



Netherlands Enterprise Agency

# Site Studies Wind Farm Zone Hollandse Kust (zuid)

*Archaeological desk study*

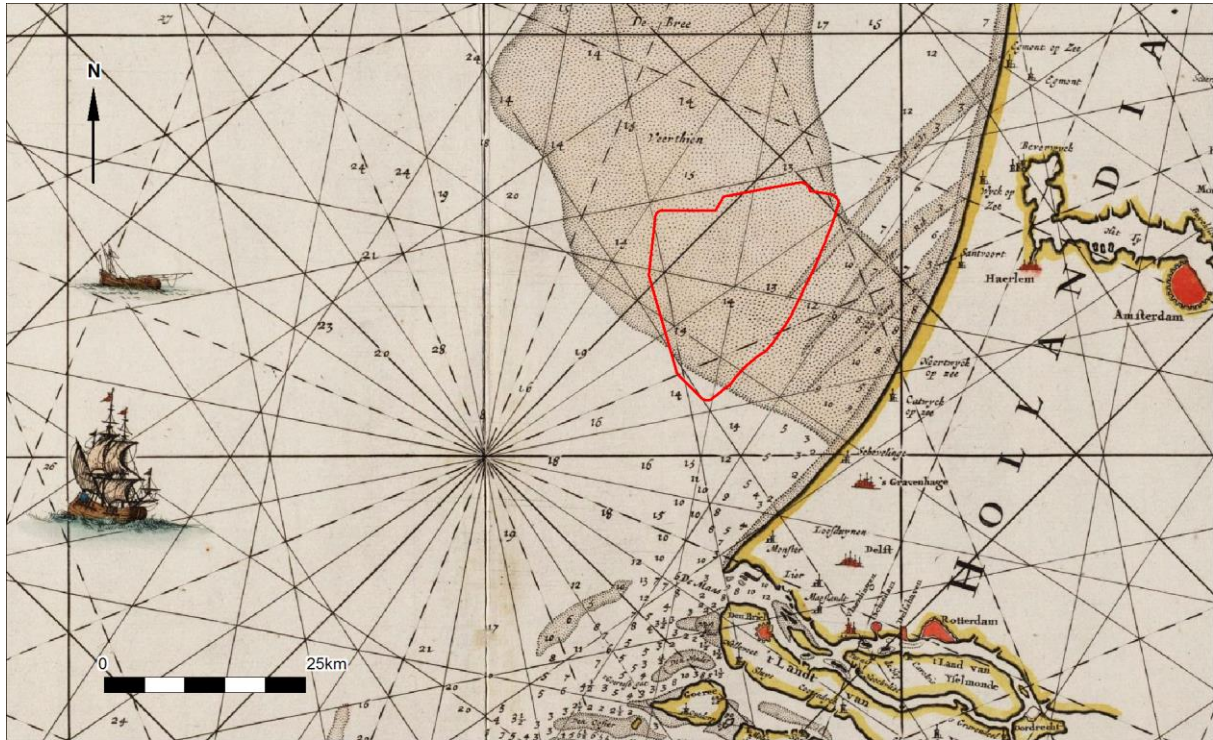
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**Desk study archaeological assessment**

**Hollandse Kust (Zuid)**



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At the request of

**Rijksdienst voor Ondernemend Nederland (RVO)  
Netherlands Enterprise Agency**

Document Control	
Document HKZ_20160129_Periplus_Archaeology_Desk_Study_V4.0_F	
Revision	4.0 (final)
Date	29-01-2016
Periplus Archeomare Reference	15A024-01
RVO reference	WOZ1500039

Reviewers	
Organization	Name
RVO	F. van Erp
BLIX	B. de Sonnevile
Rijksdienst voor het Cultureel Erfgoed	M.C. Houkes, A. Klomp

## Colophon

Periplus Archeomare Report 15A024-01

Desk study archaeological assessment Hollandse Kust (Zuid)  
 Authors: S. van den Brenk, R. van Lil and E.A. van den Oever

At the request of: Rijksdienst voor Ondernemend Nederland (RVO)  
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ISSN 2352-9547

### Revision details

Revision	Description	Authors	Checked by	Autorisation	Date
4.0	Final	SvdB/RvL/EvdO	BvM	B.G.	29-01-2016
3.0	Draft	SvdB/RvL/EvdO	BvM	B.G.	08-01-2016
2.0	Draft	SvdB/RvL/EvdO	BvM	B.G.	22-12-2015
1.0	Draft	SvdB/RvL/EvdO	BvM	B.G.	09-12-2015

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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	
Toponiem Dutch:	Hollandse Kust (Zuid)	
Chart:	1801-01	
Coordinates		ETRS89 UTM31N
Geodetic datum: ETRS89	Centre	E 521414, N 5713293
Projection: UTM31N	NW	E 564404, N 5804398
	NE	E 585968, N 5809727
	SW	E 565471, N 5784280
	SE	E 567997, N 5781570
Depth (LAT):	16,9 to 27,4, average 21,5 meter	
Surface area	435,35 square km	
Environment:	Tidal currents, salt water	
Area use:	Shipping lane, fishing and recreation, sand extraction	
Area administrator:	Rijkswaterstaat Zee en Delta	
ARCHIS-research report (CIS-code):	3980221100	
Periplus-project reference:	15A024-01	
Period	December 2015	

## Samenvatting (in Dutch)

In opdracht van de Rijksdienst voor Ondernemend Nederland (RVO) heeft Periplus Archeomare B.V. een archeologisch bureauonderzoek uitgevoerd voor het toekomstige windpark Hollandse Kust (Zuid).

Voor het onderzoeksgebied bestaat een hoge verwachting voor de aanwezigheid van (resten van) scheepswrakken en vliegtuigwrakken uit de Tweede Wereldoorlog. Daarnaast is het aannemelijk dat vanwege de post-glaciale zeespiegelstijging *in situ* resten van kampementen van jagers/verzamelaars uit het Late-Paleolithicum en het Vroege-Mesolithicum kunnen worden aangetroffen.

Delen van het onderzoeksgebied zijn in het verleden al vlakdekkend onderzocht met geofysische technieken.

Tijdens de geofysische survey voor windgebied Luchterduinen, wat ongeveer 5 procent van het windgebied Hollandse Kust (Zuid) beslaat, is aan drie objecten een mogelijke archeologische waarde toegekend.

Tijdens de geofysische survey voor Delta Hydrocarbons, wat ongeveer 2 procent van het windgebied Hollandse Kust (Zuid) beslaat, zijn geen objecten met mogelijke archeologische waarde gerapporteerd.

Meer dan 90 % van het windgebied is nog niet in detail onderzocht door middel van een geofysische survey. Het is mogelijk dat onbekende (resten van) wrakken aanwezig zijn.

### Scheepswrakken

Binnen het onderzoeksgebied zijn in totaal 19 scheepswrakken bekend. De exacte locatie en verdere details als scheepsnamen, scheepstypes zijn niet bekend. Aanvullend onderzoek is nodig om de cultuur-historische waarde van deze wrakken vast te stellen.

### Vliegtuigwrakken

Gedurende de Tweede Wereldoorlog zijn veel vliegtuigen neergestort in de Noordzee. Verschillende bronnen zijn onduidelijk over het aantal vliegtuigen dat nog vermist wordt, maar het moeten er honderden zijn. Zowel tijdens zandwinning en kust beschermingsprojecten als door vissers worden regelmatig resten van vliegtuigen aangetroffen. In de omgeving van het onderzoeksgebied zijn vier locaties bekend met vliegtuigresten.

### Prehistorie

De verwachting voor de Prehistorie (Paleo-Meso) is hoog onder hogere zandduinen en richels (Wierden Member), op de afgedekte rivier duinen (Delwijnen Member) en oeverafzettingen (Wijchen Member). In het Basisveenpakket is de verwachting hoog voor wat betreft losse vondsten en rituele deposities. De archeologisch interessante niveaus liggen onder de afzettingen van het Blich Bank Member pakket met een dikte van 0 tot 5m dikte. Resten van Neanderthaler kampen kunnen worden verwacht in de Onder de lacustriene kleiafzettingen van de Brown Bank Member is een hoge verwachting voor het Paleolithicum (Neanderthaler). De Brown Bank Member afzettingen zijn veelal afgedekt door de Kreftenheye Formatie.

Op dit moment is weinig bekend over de integriteit van het Pleistocene landschap. De Pleistocene liggen dicht onder de zeebodem. Hierdoor is de kans op erosie aannemelijk. Lokaal kan het bovengelegen Basisveen het Pleistocene landschap hebben beschermd tegen erosie. Voor beter onderbouwd verwachtingsmodel adviseren wij een *subbottom profiling* onderzoek uit te voeren in combinatie met de analyse van *vibro core* samples. Daarmee kunnen het basisveen en de onderliggende goed bewaarde archeologische lagen beter worden gekarteerd. De aanwezigheid van Paleolithische en Mesolithische nederzettingen is op basis van dit onderzoek echter niet met volledige zekerheid vast te stellen. Het daardoor lastig om archeologische beperkingen op te leggen aan de ontwikkeling van het windpark.

In overeenstemming met de AMZ-cyclus wordt geadviseerd om een *Inventariserend veldonderzoek opwaterfase* uit te voeren om:

- De locaties van bekende wrakken in meer detail te karteren;
- De delen van het gebied waar nog geen survey opnames zijn uitgevoerd te inventariseren.

Vergelijkbare geofysische onderzoeken bestaan over het algemeen uit surveys met *side scan sonar*, *magnetometer* en een *subbottom profiler*. De resulterende data moeten geanalyseerd worden na oplevering van de gegevens door het surveybedrijf. De archeologische analyse van de gegevens dient te gebeuren door een geofysisch specialist (KNA prospector waterbodems).

Het onderzoek moet voldoen aan de Kwaliteitsnorm Archeologisch onderzoek (KNA). Om dit te waarborgen worden de eisen voorafgaand aan het onderzoek vastgelegd in een Programma van Eisen (PvE), dat is goedgekeurd door het bevoegd gezag.

Zoals gezegd blijven onzekerheden bestaan omtrent de aanwezigheid van archeologische waarden in het plangebied. Dat betekent dat dat ook tijdens de bouw onverwacht archeologische waarden kunnen worden aangetroffen. De civiel uitvoerder is conform de Monumentenwet 1988 (herzien in 2007) verplicht om dergelijke vondsten te melden bij de bevoegde overheid. Deze meldingsplicht voor archeologische vondsten moet als protocol in het bestek of Plan van Aanpak van het werk worden opgenomen.



## Summary

Periplus Archeomare was assigned by RVO to conduct an archaeological assessment of the Hollandse Kust (Zuid) Windfarm Zone.

Within the investigated area of the wind farm zones there is a high expectation for the presence of (remains of) ship wrecks and WWII plane wrecks. Locally *in situ* remains of Late Paleolithic and Early Mesolithic camp sites might be present.

Parts of the research area have been investigated by geophysical surveys in the past.

During the geophysical survey for Luchterduinen, which covers approximately 5 percent of the area, three objects were classified as of possible archaeological value.

During the geophysical survey for Delta Hydrocarbons, which covers approximately 2 percent of the area, no objects were classified as of possible archaeological value.

Over 90 % of surface of the wind farm area has not been investigated by detailed geophysical surveys. The area may contain more undiscovered shipwrecks or remains of shipwrecks.

### Shipwrecks

A total of 19 shipwrecks are known in the area. Details like names, types and date of sinking are not known, nor are the exact locations. Further research is needed to determine the cultural-historical value.

### Plane wrecks

During World War II, many airplanes crashed into the North Sea. Several sources are ambiguous about the number of aircraft still missing. It is at least hundreds. Remains are found on a regular base by fishermen or during sand extraction. In the vicinity of the research area, four locations of plane wrecks are known. It is quite possible to expect plane wrecks within the research area.

### Prehistory

Remains of prehistoric camp sites are expected *in situ* in cover of sand dunes and ridges (Wierden Member), river dunes (Delwijnen Member) and river bank deposits (Wijchen Member) provided these units are un-eroded. Within the Basal Peat Bed well-preserved lost objects and dumps can be encountered. The archaeological levels of interest are located under a 0 - 5 meter cover of the Bligh Bank Member. Remains of Neanderthaler camp sites can be expected within lacustrine clays of the Brown Bank Member which is covered by the Kreftenheye Formation.

At this stage little is known about the integrity of the Pleistocene landscape. The Pleistocene units are encountered at shallow depths. Therefore erosion of these units and archaeological remains therein seems likely. Locally the Basal Peat Bed might have protected the Pleistocene landscape against erosion. By means of subbottom profiling in combination with analysis of *vibro core* samples the Basal Peat Bed and the underlying well-preserved archaeological level can be mapped. It is unlikely however that archaeological remains of Paleolithic and Mesolithic camp sites can be identified with sufficient certainty (based on the geophysical and geotechnical surveys) to impose restrictions on wind farm development.

In accordance with the AMZ cycle it is advised to conduct a field investigation (in Dutch '*Inventariserend veldonderzoek opwaterfase*') in order to:

- Map the locations of known wreck sites in great detail;
- Make an inventory for the parts of the area which have not been covered in previous surveys

In general, similar investigations carried out in the past consist of a geophysical survey with *side scan sonar*, *magnetometer* and *subbottom profiler*. The resulting data should be assessed after the general processing,

interpretation and reporting has been performed by the survey contractor, if possible in combination with analysis of core samples. The archaeological assessment of the data has to be conducted by a geophysical specialist (KNA prospector Waterbodems).

The data quality expected from the surveys need to match the demands for this archaeological assessment. To ensure compatibility between the site investigation and the required quality for this assessment it is recommended to define a Program of requirements (In Dutch: '*Programma van Eisen*') in accordance with the 'KNA' (the Dutch quality standards for archeological research), to be authorized by the competent authority.

During the installation of the wind turbines and construction of the cables archaeological remains may be encountered that were fully covered by sediment or not identified as archaeological remains during the geophysical survey. In accordance with the Malta convention incorporated in the Monuments Act through the Archaeological Heritage Management Act (Revised 2007) it is required to report those findings to the competent authority. This notification for archaeological finds should be included in the specifications or scope of work.

# 1 Introduction

Periplus Archeomare was assigned by RVO to conduct an archaeological assessment of the Hollandse Kust (Zuid) Windfarm Zone. The research area of nearly 400 km<sup>2</sup> is located in the North Sea, 20 km of the coast of Katwijk.

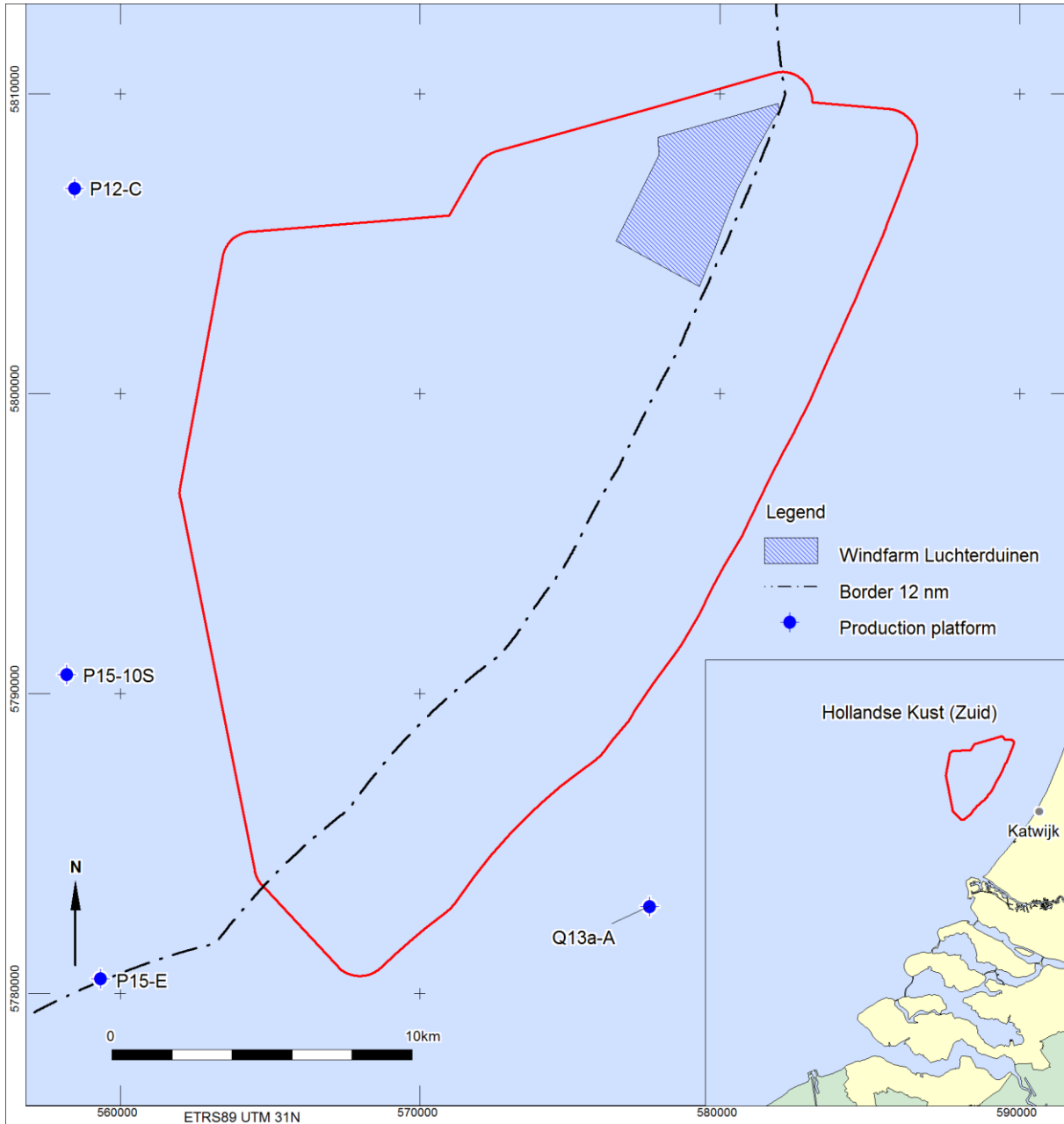


Figure 1. Overview of the research area

The assessment and reporting were carried out in accordance with the Dutch quality standards for archaeological research<sup>1</sup>.

<sup>1</sup> Kwaliteitsnorm Nederlandse Archeologie (KNA waterbodems 3.2).

## 1.1 Motive

In 2013 more than 40 organizations and the Government entered into the Energy Agreement for Sustainable Growth (Energieakkoord voor Duurzame Groei). An important part of this agreement includes scaling up of offshore wind power development. The Ministry of Economic Affairs presented a road map outlining how the Government plans to achieve its offshore wind goals in accordance with the time line agreed upon in the Energy Agreement.

The road map sets out a schedule of tenders offering 700 MW of development each year in the period 2015 – 2019. The Dutch Government has developed a systematic framework under which offshore wind farm zones are designated. Any location outside these wind farm zones are not eligible to receive a permit. Within the designated wind farm zones the government decides the specific sites where wind farms can be constructed using a so-called Wind Farm Site Decision ('Kavelbesluit'). This contains conditions for building and operating a wind farm on a specific site. The Dutch transmission system operator TenneT will be responsible for grid connection.

Winners of the site development tenders will be granted a permit to build a wind farm according to the Offshore Wind Energy Act (Wet Windenergie op Zee<sup>2</sup>), a SDE+ grant and offered a grid connection to the main land. The Ministry provides all relevant site data, which can be used for the preparation of bids for these tenders. This Archeological Desk Study is part of the site data for Wind Farm Zone Hollandse Kust (Zuid).

In the Law on Archaeological Heritage (2007), emerged from the Malta Convention (1992), incorporated in the Monuments Act through the Archaeological Heritage Act, the protection of the archaeological heritage is regulated. Planned activities, such as the installation of wind turbines and cables in the North Sea, may affect the archaeological values if present. If the remains are threatened there is a statutory obligation to conduct archaeological research. This process is also outlined in the law "Windenergie op Zee".

This archaeological desk study for the proposed Wind farm Zone Hollandse Kust (Zuid) is the first step in the archaeological process as part of the so-called AMZ cycle.

## 1.2 Objective

The purpose of the desk study is to establish whether archaeological remains are, or are likely to be, present within the wind farm zone as well as a 1 km wide buffer zone around it, and whether these (possible) remains are threatened by the development of offshore wind farms within the area. Where possible, the desk study aims to give insight into the archaeological value of these (possible) remains in terms of their physical or scientific value, such as the overall quality of preservation and the rarity of the remains. Furthermore, this report aims to make recommendations regarding subsequent steps in dealing with known and expected archaeological remains within the wind farm zone and the buffer zone (1km).

The archaeological management procedure ('AMZ-cycle') is a defined sequence of steps and decisions within archaeological heritage management in the Netherlands. The procedure is embedded in the Dutch Quality Standard for Archaeology (KNA Waterbodems 3.2) as the mandatory workflow for archaeologists. A detailed description of the different phases of archaeological research is included in appendix 1.

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<sup>2</sup> <http://wetten.overheid.nl/BWBR0036752>

### 1.3 Research questions

For an archaeological desk study, the following research questions are applicable:

- Are there any known archaeological values present within the research area? If so, what is the nature, extent (depth) location and dating of these sites?
- Are there, in addition to any known values, archaeological remains be expected? If so, what is the nature, extent (depth) location and date of the expected archaeological remains?
- Do the proposed activities in the wind farm zones threaten known or expected archaeological values? If so, can an impact on archaeological assets be prevented or restricted by planning adaptation?
- If the archaeological values cannot be saved:  
What kind of further research is needed to determine the presence of archaeological values and their size, location, type and date to be determined enough to come to a selection decision?

In addition, the following points of attention and questions have been defined by RVO:

- Define an overview of the archaeological aspects on which basis the wind farm zone will be assessed.
- Assess whether there are (indications for) areas with specific archaeological interest (wrecks and prehistoric life) at the Hollandse Kust (Zuid) wind farm zone.
- If present, define expected location, size and dating of the areas with specific archaeological interest.
- Determine the possible effect of the installation of offshore wind farms on the areas with specific archaeological interest.
- Assess possibilities to mitigate the disturbance of areas with specific archaeological interest as a result of installing offshore wind farms.
- Identify whether any further investigations should be carried out from archaeological point of view and make a recommendation on the scope and specifications of these investigations.
- Define requirements for any activity carried out in the wind farm area (investigations or monitoring activities, installation activities, operational activities) that could have an effect on archaeological aspects in the wind farm area.
- What is the expectation of the physical quality of possible archaeological sites and objects?
- Which lithostratigraphic units can be determined and what is their spatial distribution (both horizontal and vertical)?
- Allocate archaeological levels within the lithostratigraphic sequence
- Is it possible to define zones where the (buried) prehistoric landscape is eroded or intact? Are the expected lithostratigraphic boundaries erosive or non-erosive?
- If so, are these zones threatened by the work envisaged?
- Investigate whether human activities which could have led to a disturbance of the seabed and archaeological remains therein.
- If present, define the expected intrinsic quality in terms of rarity, research potential, group value and representativeness of the areas with specific archaeological interest.
- Define the expected physical quality in terms of integrity and preservation of the areas with specific archaeological interest.



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## 2 Methodology

The desk study was conducted in accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 3.2, Protocol 4102). 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 is carried out according to the scope of Work as described in 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 a specified archaeological expectation is defined. It is expressed whether, and if so, which archaeological values can 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 four. The study concludes with a summary and recommendation in chapter five.

The research and reporting were conducted by S. van den Brenk and R. van Lil (both senior prospector) and E. van de Oever (prospector). The results were approved and authorized by B. Goudswaard (Senior KNA archaeologist).

### 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 corings and maps
- Archis III, archaeological database of the Dutch Cultural Heritage Agency
- Databases of Periplus Archeomare
- Dutch Federation for Aviation Archaeology (NFLA)
- Stichting Aircraft Recovery Group 40-45
- Various sources from the Internet
- HKZ\_20151203\_RVO\_STARTING POINTS ASSUMPTIONS\_PART I GENERAL\_F
- HKZ\_20151203\_RVO\_STARTING POINTS ASSUMPTIONS\_PART II RVO\_F

For a complete overview of the sources and literature see references on page 43.

Words in *italics* and abbreviations are explained in the glossary on page 42.

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### 3 Results

#### 3.1 Definition of the research area and consequences of future use (LS01wb)

The Hollandse Kust (Zuid) Wind Farm Zone (HKZWFZ) is located 12 Nautical Miles off the west coast of the Netherlands. It is the intention of the government to expand the HKZWFZ 2 Nautical Miles on the east side<sup>3</sup>. Wind farm Luchterduinen lies within the Wind Farm Zone.

The HKZWFZ is surrounded by:

- An active sand extraction area (east side)
- Anchoring area (north)
- Shipping lanes (west)
- Gas exploration (west)
- Gas pipe line (south)

Five active telecom cables and a pipeline are crossing the Wind Farm Zone. Several operational and abandoned cables and pipelines cross the wind farm zone.

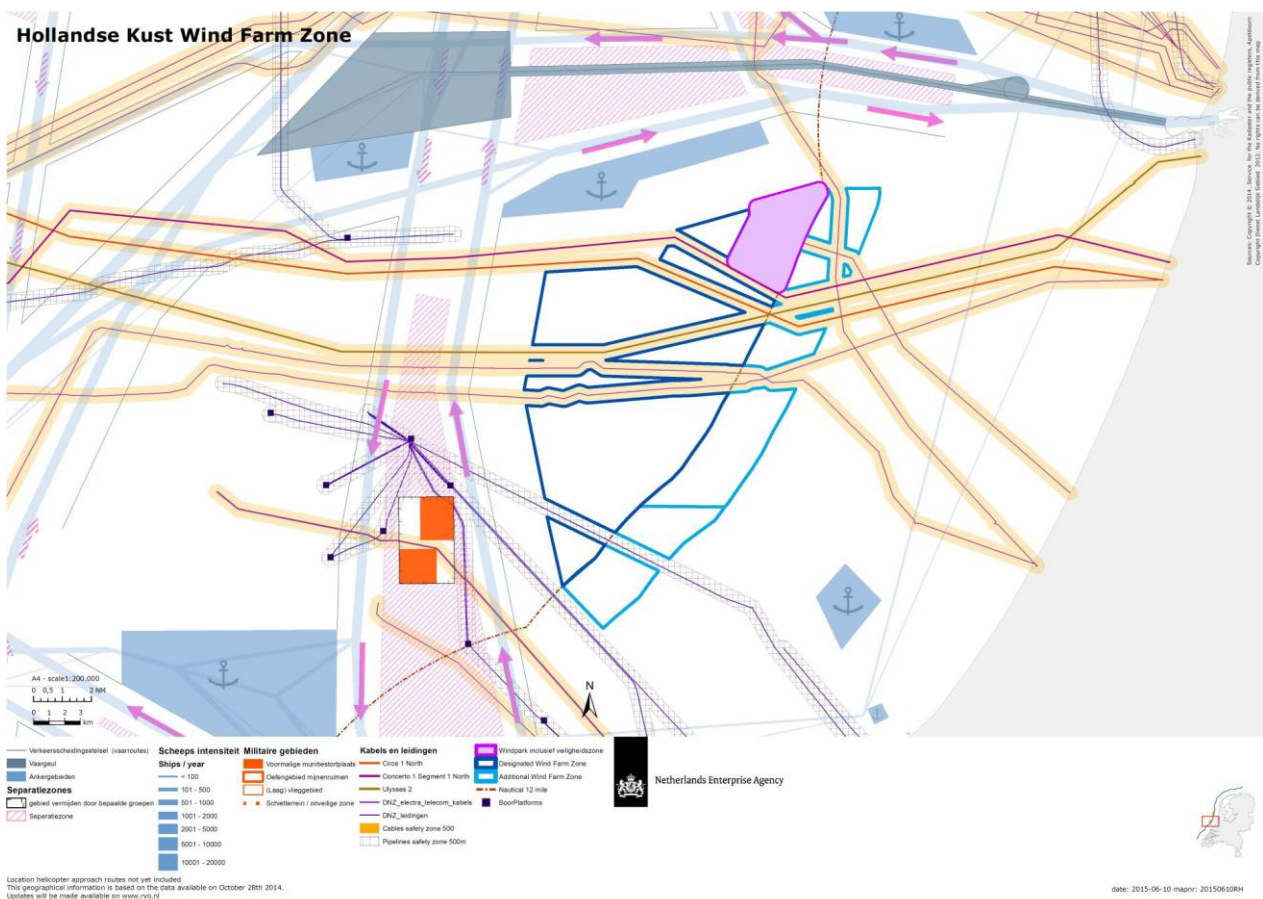


Figure 2. Overview of the research area

The wind farm zone of approximately 214 km<sup>2</sup> will be sub-divided into four wind farm sites. In total, 1,400 MW offshore wind is planned in the zone, roughly 350 MW per site.

<sup>3</sup> RVO starting point assumptions 20151026

The wind farm zone has the following general characteristics, as shown in the table below.

Water depth	16.9 to 27.4m
Distance from shore	From 22.2 km (12 nautical miles )
Distance from shore including expanded zone	From 18.5 km (10 nautical miles )
Surface area (excl. safety zones)	213.8 km <sup>2</sup>
Surface of Wind Farm Site I	56.2 km <sup>2</sup>
Wind Turbine Density site I	6.2 MW/km <sup>2</sup>
Surface of Wind Farm Site II	47.7 km <sup>2</sup>
Wind Turbine Density site II	7.6 MW/km <sup>2</sup>
Surface of Wind Farm Site III	46 km <sup>2</sup>
Wind Turbine Density site III	7.6 MW/km <sup>2</sup>
Surface of Wind Farm Site IV	63.6 km <sup>2</sup>
Wind Turbine Density site IV	5.5 MW/km <sup>2</sup>

*Table 3. General characteristics of the wind farm zone*

The installation of the windfarm will have a direct impact on the seafloor. Monopoles and foundations need to be installed, and trenches are created for the connecting cables, causing a threat for the possible presence of cultural heritage.

In the longer term, wind turbines can cause a change in seafloor morphology due to change of tidal currents. This may in turn cause buried ship wrecks to emerge at the surface, exposing them to erosion.



**Previous research**

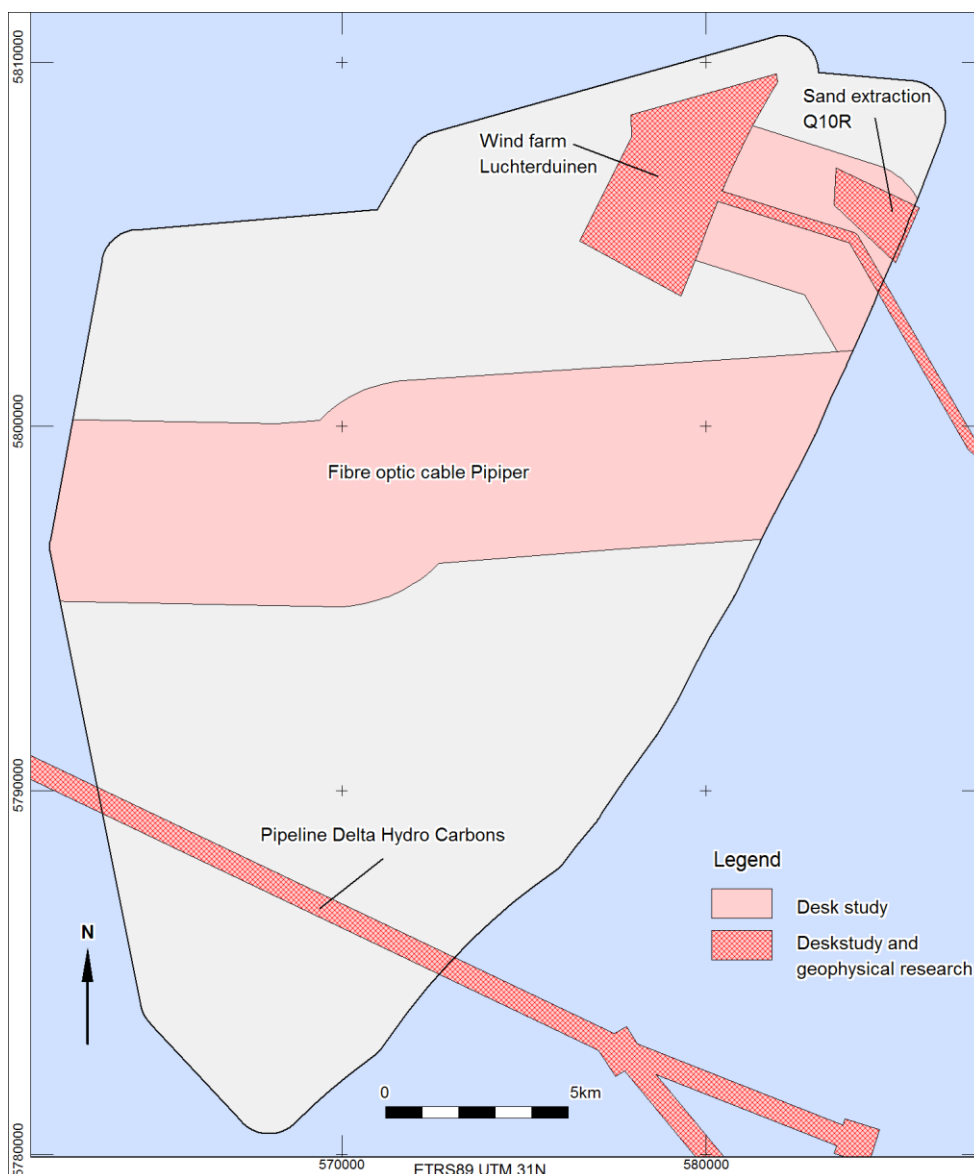


Figure 3 Area covered by earlier conducted geophysical surveys (in red).

Parts of the research area have been investigated in the past for archaeological purposes:

- Route survey pipeline Delta Hydrocarbons 2009. Archaeological desk study and assessment of geophysical survey data<sup>4</sup>;
- Windfarm Luchterduinen 2013. Archaeological desk study and assessment of geophysical survey data<sup>5</sup>;
- Sand extraction area Q10R, 2014. Archaeological desk study and assessment of geophysical survey data<sup>6</sup>;
- Fibre Optic Cable Pipiper, 2015. Archaeological desk study<sup>7</sup>.

The results of these investigations have been incorporated in paragraph 3.5, description of known archaeological values.

<sup>4</sup> Van Mierlo et al., 2009

<sup>5</sup> Van den Brenk and van Lil, 2013

<sup>6</sup> R. van Lil, 2014

<sup>7</sup> Van Lil and Muis, 2015

### 3.2 Description of the current situation (LS02wb)

The water depth within the research area varies from 16.9 to 27.4 meter (LAT), with an average of 21.5 meter (LAT). The figure below shows a color depth map based on data from the Hydrographic service (25m grid) combined with multibeam echosounder data from the Luchterduinen survey (2011).

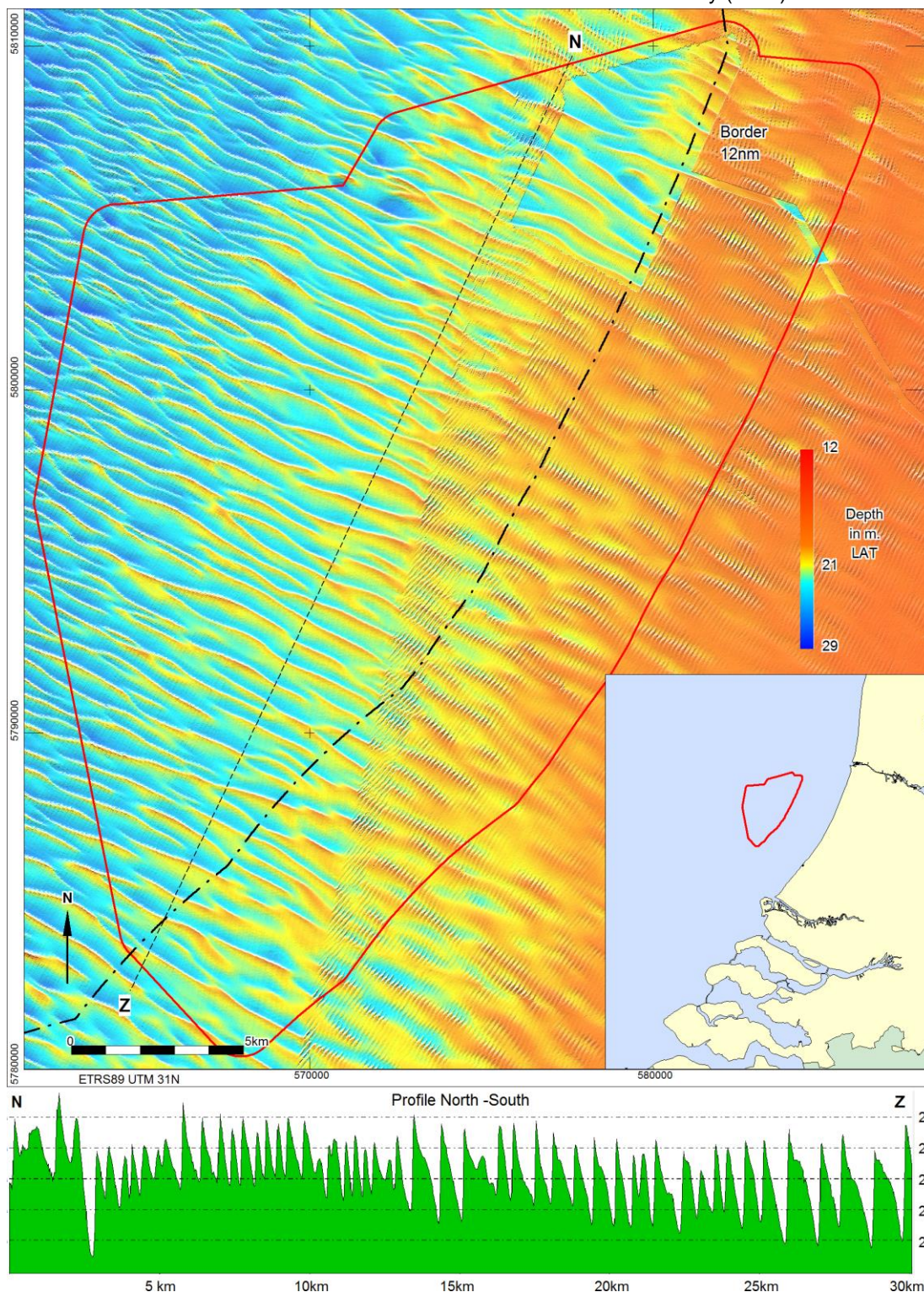


Figure 4. General bathymetry of the seabed

The seabed consists of sand dunes with a west-northwest-east-southeast orientation and an average height of three meters. The distance between the crests amounts to 500 meter. The dunes are superimposed by current ripples.

### 3.3 Description of geological data (LS04wb)

The archaeological prospect for (pre)historic settlements to occur is strongly related to the geogenesis of the plan area. The geogenesis is reflected by the lithostratigraphic units present, the character of layer boundaries (erosive vs non-erosive) and indications for the formation of soils within the sediments. Therefore geophysical and geological data are an important source to answer questions with respect to the nature, age, depth and location of occurrence, integrity and preservation of the archaeological remains which are to be expected within the plan area.

Figure 6 shows the occurrence of Pleistocene formations in the area with an indication of the Holocene sediment cover. This map is based on the Top Pleistocene Formations map of the North Sea area and a recent geological study of the HKZ wind farm zone.<sup>8,9</sup> These sources indicate the presence of the Kreftenheye Formation to be the dominant unit. In the western part of the wind farm area Laban mapped sub-crops of the Twente Formation, nowadays classified as the Boxtel Formation. DINO-boreholes from which formations are interpreted and recorded in the DINO-database are plotted on the map. From these borehole data a profile is deduced.

#### Kreftenheye Formation

The descriptions of the DINO-boreholes samples confirm the presence of the Kreftenheye Formation throughout the area. On request Deltares has provided Periplus with grid models (MSL) of a) the depth at which the formation transitions are to be expected within the North Sea area and b) the thicknesses of these units. The depth below the seabed at which the Kreftenheye Formation is picked in the 11 DINO-samples studied varies from 0.2 meters (BQ100194) to 5 meters (BQ150242) averaging 2.5 meters. The DINO-data coincide with the depth contours of the top Kreftenheye Formation. These contours are mapped by means of the grids supplied by Deltares and a 5 meter dtm-grid (LAT) of the plan area. An average offset of -0,85 meter was applied to the resultant top of the Kreftenheye Formation grid to correct for the difference between MSL and LAT.

The Kreftenheye Formation is made up of fluvial deposits of the Rhine which were deposited during the Weichselien.<sup>10</sup> In the warmer summer periods peak discharges of melt water resulted in the transport of fast amounts of sand and gravel to the North Sea area. Because large amounts of water were captured in the polar ice sheets the sea level was significantly lower: the Netherlands including the North Sea area formed a dry periglacial landscape. The Rhine was a braiding river running through this landscape.

At the top of the Kreftenheye Formation the Wijchen Member might be present. This member consists of silty and sandy clay. The matured clay can contain a well-developed paleosol. The Wijchen Member and part of the youngest sandy deposits of the Kreftenheye Formation were formed by meandering rivers during the Allerød and Early Holocene.<sup>11, 12</sup> The Wijchen Member has not been encountered in the DINO-boreholes in the wind farm area.

#### Boxtel Formation

The Boxtel Formation mapped by Laban presumably consists of eolian deposits of the Wierden Member (cover sands) and Delwijnen Member (river dunes). These very fine to medium fine grained sands have been deposited on the Kreftenheye Formation. The DINO-boreholes studied did not contain deposits of the Boxtel Formation. However, cover sand ridges and dunes as well as river dunes might have been preserved in isolated areas. If so, it is to be questioned if the top of these units is intact or eroded. The top of the Boxtel Formation is expected to be covered by the Basal Peat Bed marking the Early Holocene transgression in the area. The presence of the Basal Peat Bed is a clear indication that the underlying Boxtel Formation might be intact.

#### Bligh Bank Member

The Bligh Bank Member covering the Kreftenheye Formation / Boxtel Formation consists of a mobile sand layer in which sand dunes and mega-ripples have developed.

<sup>8</sup> Laban 2004.

<sup>9</sup> De Bruijn 2015.

<sup>10</sup> Weichselien: ice age which lasted from 115.000 till 12.000 years ago.

<sup>11</sup> Allerød: interstadial (warm) period with the Weichselien appr. from 14.000 till 13.000 years ago.

<sup>12</sup> Makaske 1995.



This unit consists of marine, medium- or fine to medium-grained, clean, yellow-brown sands with local mud laminae. The formation often has a more gravelly structure towards the base. The gravelly components at the base probably are reworked sediments from the underlying Kreftenheye Formation. The thickness of the Bligh Bank Member ranges from 0 meter in the valleys of the sand dunes to 5 meters at the crests of the sand dunes. The Kreftenheye Formation is expected to be locally exposed at the sea floor.

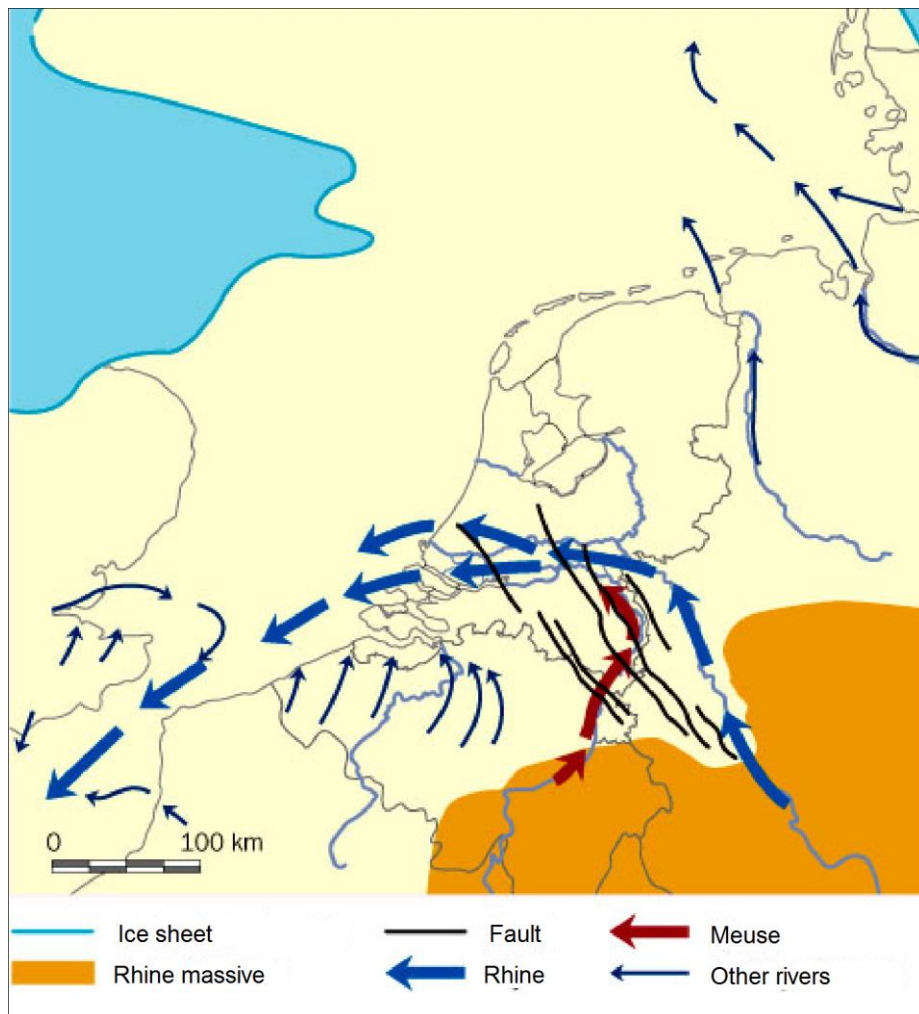


Figure 5. Course of the river Rhine (blue arrows) during the Weichselien (source: TNO)

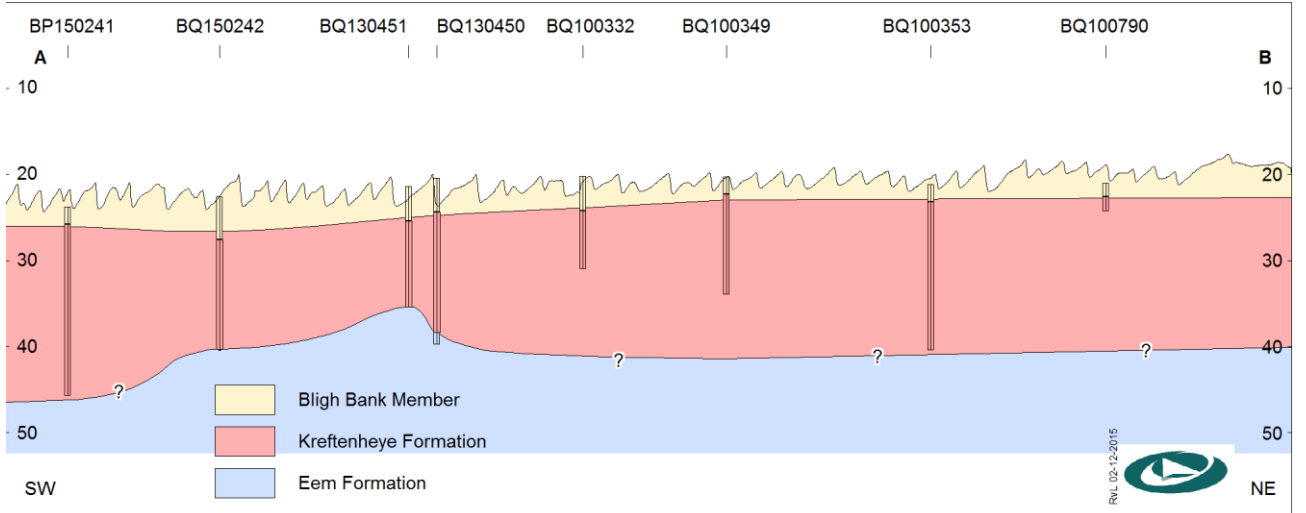
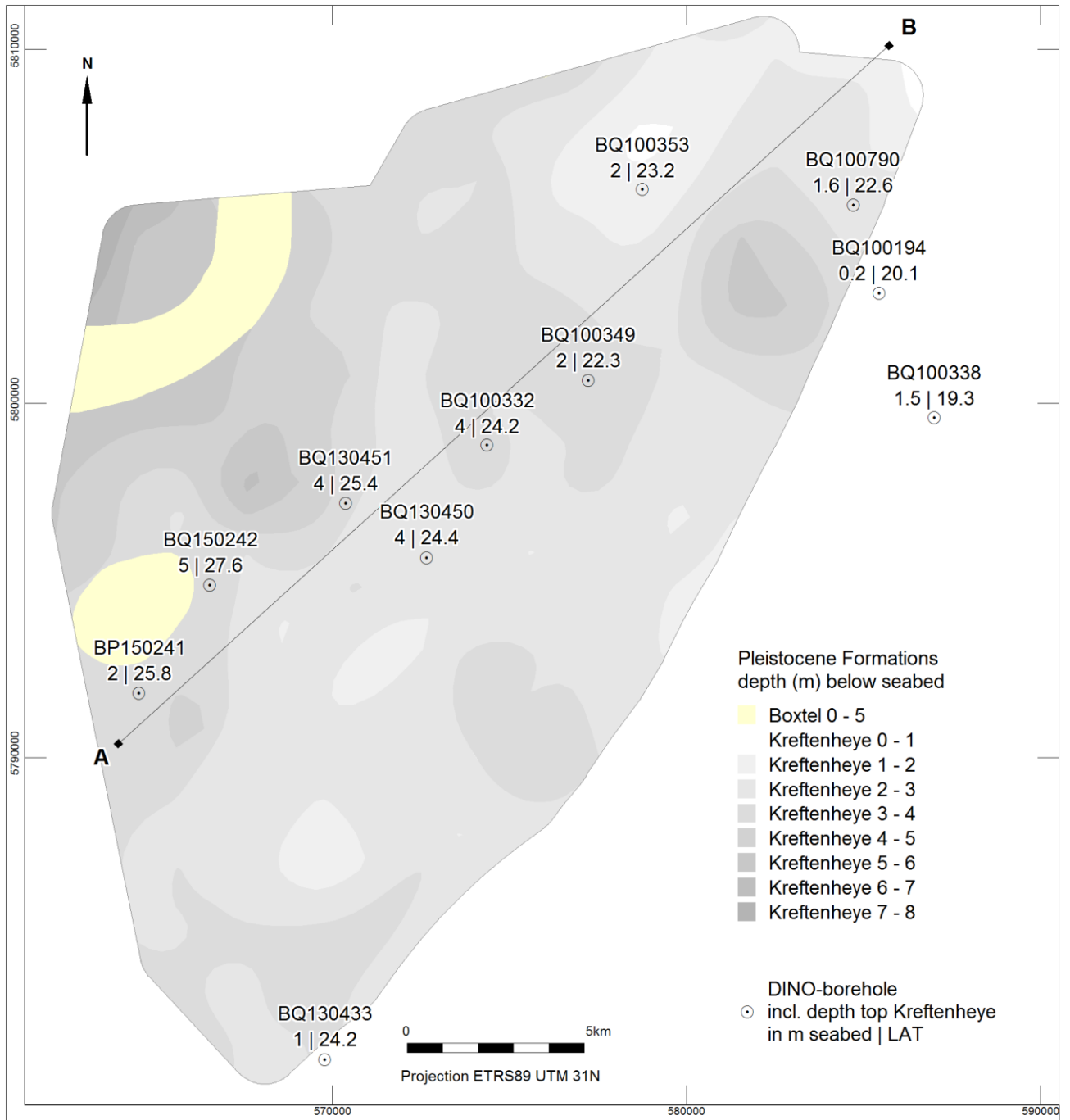




Figure 6. Subcropmap of Pleistocene lithostratigraphic units including a southwest – northeast profile

### Eem Formation

The Eem Formation is encountered in 3 DINO-borehole samples. The top of the formation was determined at 14.0 meters (BQ130450), 17.7 meters (BQ150242) and 18.0 meters (BQ130450) below the seabed, which coincides with 35.4, 38.4 and 40.3 meters LAT. The depths with respect to LAT are calculated using the DTM presented in this report. The sediments described comprise clay and loam of the Brown Bank Member. The Brown Bank Member was previously referred to as Brown Bank Bed or Brown Bank Formation. Zagwijn describes the unit as follows: *'The Brown Bank Formation is of fresh-water origin except for its lowermost layers, which are marine in some places. It was deposited in a lagoon or a lake. Underlying these beds there are marine Shelly sands which contain a fauna characteristic of the Eemian. These sands are rarely absent. Their thickness varies from around 10 m in the south to more than 20 m locally in the north. The base of these sands is flat in the south (at about 46 to 47.5 m below the present sea-level) and more sloping in the north.'* The description of Zagwijn refers to a north-south profile located 50 kilometers west of the HKZ wind farm area. Nowadays the Brown Bank unit is defined as a member the Eem Formation. The Bligh Bank Member is considered to be the top of the Eem Formation which has been deposited during transgression at the end of the Eemien.<sup>13</sup>

The profile in figure 6 shows question marks at the inferred transition between the Eem Formation and overlying Kreftenheye Formation. This is done because the depth at which the top of the Eem Formation occurs within the wind farm area is uncertain. In the centre of the area the Brown Bank Member is mapped. This member was encountered in 3 DINO-borehole samples south of the area mapped. Possibly the extent of the occurrence of the Brown Bank Member in the wind farm area is larger than the area mapped by Laban. Borehole data which are deep enough to verify this idea are not available in DINO. The Brown Bank Member is mapped as part of the Eem Formation and not as a separate unit in the profile of figure 6.

In a geological study of the Q10 wind farm area performed in 2009 the top of the Eem Formation is put at a depth of 22.9 - 39.0 meters below the seabed; the Kreftenheye Formation at 21.9 - 28.1 meters below the seabed.<sup>14</sup> The transition between the Kreftenheye and Eem Formation is clear at places where a gravel bed is present at the base of the Kreftenheye Formation or the Brown Bank Member is present at the top of the Eem Formation. If both formations consist of sandy sediments it may be hard to distinguish both units and pick the boundary between the two. This is particularly the case when the Kreftenheye Formation contains eroded shells from the underlying Eem Formation.

<sup>13</sup> Eemien: interglacial period between 130.000 and 115.000 years ago.

<sup>14</sup> Van Dijk 2009.

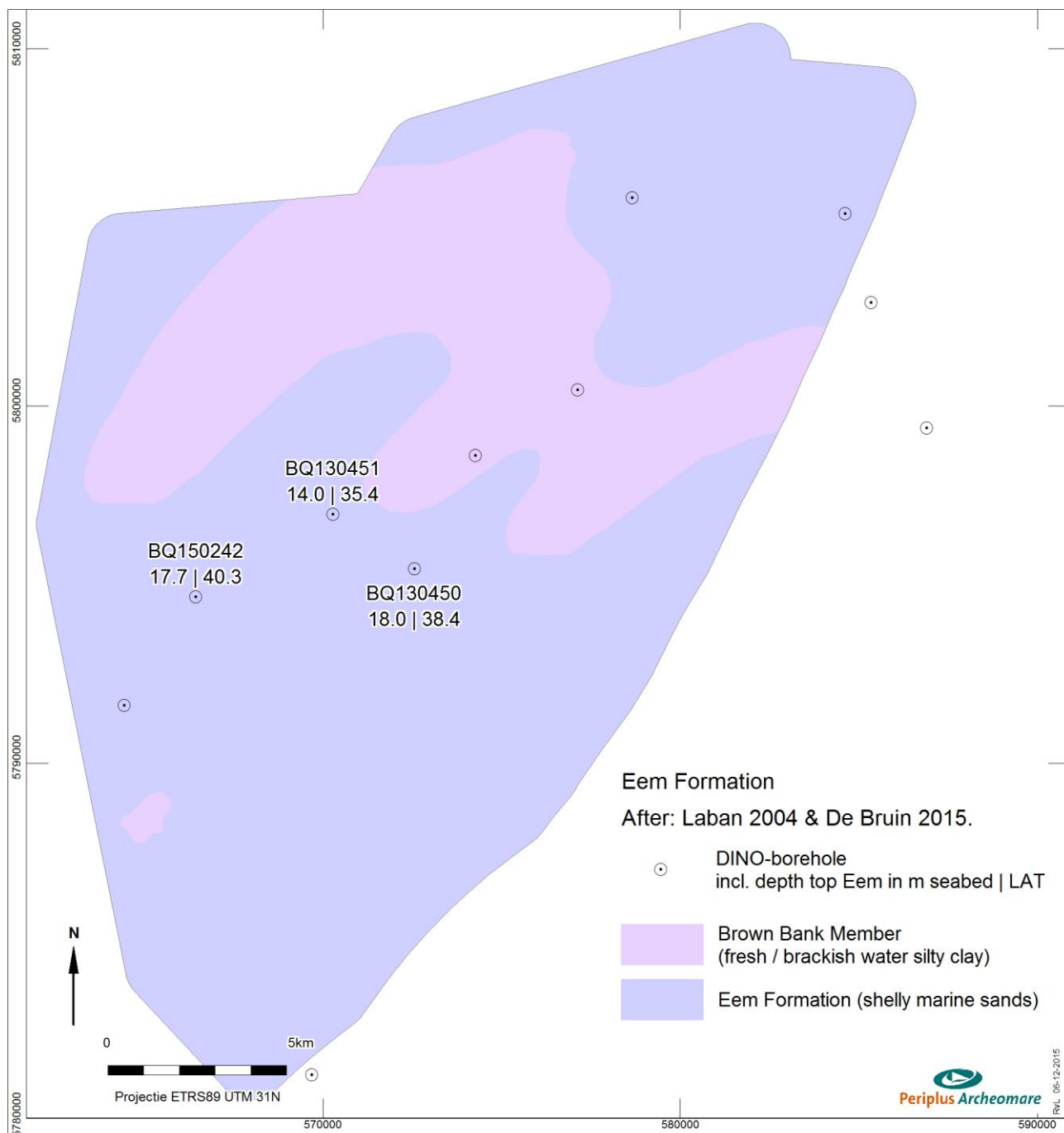


Figure 7. Subcropmap of Eem Formation

### 3.4 Description of the historical situation and possible disturbances (LS03wb)

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 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<sup>15</sup>.

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. Closer to the research artifacts of bone and antler were found<sup>16</sup>.



Figure 8. Reconstruction of the historical coast lines in the North Sea basin

Due to the sea level rise the ancient landscapes drowned. These landscapes are depicted through geophysical and geotechnical engineering. Recently, for example, on the basis of seismic data from the oil industry a prehistoric landscape was reconstructed near the east coast of England<sup>17</sup>.

#### 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.

<sup>15</sup> Gaffney e.a. 2005.

<sup>16</sup> Louwe Kooijmans 1970.

<sup>17</sup> Project 'North sea paleo-landscapes' of the University of Birmingham



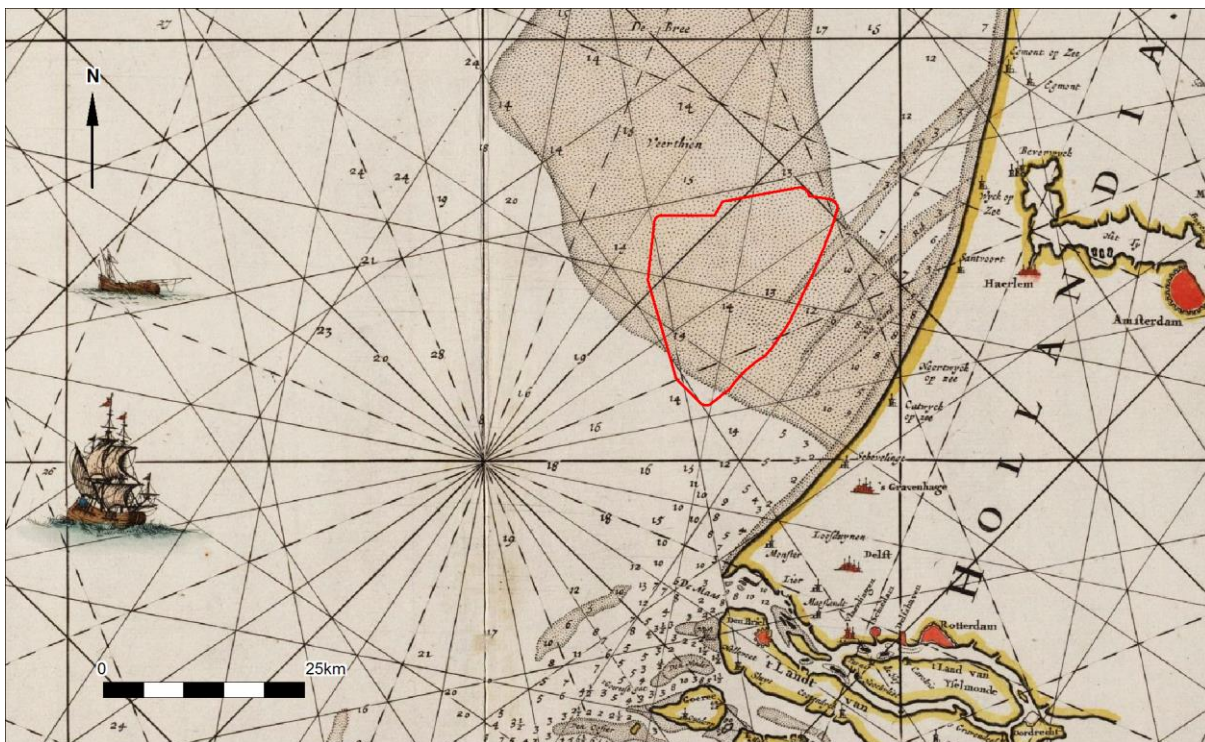


Figure 9. Research area on the historical map of 1675 (Pascaert de Wit, 1675)

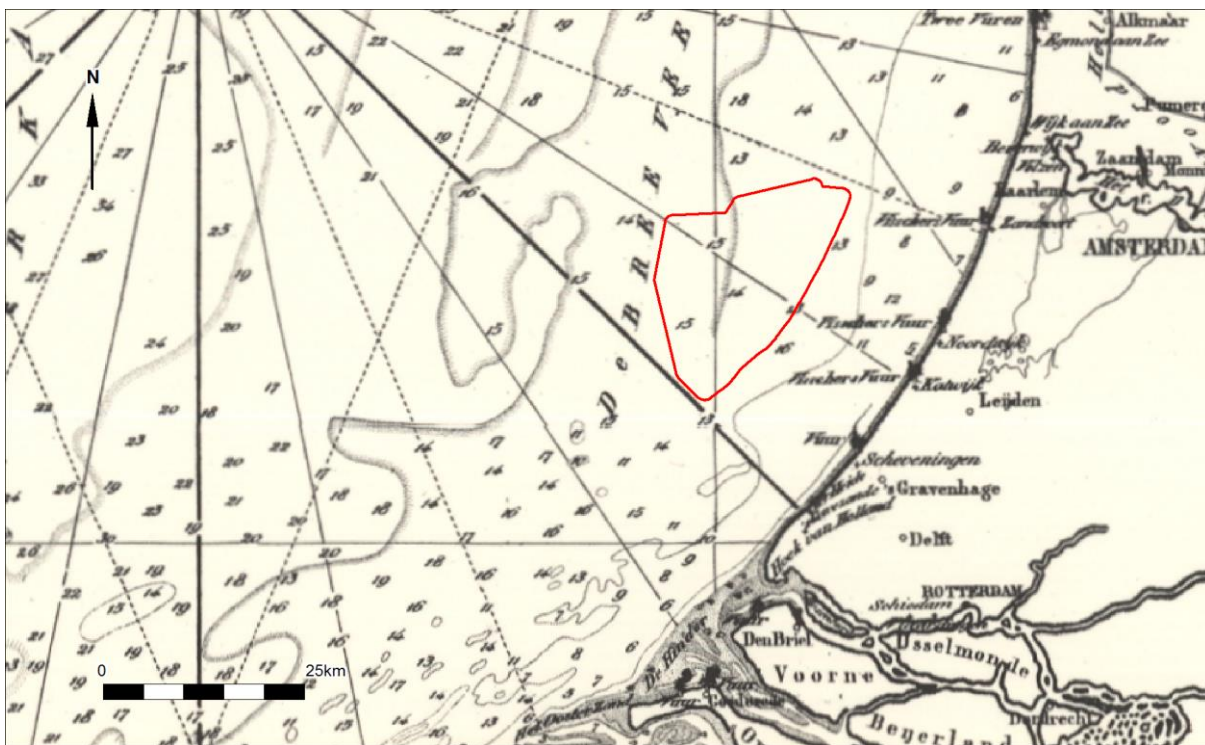


Figure 10. Research area on the historical map of 1852 (Jacob Swart, 1852)

**Known disturbances in the research area**

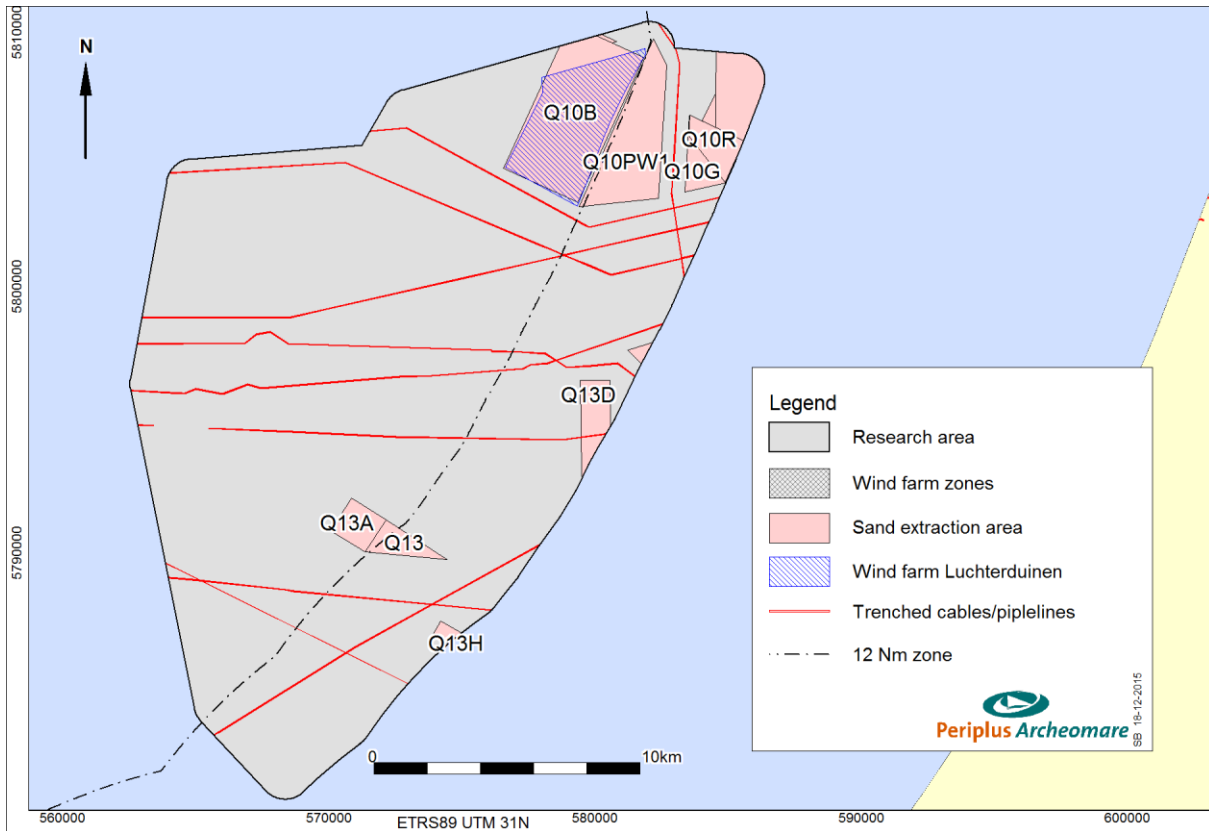


Figure 11. Known seabed disturbances within the research area

In the past, parts of the seabed within the research area have been disturbed by cable trenches and sand extraction. Recently also windfarm Luchterduinen has been installed within the plan area. The tables below describe these different areas.

Name	Used up	Description	Name	Used up	Description
Q13A	No	Sand extraction	Q13E	No	Sand extraction beach replenishment
Q13	No	Sand extraction	Q13D	No	Sand extraction beach replenishment
Q10PW1	No	Pilot extraction	Q10B	No	Sand extraction
Q10A	Yes	Sand extraction	Q13H	No	Sand extraction beach replenishment
Q10G	No	Sand extraction beach replenishment			

Table 4. Overview of sand extraction areas within the research area

Name	Trace	Type	Status
Circe 1 North	Zandvoort (NL) to Lowesoft (GB)	Fibre Optic	In use
Concerto 1 Segment 1 North	Zandvoort (NL) to Sizewell (GB)	Unknown	In use
Concerto 1 Segment 1 North	Zandvoort (NL) to Zeebrugge (B)	Fibre Optic	In use
Flute Ltd	Zandvoort (NL) to Zeebrugge (B)	Fibre Optic	In use
GTS	Zandvoort (NL) to Aldeburgh (GB)	Fibre Optic	In use
TAT14 Segment I	Katwijk (NL) to Saint Valery en Caux (F)	Fibre Optic	In use
TAT14 Segment J	Katwijk (NL) to Norden (D)	Fibre Optic	In use
UK - NL 6	Katwijk (NL) to Covehite (GB)	Coax	Abandoned
UK - NL 7	Katwijk (NL) to Covehite (GB)	Coax	Abandoned
Ulysses 2	IJmuiden (NL) to Lowesoft (GB)	Fibre Optic	In use

Table 5. Overview of cable trenches within the research area

In general, the seabed in parts of the area may have been disturbed by fishing nets and anchoring during cable-lay operations.



### 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<sup>18</sup> (see figure 12).

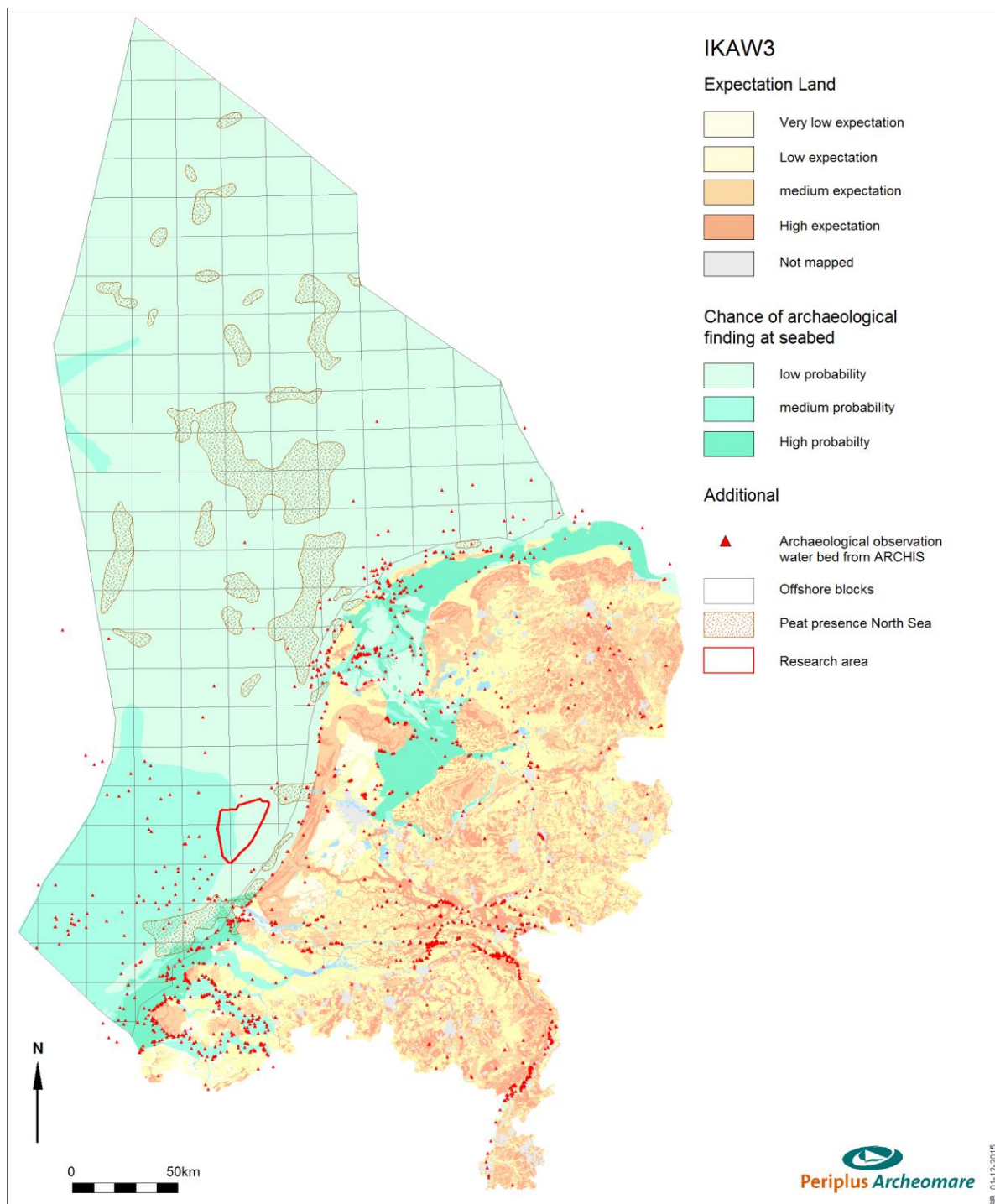


Figure 12. Overview indicative map of archaeological values (IKAW)

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

<sup>18</sup> IKAW 3e generatie, RCE 2008

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<sup>19</sup>.

**Details research area**

Figure 13 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.

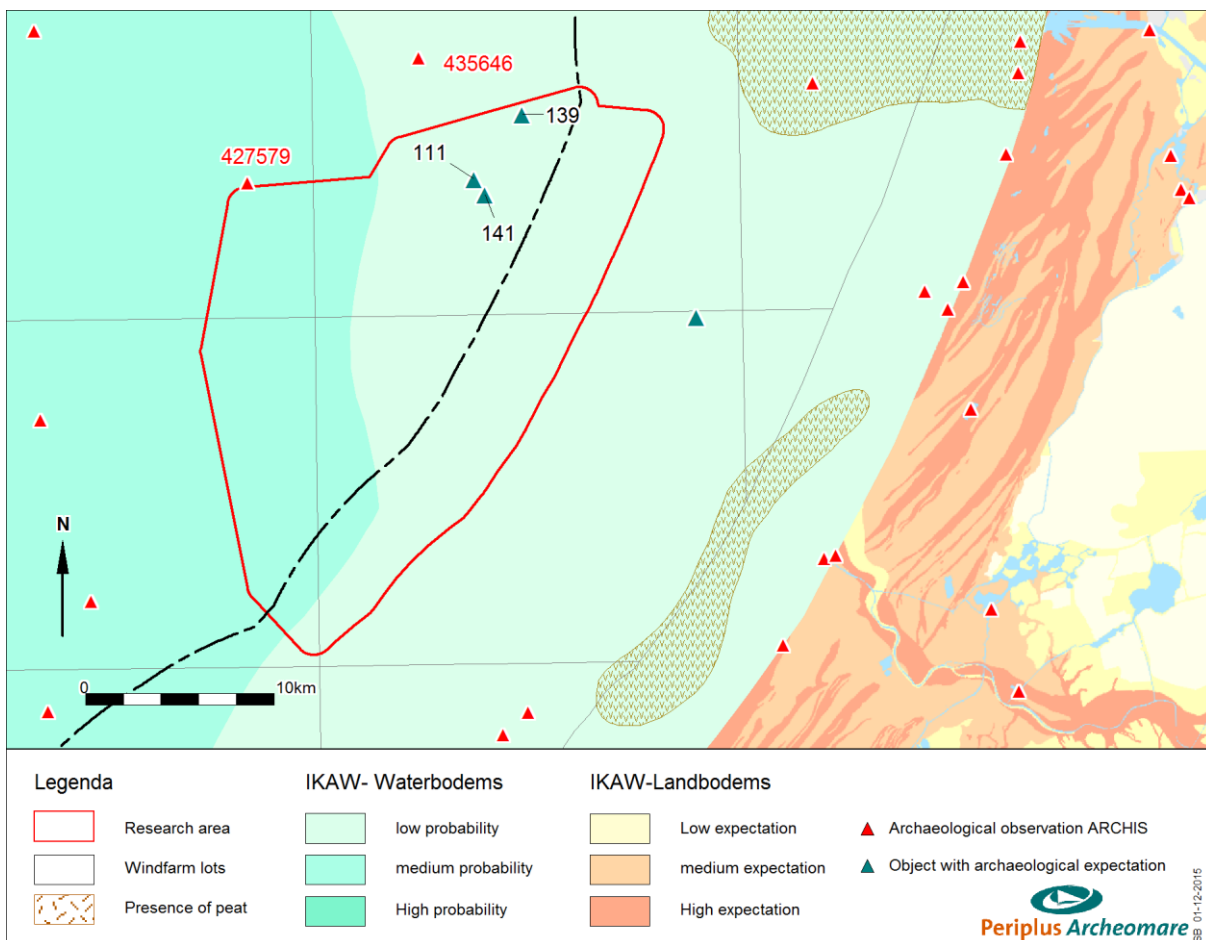


Figure 13. Detail indicative map of archaeological values (IKAW)

<sup>19</sup> North Sea paleolandscapes' of the University van Birmingham and North Sea Research and management Framework 2009 (Peeters e.a. 2009).

Within the vicinity of the plan area only two sites are reported, but both are located outside the research area.

NCN	ARCHIS	Easting	Northing	Description
258	427579	564478	5805694	Shipwreck freighter
1982	435646	573593	5812307	Shipwreck Steamer

Table 6. Observations from ARCHIS within the vicinity of the research area

During the geophysical survey for Windfarm Luchterduinen<sup>20</sup> in 2011, four objects were classified as of potential archaeological value. Three of these objects lay within the research area. These will be discussed in table 11.

**Plane wrecks**

During World War II, many airplanes crashed into the North Sea. Several sources are ambiguous about the number of aircraft still missing. It is at least hundreds<sup>21</sup>. Remains are found on a regular basis by fishermen or during sand extraction or and beach protection projects. For example, parts of a B17 bomber were discovered south of the research area near Hoek van Holland in 2009. The figure below shows the known locations of plane wreck findings. Additional information for the research area is requested from the salvage officer from the Royal Netherlands Air Force<sup>22</sup>, but no information is available at this moment.

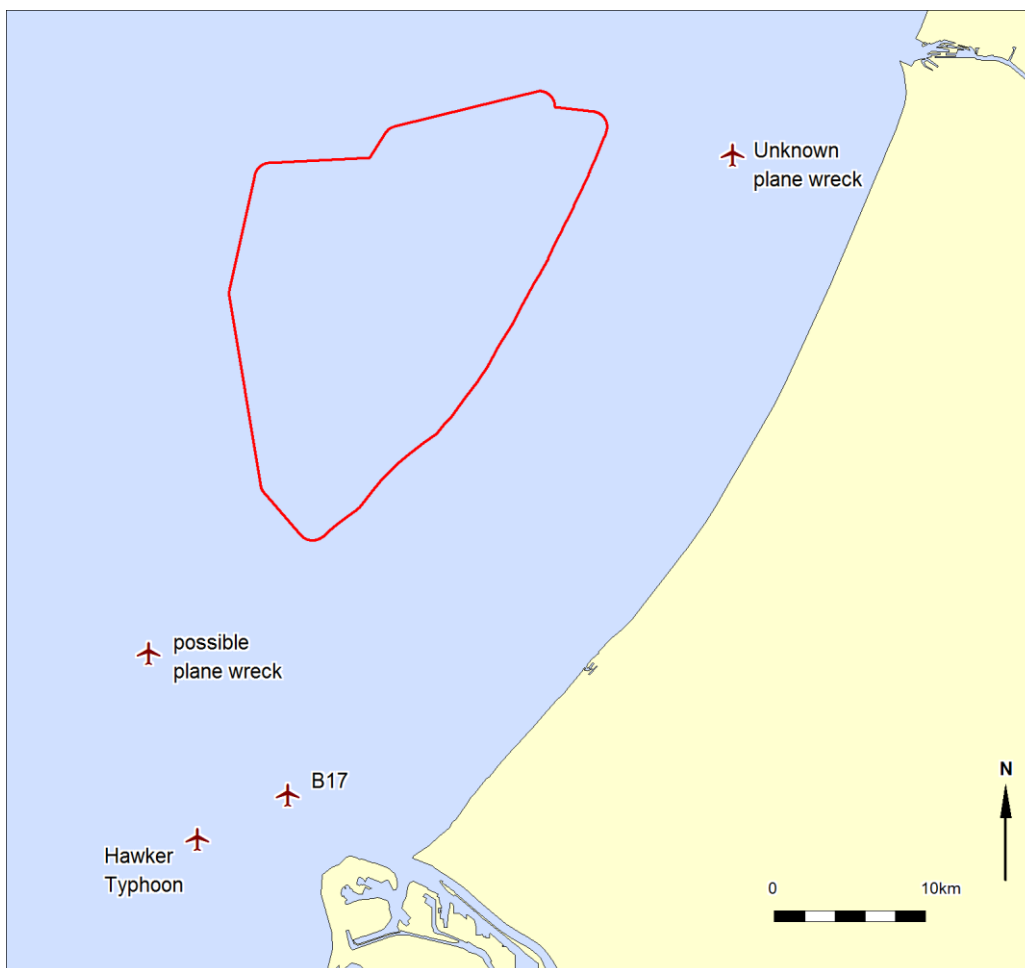


Figure 14. Known locations of plane wrecks in the vicinity of the research area

<sup>20</sup> Van den Brenk en van Lil, 2013

<sup>21</sup> Dutch Federation of Aviation Archaeology

<sup>22</sup> Email Major A. Kappert

## Shipwrecks

In general, when a sinking ship ends up on the seabed, the tidal currents will create scouring around the wreck, bury it down to a level of a harder surface within the sedimentary sequence. The thicker the layer of loose material, the more the ship will be packaged therein and will be retained. Especially in areas where the sediments have a high clay content the wreck remains will be sealed and well preserved. In more sandy areas this effect is much smaller. Uncovered wooden parts may be effected by a naval shipworm (*Teredo Navalis*).

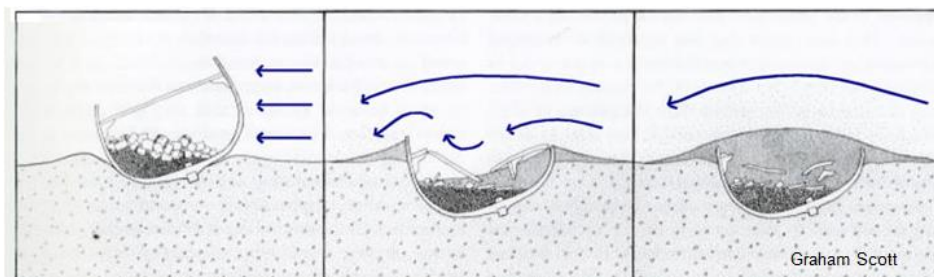


Figure 15. Example of wreck site formation (Graham Scott)

## Known objects and shipwrecks

For a listing of known objects and shipwrecks within the research area, the united NCN database is consulted<sup>23</sup>.

### The National Contact Number (NCN)

The NCN database combines the data from three governmental databases:

- The Dutch Continental Shelf and Westerschelde wrecks register from The Hydrographic Service of the Royal Netherlands Navy.
- The SonarReg92 object database of Rijkswaterstaat
- The ARCHIS database (the official archaeological database of the Ministry of Cultural Heritage)

The permission for the use of the NCN database for the analysis was granted by the owner (Rijkswaterstaat Sea and Delta)

Additional information of known wrecks and background information was kindly supplied by wreckdive team Bernicia<sup>24</sup> and retrieved from the website of wrecksite.eu.

According to the NCN database 55 known objects are present within the research area.

NCN type	Known
Shipwreck remains	19
Other (obstacle)	36
<b>Total</b>	<b>55</b>

Table 7. Observations of known objects

The map and table on the next pages show all known observations in the research area.

<sup>23</sup> With permission of G. Poot, data manager Rijkswaterstaat Centrale Informatievoorziening

<sup>24</sup> Hans van der Weide, by email

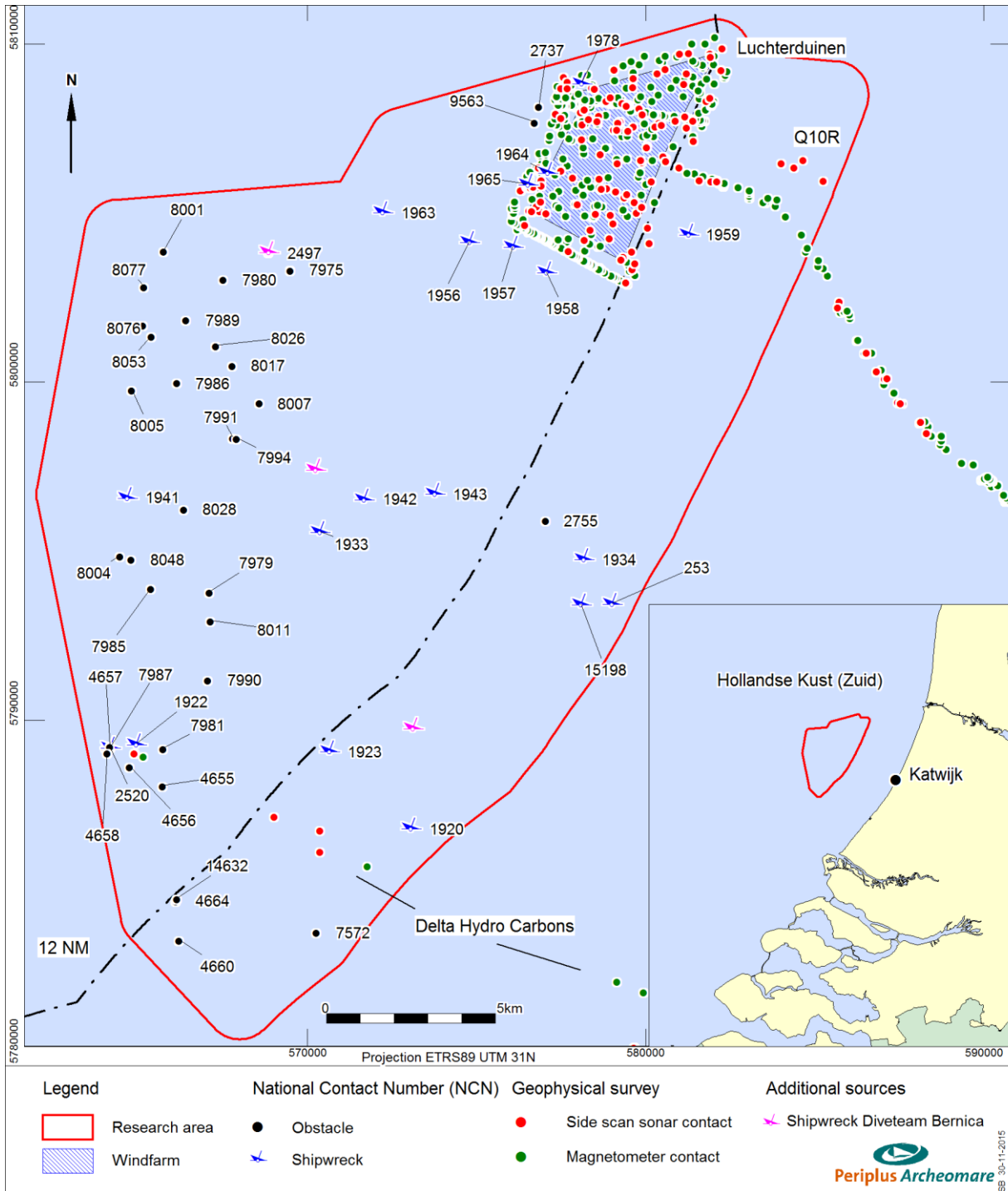


Figure 16. Overview of known objects and contacts in the research area



The tables below lists the known objects and contacts within the twelve mile nautical zone.

NCN	SR92	DHY	Easting	Northing	R95	Description
253	167	2087	578989	5793459	5	Wreck Swept by wire drag 41.5x8m. Additional info dive team Bernica: Fishing vessel, 45x8m, used in WOII by Germans
1920	-	2073	573048	5786823	0	Wreck Unknown Unknown
1923	-	2079	570643	5789106	5	Wreck Swept by side scan sonar
1934	-	2093	578156	5794786	5	Wreck Found by multi-beam 3x2m. Additional info dive team Bernica: "Juffermanswrak, olieleidingwrak", 30x8m
1959	-	2121	581257	5804376	5	Wreck Found by echo sounder 34x11m. Additional info dive team Bernica: "Hamertjeswrak"
2755	-	3302	577040	5795934	1000	Foul, archived - BDS 1242/05
4660	3261	-	566205	5783526	5	Elongated object (4.1x0.6), discovered in 2009
4664	3265	-	566116	5784683	5	Object (4,7x3,5x0,7) with scouring, discovered in 2009
7572	6186	-	570270	5783757	5	Possible cable or chain, 2010
14632	-	3758	566137	5784742	5	Obstruction Found by multi-beam 2x2m
15198	11936	-	578092	5793448	5	Wreck remains HY 2087, 1995. ROV images available

Table 8. Overview of known objects and contacts in the research area within the 12NM zone



Figure 17. ROV recording NCN 15198 / SR92 11936

The figure above shows an ROV recording of a wreck within the 12nm zone (NCN 15198, source: Rijkswaterstaat Zee en Delta).



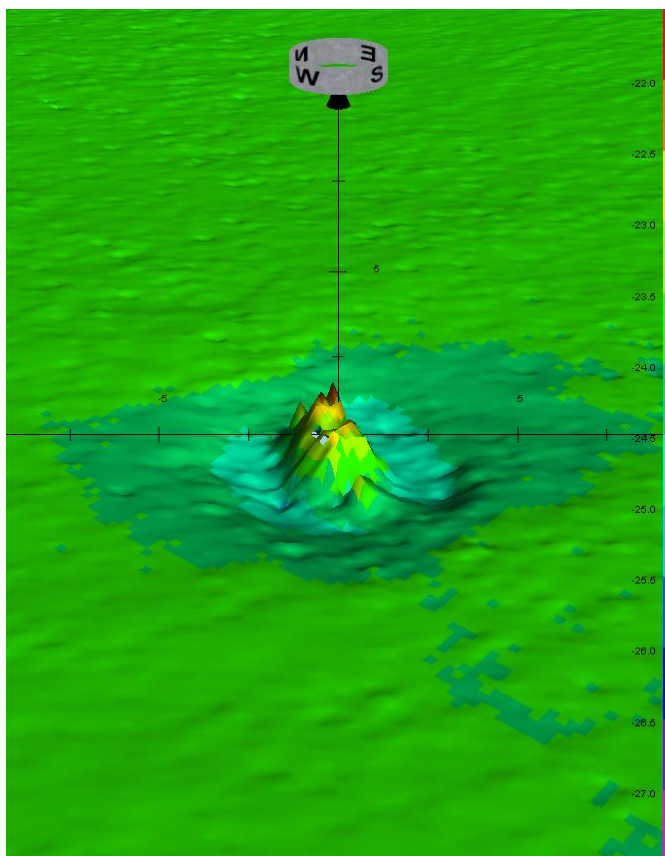


Figure 18. Multibeam recording NCN 4664 / SR92 3265

The figure above shows a 3D view of a multibeam recording of an unidentified object within the 12nm zone, discovered in 2009 (NCN 4664, source: Rijkswaterstaat Zee en Delta).

The tables below lists the known objects and contacts outside the twelve mile nautical zone.

NCN	SR92	DHY	Easting	Northing	R95	Description
1922	-	2078	564932	5789305	5	Possible wreck of Thisbe; French steamer by Dundee; for Maison Verel; 1903; 66x10,05x4,1m; 800 n.h.p.; coal fired engines. The Thisbe was sunk near to IJmuiden during a violent gale on 3rd December 1909. There were no victims (Noordzeeduiken.nl)
1933	-	2092	570361	5795591	5	Wreck, archived - BDS 1699/2007
1941	-	2100	564665	5796595	5	Wreck Found by echo sounder
1942	-	2101	571658	5796547	5	Wreck Found by echo sounder Unknown 24x24m
1943	-	2102	573754	5796722	5	Wreck Unknown. Additional information dive team Bernicia: Fishing vessel, sunk 10-08-1907
1956	-	2118	574777	5804155	5	Wreck Found by echo sounder
1957	-	2119	576065	5804020	5	Wreck Found by echo sounder
1958	-	2120	577061	5803263	5	Wreck Found by echo sounder
1963	-	2128	572212	5805044	5	Wreck, archived - BDS 1699/2007
1964	-	2129	577090	5806199	5	Wreck Found by echo sounder
1965	-	2130	576505	5805858	5	Wreck Found by echo sounder 20x7m
1978	-	2146	578107	5808842	5	Wreck Found by echo sounder
2497	-	2903	568847	5803855	5	Foul Found by echo sounder Unknown 20x0m
2520	-	2943	564167	5789208	5	Wreck Found by multi-beam 2x2m. Additional information dive team Bernicia: Submarine Wiljo3.
2737	-	3265	576849	5808168	5	Obstruction Swept by side scan sonar
4655	3256	-	565725	5788081	5	Elongated object, discovered in 2009
4656	3257	-	564748	5788653	5	Small (1.8 x 1.4x0.1) object, discovered in 2009
4657	3258	-	564156	5789245	5	Small (1.9 x 1.2x0.2) object, discovered in 2009
4658	3259	-	564078	5789057	5	Small (3.4 x 1.0x0.3) object, discovered in 2009
7974	6605	-	569498	5803345	5	Cluster of small objects (1.7x1.1x0.3), 2009
7975	6606	-	569493	5803334	5	Cluster of small objects (1.7x1.1x0.3), 2009

NCN	SR92	DHY	Easting	Northing	R95	Description
7979	6610	-	567111	5793814	5	Possible cable or chain, 2010
7980	6611	-	567518	5803057	5	Elongated object (5.8x0x0), discovered in 2010
7981	6612	-	565734	5789186	5	Contact or seabed disturbance (1.9x1.2x0.5m)
7985	6616	-	565380	5793913	5	Possible cable or chain, 2010
7986	6617	-	566148	5800001	5	Ridge (8.7x1.5x0.1m) 2010
7987	6618	-	564183	5789210	5	Seabed disturbance (17.2x9.3m)
7989	6620	-	566418	5801866	5	Elongated object (2.8x0.8x0.1), discovered in 2010
7990	6621	-	567064	5791212	5	Elongated object (2.7x0.6x0.0), discovered in 2010
7991	6622	-	567790	5798376	5	Small (2.2 x 0.6x0.2) object, discovered in 2010
7994	6625	-	567908	5798358	5	Elongated object (2.7x0.6x0.0), discovered in 2010
8001	6632	-	565751	5803886	5	Possible cable or chain, 2010
8004	6635	-	564462	5794879	5	Small (1.3 x 1.0x0.2) object, discovered in 2010
8005	6636	-	564808	5799794	5	Small (2.1 x 1.0x0.3) object, discovered in 2010
8007	6638	-	568586	5799408	5	Contact or seabed disturbance (3.4x1.4x1.1m)
8011	6642	-	567134	5792960	5	Manmade object (4.1x1.8x0.4) 2010
8017	6648	-	567774	5800510	5	Small (1.4 x 1.1x0.2) object, discovered in 2010
8026	6657	-	567293	5801089	5	Object (2.2 x 2.1x0.2), discovered in 2010
8028	6659	-	566349	5796268	5	Possible cable or chain, 2010
8048	6679	-	564793	5794782	5	Possible cable or chain, 2010
8053	6684	-	565390	5801373	5	Small object (1.5 x 1.0x0.1), discovered in 2010
8076	6707	-	565132	5801701	5	Small object (1.7 x 1.0x0.1), discovered in 2010
8077	6708	-	565170	5802833	5	Cluster of small objects (1.6x1.0x0.0), 2010
9563	1105	-	576711	5807696	5	Wreck remains at 1831m of wreck HY 2130

Table 9. Overview of known objects and contacts in the research area outside the 12 NM zone

For none of the 55 known objects in the area (19 shipwrecks and 36 obstacles) the archaeological value has been determined. Also it is not known which of these objects, listed in the different databases, are still present. Further geophysical research is needed to ascertain the presence and the cultural-historical value of these objects.

During geophysical surveys for Windfarm Luchterduinen (2013)<sup>25</sup> and a pipeline for Delta Hydro Carbons (2009)<sup>26</sup> several objects were mapped with side scan sonar and magnetometer:

Survey	Side scan sonar	Magnetometer anomalies	Of archaeological interest
Delta Hydro Carbons 2009	5 unknown objects	2	0
Luchterduinen 2013	117 (89 unknown objects)	331 (117 cable contacts)	3

Table 10. Results from geophysical surveys within the research area

For Luchterduinen, three objects were classified as of possible archaeological value.

Nr	Description	Interpretation	Magnetic anomaly	L (m)	B (m)	H (m)
111	Shipwreck	Ship wreck HY2130 (=NCN 1965)	MAG 204	29.0	14.6	2.1
139	Cluster of small contacts corresponding with magnetometer anomaly	Unknown object	MAG 391	7.7	4.5	0.0
141	Elongated slightly bended object, corresponds with magnetometer anomaly	Unknown object	MAG 174	5.3	1.1	0.0

Table 11. Locations from Luchterduinen survey with an archaeological expectation

<sup>25</sup> Van den Brenk and van Lil, 2013

<sup>26</sup> Van Mierlo et al, 2009

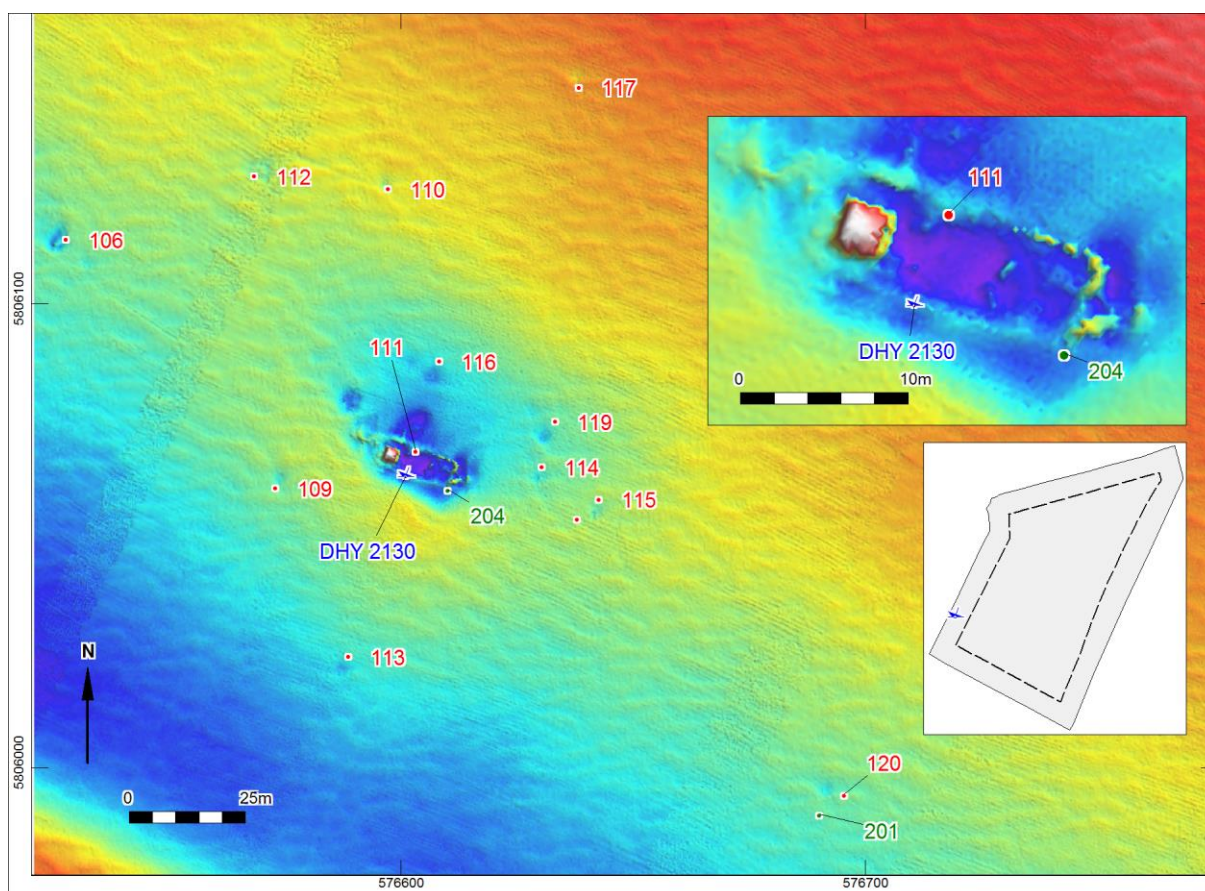


Figure 19. Multibeam image NCN 1965 / DHY 2130 recorded during geophysical survey Luchterduinen

Currently no further information is available regarding these objects.

### 3.6 Specified archaeological expectation (LS05wb)

#### Shipwrecks

The area has a high expectation for shipwrecks from all periods. A total of 19 shipwrecks are known in the area. Details like names, types and date of sinking are not known, nor are the exact locations. Further research is needed to determine the cultural-historical value.

During the geophysical survey for Luchterduinen, which covers approximately 5 percent of the area, three objects were classified as of possible archaeological value.

During the geophysical survey for Delta Hydrocarbons, which covers approximately 2 percent of the area, no objects were classified as of possible archaeological value.

Over 90 % of surface of the wind farm area has not been investigated by detailed geophysical surveys. The area may contain more undiscovered shipwrecks or remains of shipwrecks.

#### Plane wrecks

The area has a high expectation for plane wrecks from the Second World War. Several sources are ambiguous about the number of aircraft still missing. It is at least hundreds<sup>27</sup>. Four locations of plane wreck sites are known in the vicinity of the research area.

<sup>27</sup> Dutch Federation of Aviation Archaeology

## Prehistory

The area has a high expectation for prehistory sites dating from Paleo- and Mesolithic. The study of prehistoric settlements which might occur in the wind farm area has been determined by looking into the presence and integrity of buried prehistoric landscapes. Emphasis is put on camps or settlements in relation to the changing landscape. Off-site finds like special purpose sites, depositions and e.g. canoes are not included. This group belongs to a category of archaeological finds which have to be taken into account, but from which the occurrence - considering the sources and methods available - is hard to predict.

During the last ice age the research area was exposed due to very low sea levels. The Pleistocene landscape was occupied by hunters and gatherers in Late Paleolithic and Early Mesolithic times. Therefore camps sites are to be expected in the top of Pleistocene formations. The archaeological expectation is discussed below by means of the geogenesis of the area and lithostratigraphic units present.

### Sites of the Kreftenheye Formation

The braided river Rhine ran through the area depositing poorly sorted sand and gravel. In the warmer interstadial periods and at the onset to the Holocene the river reclaimed a meandering course and apart from sand silty clay and loam was deposited. A well-developed paleosol is often encountered in the clay/loam layer. The sandy deposits are classified as the Kreftenheye Formation; the deposits of clay and loam are separately classified as the Wijchen Member within the Kreftenheye Formation. The Wijchen Member can be considered as a level at which *in situ* archaeological remains can be encountered.

### Sites of the Boxtel Formation

During very cold and dry conditions at the end of the Weichselien the landscape was covered by eolian sands. The cover sand landscape with alternating dunes, ridges and valleys which formed at the end of the last ice age is known to be occupied intensively in prehistoric times. Also river dunes formed which formed within and alongside the Rhine valley are known to contain many prehistoric sites. River dunes (Delwijnen Meber) and cover sands (Wierden Member) are part of the Boxtel Formation. The Boxtel Formation is mapped in the western parts of the area. The area in which the Boxtel Formation is present can be outlined in more detail by the execution of subbottom profiler survey and by the sampling of vibro cores. Also the integrity of the top of this unit can be judged in this way. Levels of archaeological interest are paleosols within the sandy sediments. Known paleosols are the 'Usselo' soil formed during the Allerød and a podzol formed in the Early Holocene.<sup>28</sup>

### Eem Formation

The Eem Formation consists predominantly of marine sand which was deposited in the Eem Sea during the Eemien.<sup>29</sup> Within the sandy Eem deposits no archaeological remains are expected. The Brown Bank Member at the top of the Eem Formation consists of lacustrine fresh water and coastal marine brackish water deposits of silty clay. At the end of the Eemien the sea regressed and the Brown Bank clays were deposited. This layer can contain artifacts from or remains of Neanderthaler who in this period populated the Netherlands and the North Sea area. Little archaeological research has been done into this often deep-seated stratigraphical unit.

Archaeological markers consist of flint and bone artifacts, burnt nuts and seeds and charcoal. Zones of interest are locations where the top of the cover sands and river dunes (if present) are not eroded. The presence of the Basal Peat Bed indicates that underlying Boxtel Formation and possible archaeological remains herein are intact. The Wijchen Member and Basal Peat Bed can also contain archaeological remains. These remains comprise of attributes used for hunting which because of the low levels of oxygen and wet conditions might be well preserved.

<sup>28</sup> Allerød: interstadial which lasted from 14.000 till 13.000 years ago.

<sup>29</sup> Eemien: interglacial which lasted from 130.000 till 115.000 years ago.



## 4 Synthesis

Based on the results of the data analysis the research questions are answered. All answers apply to the areas within and outside the 12 nautical mile border, unless specified differently.

- *Are there any known archaeological values present within the research area? If so, what is the nature, extent (depth) location and dating of these sites?*  
No proven archaeological values are known within the research area. During the geophysical survey for Windfarm Luchterduinen, three objects (outside the 12 nautical mile border) were classified with a possible archaeological expectation, but no detailed information is currently available. A total of 19 shipwrecks (6 within the 12 nm) are reported in the NCN database, but additional information is not available. The cultural historic value of these wrecks has yet to be determined.
- *Are there, in addition to any known values, archaeological remains be expected? If so, what is the nature, extent (depth) location and date of the expected archaeological remains?*  
More than 90 % of surface of the wind farm area has not been investigated by detailed geophysical surveys. The area may contain more undiscovered shipwrecks, remains of shipwrecks or remains of airplanes from the Second World War. Apart from wrecks archaeological remains of Paleolithic and Mesolithic camp sites of hunters and gatherers can be encountered. These sites are characterized by the presence of flint and bone artifacts, burnt nuts and seeds, charcoal and hunting gear.
- *Do the proposed activities in the wind farm zones threaten known or expected archaeological values? If so, can an impact on archaeological assets be prevented or restricted by planning adaptation?*  
This question can only be answered once the area has been geophysical investigated and when the cultural historic value of the objects in the area has been determined.
- *If the archaeological values cannot be saved:*
  - *What kind of further research is needed to determine the presence of archaeological values and their size, location, type and date to be determined enough to come to a selection decision?*  
If archaeological values are present, additional dive research is required to investigate the objects in order to define a selection decision. (in Dutch: KNA onderwater verkennend/ waarderend onderzoek, see also appendix 1.
  - *What are the possible effects of the installation of offshore wind farms on the areas with specific archaeological interest?*  
Cable-lay operations are conducted with trenching which can destroy present archaeological values, which are situated on or close to the seabed. In addition the construction of wind turbines will have an effect on the morphology of the seabed and might affect the prehistoric landscape. They will have an effect on tidal currents creating scouring, which might uncover buried values and expose them to the erosional seabed surface.
- *What are the possibilities to mitigate the disturbance of areas with specific archaeological interest as a result of installing offshore wind farms?*  
In general, a buffer or safety zone of 100 meters around an archaeological object or an object with an archaeological expectation is to be defined in which no activities such as trenching or anchoring are allowed<sup>30</sup>. If additional research shows that the object has no archaeological value, the location and the buffer zone can be omitted.
- *Should further investigations be carried out from archaeological point of view and what are the recommendations on the scope and specifications of these investigations?*  
Additional research in the form of a geophysical survey is standard in the process of archaeological investigations. (in Dutch: *Inventariserend veldonderzoek opwaterfase*). The scope and specifications for this geophysical survey are to be recorded in a mandatory Program of Requirements (PvE). Typical requirements include restrictions about the maximum range and minimum frequency of the side scan sonar, survey speed and line spacing.

<sup>30</sup> Beleidsregels ontgravingen in Rijkswateren, see <http://wetten.overheid.nl/BWBR0028498/>

- *What are the requirements for any activity carried out in the wind farm area (investigations or monitoring activities, installation activities, operational activities) that could have an effect on archaeological aspects in the wind farm area?*

In general, a buffer or safety zone of 100 meters around an archaeological object is to be defined in which no activities such as trenching or anchoring are allowed. This applies only for objects with an archaeological expectation. If additional research shows that the object has no archaeological value, the location and the buffer zone can be omitted, and the objects may be removed during a debris clearance campaign. Additional prospection will clarify if it is feasible to keep the depth of the cables above possible archaeological levels.

*What is the expectation of the physical quality of possible archaeological sites and objects?*

The physical quality of wreck sites is expected to be high in case these wrecks are covered with sediments. If wooden ship wrecks are exposed at the seafloor biological deterioration by the naval shipworm could result in a lowering of the level of preservation. Moreover these wrecks are subject to demolition by anchors and fishing nets which will result in a lowered integrity of the wreck site.

- *Which lithostratigraphic units can be determined and what is their spatial distribution (both horizontal and vertical)?*

The following units have been determined:

Unit	Top -seabed	Base -seabed	Occurrence	Remark
Bligh Bank Member	0 - 5	0 - 5	total area	mobile layer, seabed
Basal Peat Bed	0 - 5	0 - 5	total area	presence uncertain
Boxtel Formation - Wierden Member - Delwijnen Member	0 - 5	0 - 5	western part (outside 12 nm)	occurrence and integrity uncertain
Kreftenheye - Wijchen Member	0 - 5	10 - 20	total area	layer boundary with Eem Formation uncertain
Eem Formation - Brown Bank Member	10 - 20	10 - 30	total area(?)	top and bottom of formation uncertain

Table 12. Different lithostratigraphic units with in the area of interest

- *What are the archaeological levels within the lithostratigraphic sequence?*

Unit	Archaeological remains	In situ
Bligh Bank Member	reworked flint and bone artifacts	no
Basal Peat Bed	in situ finds: lost objects, dumps	yes
Boxtel Formation - Wierden Member - Delwijnen Member	camp sites of hunters and gatherers; flint and bone artifacts; burnt nuts and seeds; charcoal; hunting gear	yes yes
Kreftenheye - Wijchen Member	reworked flint and bone artifacts lost objects, dumps; possible camp sites	no yes
Eem Formation - Brown Bank Member	reworked flint and bone artifacts camp sites Neanderthaler; flint artifacts	no yes

Table 13. Different archaeological levels within the lithostratigraphic units

- *Is it possible to define zones for windfarms where the (buried) prehistoric landscape is eroded or intact? Are the expected lithostratigraphic boundaries erosive or non-erosive?*

No, the data available do not contain information from which can be deduced if the (buried) prehistoric landscape is intact. However, the major unit (Boxtel Formation) is expected to contain *in situ* remains of prehistoric settlements occurs at shallow depths. The chance that these sandy sediments and the archaeological levels herein are eroded by the covering Bligh Bank Member is considerable. A subbottom profiling survey in combination with vibro core sampling could result in the information needed to map the occurrence of the Basal Peat Bed and provide with information on the zones where the prehistoric landscape is expected to be intact.



The Brown Bank Member is expected to be preserved intact. The depth at which this unit occurs is uncertain at this stage, but can also be deduced from subbottom profiling data.

- *If so, are these zones threatened by the work envisaged?*

If the archaeological levels within the Kreftenheye Formation, Boxtel Formation and Basal Peat Bed are intact, these levels will - considering their occurrence close to the seabed - be threatened by work envisaged. After installation scouring in the vicinity of the monopiles will result in erosion of archaeological levels.

- *Could human activities have led to a disturbance of the seabed and archaeological remains therein?*

Yes. In the past, several cables were trenched in the area (general up to one meter below the seabed), and sand has been extracted from sand extraction areas. Furthermore, fishing activities using trawls may have damaged archaeological remains at the seabed surface.

- *What is the expected intrinsic quality in terms of rarity, research potential, group value and representativeness of the areas with specific archaeological interest?*

This question can only be answered when the cultural historic value of the objects in the area has been determined. Therefore, additional research is required.

- *What is the expected physical quality in terms of integrity and preservation of the areas with specific archaeological interest?*

The physical quality of prehistoric settlements in the North Sea area is to a large extent dependent on the integrity of archaeological levels. The chance that these levels have deteriorated due to erosion or human activities is considerable. On the other hand archaeological remains are expected to be well-preserved under water. Therefore if the archaeological levels have not been altered by natural or human causes, prehistoric settlements of high physical quality are to be expected.

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## 5 Summary and advice

Within the investigated area of the wind farm zones there is a high expectation for the presence of (remains of) ship wrecks and WWII plane wrecks. Locally *in situ* remains of Late Paleolithic and Early Mesolithic camp sites might be present.

Parts of the research area have been investigated by geophysical surveys in the past.

During the geophysical survey for Luchterduinen, which covers approximately 5 percent of the area, three objects were classified as of possible archaeological value.

During the geophysical survey for Delta Hydrocarbons, which covers approximately 2 percent of the area, no objects were classified as of possible archaeological value.

Over 90 % of surface of the wind farm area has not been investigated by detailed geophysical surveys. The area may contain more undiscovered shipwrecks or remains of shipwrecks.

### Shipwrecks

A total of 19 shipwrecks are known in the area. Details like names, types and date of sinking are not known, nor are the exact locations. Further research is needed to determine the cultural-historical value.

### Plane wrecks

During World War II, many airplanes crashed into the North Sea. Several sources are ambiguous about the number of aircraft still missing, but is at least hundreds. Remains are found on a regular base by fishermen or during sand extraction. In the vicinity of the research area, four locations of plane wrecks are known. It is quite possible to expect plane wrecks within the research area.

### Prehistory

Remains of prehistoric camp sites are expected *in situ* in cover sand dunes and ridges (Wierden Member), river dunes (Delwijnen Member) and river bank deposits (Wijchen Member) provided these units are un-eroded. Within the Basal Peat Bed well-preserved lost objects and dumps can be encountered. The archaeological levels of interest located under a 0 - 5 meter cover of the Bligh Bank Member. Remains of Neanderthaler camp sites can be expected within lacustrine clays of the Brown Bank Member which is covered by the Kreftenheye Formation.

At this stage little is known about the integrity of the Pleistocene landscape. The Pleistocene units are encountered at shallow depths. Erosion of these units and archaeological remains therein therefore seems likely. Locally the Basal Peat Bed might have protected the Pleistocene landscape against erosion. By means of subbottom profiling in combination with analysis of vibro core samples the Basal Peat Bed and the underlying well-preserved archaeological level can be mapped. It is unlikely however that archaeological remains of Paleolithic and Mesolithic camp sites can be identified with sufficient certainty (based on the geophysical and geotechnical surveys) to impose restrictions on wind farm development.

In accordance with the AMZ cycle it is advised to conduct a field investigation (in Dutch '*Inventariserend veldonderzoek opwaterfase*') in order to:

- Map the locations of known wreck sites in great detail;
- Make an inventory for the parts of the area which have not been covered in previous surveys

In general, similar investigations carried out in the past consist of a geophysical survey with *side scan sonar*, *magnetometer* and *subbottom profiler*. The resulting data should be assessed after the general processing, interpretation and reporting has been performed by the survey contractor, if possible in combination with analysis of core samples. The archaeological assessment of the data has to be conducted by a geophysical specialist (KNA prospector Waterbodems).

The data quality expected from the surveys need to match the demands for this archaeological assessment. To ensure compatibility between the site investigation and the required quality for this assessment it is recommended to define a Program of requirements (In Dutch: ‘*Programma van Eisen*’) in accordance with the ‘KNA’ (the Dutch quality standards for archeological research), to be authorized by the competent authority.

During the installation of the wind turbines and construction of the cables archaeological remains may be encountered that were fully covered by sediment or not identified as archaeological remains during the geophysical survey. In accordance with the Malta convention incorporated in the Monuments Act through the Archaeological Heritage Management Act (Revised 2007) it is required to report those findings to the competent authority. This notification for archaeological finds should be included in the specifications or scope of work.

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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	Programma van Eisen
RCE	Rijksdienst voor het Cultureel Erfgoed
ROV	Remotely Operated Vehicle
Side scan sonar	Acoustic instrument that registers the strength of reflections of the seabed. The resulting images are similar to a black / white photograph. The technique is used to detect objects and to classify the morphology and type of soil
Current ripples	Asymmetrical wave pattern at the seabed caused by currents. The steep sides of the ripples are always on the downstream side.
Subbottom profiler	Acoustic system used to create seismic profiles of the subsurface.
Trenching	Construction of a trench for the purpose of burying a cable or pipeline
Vibrocore	Vibrocore bore is a special drilling technique where a core tube is driven by means of vibration energy in the seabed. In addition, the core tube is provided with a piston so that the bottom material in the core tube remains in place.

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## Atlases and Maps

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

## Sources from the Internet

- Geologische Dienst Nederland - Data Informatie Nederlandse Ondergrond ([www.dinoloket.nl](http://www.dinoloket.nl))
- Dienst der Hydrografie ([www.hydro.nl](http://www.hydro.nl))
- Noordzeeloket ([www.noordzeeloket.nl](http://www.noordzeeloket.nl))
- Olie en Gasportaal ([www.nlog.nl](http://www.nlog.nl))
- Stichting Infrastructuur Kwaliteitsborging Bodembeheer (SIKB.nl)
- North sea paleolandscapes, University of Birmingham ( <http://www.iaa.bham.ac.uk>)
- Dutch Federation of Aviation Archaeology ([www.nfla.nl](http://www.nfla.nl))
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- Archis III, archeologische database Rijksdienst voor het Cultureel Erfgoed
- Databases Periplus Archeomare
- Duikteam Bernicia, contactpersoon Hans van der Weide, [www.duikvaker.nl](http://www.duikvaker.nl)
- KNA Waterbodems 3.2
- Nationaal Contactnummer Nederland (NCN)
- SonarReg92, objectendatabase Rijkswaterstaat Noordzee en Delta

## Appendix 1. Phases of maritime archaeological research

The Dutch Quality Standard for Archaeology (KNA waterbodems, version 3.2) 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 echosounder recordings, subbottom profiling and magnetometer measurements. The requirements of the survey are based on the desk study and should be included in a program of requirements which must be approved by the competent authorities.

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

### 3. Exploratory field research (onderwaterfase verkennend)

The suspected sites are investigated by specialized divers in order to identify the objects. The requirements of the underwater research are included in a program of requirements which must be approved by the competent authorities.

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

### 4. Appreciative field research (onderwaterfase waarderend)

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

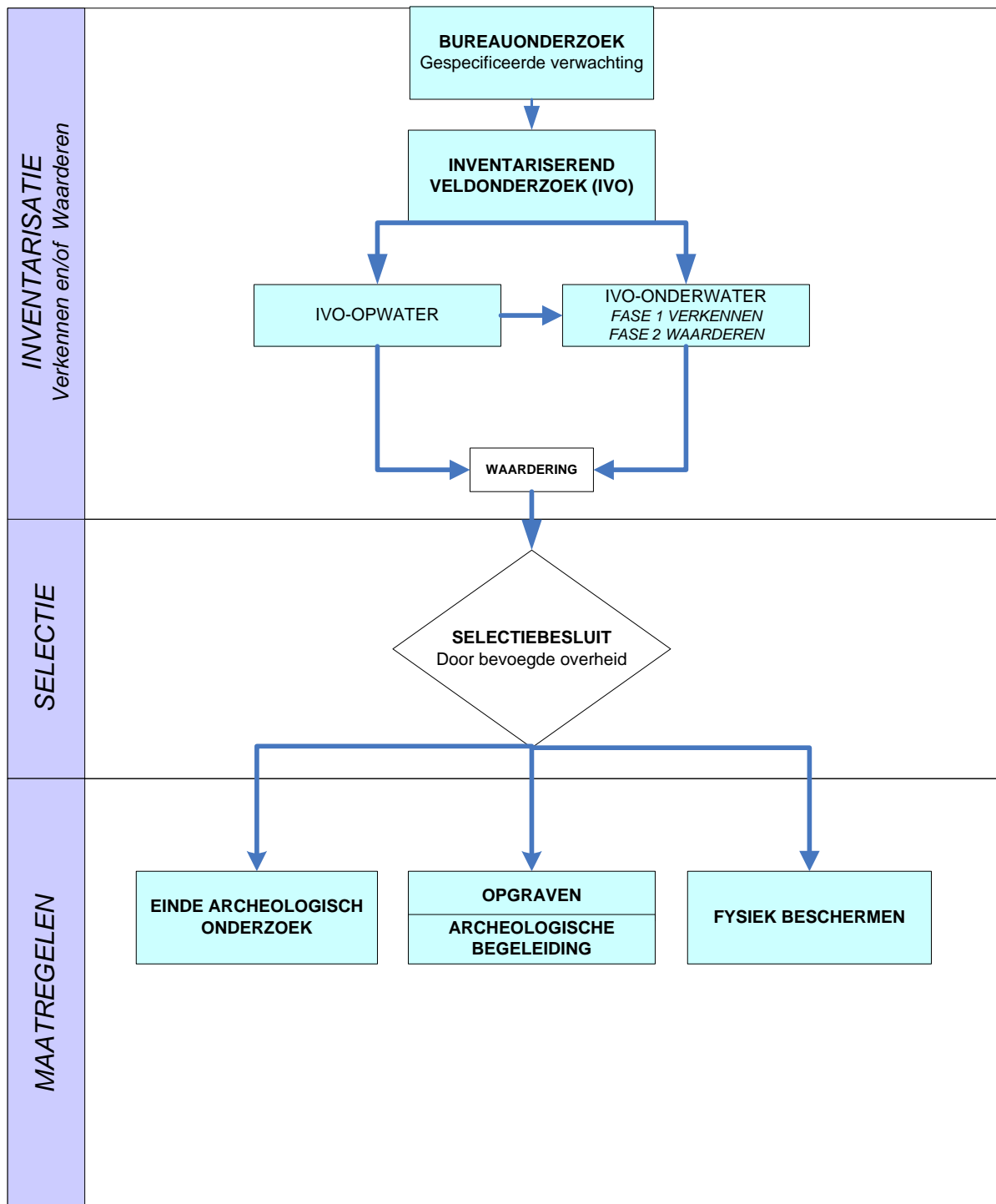
### 5. Archaeological excavation

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

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

## Schematic overview KNA Waterbodems version 3.2

(in Dutch)





## Appendix 2. CD with digital GIS files





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Netherlands Enterprise Agency (RVO.nl) | January 2016