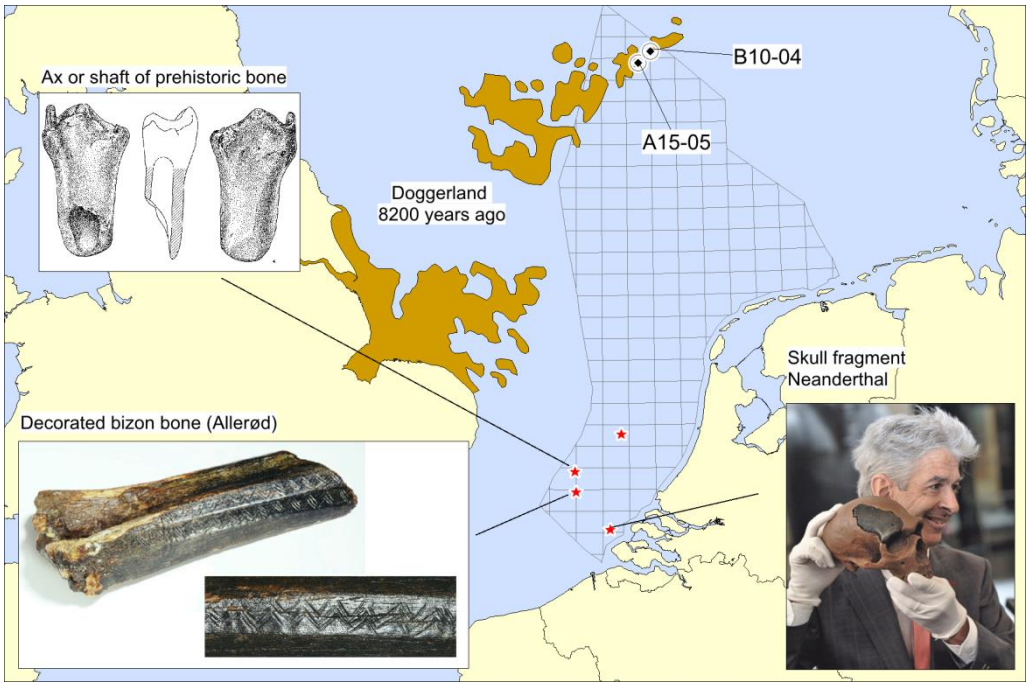
Periplus Archeomare

Appraisal Wells B10-04 and A15-05
North Sea

Archaeological desk study



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At the request of:

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Petrogas E&P Netherlands B.V.

Document Control	
Document 18A021-01-Desk study Petrogas	
Revision	2.1 (Final)
Date	15-03-2019
Reference Periplus Archeomare	18A021-02
Reference client	

Reviewers	
Organisation	Name
Petrogas Netherlands B/V.	J. Kwakernaak
Rijksdienst voor het Cultureel Erfgoed	M. Snoek, B. Smit, J. Opdebeeck

Colophon

Periplus Archeomare Report 18A021-02

Appraisal Wells B10-04 and A15-05, North Sea
Archaeological desk study

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ISSN 2352-9547

Revision details

Revision	Status	Description	Author	Checked by	Autorisation	Date
2.1	Final	Dutch summary added	RvL/SvdB/RC	BvM	BvM	15-03-2018
2.0	Final	Comments RCE addressed	RvL/SvdB/RC	BvM	BvM	01-11-2018
1.0	Draft	First issue	RvL/SvdB/RC	BvM	BvM	23-09-2018

Authorization:

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Table 1. Dutch archaeological 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	Appraisal Well Locations B10-04 and A15-05			
Chart:	BA 267			
Coordinates:	Well	Datum	X [m]	Y [m]
	B10-04	ED50	563,418.00	6,140,534.00
		ETRS89	563,324.36	6,140,321.18
	A15-05	ED50	552,758.00	6,130,353.00
		ETRS89	552,664.42	6,130,140.24
Depth (LAT):	B10-04: 28.1 to 28.5 meter, average 28.3 meter A15-05: 28.8 to 30.8 meter, average 28.9 meter			
Research Area (sqkm)	B10-04: 1 sqkm; A15-05: 1sqkm			
Environment:	Tidal currents, salt water			
Area use:	Shipping lane, fishing			
Area administrator:	Rijkswaterstaat Zee en Delta			
ARCHIS-research report (CIS-code):				
Periplus-project reference:	18A021-02			
Period	September 2018			

Samenvatting (Summary in Dutch)

Periplus Archeomare heeft in opdracht van Petrogas een archeologisch bureauonderzoek uitgevoerd voor de boorlocaties van twee evaluatieputten: B10-04 en A15-05.

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. Binnen de onderzoeksgebieden rond de boorlocaties zijn geen wrakken bekend, maar de aanwezigheid van onontdekte wrakken kan niet worden uitgesloten.

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 de platforms zullen geofysische en geotechnische surveys worden uitgevoerd. De ingewonnen data van deze surveys kunnen worden gebruikt voor het toetsen van de archeologische verwachting (zie tabel).

Archeologische verwachting	**Methode**	**Doel**	**Opmerkingen**
Scheeps- en vliegtuigwrakken	Side Scan Sonar	Opsporen en karteren van wrakken	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 nederzettingen (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 indicaties 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.

Boor- en sondeergegevens helpen niet alleen bij de interpretatie en laterale correlatie van seismische en lithostratigrafische eenheden, maar kunnen ook worden gebruikt om in inzicht te krijgen in de geogenese van het Doggerland gebied en het archeologische verwachtingsmodel te verfijnen en te toetsen. Speciale aandacht dient te worden besteed aan de aard en intactheid van de begraven landschappen en de identificatie van fenomenen die veroorzaakt kunnen zijn door de tsunami 6250 BC.

Als boringen en sonderingen deel uitmaken van het geotechnische programma wordt geadviseerd om een archeologische analyse uit te voeren sonderingsgrafieken en de boorkernen te onderzoeken. Het is van belang om de laboratoriumwerkzaamheden, waaronder mogelijk destructieve proeven, af te stemmen met de het archeologisch onderzoek. In andere woorden, een (senior) KNA-prospector dient bij de opening van de monsterbussen in het laboratorium aanwezig te zijn.

Tot slot 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 (conform KNA waterbodems 4.1; protocol 4001). Dit Programma van Eisen dient te worden geautoriseerd door het Bevoegd Gezag.

Summary

Periplus Archeomare has been assigned by Petrogas Netherlands B.V. to conduct an archaeological desk study for the appraisal well locations B10-04 and A15-05.

The desk study has shown that within the research areas ship and aircraft wrecks and, if the *Pleistocene* landscape is intact*, in situ* prehistoric remains can be expected. No ship or plane wrecks are known to date within the research areas, but undiscovered wrecks can be present.

Based on the outcome of the desk study, it is recommended to carry out an inventory geophysical survey to test the archaeological expectation. Prior to the installation of the jack-up rigs a geophysical and geotechnical survey will be carried out. The data from this survey can be used for the test the archaeological expectancy (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 data are of sufficient quality, the necessary archaeological assessment of the appraisal well sites can be carried out.

Borehole and CPT data not only aid in the interpretation and lateral correlation of seismic and lithostratigraphic units, but can also be utilized to obtain insight in the geogenesis of the Doggerland area and test and refine the archaeological expectancy model. Special focus shall be put on the determination of the type and integrity of buried landscapes, and the identification of phenomena which could be caused by a tsunami 6250 BC.

It is advised to perform an archaeological assessment on borehole samples and CPT data, if borehole or vibrocore sampling and/or CPT's are part of the geotechnical program. It is important to align laboratory works, which might include destructive tests, with the archaeological assessment. In other words, a (senior) KNA-prospector shall visit the laboratory when the sample liners are to be opened.

It is recommended 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 in accordance with the Dutch Quality Standard (KNA waterbodems protocol 4001). This Program of Requirements shall be authorized by the Competent Authorities.

1 Introduction

Periplus Archeomare has been assigned by Petrogas Netherlands B.V. to conduct an archaeological desk study for the appraisal well locations A15-05 and B10-04. The research areas include an area of 1 sqkm at each of the As Planned centre locations. The research area are located in the northern part of the Dutch Economical Zone. A15-5 is located 269km (145nm) north of Den Helder; B10-04 is located 277km (150nm) north of Den Helder.

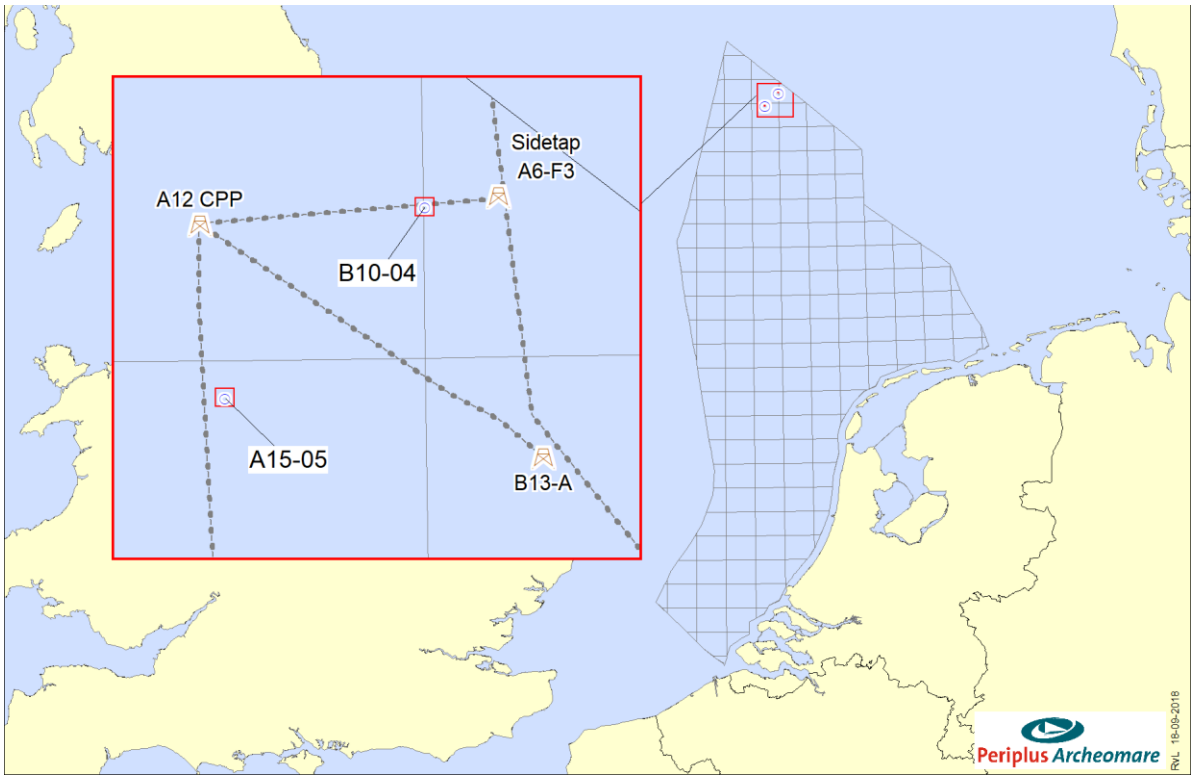

Figure 1. Location map

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 have already been developed. Petrogas plans to drill appraisal wells at the locations B10-04 and A15-05 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 is 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 of 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 3. 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), R. Cassée (archaeologist) 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 33. Words in *italics* and abbreviations are explained in the glossary on page 36.

3 Results – archaeological desk study

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

The research areas comprise two appraisal well sites (B10-04 and A15-05). At the well locations a jack-up rig will be installed. During the planned period of 30 days a vertical well will be drilled to obtain detailed information on the reservoir dimensions and potential.

Figure 2. Definition of the research areas (red squares); known gas fields shown in green

The jack-up rig contains three legs with spudcans which will be installed onto the seabed. The rig installation causes a local disturbance of the seabed during spud operations due to a few meter seabed penetration of the legs.

After installation scouring could lead to a disturbance of the seabed adjacent to the legs. After completion of the appraisal drilling activities the rig will be removed and a platform will be installed at another location to penetrate the reservoir at an optimal angle for production.

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 research areas are located on a topographic high of the Dogger Bank. Depth variations within the research areas are limited and the depth differences between the B10-04 and A15-05 locations are small (see table 3). The seabed is characterized by a smooth surface and the absence of sedimentary structures like current ripples or sand dunes. Southeast of the planned locations a southeast dipping slope occurs. Towards the southeast this slope diminishes and grades into a flat low-laying area.

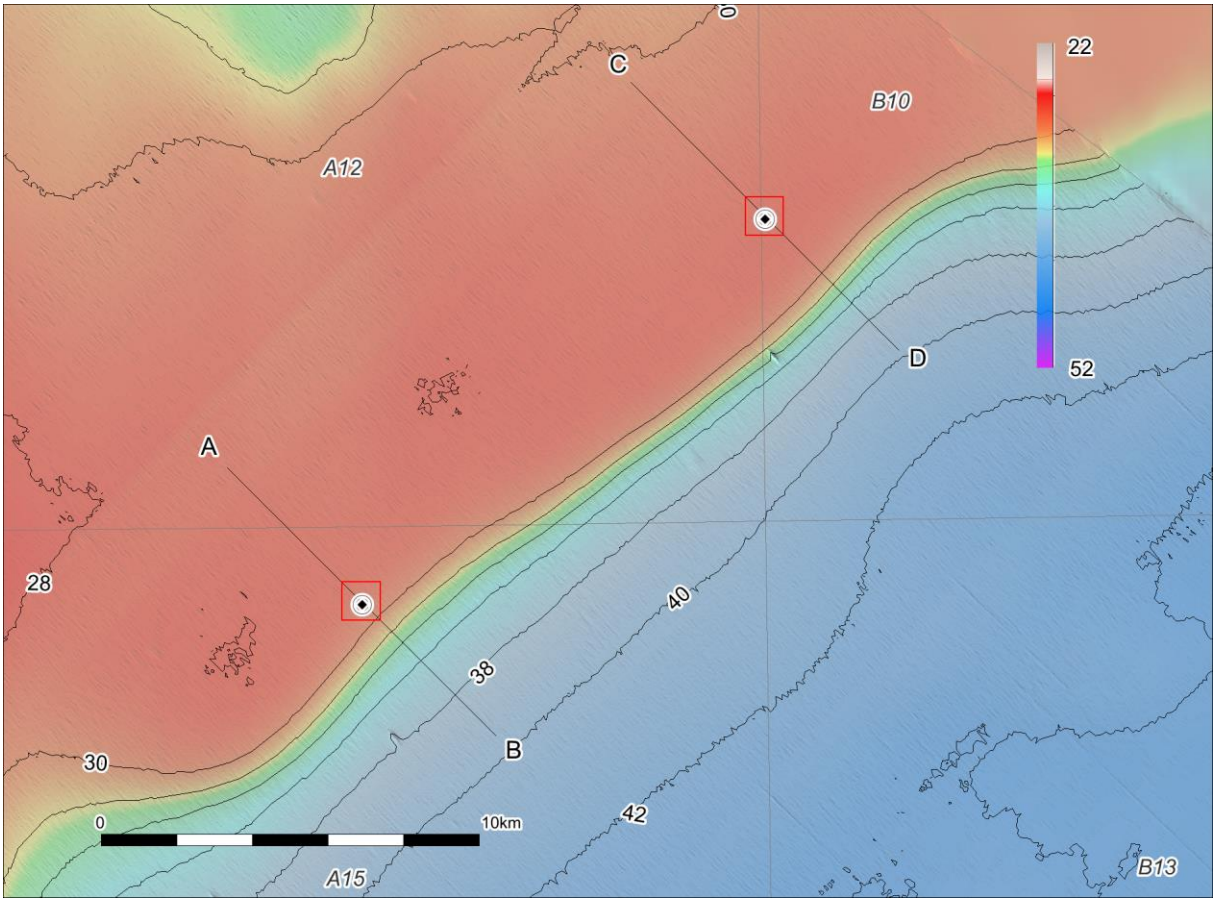

Figure 3. Bathymetry (source DTM: Hydrographic Service 2009 and Emodnet 2018)

The Hydrographic Service data (up to and including 2009) and the Emodnet data (up to 2018) hardly differ indicating that the seabed morphology changes little overtime.

[2] Hydrographic survey, 2009.

Data	Depth at B10-04 (mLAT)				Depth at A15-05 (mLAT)			
	Center Location	Research Area			Center Location	Research Area		
		Min	Max	Avg		Min	Max	Avg
Hydrographic Service 2009	28.3	28.1	28.5	28.3	28.8	28.3	30.3	28.9
Emodnet 2018	28.3	28.1	28.4	28.3	28.8	28.3	30.4	28.9

Table 3. Depths at the centre locations and within the research areas

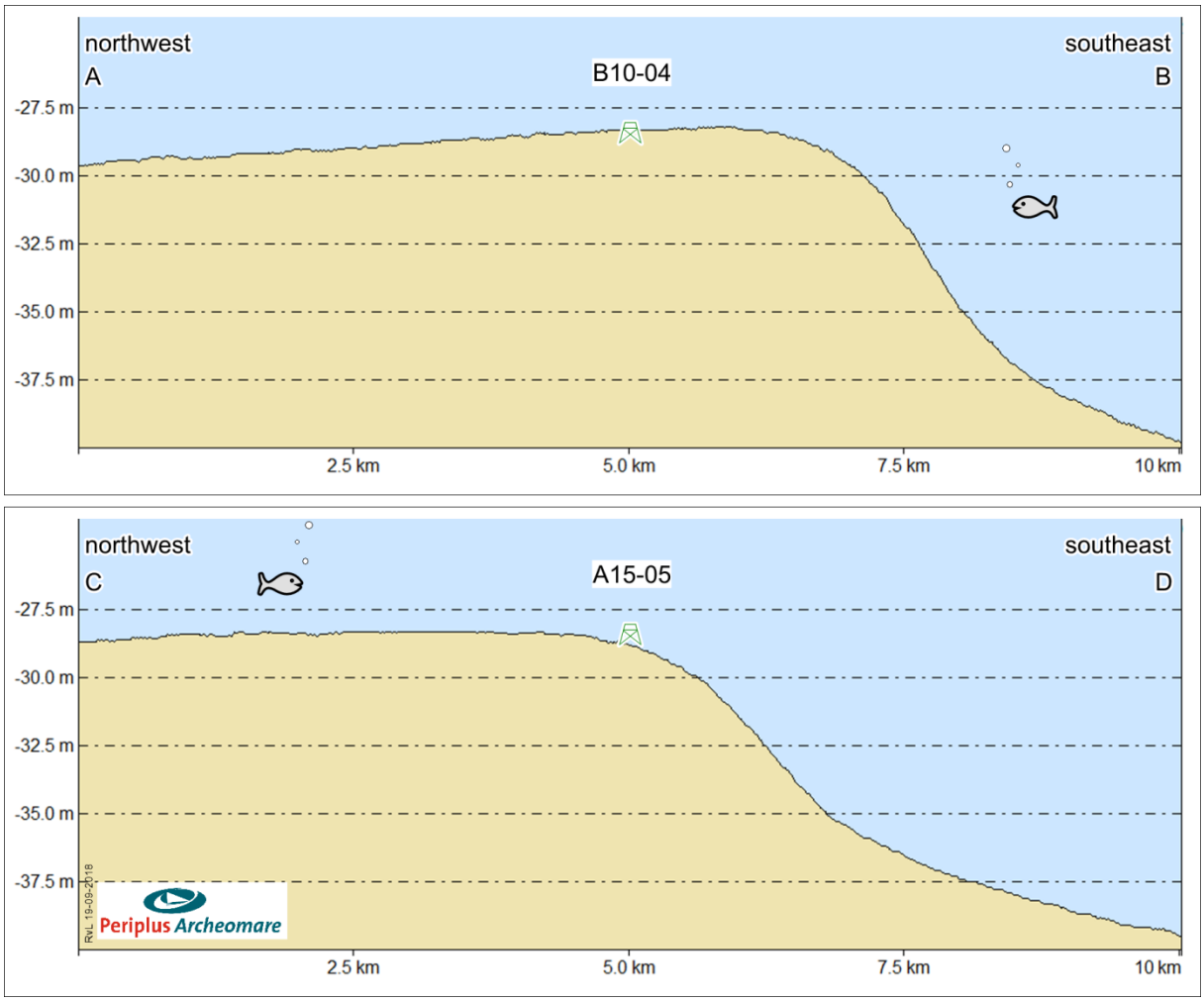

Figure 4. NE-SW profiles illustrating the seabed morphology (height in mLAT)

Pipelines and cables

One pipeline crosses the research B10-04 research area.[3] The 16-Inch active gas pipeline from A12-CCP to Sitetap A6-F3 has been laid at 134m north of the B10-04 location. No (known) pipelines or cables cross the A15-05 research area.

Operator	From	To	Status	Type	Diameter
Petrogas E&P Netherlands B.V.	A12-CPP	Sidetap A6-F3	Active	Gas	16 inch

Table 4 Pipelines crossing the research area

[3] Rijkswaterstaat cables and pipelines, November 2017.

Exploration wells have been drilled in the vicinity of both research areas, but none are located within the boundaries of the 1sqkm research areas.

3.3 Historic situation and known disturbances

The fluctuating climatic conditions in the North Sea area at the end of the Pleistocene and continued warming in Early Holocene was accompanied by the evolution of diverse ecosystems. Armkreutz et al. (2018) provide an insight the occupation of the North Sea area by hunter-gatherers and the way they adapted to the changing conditions by discussing recent finds from the Allerød interstadial (warm) period. The following text outlines the environmental and archaeological setting.[4]

'The end of the last Ice Age is characterised by dramatic climatic fluctuations (Hoek 2008). After an initial rapid rise in temperature at the beginning of Greenland Interstadial 1e (Bølling, 14600–13900 cal BP), temperatures gradually dropped during Greenland Interstadial 1c–a (Allerød, 13900–12800 cal BP). The cooling trend culminated in the cold spike of Greenland Stadial 1 (Younger Dryas, 12800–11700 cal BP), after which temperatures rose quickly during the Early Holocene. The open grass steppe of Northern Europe was gradually replaced by an open birch and pine forest. Steppe fauna was replaced by species adapted to warmer temperatures and more forested environments with lakes and marshes. Global sea levels rose at an average rate of 12m per thousand years during the Late Glacial (Lambeck et al. 2014). During the Allerød, sea levels were 60–80m below the modern level (Lambeck et al. 2002). Most of the North Sea was still dry land, with only the northern part of the North Sea being submerged, due to meltwater from the Scandinavian ice sheet draining through the Norwegian Channel into the northern North Sea (Boulton et al. 2001). A birch and pine forest probably dominated the higher elevations.

Open herbaceous vegetation characterised the valley floors (Hoek 2000). Red deer (Cervus elaphus) and European elk (Alcesalces)were typical herbivore species (Baales et al. 2002; Aaris-Sørensen 2009). During the cold spike of the Younger Dryas, the vegetation opened up again and aeolian activity increased (Hoek 1997). At the end of the last Ice Age, human populations recolonised the northern regions of Europe, reaching as far north as southern Scandinavia (Housley et al. 1997; Wygal & Heidenreich 2014). Ancient mitochondrial DNA indicates that a major population turnover took place in Europe during the Late Glacial (Posth et al. 2017). Important changes in, for example, mobility patterns, settlement structure, subsistence economy, technology and social organisation took place in this period. These were signalled by the transition from the Late Magdalenian tradition (sensu lato including Creswellian and Hamburgian) to the Federmesser-Gruppen or Arch-Backed Point groups, followed by traditions such as Ahrensburgian, Brommian, Laborian and Swiderian during the Younger Dryas. One of the most striking phenomena is the disappearance of naturalistic art (exemplified by Palaeolithic cave art) and the elaboration of geometric art that is more characteristic of the Mesolithic.'

The Dogger Bank in the North of the Dutch Continental Shelf is an example of an elevated area. Remnants of 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 spear heads) and mammal remains (mammoth and rhinoceros teeth) have been dredged from the Dogger Bank and it has been assumed that

[4] Wording taken unchanged from: Armkreutz 2018.

the finds have been retrieved from the seabed (2002).[5] 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]

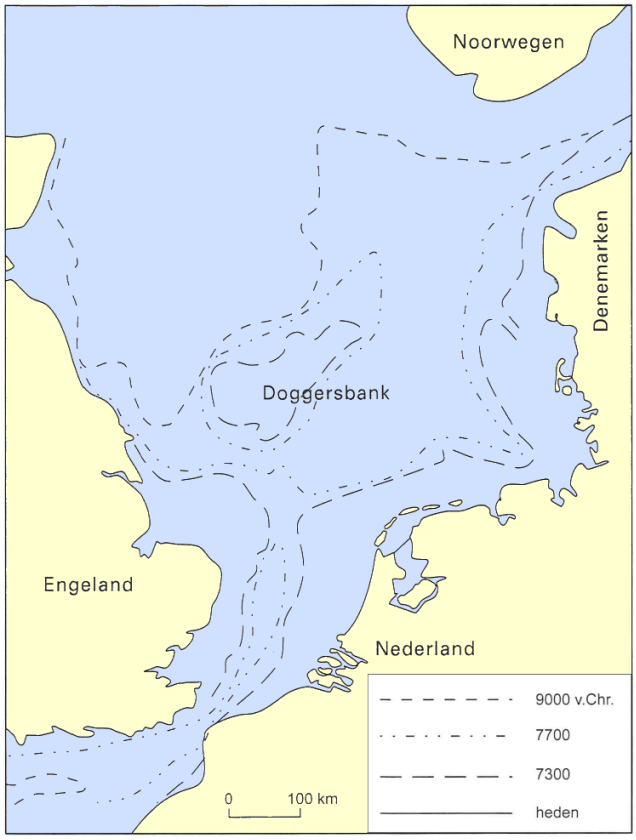

Figure 5. Reconstruction of the historical coast lines in the North Sea basin (after Jelgersma 1979)

The archaeological prehistoric finds 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 various bone artefacts from the early *Paleolithic and Mesolithic* were discovered.[8]

[5] Fleming 2002.

[6] Louwe Kooijmans 1970.

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

[8] Verhart 2005 159.

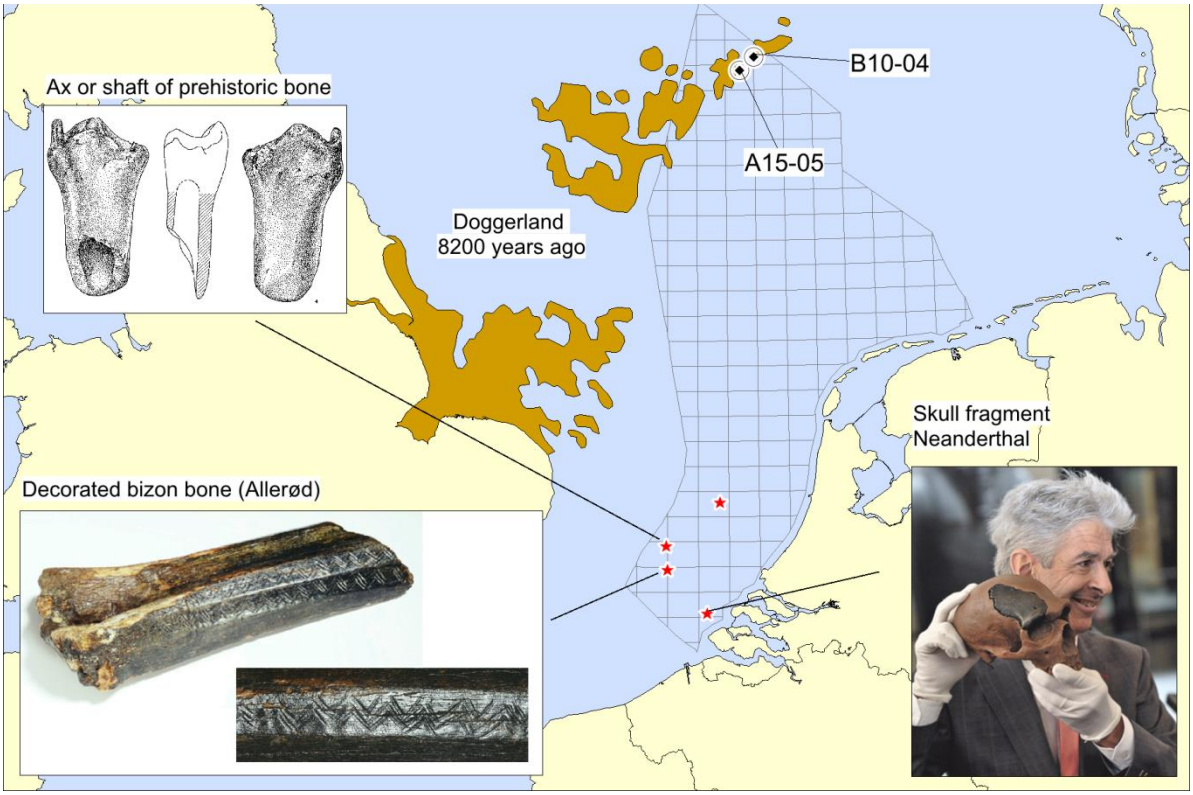

Figure 6. Example of prehistoric artefacts from the North Sea (Kooijmans 1970; Amkreutz 2018; Hill 2017)

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.

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 A12-CCP to Sidetap A6-F3 pipeline which crosses the B10-04 research area has 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. Disturbances from former drilling activities (boreholes, scours, etcetera) are not expected as no borehole locations are present within the 1sqkm research areas.

3.4 Description of geological data (LS04wb)

The seabed consists of gravelly sand. Southeast of B10-04 and east of A15-05 an area of peat has been mapped (figure 9). The occurrence of gravelly sand appears to correlate with the elevated area of the Doggerbank at depths ranging from 28m to 30m LAT. The peat is found in the lower parts flat part of the seabed at depths ranging from 40m to 44m LAT. To illustrate this apparent relation between surface sediments and depths, contours of elevations of the seabed have displayed in the seabed sediment image below.

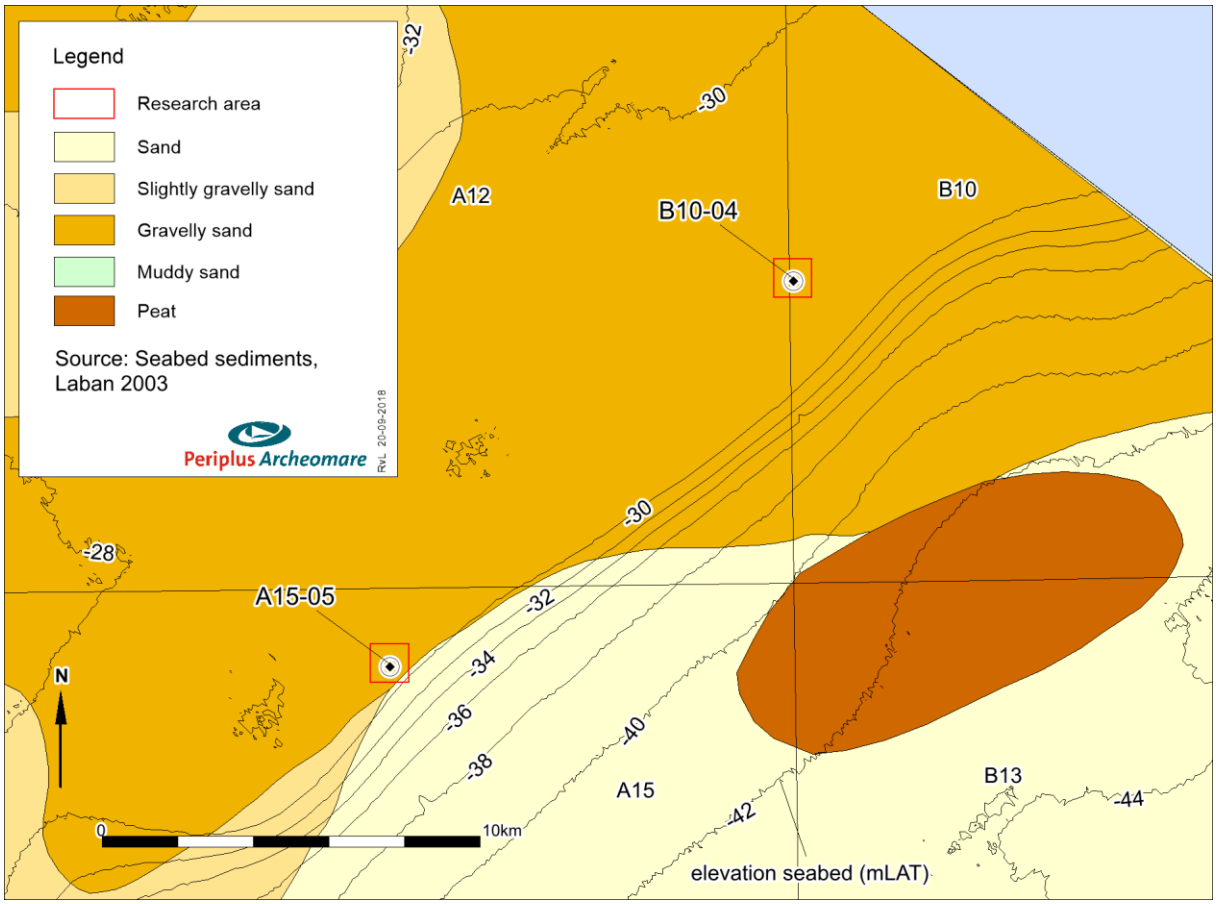

Figure 9. Seabed Sediments (source: Laban 2003)

The mobile top layer has been classified in the past as the Nieuw Zeeland Gronden Formation. According to the current nomenclature the Nieuw Zeeland Gronden Formation is classified as the Terschellingerbank

[9] Information supplied by client.

Member.[10] The thickness of the Terschellingerbank Member varies from less than 1 meter to 20 meters. The exact thickness in the research area is not known.

The Geological Survey of the Netherlands (Dutch: Rijks Geologische Dienst) and the British Geological Survey have mapped the quaternary geological units in the area.[11] The names of those units have since changed.[12] In this report we will use the current names of the lithostratigraphic units.

	Current name		Environment	Old name
Holocene	Terschellingerbank Mb Part of Southern Bight Fm		Marine (exposed at seabed)	Nieuw Zeeland Gronden Fm
	Wormer Mb (base)		Tidal clay and fine sand	Elbow Fm
	part of Naaldwijk Fm	Velsen Bed	Coastal clay	
	Basal Peat Bed		Coastal peat	
Pleistocene	Boxtel Fm		Local terrestrial	Twente Fm
	Dogger Bank Mb part of the Dogger Bight Fm		Glaciolacustrine clay	Dogger Bank Fm
	Uitdam Mb part of the Drente Fm		Glaciolacustrine clay, silt and fine sand	Cleaver Bank Fm

Table 5. Old and new names of lithostratigraphic units in the area

Underneath the Terschellingerbank Member Early *Holocene* deposits of the Wormer Member, Velsen Bed and/or Basal Peat Bed are expected at the A15-05 location (see figure 10).[13] The mapped thickness of the unit is less than 5m. The expected occurrence of peat as also indicated in figure 9 could possibly relate to an Early Holocene lake in the low lying area southeast of the research locations.

In july 2005 Gardline Geosurvey Limited performed a platform site survey at the proposed A12-CPP location and a route survey for the pipeline from the A12-CPP location to the B-10 Side Tap.[14] The pipeline route corridor was 16.033km long and 1 km wide. The survey consisted of 11 survey lines with lines offset 50m, 100m, 200m and 300m either side of the route centre line. The survey included *side scan sonar* (500kHz/100kHz), *multibeam* echo sounder, *magnetometer* and seismics.

The lithostratigraphy interpreted from boomer data combined with borehole date at the A12-CPP have been described by Gardline as follows:

'Good quality boomer data were acquired across the site. Penetration on the boomer was observed to in excess of 20 metres sub-seabed depending upon the nature of the underlying Quaternary geology. Throughout the length of the pipeline route survey, the shallow soils comprise in excess of 10m of Holocene fine SAND with shell fragments becoming silty from 3.5m. The base of the Holocene sands has not been mapped due to its depth below seabed. Beneath the Holocene sand, interbedded very stiff sandy CLAY and silty fine SAND with partings of CLAY (Dogger Bank Formation) is expected. In places, the Dogger Bank

[10] Rijsdijk 2005.

[11] Jeffery et al, 1991.

[12] Rijsdijk 2005.

[13] Jeffery 1990.

[14] The Platform and pipeline had not been installed yet.

Formation is thin leading to Cleaver Bank Formation sub-cropping the Holocene sand. Cleaver Bank Formation comprises very stiff CLAY with partings of SILT.'

Pleistocene units in the area date from the Late *Weichselian* and consist of the Dogger Bank Member. At the B10-4 location the Dogger Bank Member is expected to be covered by the Boxtel Formation. Figure 10 shows that the Elbow Formation (comprising the current Basal Peat Bed, Velsen Bed and part of the Wormer Member) has not been mapped at the B10-04 location. In places where the sequence of *Holocene* units is thin, local outcrops of *Pleistocene* deposits could occur at the seabed.

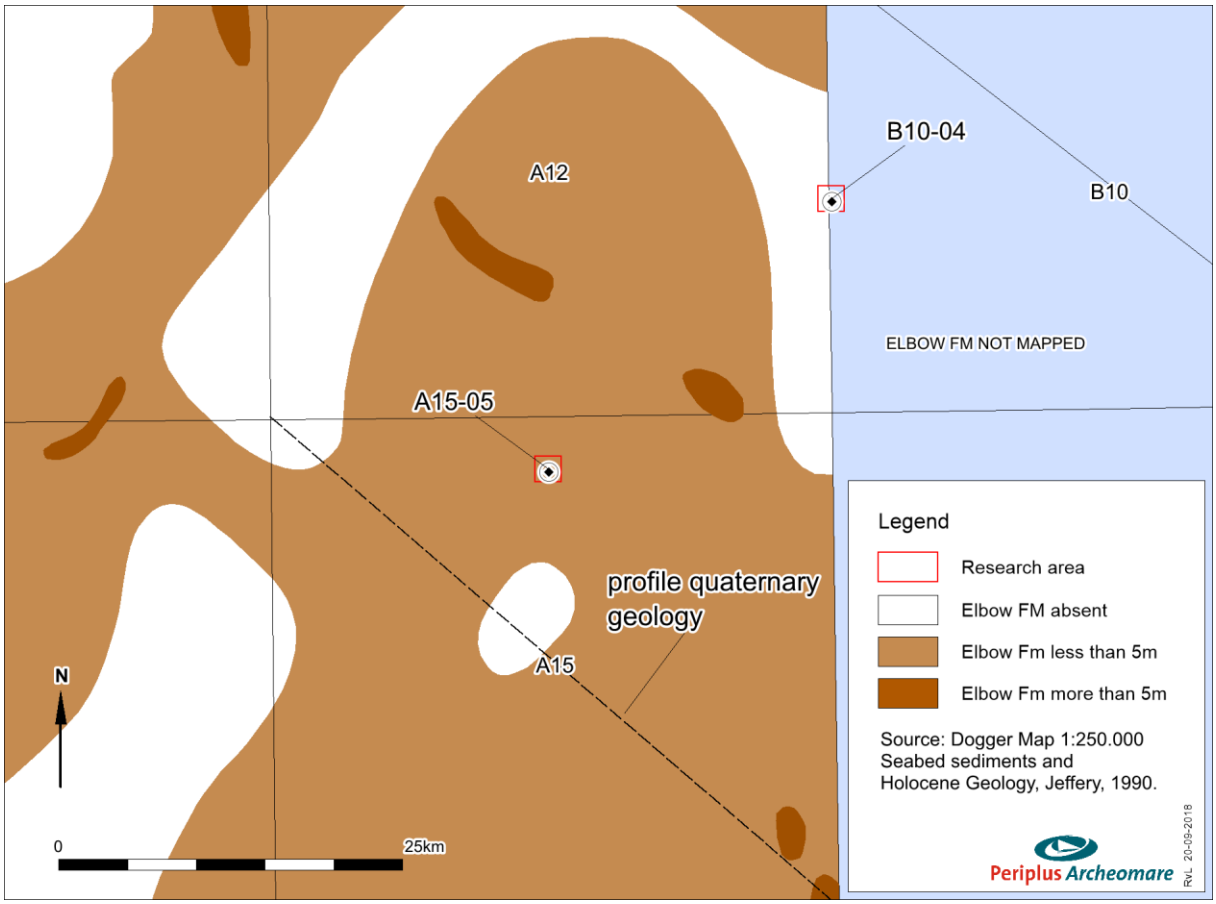

Figure 10. Occurrence of the Elbow Formation currently referred to the combined Wormer Member (Velsen Bed) and Basal Peat Bed (after Jeffery et al. 1990 Sea Bed Sediments and Holocene Geology 1 : 250.000 map)

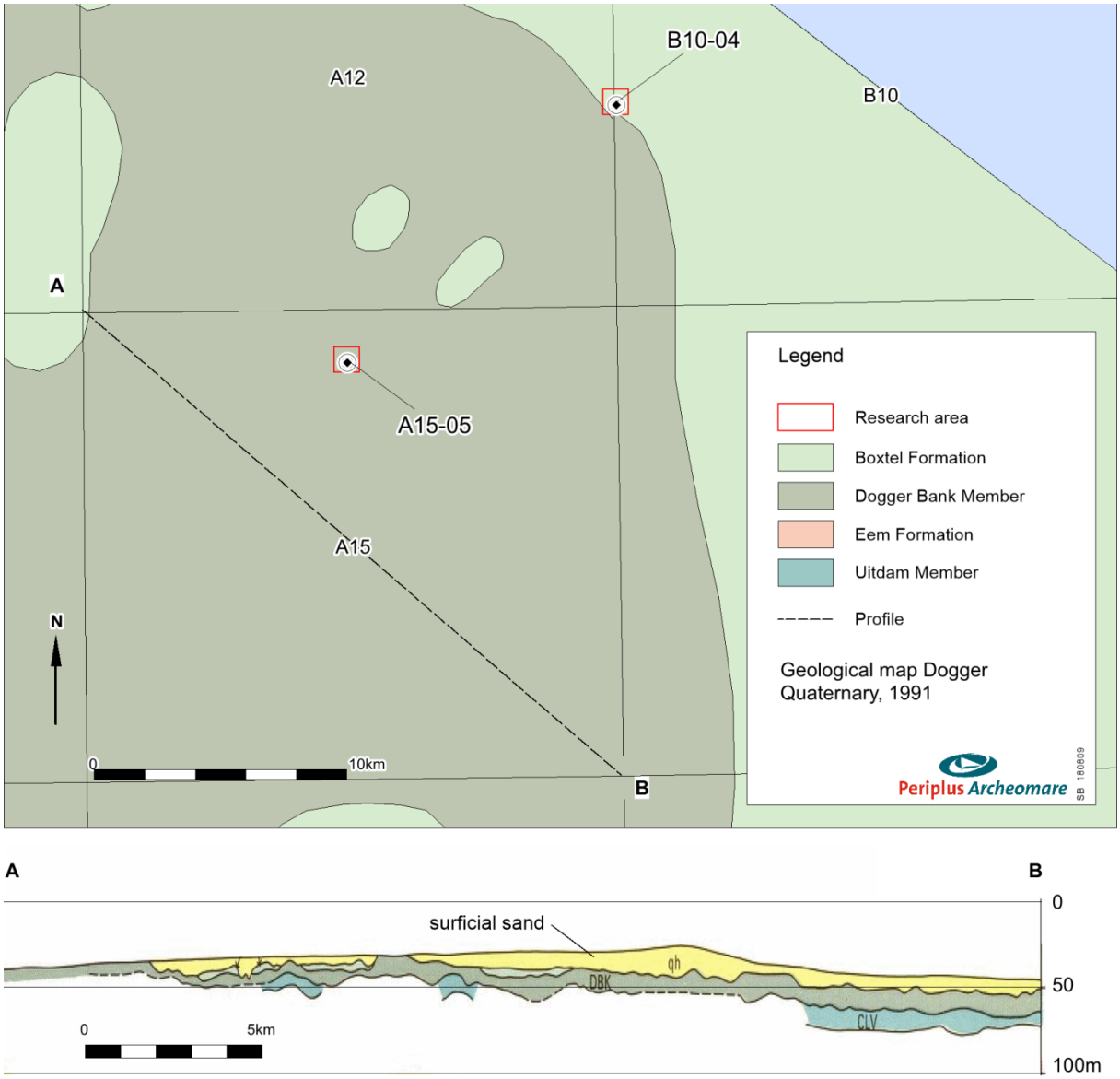

Figure 11. Quaternary geology with profile (Jeffery et al. 1991: Quaternary Geology Dogger 1 : 250.000 map and Tail End map (not available) interpreted from Laban Top Pleistocene Map 2003)

The Boxtel Formation predominantly consists of very fine to fine sand with peat detritus. The sediments comprise well sorted sand of aeolian origin (Wierden Member) and local beak deposits including sand, loam, clay and peat (Singraven Member). 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. At the A12-CPP location the thickness of the Dogger Bank Member is 10m.

The Eem 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 morphology of the seabed is dictated by the geological constellation of the area. The southwest-northeast trending ridge at which the B10-04 and A15-05 sites are located is a thrust moraine complex.[15] 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. However, 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 Doggerbank 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.[16] The sample was taken from a depth of 38.8m (seabed). The lithology found is listed in the table 6.

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. 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	Terschellingerbank 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 6. Lithological description of borehole sample used for pollen analysis (from: Krüger 2017); lithostratigraphic interpretation by Periplus Archeomare

[15] Phillips 2018.

[16] Krüger 2017.

In figure 12 an indication is given of the drowning history of the research area. The figure is based on a sea level curve for the Doggerbank presented in a publication by Vink[17] and current depth data from Hydrographic Service 2009 and Emodnet 2018. The publication contains smooth RSL curves for various locations in the Netherlands Germany and the North Sea area (refer to figure 9 in Vink's article). In order to make a best estimate for the timing of drowning of the Doggerbank area we drew up the following formula:

Age = 0.1 * Depth + 6 -> Depth = 10 * (Age - 6)

with:
Age : Cal. ka BP
Depth : m below mean high water (MHW)
Applicable for depths ranging from 10m to 40m

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.

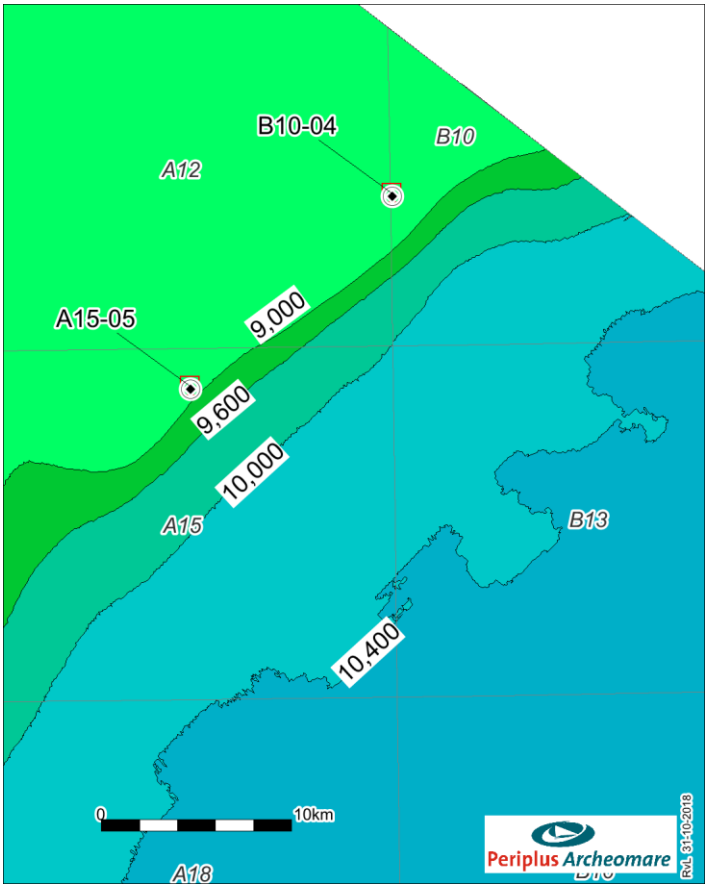

Figure 12. Possible date of drowning in cal. years BP interpreted from bathymetry (based on sea level curve Doggerbank, Vink 2007)

[17] Vink 2007.

Around 8200 cal. years BP (=6250 BC) Doggerland is believed to be struck by a major tsunami.[18] This Storegga Slide tsunami was generated on the Norwegian coastal margin by a submarine landslide. Sea level had at that time risen to -16m. Possibly the top of the higher parts of the Doggerland landscape 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.

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 13).[19]

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.

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.[20]

[18] Weninger 2008.

[19] IKAW 3rd generation, RCE 2008.

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

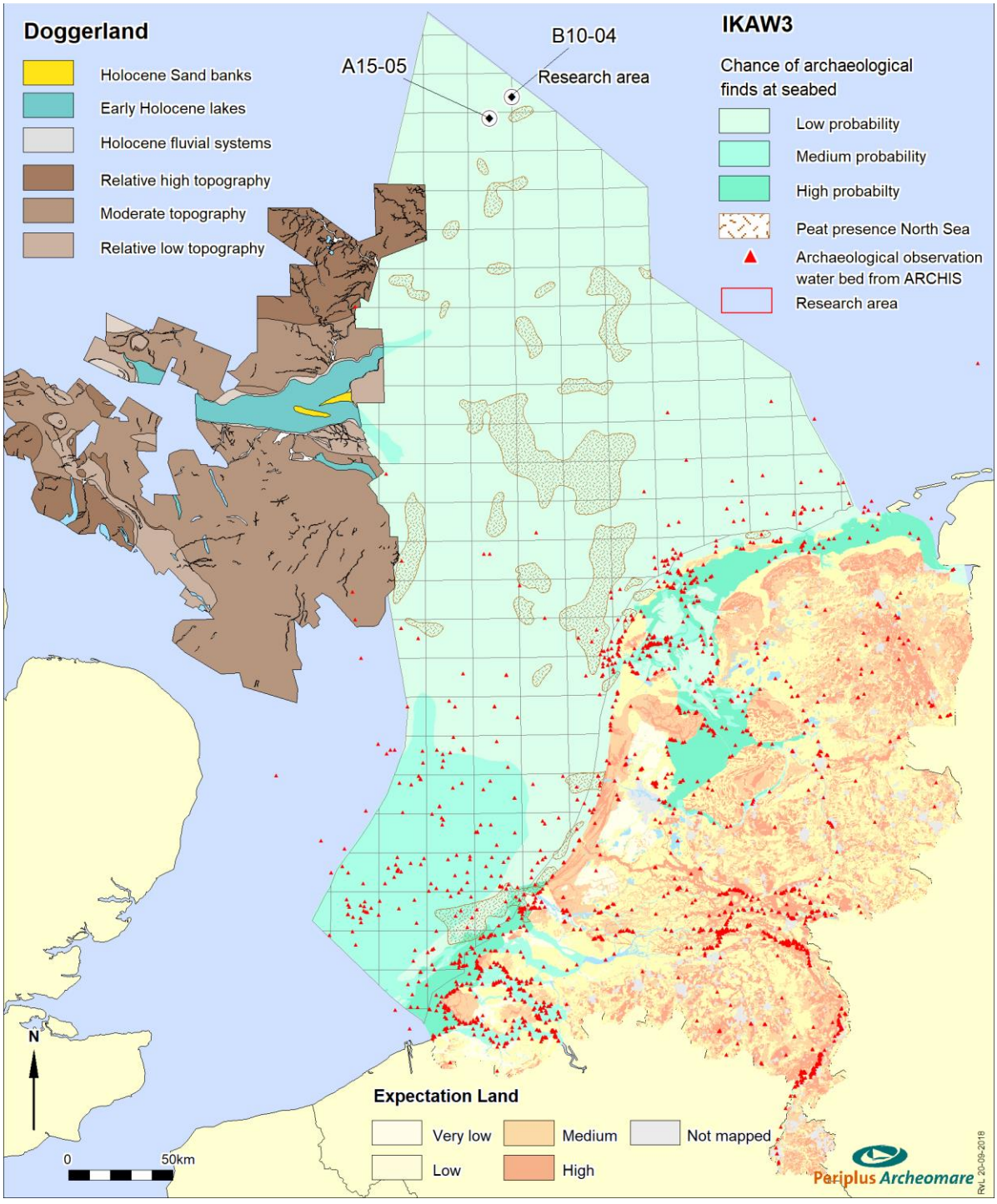

Figure 13. Overview of archaeological expectation in the Netherlands including the Dutch Continental Shelf

Prehistory

In 2016 Deltares started with the production of a chart on which the expectation for archaeological remains from prehistoric times is mapped.[21] 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

[21] Vonhögen – Peeters 2016.

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.

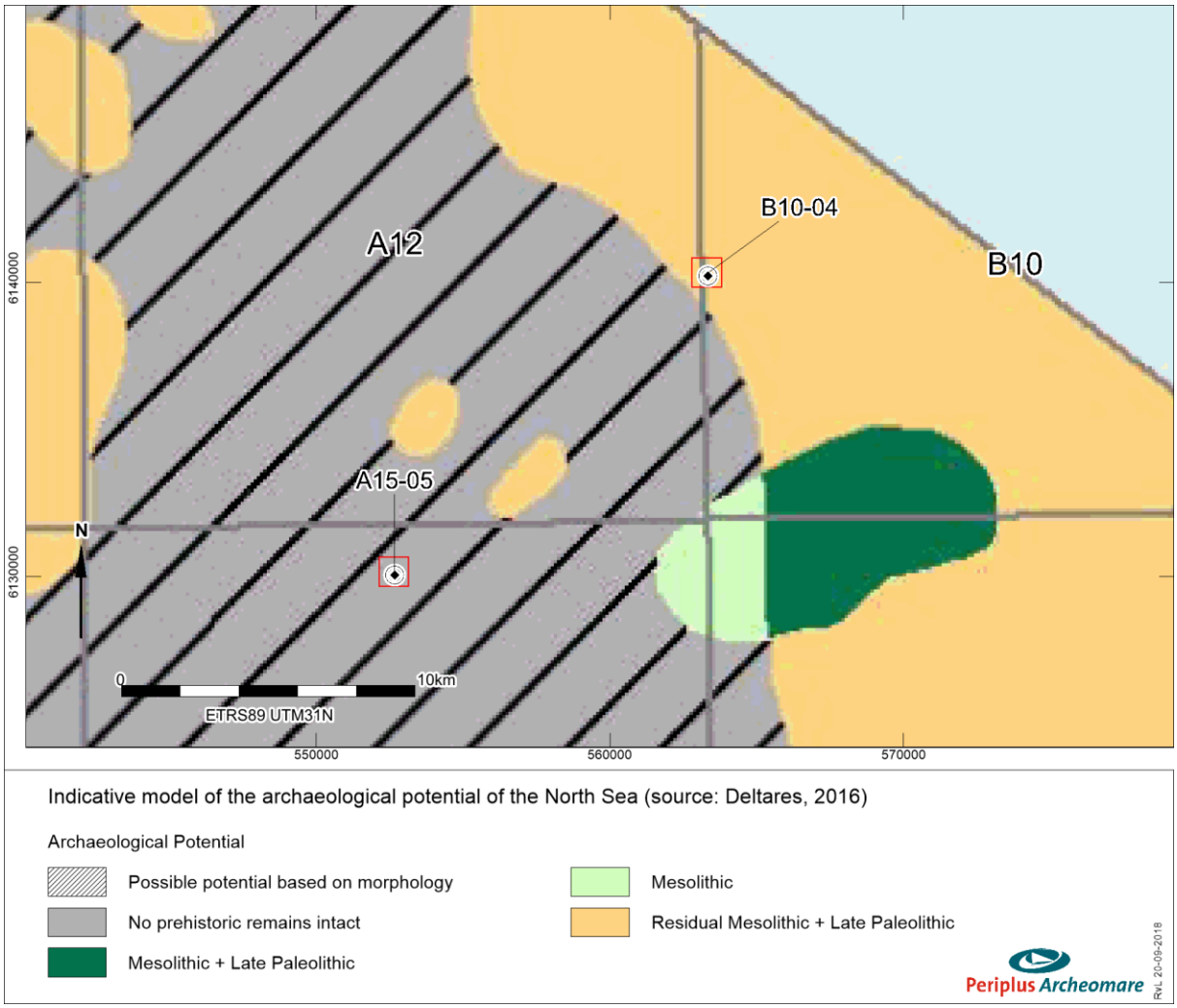

Figure 14. Indicative model of the archaeological potential of the site locations (Deltares 2016)

According to this model a no prehistoric intact remains are to be expected within the A15-05 research area, except for finds related to Doggerland which can be present under specific circumstances, based on the local geomorphology.

Within the B10-04 research area, 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 11. 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*. It should however be kept in mind that the model of the archaeological potential is indicative. The morphological constellation indeed aids to the archaeological potential of the research are as will be discussed in section 3.6. Further the accuracy of the mapped areas and coherent archaeological potential in Deltares' model is limited due relatively small number of borehole data it is based on.

Details research area

Figure 15 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)[22], the Cultural Heritage Agency (Dutch: Rijksdienst voor het Cultureel Erfgoed) and Rijkswaterstaat.

The research areas do not contain known objects. 2270m northeast of the centre location of A15-05 one contact known from the NLHono database occurs: NCN2478/NLHono 2872. The location of the unknown wreck is accurately known within 5m.

NCN	SR92	Nlhono	Easting	Northing	R95	Description
2478	-	2872	542917	6135545	5	Unknown wreck surveyed 24-09-2013

Table 7. Known objects

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

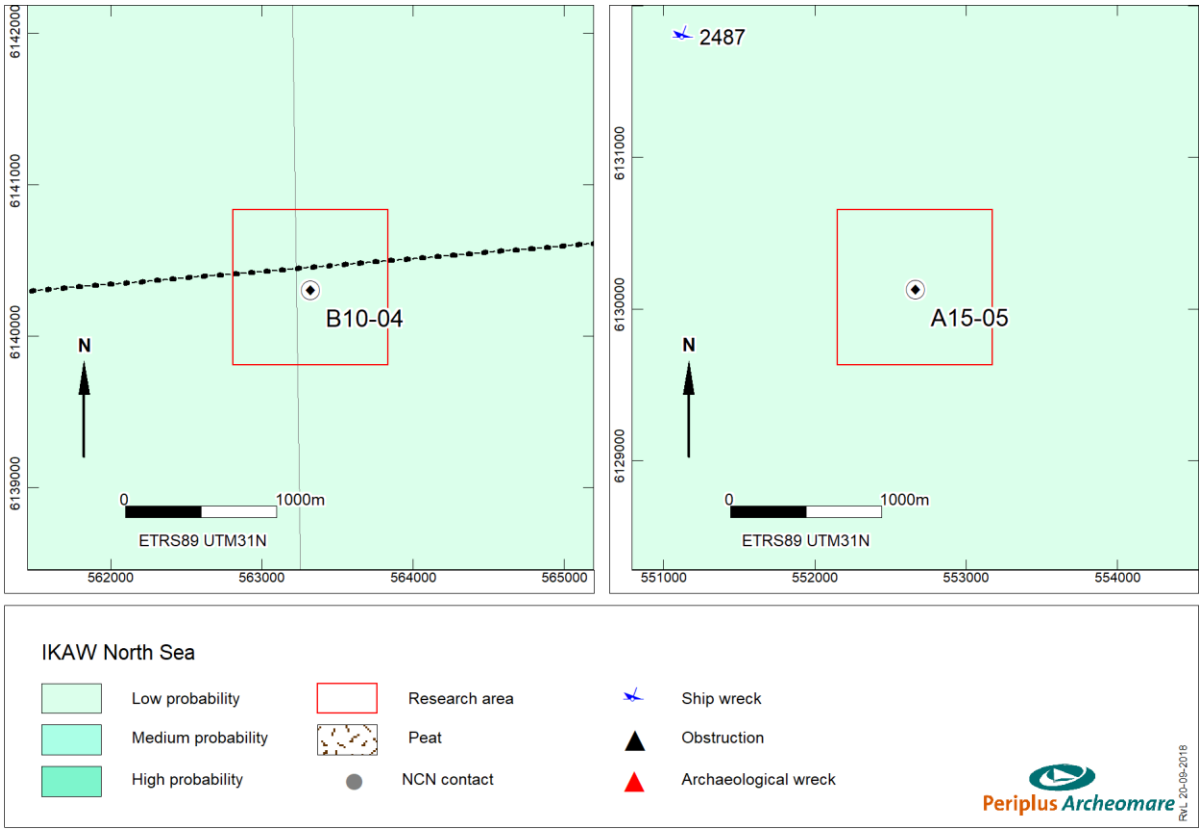

Figure 15. Known object within the research areas

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 research areas are located on the edge of a plateau, which in Early Holocene times bordered a large lake. Those transitions in the landscape attracted hunter-gatherers, because of the possibility the landscape offered to install camp sites at high grounds overviewing hunting grounds, the presence of nearby fresh water from the lake, the animals living in and foraging at the lake-site and variety in plant species available. Therefore the position of the research areas aid to archaeological expectation for prehistoric remains.

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 research areas of B10-04 and A15-05 no wreck sites are known. Undiscovered wrecks, however, might be present. For the B10-04 area this change is considered small, as major part of the area has been covered by a pre-lay route survey in 2005 which was carried out for the - at the time planned - pipeline from A12-CPP to Sidetap A6-FA. With geophysical techniques employed (*side scan sonar*, *multibeam*, *magnetometer* and seismics) no wrecks were found.

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)*.

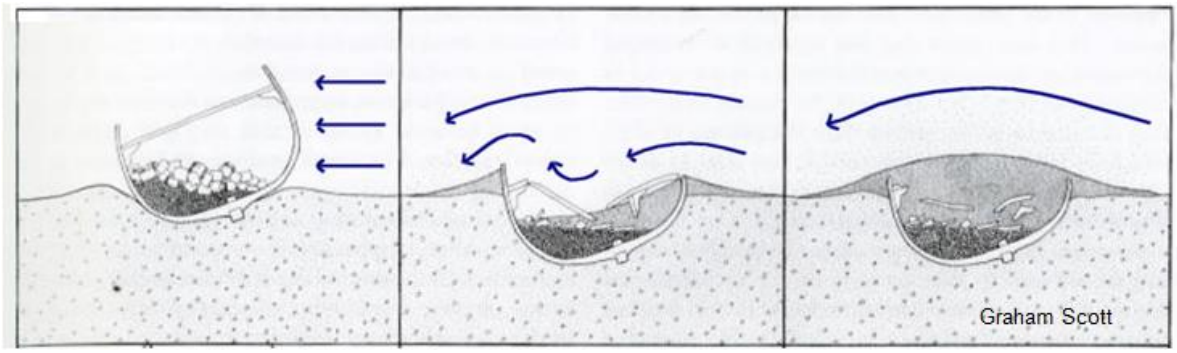

Figure 16. Example of wreck site formation (Graham Scott)

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, no archaeological values are known in the research areas of B10-04 and A15-05.

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

This question is not applicable.

What is the integrity and conservation of the site?

This question is not applicable.

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 areas. This applies especially for the A15-05 locations, because contrary to the B10-04 area, this site has - as for as we know - not been surveyed before.

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 and the Boxtel Formation. The top of the *Pleistocene* units has been found at 11m below the seabed at the A12-CPP location, but is not known at the B10-04 and A15-05 sites.

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. Based on the available geological maps no occurrences of peat are known in the research areas.

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 the platform installation. 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 areas ship and aircraft wrecks and, if the *Pleistocene* landscape is intact*, in situ* prehistoric remains can be expected.

Within the areas studied no remains of ship or plane wrecks are known. Undiscovered wrecks, however, can be present; in particular in the research area of A15-05, since this site - contrary to site B10-04 - has not been surveyed before.

Based on the outcome of the research, it is recommended to carry out an inventory geophysical survey to test the archaeological expectation.[23] Prior to the installation of the jack-up rigs a geophysical and geotechnical survey will be carried out. The data from this survey can be used for the test the archaeological expectancy (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 8. Testing of archaeological expectation with geophysical and geotechnical methods

If the data are of sufficient quality, the necessary archaeological assessment of the appraisal well sites can be carried out.

Borehole and CPT data not only aid in the interpretation and lateral correlation of seismic and lithostratigraphic units, but can also be utilized to obtain insight in the geogenesis of the Doggerland area and test and refine the archaeological expectancy model. Special focus shall be put on the determination of the type and integrity of buried landscapes, and the identification of phenomena which could be caused by a tsunami 6250 BC.

[23] In accordance with KNA waterbodems protocol 4103.

It is advised to perform an archaeological assessment on borehole samples and CPT data, if borehole or vibrocore sampling and/or CPT's are part of the geotechnical program. It is important to align laboratory works, which might include destructive tests, with the archaeological assessment. In other words, a (senior) KNA-prospector shall visit the laboratory when the sample liners are to be opened.

It is recommended 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 (Dutch: '*Programma van Eisen*') in accordance with the Dutch Quality Standard (KNA waterbodems protocol 4001). This Program of Requirements shall be authorized by the Competent Authorities.[24]

[24] In accordance with KNA waterbodems protocol 4001.

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Glossary and abbreviations

Terminology	Description
AMZ	Archeologische Monumenten Zorg
CPT	Cone penetration test
Eemian	Warm period (Interglacial), like the Holocene period we live in now which lasted approximately from 128.000 to 116.000 years ago.
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.
Saalian	Penultimate Ice Age (Glacial period) which lasted from approximately from 238.000 to 128.000 years ago
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.
Weichselian	Last Ice Age (Glacial period) which lasted from 116.000 to 12.000 years ago.

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- 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		250.000
			Hengelo	41.500					
				45.000					
		Pleniglaciaal V	Moershoofd	50.000					
				71.000					
		Vroeg Glaciaal	Odderade	74.000			Oud		
			Brørup						
			Amersfoort						
				114.000					
	Eemien			126.000					
	Saalien			236.000					
	Oostermeer			241.000					
	onbenoemd			322.000					
	Belvédère			336.000					
	onbenoemd			384.000					
	Holsteinien			416.000					
	Elsterien			463.000					

Appendix 2. 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.