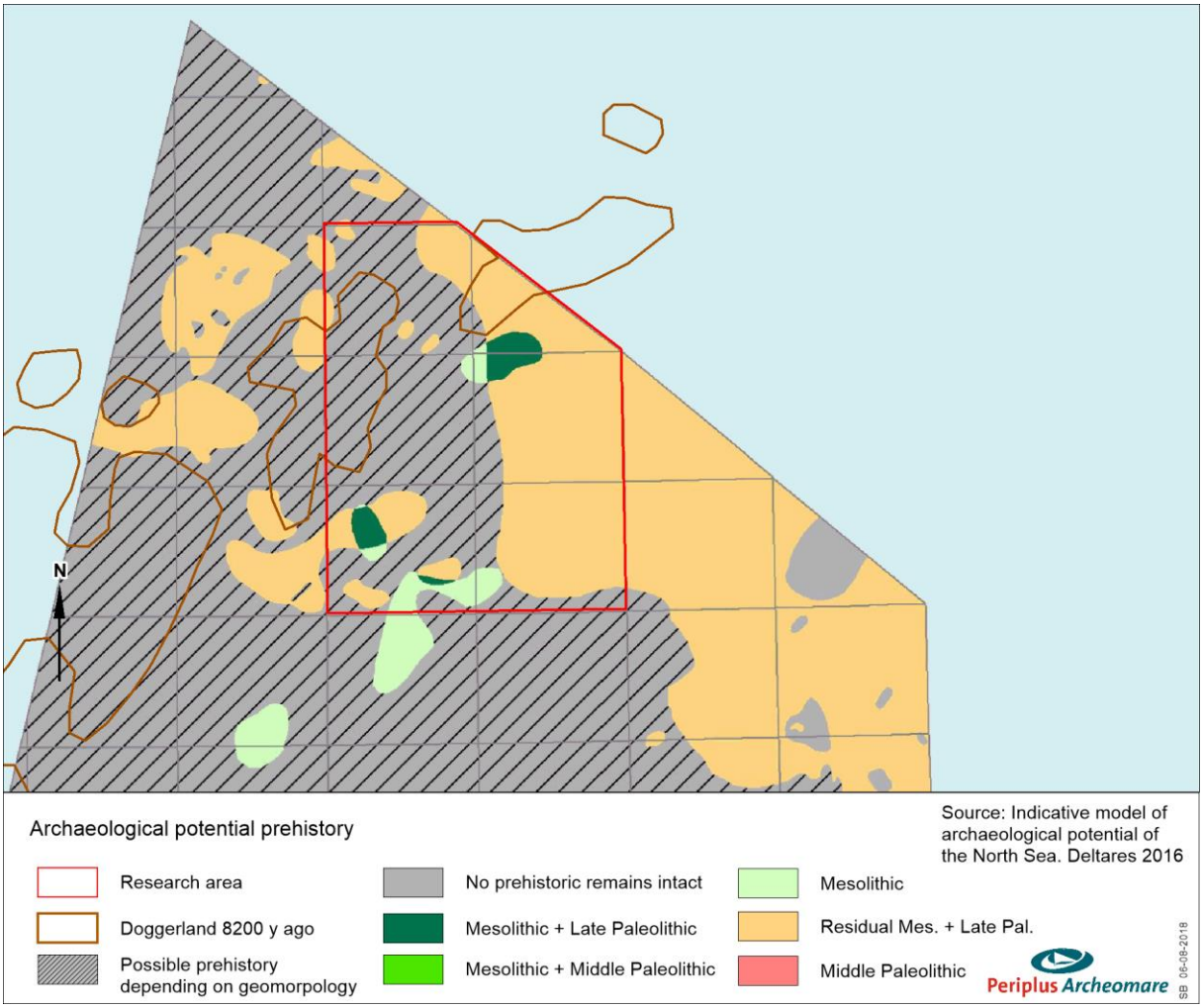

Figure 13. Indicative model of the archaeological potential in the research area

[17] North Sea paleolandcapes' of the University van Birmingham and North Sea Research and management Framework 2009 (Peeters e.a. 2009).

[18] Vonhögen – Peeters 2016.

For the northwestern part of the research area no prehistoric intact remains are to be expected, except for finds related to Doggerland which can be present under specific circumstances, based on the local geomorphology. In the southwestern and eastern part, residual Late Paleolithic and Mesolithic remains can be expected.

Deltares' indicative model closely relates to the geological maps discussed in section 3.4. The areas in which Late Paleolithic and Mesolithic remains are to be expected coincide with the Boxtel Formation mapped in figure 10. Major part of the part of the Boxtel Formation is expected to solely contain 'residual' remains, meaning the archaeological remains are expected to be disturbed to unknown extent, probably because of erosion. Within the Boxtel Formation some isolated areas indicated in dark green. Those areas comprise locations where peat has been found. In Early Holocene times the Pleistocene landscape drowned and peat was deposited. This layer of peat, classified as the Basal Peat Bed, is found in areas in which no erosion of the Pleistocene landscape has taken place after deposition of the peat. The change that the top of the Boxtel Formation, and possible archaeological remains herein, is still intact is considered to be relatively high. Because of this, the assumption is made that *in situ* remains are to be expected in those areas.

The areas labeled with 'possible prehistory depending on geomorphology' coincide with the areas in which the Bolder Bank Member is mapped. The light green areas represent locations where peat occurs. According to Deltares those are the locations where Mesolithic remains are to be expected *in situ*.

Details research area

Figure 14 shows a detailed map of the research area and the officially known archaeological finds in the surrounding area. ARCHIS III is the official database of the National Cultural Heritage Agency in which all archaeological findings and observations in the Netherlands and territorial waters are stored. The database contains more than 85,000 underwater locations (mainly land-based) where archaeological observations have been made. Within the research area no archaeological sites are reported.

Known objects

Known objects other than the ARCHIS observations have been assessed. For this assessment a variety of sources have been consulted, among which the National Contact Number (NCN). The NCN contains a compilation data from databases of the Hydrographic Survey (Dutch: Dienst Hydrografie)[19], the Cultural Heritage Agency (Dutch: Rijksdienst voor het Cultureel Erfgoed) and Rijkswaterstaat.

[19] The Hydrographic Survey database is known as the 'NLhono' database.

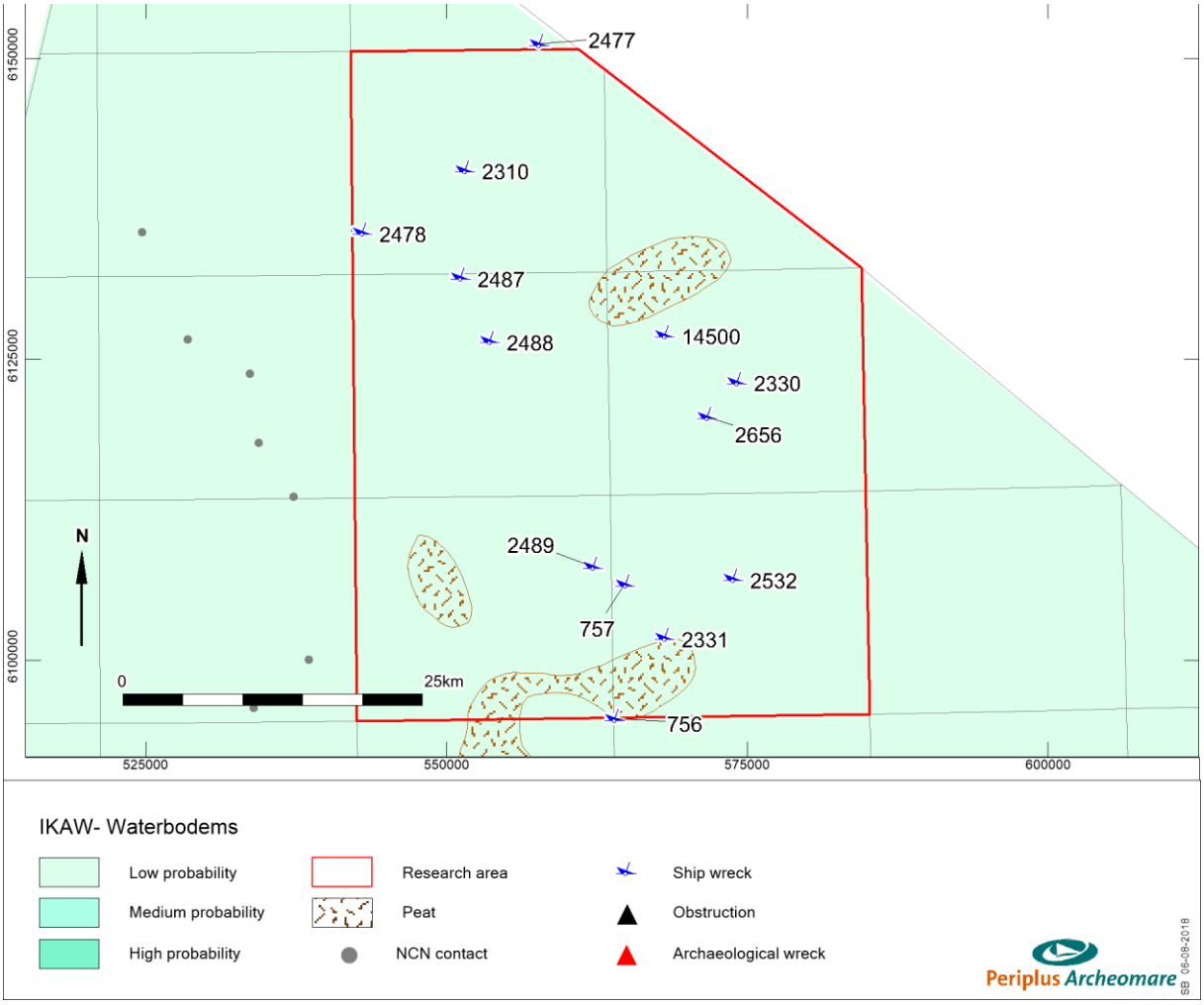

Figure 14. Known object within the research area

The research area contains 13 known objects. The objects comprise one contact from the SonarReg database, twelve contacts from the NLhono database and none from the ARCHIS database. The contacts are listed in the table below.

NCN	SR92	Nlhono	Easting	Northing	R95	Description
756	-	319	563877	6095169	1000	Wreck wooden three-masted barque Tjerimai, sunk 1925,found by SSS 07-08-1999
757	-	320	564781	6106312	1000	Wreck San Miguel, sunk 18-11-1915, found by sss 07-08-1999
2310	-	2553	551461	6140730	5	Unknown wreck surveyed by Svitzer in 2001
2330	-	2583	574073	6123153	0	Wreck submarine U50, sunk 01-09-1917, surveyed 18-01-1988
2331	-	2584	568040	6101877	1000	Unknown wreck surveyed 08-07-1999
2477	-	2871	557621	6151191	5	Unknown wrak reported found during SSS survey 25-04-1998. Width approx. 13m
2478	-	2872	542917	6135545	5	Unknown wreck surveyed 24-09-2013
2487	-	2891	551120	6131801	5	Unknown wreck in 2 parts, surveyed 12-06-1999, researched by duikteam Zeester in 2014
2488	-	2892	553530	6126541	5	Unknown wreck surveyed 25-09-2013
2489	-	2893	562084	6107804	5	Unknown wreck surveyed 08-07-1999
2532	-	2963	573729	6106769	5	Unknown wreck surveyed in 2000
2656	-	3123	571593	6120234	5	Unknown obstruction or wreck, surveyed 04-06-2002

NCN	SR92	Nlhono	Easting	Northing	R95	Description
14500	11309	-9999	568064	6127029	50	Anchor with chain reported lost by MV Rig Expressin 2011

Table 6. Known objects

Within the area, 12 wreck sites are known. The possible archaeological value for these wrecks have not been established.

3.6 Archaeological expectancy

Prehistoric remains

The archaeological expectancy for remains from prehistoric times is related to the geogenesis of the area. The geogenesis is reflected by the current sequence of lithostratigraphic units. Pleistocene and Early Holocene formations are considered to be potential containers of archeological remains.

Archaeological levels are formed by the top of the Dogger Bank Member and the entire sequence of the overlying Boxtel Formation. Especially in areas where those units have been covered by Early Holocene peat (Basal Peat Bed) or clay (Velsen Bed) well-preserved *in situ* remains of high integrity are to be expected. The expected remains include Late Paleolithic and Mesolithic camp sites, burials, lost or dumped objects such as flint and bone artifacts, hunting gear and canoes. Prehistoric camp sites in the context of sandy deposits of the Boxtel Formation are characterized by the scattered occurrence of flint artifacts and debris resulting from the production of flint tools accompanied by burnt seeds (hazel nuts), charcoal and bone. The camp sites are generally small with little remains, though larger sites with a medium to high density of flint artifacts can occur in case a site has been used repeatedly and/or for a prolonged period of time.

The top of the Pleistocene landscape is expected to occur at depths below the seabed ranging from less than 1m in the western part of the area to over 20m in the center.

To date it is unknown if the catastrophic tsunami event which occurred around 6250 BC has eroded the Dogger Bank Member and the Boxtel Formation in the area. If so, the integrity of archeological remains is might be affected to a large extent. Apart from this catastrophic event, the archaeological remains could have been subject to erosion caused by wave action and tidal currents after the area drowned.

The expectancy for prehistoric remains can be tested by a geo-archaeological assessment of subbottom data. If the lithostratigraphic units and coherent archaeological levels are found at depths larger than 3m, it is not considered likely that prehistoric remains will be affected by the installation of the pipelines.

Historical ship wrecks

Within the area, 12 wreck sites are known. The possible archaeological value for these wrecks have not been established.

Apart from the known ship wreck undiscovered wrecks might be present in the research area. In general, when a sinking ship ends up on the seabed, the tidal currents will create scouring around the wreck, and bury it down to a level of a harder surface within the sedimentary sequence. A thick top layer of loose material contributes to the covering and preservation of a ship wreck. Especially in areas in which the

upper seabed layer contains a significant admixture of clay will seal and thus promote conservation. This effect will be less if the top layer solely consists of sand or gravel. Wooden parts of wrecks which are exposed at the seabed are subject to biodetoriation by marine fauna like the naval ship-worm (*Teredo Navalis)*.

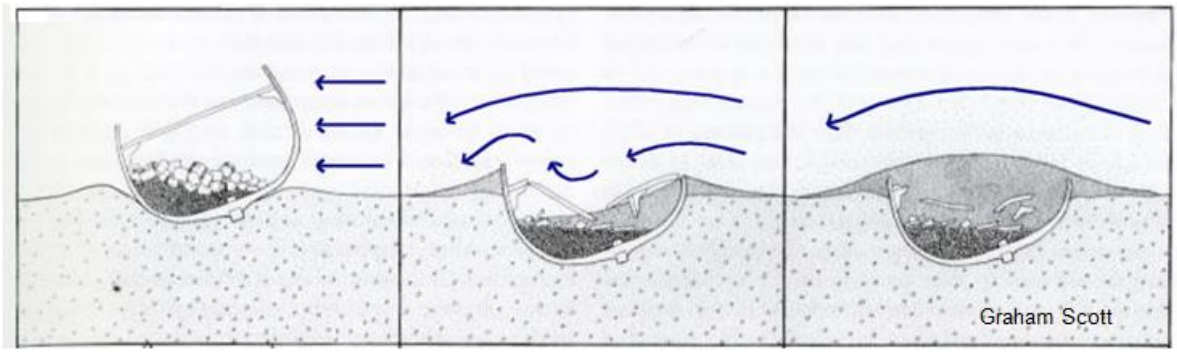

Figure 15. Example of wreck site formation (Graham Scott)

Ship wrecks and aircrafts from World War I & II

The number of aircrafts from the Second World War missing is not exactly known. It is however plausible to assume that to date solely for the North Sea area hundreds of planes have never been found. Also submarines and other ships that were sunk during both World Wars can be expected.

4 Answers to research questions and conclusions

Are archaeological values known in the research area?

No, formal archaeological values within the research area are not known. But within the area, 12 wreck sites are known of which the possible archaeological value has not been established yet.

If so:
What is the nature, size, location, depth of occurrence and age of the site?

Three of the registered objects are classified as ship wreck:
Three of the known ship wrecks have been identified:

1. Wooden three-masted barque Tjerimai, sunk in 1925
2. San Miguel, sunk 18-11-1915
3. Submarine U50, sunk 01-09-1917

For the other 9 wrecks additional information is not available.

What is the integrity and conservation of the site?

The integrity and conservation of the wrecks is not known.

Are - apart from any known sites - archaeological values to be expected in the research area?

Yes, prehistoric remains and thus far undiscovered ship and plane wrecks are to be expected in the research area.

What is the expected nature, size, location, depth of occurrence and age of the archaeological remains?
Archaeological remains can occur within the top of the Dogger Bank Member. The top of this unit has been found at depths ranging from 3.5m to 15m below the seabed.

The expected remains include Late Paleolithic and Mesolithic camp sites, burials, lost or dumped objects such as flint and bone artifacts, hunting gear and canoes. Prehistoric camp sites in the context of sandy deposits of the Boxtel Formation are characterized by the scattered occurrence of flint artifacts and debris resulting from the production of flint tools. Other indicators are burnt seeds (hazel nuts), charcoal and bone. The camp sites are generally small with little remains, though larger sites with a medium to high density of flint artifacts can occur in case a site has been used repeatedly and/or for a prolonged period of time.

What is the expected integrity and conservation of the anticipated archaeological remains?
Especially in areas where the Dogger Bank Member and Boxtel Formation have been covered by Early Holocene peat (Basal Peat Bed) or clay (Velsen Bed) well-preserved *in situ* remains of high integrity are to be expected.

To date it is unknown if the catastrophic tsunami event which occurred around 6250 BC has eroded the Dogger Bank Member and the Boxtel Formation in the area. If so, the integrity of archeological remains is might be affected to a large extent. Apart from this catastrophic event, the archaeological remains could have been subject to erosion caused by wave action and tidal currents after the area drowned.

Are the known or expected archaeological remains affected by the installation of platforms and pipelines?
From the expected depth of occurrence of archaeological levels (up to 20m below the seabed) in relation to the planned depth of installation of pipelines (up to 2m below the seabed) it can be concluded that prehistorical remains presumably will not be affected by pipeline constructions. However, the expected depth of the Pleistocene units and the potential archaeological horizons contained in these units has to be confirmed by the subbottom profiler survey.

5 Summary and recommendations

The desk study has shown that within the research area ship and aircraft wrecks and, if the *Pleistocene* landscape is intact*, in situ prehistoric* remains can be expected.

Within the area studied, remains of twelve shipwrecks are known whose archaeological value has not yet been determined. The expectation is that within the research area undiscovered wrecks can be present.

Based on the outcome of the research, it is recommended to carry out an inventory geophysical survey to test the archaeological expectation.[20] Prior to the installation of platforms and pipelines at sea, a geophysical and geotechnical *pre-lay route survey* is carried out as standard. The data from this survey can be used for the test (see table below).

Archaeological Expectancy	**Method**	**Goal**	**Remarks**
Ship and aircraft wrecks	Side Scan Sonar	detect and map wreck sites	wrecks exposed at, or protruding from the seabed
	Multibeam	characterize wreck sites morphologically; detect (partially) buried wrecks by the occurrence of scours	in addition to side scan sonar
	Sub-bottom Profiler	detect buried objects including possible ship wrecks and remains of aircraft	nature of the buried object cannot be determined directly
	Magnetometer		
Prehistoric settlements (camp sites)	Sub-bottom Profiler	map the Pleistocene landscape; specify expectancy	supported by, and validated with drill data
	Geological Drilling	determine lithostratigraphy, soil layer boundaries (erosive or gradual) and characteristics of soil formation and maturation; specify expectancy	bore hole descriptions must meet the objective
	Cone Penetration test	determine lithostratigraphy	correlate with drilling data

Table 7. Testing of archaeological expectation with geophysical methods

If the research methods described in the table are applied during the route survey and when the data obtained is of sufficient quality, the necessary archaeological assessment of the cable route can be carried out. It is advisable to coordinate the technical Scope of Work with the archaeological team before starting the survey activities. The requirements for the geophysical recordings must be laid down in a Program of Requirements.[21]

[20] In accordance with KNA waterbodems protocol 4103.

[21] In accordance with KNA waterbodems protocol 4001.

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Glossary and abbreviations

Terminology	Description
AMZ	Archeologische Monumenten Zorg
CPT	Cone penetration test
Ferrous	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	Program of Requirements (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 sub surface.
Trenching	Construction of a trench for the purpose of burying a cable or pipeline
Vibrocore	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.

References

- Behre, K.-E., 2007: A new Holocene sea-level curve for the southern North Sea. Boreas, Vol. 36, pp. 82–102. Oslo.
- Bosch, J.H.A., F.S. Busschers & H.J.T. Weerts 2003: Eem Formatie. In: Lithostratigrafische Nomenclator van de Ondiepe Ondergrond. Retrieved 23-12-2016 from https://www.dinoloket.nl/eem-formatie.
- De Bruin, R., Forzoni, A., de Kleine, M., de Lange, G., Mesdag, C. and Vermaas, T., 2015. Geological study Hollandse Kust (zuid) Wind Farm Zone. Deltares rapport 1221136-000-BGS-0006.
- Deeben, J., D.P. Hallewas & Th.J. Maarleveld, 2002: Predictive modelling in Archaeological Heritage Management of the Netherlands: the Indicative Map of Archaeological Values (2nd Generation), Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek 45, 9-56.
- Fitch, S, Thomson, K. and Gaffney, V., 2005. Late Pleistocene and Holocene depositional systems and the palaeogeography of the Dogger Bank, North Sea. Elsevier Quaternary research 64 (2005) p 185-196
- Flemming, N.C., 2002. The Scope of Strategic Environmental Assessment of North Sea Areas SEA3 and SEA2 in Regard to Prehistoric Archaeological Remains. Department of Trade and Industry (Report TR014).
- Gaffney, V., Thomson, K. and Fitch, S., 2009. Mapping Doggerland. The Mesolithic Landscapes of the Southern North Sea.
- IMAGO projectgroep, 2003: Eindrapportage IMAGO: Samenvatting en conclusies, RDIJ rapport 2003-13a.
- Jelgersma, S., 1979. Sea-level changes in the North Sea basin. In: Oele, E., Schuttenhelm, R.T.E., Wiggers, A.J. (Eds.), The Quaternary History of the North Sea, Acta Universitatis Upsaliensis: Symposium Universitatis Upsaliensis Annum Quingentesimum Celebrantis, vol. 2, pp. 233–248.
- Krüger, S., Dörfler, W., Bennike O. & Wolters, S., 2017: Life in Doggerland – palynological investigations of the environment of prehistoric hunter-gatherer societies in the North Sea Basin. – E&G Quaternary Science Journal, 66 (1): 3–13. DOI: 10.3285/eg.66.1.01.
- Laban, C. 2003: Seabed Sediments map, Netherlands Institute of Applied Geoscience TNO, Department of Geo Marine and Coast, Utrecht.
- Laban, C. 2004: Top Pleistocene Formations map, Netherlands Institute of Applied Geoscience TNO, Department of Geo Marine and Coast, Utrecht.
- Louwe Kooijmans, L.P., 1970– 1971. Mesolithic bone and antler implements from the North Sea and from the Netherlands. Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek 20/21, 27–73.
- Maarleveld, TH.J. , Almere 1998: Archaeological heritage management in Dutch waters: exploratory studies.
- Mulder, E.F.J. de, M.C. Geluk, I. Ritsema, W.E. Westerhoff & T.E. Wong, 2003: De Ondergrond van Nederland. WoltersNoordhoff, Groningen.
- Peeters, J.H.M. & Momber, G. (2014): The southern North Sea and the human occupation of northwest Europe after the Last Glacial Maximum. – Netherlands Journal of Geoscience. Geologie en Mijnbouw 93 1/2: 55−70.
- Rijsdijk, K.F., S. Passchier, H.J.T. Weerts, C. Laban, R.J.W. van Leeuwen & J.H.J. Ebbing, 2005: Revised Upper Cenozoic stratigraphy of the Dutch sector of the North Sea Basin: towards an integrated

lithostratigraphic, seismostratigraphic and allostratigraphic approach. Netherlands Journal of Geosciences — Geologie en Mijnbouw | 84 – 2 |129 - 146 | 2005.

- Tamis, J.E., M.G.D.Smit, K.I E. Holthaus, N.H.B.M. Kaag en C.C. Karman, 2006. MER voor de ontwikkeling van de gasvelden in de A en B blokken in het Nederlandse deel van het continentale plat.
- Van der Velde, M., 2015. MER beoordelingsnotitie Diepboring en installatie platform A18. A/B Development Stage 1C, A18 project – Phase 4. Petrogas document number A18-0009-HES-RPT-PTG-0000-00009-00
- Vonhögen-Peeters, L.M., van Heteren, S. en Peeters, J.H.M., 2016. Indicatief model van het archeologisch potentieel van de Noordzeebodem. Deltares rapport 1209133-000.
- Weninger, B., R. Schulting, M. Bradtmöller, L. Clare, M. Collard, K. Edinborough, J. Hilpert, O. Jöris, M. Niekus, E. J. Rohling, B. Wagner, 2008: The catastrophic final flooding of Doggerland by the Storegga Slide tsunami. Documenta Praehistorica XXXV (2008).

Various Sources

- Archis III, archeologische database Rijksdienst voor het Cultureel Erfgoed
- Databases Periplus Archeomare
- Wrecksite, www.wrecksite.eu
- KNA Waterbodems 4.1
- Nationaal Contactnummer Nederland (NCN)
- SonarReg92, objectendatabase Rijkswaterstaat Noordzee en Delta
- Ontwerp Beleidsnota Noordzee 2016-2021

Appendix 1. Geological and archaeological time scale (Dutch)

CHRONOSTRATIGRAFIE				ARCHEOLOGISCHE PERIODE				
SERIE	ETAGE - CHRONOZONE		TIJD	TIJDPERK				DATERING
Holoceen	**Laat Subatlanticum**		**1150 n. Chr**	Nieuwe tijd			C	1850
							B	1650
							A	1500
				Middeleeuwen		Laat	B	1250
							A	1050
						Vroeg	D	900
							C	725
							B	525
							A	450
	Vroeg Subatlanticum		0	Romeinse tijd			Laat	270
							Midden	70 n. Chr.
							Vroeg	15 v. Chr.
			450 v. Chr	Prehistorie	Metaaltijden	IJzertijd	Laat	250
							Midden	500
							Vroeg	800
	Subboreaal		3700			Bronstijd	Laat	1100
							Midden	1800
							Vroeg	2000
	Atlanticum		7300		Steentijd	Neolithicum	Laat	2850
							Midden	4200
							Vroeg	4900/5300
	Boreaal		8700			Mesolithicum	Laat	6450
							Midden	8640
	Preboreaal		9700				Vroeg	9700
Pleistoceen	Weichselien	Laat Glaciaal	Jonge Dryas	11.000		Paleolithicum	Laat	B	12.500
			Allerød	12.000					
			Oude Dryas	12.100					
			Bølling	13.000					
		Pleniglaciaal L		17.000			Jong		16.000
			Late Glacial Max	20.000					
				31.500				A	35.000
			Denekamp	34.000					
		Pleniglaciaal M		40.000			Midden		
			Hengelo	41.500					
				45.000					
		Pleniglaciaal V	Moershoofd	50.000					
				71.000					250.000
		Vroeg Glaciaal	Odderade	74.000					
			Brørup						
			Amersfoort						
				114.000					
	Eemien			126.000			Oud		
	Saalien			236.000					
	Oostermeer			241.000					
	onbenoemd			322.000					
	Belvédère			336.000					
	onbenoemd			384.000					
	Holsteinien			416.000					
	Elsterien			463.000					

Appendix 1. Phases of maritime archaeological research

The Dutch Quality Standard for Archaeology (KNA Waterbodems, version 4.1) describes all procedures and requirements for the archaeological research process. 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 echo sounder 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 before contain a number of decision points that are dependent on the detected archeological objects. The figure below shows these moments schematically.