

Pilot archaeological analysis of geophysical and geotechnical data BWFZ

Authors

S. van den Brenk
R. van Lil
E.A. van den Oever

At the request of

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Contact: ir. F. van Erp

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Authorization:



B.E.J.M. van Mierlo
Senior KNA prospector



Periplus Archeomare

Kraanspoor 14

1033 SE - Amsterdam

Tel: 020-6367891

Fax: 020-6361865

Email: info@periplus.nl

Website: www.periplus.nl

Contents

Samenvatting (in Dutch)	3
Summary	5
1 Introduction	7
1.1 Developments in offshore wind power	7
1.2 Site surveys	7
1.3 Objective	8
1.4 Archaeological desk study	9
1.5 Geophysical surveys	10
2 Methodology	12
3 Results	13
3.1 General	13
3.2 Selection of contacts	13
3.3 Wreck sites	19
3.4 Additional remarks	21
4 Conclusions and recommendations	22
List of figures	24
List of tables	24
Glossary and abbreviations	25
References	26
Appendix 1. Phases of maritime archaeological research	27

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.
Palaeolithic (Early Stone Age)	300.000	B.C.	-	8800	B.C.

Table 2. Administrative details

Location:	North Sea		
Toponiem Dutch:	Borssele Offshore Wind Farm		
Chart:	1801-01		
Geodetic datum:	ETRS89		
Projection:	UTM31N		
Coordinates WFS III*	Centre	E 497377, N 5723739	
	N	E 497246, N 5730969	
	NE	E 502535, N 5728489	
	W	E 492219, N 5724695	
	SE	E 500671, N 5716509	
WFS IV	Centre	E 491927, N 5731392	
	S	E 491498, N 5725394	
	NE	E 499676, N 5737390	
	W	E 484179, N 5732483	
Depth (LAT):	WFS III*:	min 23, max 37, avg 29,5 meter	
	WFS IV:	min 15, max 36, avg 27,0 meter	
Surface area	WFS III*:	7920 ha	
	WFS IV:	7235 ha	
Environment:	Tidal currents, salt water		
Current use:	Shell extraction, nature reserve Zeeuwse Banken, fishing, recreation and sand extraction (abandoned)		
Area administrator:	Rijkswaterstaat Zee en Delta		
ARCHIS-research report (CIS-code):	N/A		
Periplus-project reference:	16A001-01		
Period	February - March 2016		

*Note: listed figures are of the initial area of WFS III which currently is split into WFS III and WFS V.

Samenvatting (in Dutch)

In 2015 zijn twee afzonderlijke geofysische surveys uitgevoerd in de Borssele Wind Farm Zone (BWFZ). De gebieden zijn onderzocht met geofysische en geotechnische technieken. Het doel van deze onderzoeken was om een accuraat geologisch model op te stellen en mogelijke obstakels in kaart te brengen. De resultaten van het onderzoek vormen een belangrijke bron van informatie voor aanbestedingspartijen en toekomstige ontwikkelaars van het windpark.

De hoeveelheid en de kwaliteit van deze geofysisch en geotechnische gegevens zouden kunnen volstaan om een archeologische analyse uit te kunnen voeren. Dit maakt het mogelijk om objecten uit te sluiten die anders gevolgen zouden kunnen hebben voor de ontwikkeling van het windpark. De Rijksdienst voor het Cultureel Erfgoed en RVO.nl zijn overeengekomen om een pilot uit te voeren. Doel van de pilot is het vaststellen in hoeverre de reeds opgenomen geofysische data geschikt is om te gebruiken in het kader van archeologisch onderzoek. Voor deze pilot zijn alleen de resultaten van de gebieden III (omvat het huidige gebied III + V) en IV gebruikt.

Conclusies

Algemeen

De kwaliteit en de resolutie van de geofysische data is voldoende voor een eerste archeologische beoordeling van de waargenomen contacten en beschreven doelen. De resultaten en interpretaties uit de survey rapporten van de uitvoerder kunnen worden gebruikt als basis voor een eerste beoordeling; aanvullende analyse van de ruwe onderzoeksgegevens van potentiële archeologische contacten door een specialist is noodzakelijk.

Met betrekking tot de evaluatie en de identificatie van twintig willekeurig gekozen side scan sonar contacten kan worden geconcludeerd dat het haalbaar is om de contacten in meer detail te beschrijven en uit te sluiten dat het hier om archeologische waarden gaat. Dit geldt ook voor het enige scheepswrak dat is aangetroffen.

Met betrekking tot het wrak wordt het volgende geconcludeerd:

1. Binnen de twee onderzoeksgebieden is slechts een scheepswrak aangetroffen. Dit wordt bevestigd door nadere analyse van de data.
2. De kwaliteit van de dataset is voldoende om het wrak te identificeren. De identificatie wordt ondersteund door de integratie van de verschillende geofysische gegevens.
3. De vergelijking van de surveyresultaten met informatie uit verschillende overige bronnen heeft geresulteerd tot relevante aanvullende informatie over het wrak.
4. Het wrak wordt niet beschouwd als een object met archeologische waarde. De aanwezigheid zal daarom uit archeologisch oogpunt geen belemmering opleveren voor de ontwikkeling van het windpark.

Met betrekking tot de beoordeling van de parameters van het geofysisch onderzoek en de kwaliteit van de verkregen dataset wordt het volgende geconcludeerd:

1. De verzamelde geofysische gegevens zijn van hoge kwaliteit en resolutie. De (standaard) survey rapporten zijn geschikt voor het primaire doel van de oorspronkelijke survey: het beschrijven en het opsporen van mogelijke obstakels en geohazards.
2. De (standaard) survey rapporten bevatten onvoldoende informatie om de vragen van een archeologische evaluatie te beantwoorden.
3. In de rapporten zijn een aantal aannames gedetecteerd die kunnen leiden tot een onjuiste archeologische analyse.

Aanbevelingen

Geadviseerd wordt om de archeologische evaluatie uit te breiden met overige contacten die zijn waargenomen tijdens de geofysische surveys. De eerste (beknopte) interpretatie van contacten uit de survey rapporten kan worden gebruikt als basis voor een selectie van contacten die van archeologisch belang zouden kunnen zijn. Vervolgens kunnen de ruwe data worden gebruikt om een meer gedetailleerde interpretatie van deze contacten te maken, en een archeologische verwachting op te stellen.

De resultaten kunnen worden gebruikt om een officieel rapport op te stellen dat voldoet aan de eisen van de Kwaliteitsnorm Nederlandse Archeologie (KNA Waterbodems 3.2). Het wordt aanbevolen om de archeologische evaluatie en rapportage te laten uitvoeren door gekwalificeerd personeel (actor prospector specialisme waterbodems). Aan de evaluatie en rapportage dient een goedgekeurd Programma van Eisen met onderzoeksvragen ten grondslag te liggen.

Tot slot is tijdens de analyse van de gegevens gebleken dat de database van de Dienst der Hydrografie onjuiste informatie bevat. Geadviseerd wordt om dit terug te koppelen naar de Dienst der Hydrografie.

Summary

In 2015 two separate geophysical campaigns have been executed in the Borssele Wind Farm Zone (BWFZ). The areas of interest were investigated with geophysical and geotechnical techniques. The purpose of these investigations was to establish an accurate geological model and to map possible obstructions in order to provide tendering parties with the information needed and to assist future developers in their construction decisions.

The amount and quality of these geophysical and geotechnical data might suffice to identify possible archaeological objects and in the future mitigate the possible consequences of their presence in the Wind Farm Zone. The Dutch Cultural Heritage Agency and RVO.nl agreed to conduct a pilot project to investigate to what extent the already performed geophysical surveys would be a suitable source for the required archaeological phases of investigation.

For this pilot only the results of the initial Site III (which comprises the current Site III + Site V) and Site IV were utilized.

Periplus was requested to conduct this pilot with the objective to assess whether it is feasible to:

- a) Exclude the archaeological value of detected objects based on a geophysical analysis of the survey data, and
- b) Map the locations of known wrecks in greater detail.

General conclusions

Overall

The quality and resolution of the geophysical data is sufficient for a first archaeological assessment of the observed contacts and described objects. The standard survey reports and interpretations from the survey contractor can be used as a base for an initial assessment, but additional analysis of the raw survey data around the suspected archaeological objects by a specialist is necessary.

With respect to the assessment and - if possible - identification of twenty (20) randomly chosen side scan sonar contacts the followings is concluded:

1. It is feasible to interpret the contacts in more detail, making it possible to exclude all 20 contacts and the wreck as of archaeological importance.

With respect to the wreck(s) identified the following is concluded:

1. Within the two research areas only one shipwreck was found. This is confirmed by the assessment.
2. The quality of the data set is sufficient for the identification of the ship wreck as such. The identification is supported by the integration of the different types of geophysical data available.
3. The comparison of the survey results with information from various databases provided additional and valuable information of the wreck.
4. The wreck is not considered to be of archaeological value. Therefore its presence will not - from an archaeological point of view - jeopardize the development of the wind farm.

With respect to the assessment of the parameters of the geophysical survey and the quality of the acquired dataset the followings is concluded:

1. The survey data collected is complete, and are of high quality and resolution. The (standard) survey report is fit for the primary purpose of describing detecting possible obstructions and geo-hazards.
2. The (standard) survey report contains insufficient information to answer the questions set for an archaeological assessment.
3. A few assumptions were detected in the survey reports which may lead to an incorrect archaeological assessment.

Recommendations for the way forward

It is recommended to extend the archaeological assessment with an investigation of the remainder of the contacts detected during the surveys. The initial interpretation from the survey contractors can be used as a basis for a first selection of potential interesting contacts from an archaeological point of view. Subsequently, the raw side scan sonar- and multibeam data can be used to make a more detailed interpretation of these contacts.

The results can be used to prepare a formal report which complies with the requirements of the KNA. It is recommended to have this assessment executed by qualified personnel (prospector waterbodems). Before this assessment and the subsequent report can be completed an authorized Program of Requirements (Program van Eisen) has to be put in place.

Recommendations with respect to incorrect database information

It has been found that the database of the Dutch Hydrographic Service contains incorrect information. It is recommended to report this to the Hydrographic Service.

1 Introduction

1.1 Developments in offshore wind power

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 Zee1), a SDE+ grant and offered a grid connection to the main land. The Ministry (Rijksdienst voor ondernemend Nederland) provides all relevant site data, which can be used for the preparation of bids for these tenders.

1.2 Site surveys

In 2015 two separate geophysical campaigns have been executed in the Borssele Wind Farm Zone (BWFZ). Site I and II were surveyed by DEEP BV, Site III and IV by Fugro Survey B.V.^{2, 3} The areas of interest were investigated with geophysical and geotechnical techniques. The purpose of these investigations was to establish an accurate geological model and to map possible obstructions in order to provide tendering parties with the information needed and to assist future developers in their construction decisions.

The amount and quality of these geophysical and geotechnical data might suffice to identify possible archaeological objects and in the future mitigate the possible consequences of their presence in the Wind Farm Zone. The Dutch Cultural Heritage Agency and RVO.nl agreed to conduct a pilot project to investigate to what extent the already performed geophysical surveys would be a suitable source for the required archaeological phases of investigation.

For this pilot only the results of initial Site III and IV were utilized.³ The initial Site III is currently split into Site III and Site V. In the remainder of this report Site III refers to the initial area of WFS III which includes the currently defined areas of Site III and Site V.

¹ <http://wetten.overheid.nl/BWBR0036752>.

² Marchetti 2015.

³ The surveyed area of WFS III is currently split into WFS III and WFS V.

1.3 Objective

The objective of this pilot is to assess whether it is feasible to:

- exclude the archaeological value of detected objects based on a geophysical analysis of the survey data, and
- map the locations of known wrecks in greater detail.

Deliverables

The deliverables comprise a written report in English including:

- An overview of the source data used in the assessment
- A description of the analysis carried out
- An executive summary and conclusions of the assessment (both in English and Dutch)

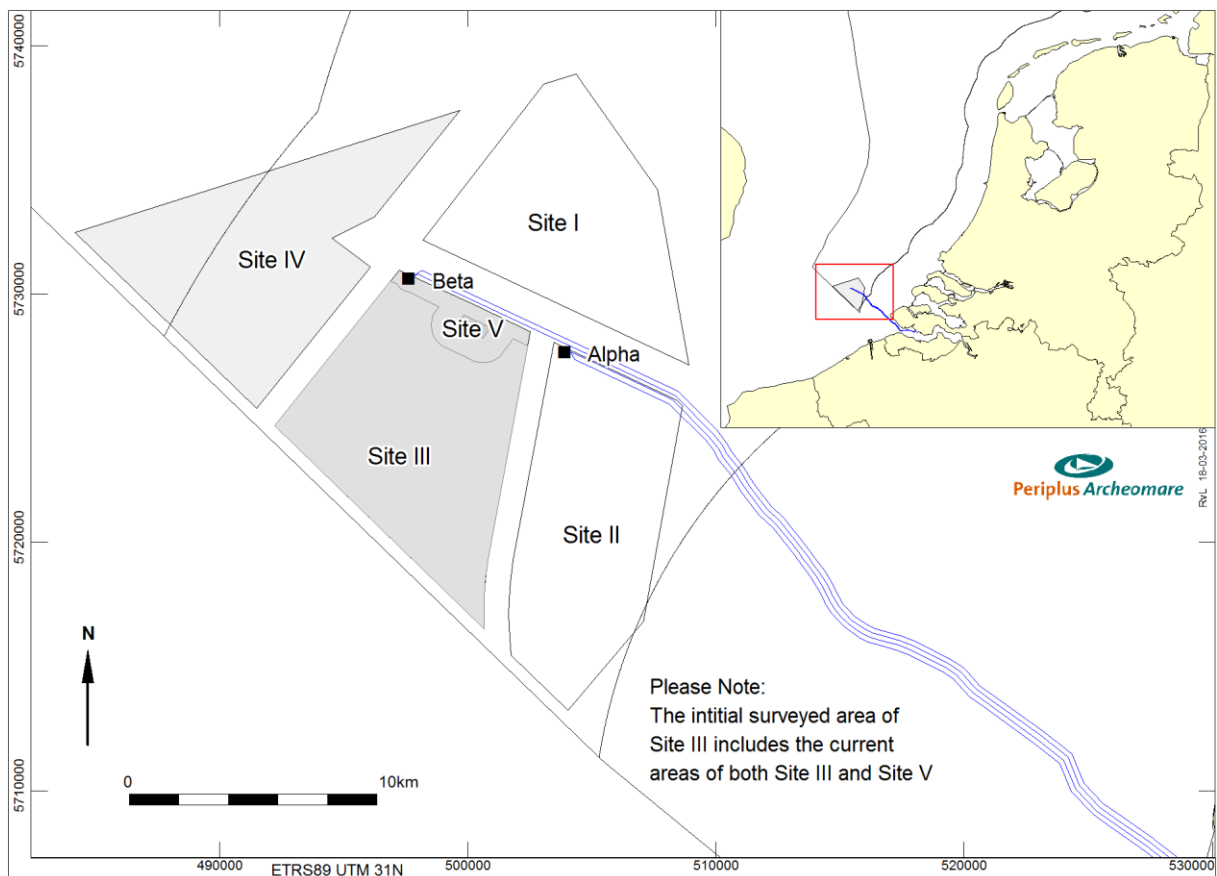


Figure 1. Overview of the research area – Site III⁴ and Site IV

⁴ The studied area of WFS III is currently split into WFS III and WFS V.

1.4 Archaeological desk study

In 2014 an archaeological desk study was conducted by Vestigia BV. A summary of the results and recommendations is presented below.

1. Due to the small chance to encounter early prehistoric archaeological sites within the wind farm zone and the limited possibilities for further research and knowledge gain, once encountered, further archaeological survey with the intention to establish prehistoric sites is not recommended.
2. In order to define areas of low, medium and high archaeological sensitivity in relation to shipwrecks and airplanes within the wind farm zone, it is recommended to perform a geophysical area survey (side scan sonar or multi beam). Such a survey and the subsequent report should meet the requirements of the KNA Waterbodems.
3. Once a wreck or other archaeological site has been identified, that lies in an area where soil disturbing activities are planned, the historic or scientific value of the site should be established, ultimately by the RCE through a so-called selectiebesluit, taken on the basis of additional research and inspection. In case a wreck or archaeological site is determined as of archaeological significance, the effects of the development can be mitigated by preferably avoiding the site, or otherwise further archaeological interventions. In case of historic wrecks this could involve archaeological excavations underwater, in case of historic airplanes, this could involve the salvage and lifting of the wreck or parts of it, and in case of early prehistoric archaeological sites an archaeological sampling strategy as was, for instance, used during the building of Maasvlakte II. These archaeological interventions can involve high costs and can only be carried out according to the rules and regulations laid out in the Dutch Monuments Act. However, in case of discovery of any of the above-mentioned archaeological sites or objects, first the historic value needs to be established by further research and inspection.
4. To draft at an early stage as possible a protocol and work plan for dealing with the archaeological heritage. In the work plan the necessary steps of further archaeological prospection and decision making in relation to the future project stages, are laid out and explained. In the protocol a procedure for dealing with 'accidental' archaeological finds during the construction and operational phases of the project is outlined. Accidental archaeological finds refer to archaeological remains that have not been identified during the stages of archaeological prospection, but are encountered unexpectedly during construction and operational phases. Such finds should always be reported according to the Monuments Act. It is in the interest of both developer and the curator (RCE) to anticipate on possible accidental finds and to make an agreement beforehand how and by whom these will be handled, and decisions on possible further actions will be reached. This saves essential time and money during operational stages. Provided that the developer has met his responsibilities with regard to archaeological prospection in the planning stages, the (financial) consequences of archaeological interventions that result from such an accidental find are not necessarily the responsibility of the developer, but a matter of negotiation between developer and the appropriate authority. In case of developments at sea, the likelihood of encountering 'accidental' archaeological finds is established beforehand based on the results of forthcoming archaeological surveys. The developer and the Cultural Heritage Agency (RCE) then agree to an additional maximum budget that the developer spends in case of accidental archaeological finds. Providing such an agreement, the responsibility of the developer for the financial consequences of accidental archaeological finds during the construction and operational phases of the project will not transcend the agreed budget.

1.5 Geophysical surveys

Survey methodology

RVO.nl contracted Fugro Survey B.V. (FSBV) to perform a geophysical soil investigation to improve the geophysical and geotechnical understanding of zones III and IV of the Borssele Wind Farm Zone (BWFZ). Geophysical information for WFS III and IV has been gathered and described in two separate reports to suitably progress the design and installation requirements.

The investigation provided geophysical bathymetric and shallow seismic data focused on the Investigation Area for Wind Farm Zones III & IV, using the following equipment: side scan sonar (SSS), magnetometer (MAG), multi- and single beam echo sounder (MBES/SBES), sub-bottom profiler (SBP) and ultra-high resolution seismic survey (UHR).

The general survey objectives for each survey site were:

- To obtain an accurate bathymetric chart of the development areas WFS III & IV;
- To identify/confirm the positions of known wrecks, pipelines, possibly electrical cables and any other natural objects
- To produce isopach charts showing the thickness of the main geological formations including any mobile sediments and any other significant reflector levels which might impact on the engineering design;
- To locate any structural complexities or geohazards within the shallow geological succession such as faulting, accumulations of shallow gas, buried channels, etc.;
- To provide detailed geological interpretation showing facies variations and structural feature changes via appropriate maps and sections;
- To list the exact position of existing (active & inactive) cables and pipelines.
- To provide proposed positions for a geotechnical sampling and testing programme following the completion of the geophysical survey;
- To prepare a comprehensive interpretative report on the survey results in order to assist design of the offshore foundations / structures and cable burial.

Survey Program

For all lines the single beam and multibeam echo sounders were used simultaneously with the side scan sonar, sub bottom profiler and magnetometer, with a main line spacing of 100 m. The multichannel seismic survey UHR data were acquired with a line spacing of 400 m. The cross lines were planned with 2000 m line spacing, but during the survey, in accordance with the Client it was decided to add 151 km of extra cross lines, in order to better understand the geology of the survey area.

The geophysical surveys were carried out between 25 May and 20 June 2015. In total 2054 survey kilometres were acquired within WFS III and WFS IV areas with the geophysical equipment (MB, SSS, Magnetometer and SBP) and 776 km survey kilometres with UHR system.

Results WFS III

Sea floor and subbottom hazards	
Wreck	
1723	As-found location position 75 m northeast from the provided location.
None of the other wrecks (2) from the provided locations have been detected with the research techniques	
Seafloor Geohazards	
Sand dunes	
Boulders	No boulders have been reported
Side scan sonar contacts	A total of 234 side scan sonar contacts observed
Magnetometer contacts	A total of 685 magnetic anomalies detected
Subbottom hazards	
Palaeo channel sediments	Typical lateral variation of sand, clay and gravel interpreted as Kreftenheye Formation
Subbottom anomalies	High amplitude reflections interpreted as layers of gravel

Results WFS IV

Sea floor and subbottom hazards	
Wreck	
3644	Possible magnetic anomaly at location
None of the other wrecks (2) from the provided locations have been detected with the research techniques	
Seafloor Geohazards	
Sand dunes	
Boulders	No boulders were identified
Side scan sonar contacts	A total of 649 side scan sonar contacts observed
Magnetometer contacts	A total of 1004 magnetic anomalies detected
Subbottom hazards	
Palaeo channel sediments	Within the palaeochannel, typical lateral variation of sand, clay and gravel interpreted as Kreftenheye Formation
Subbottom anomalies	High amplitude reflections interpreted as layers of gravel

2 Methodology

Premises

The expectancy for archaeological remains as summarized in the desk study executed by Vestigia provides the framework for this assessment.⁵ As the present investigation is a pilot, no formal authorized Scope of Work or formal Program of Requirements and no research questions are defined. The research effort focuses on the specified scope and report on the actual facts of the investigation. The results and conclusions of the investigation presented in this report have therefore not a priori come into being in accordance with the KNA norm, as usually required.

Source data

The raw geophysical data acquired by Fugro have been delivered by RVO.nl on hard disk. The formats delivered are as follows:

Technique	Data Format
SSS	Raster mosaic (binsize 0.5m) and XTF
MBES	Raster mosaic (binsize 0.5m) and raw XYZ data (11 points /m2)
MAG	CSV text files (date, nT,E,N, altitude, linename)
SBP	Seismic profiles in SGY format

Activities

The investigation comprises the following activities:

1. Assessment of the parameters of the geophysical survey and the quality of the acquired dataset.
2. Assessment and - if possible - identification of twenty (20) randomly chosen side scan sonar contacts.
3. Special interest will be given to contacts which have been identified as wrecks or wreck remains. With the available data the following will be described:
 - The quality of the data set
 - A description of the surroundings
 - A possible link to the various databases for historical wrecks
 - A possible identification of the wreck
 - An archeological value, which basically indicates what the consequences of its presence could be for the further development of the wind farm
4. Recommendations for the way forward.

Contributors

The investigation was carried out and reported by the following specialists:

- Seger van den Brenk Senior KNA Prospector / Marine Geophysicist
- Robert van Lil Senior KNA Prospector / Geologist
- Eisse van de Oever KNA Prospector (Trainee) / Geologist

For a complete overview of the sources and literature see references on page 26.

Words in *italics* and abbreviations are explained in the glossary on page 25.

⁵ Visser 2014.

3 Results

3.1 General

The quality and resolution of the geophysical data is sufficient for a first archaeological assessment. The standard survey reports and interpretations from the survey contractor can be used as a base for an initial assessment; but additional analysis of the raw survey data by a specialist proved to be necessary.

3.2 Selection of contacts

The side scan sonar event listings were delivered in Excel format. In WFS III a total of two hundred and thirty four (234) contacts have been observed; in WFS IV six hundred and forty nine (649) contacts have been observed.⁶

By means of the randomizer function in Excel twenty (20) contacts were selected; five (5) contacts in WFS III and fifteen (15) contacts in WFS IV.

In addition to these randomly selected contacts a wreck found in WFS III (SO639) was added to the list for closer investigation. Based on the magnetometer anomalies recorded Fugro suspects the presence of a possible second wreck in WFS IV.

Target	E	N	Height	Length	Width	Description	Notes	Cross check Maggy
S0639	500728	5727924	2.8	17.6	3.9	wreck 1723	Visible on the MBES	M0046
S0468	489539	5730231	1.0	3.0	1.1	debris		

Table 3. Data of side scan sonar contact SO639 (wreck)

The raw data for these contacts (side scan sonar and multibeam) were analyzed in order to make a statement on the feasibility of an archaeological assessment.

Two examples of the analysis are presented below.

⁶ The studied area of WFS III is currently split into WFS III and WFS V.

Example S0771


	S0771 <ul style="list-style-type: none"> • Sonar Time at Target: 09-Jun-15 22:59:38 • Click Position 51.6815462401 2.8859150569 (WGS84) 0.0000000000 0.0000000000 (NAD27LL) 51.6815462401 2.8859150569 (LocalLL) (X) 492112.56 (Y) 5725626.00 (Projected Coordinates) • Fish Height: 12.23 Meters • Line Name: A41086_SH_NavMerged 	Dimensions and attributes <ul style="list-style-type: none"> • Target Width: 1.12 Meters • Target Height: 0.37 Meters • Target Length: 6.67 Meters • Target Shadow: 1.84 Meters • Classification1: debris • Description: visible on the MBES
---	---	---

Figure 2. Original description and interpretation from Fugro report of contact S0771

The figure above shows the original description, interpretation and sonar image of contact nr. S0771, located in WFS IV. The supposed object has a length of more than 6 meters and a width of a meter. It was interpreted as debris, a more detailed interpretation was not possible on the basis of only the sonar image.

The original raw sonar image (figure below) shows slightly more details.

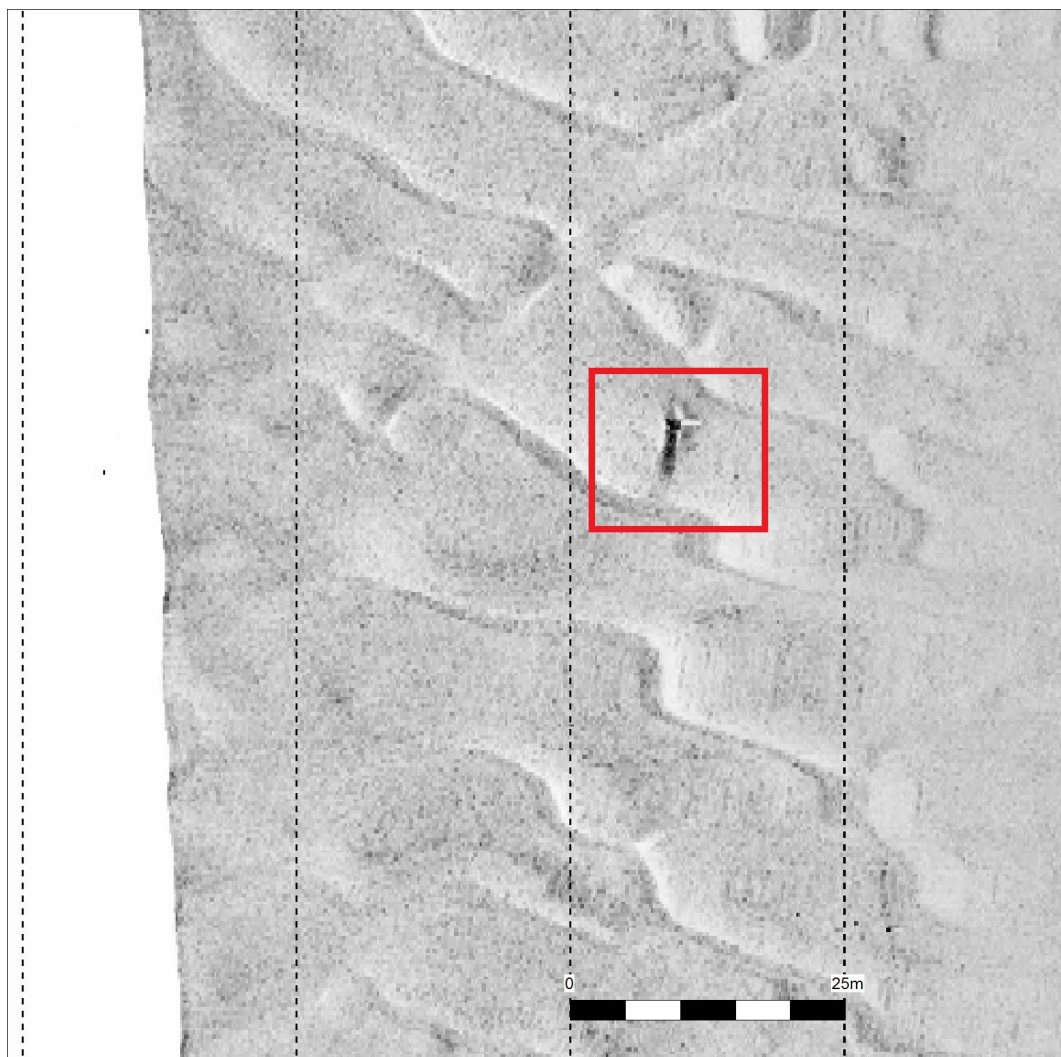


Figure 3. Raw waterfall sonar image of contact S0771

From the raw multibeam data more details can be revealed. The figure below shows the gridded data (binsize 0.5x0.5m) and an image of the raw data (density approximately 11 points per square meter).

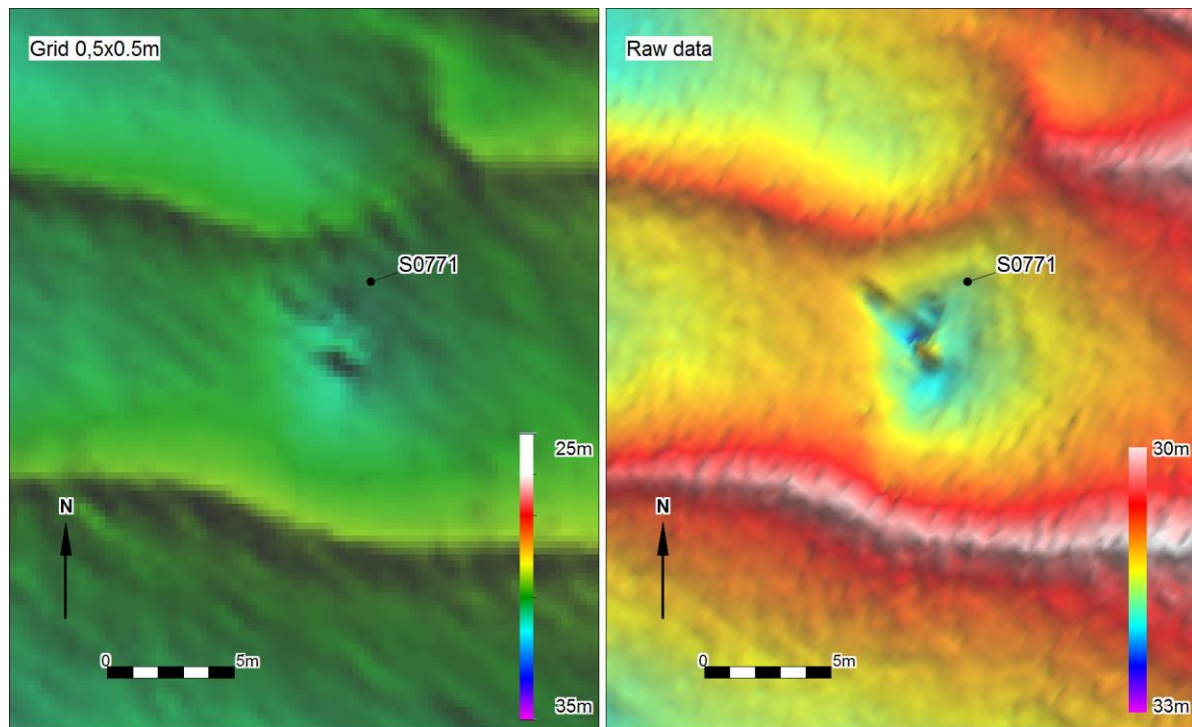


Figure 4. Gridded and raw multibeam data of contact S0771

Within the image of the raw data, two structures can be observed: one point object protruding from the seabed surrounded by a depression caused by scouring, and one elongated object with a length of 4 meters.

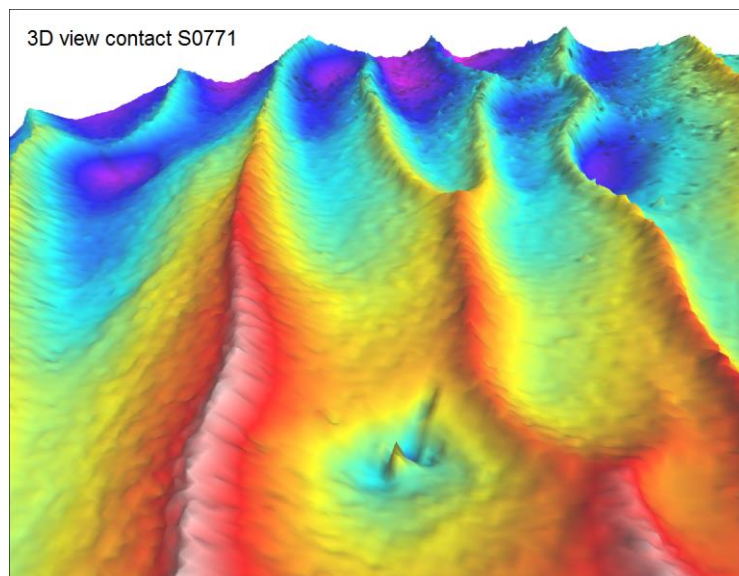


Figure 5. 3D view of raw multibeam data of contact S0771

Based on these images, the object can be interpreted as a man-made structure which is partly buried in the seabed. No magnetic anomalies have been observed at the site, but it should be noted that no acquisition lines of the magnetometer cross the site.

Example S0222


	S0222 <ul style="list-style-type: none"> • Sonar Time at Target: 06-Jun-15 05:37:02 • Click Position 51.7407362864 2.8890832572 (WGS84) 0.0000000000 0.0000000000 (NAD27LL) 51.7407362864 2.8890832572 (LocalLL) (X) 492341.60 (Y) 5732208.62 (Projected Coordinates) • Fish Height: 10.35 Meters • Line Name: A41117_SH_NavMerged 	Dimensions and attributes <ul style="list-style-type: none"> • Target Width: 0.56 Meters • Target Height: 0.17 Meters • Target Length: 2.84 Meters • Target Shadow: 1.06 Meters • Classification1: debris • Description: visible on the MBES
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Figure 6. Original sonar image and description from Fugro report of contact S0222*

The figure above shows the original description, interpretation and sonar image of contact nr. S0222 located in WFS IV. The supposed object has a length of almost 3 meters and a width of 0.6 meters. It was interpreted as debris, a more detailed interpretation was not possible on the basis of only the sonar image.

*Note: based on the side scan sonar-image presented the target appears not to be 'tagged' at the right spot.

The original raw sonar image (figure below) does not reveal more details.

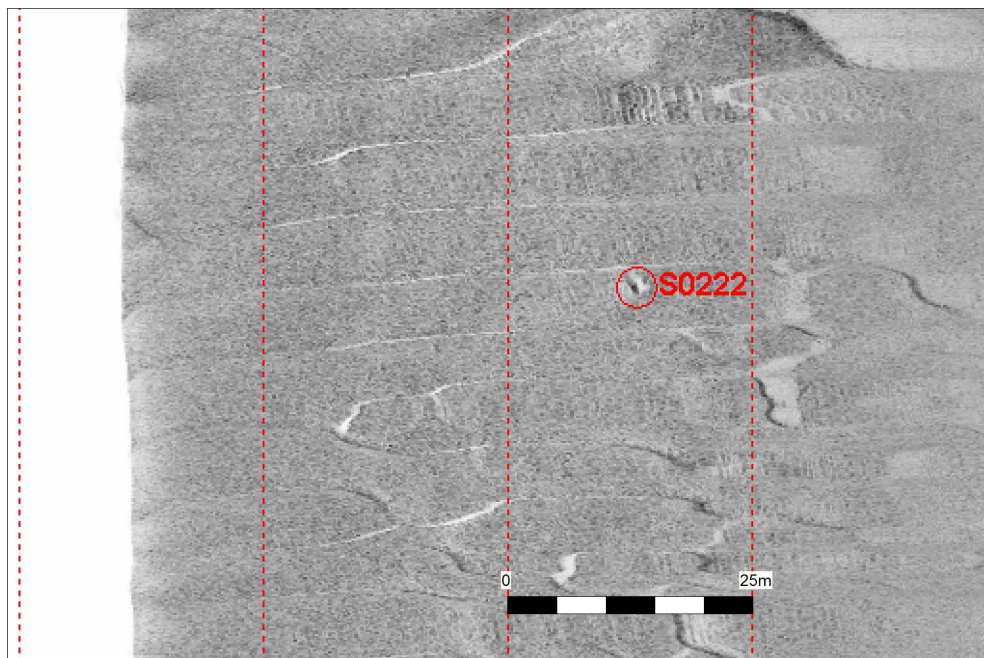


Figure 7. Raw waterfall sonar image of contact S0222

In the raw multibeam data, the object is hardly visible (figure below) due to limited height of the object (less than 0.2 m) and the fact that almost no scouring has taken place.

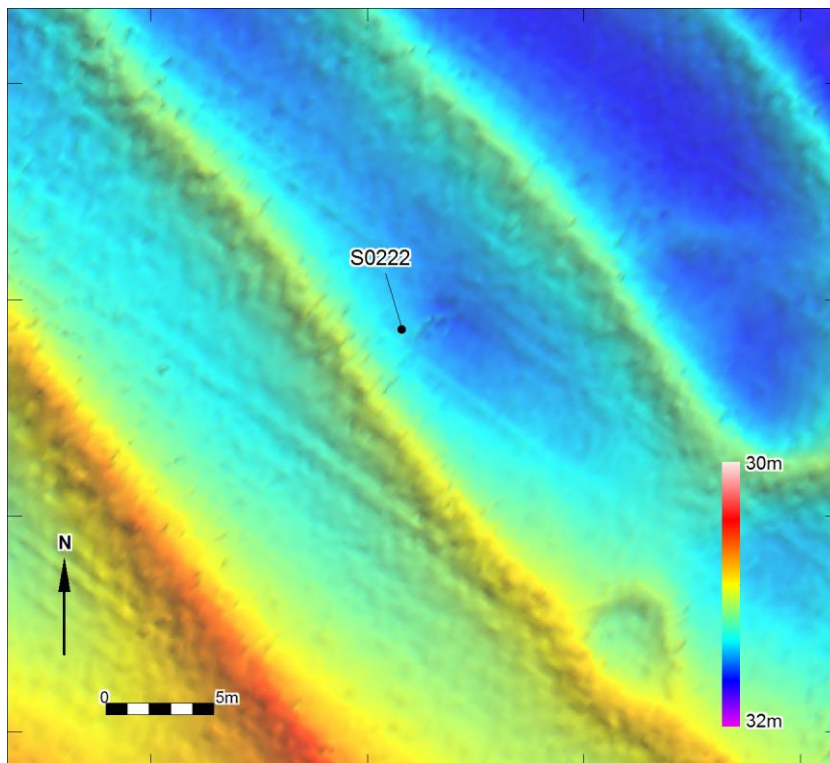


Figure 8. Raw multibeam data of contact S0222

Based on these images, the object seems to be an isolated object lying on the seabed and might be of natural origin. No magnetic anomalies have been observed at the site, but it should be noted that no acquisition lines of the magnetometer cross the site.

The results of the assessment for all the twenty contacts are listed below.

Data extracted from Fugro event listing						Archaeological Assessment	
Target	L(m)	W(m)	H(m)	Interpretation Fugro	Interpretation Periplus	Assessable?	Valuable
S0076	1.2	0.8	0.2	debris	unknown small object	Yes	No
S0112	1.7	0.7	0.2	debris	unknown elongated object	Yes	No
S0164	3	0.8	0.3	debris	unknown elongated object	Yes	No
S0214	1.8	0.4	0.3	debris	unknown angular object; possible anchor	Yes	No
S0222	2.8	0.6	0.2	debris	unknown elongated object,	Yes	No
S0223	5.5	0.6	0.1	linear debris	unknown elongated object; isolated	Yes	No
S0285	5.9	1.5	0.2	debris	unknown elongated object; isolated	Yes	No
S0296	1.8	1.1	0.6	debris	unknown small object	Yes	No
S0333	2.3	0.8	0.2	debris	unknown object	Yes	No
S0372	1.2	0.7	0.1	debris	unknown small object	Yes	No
S0421	1.7	0.5	0.2	debris	unknown small object	Yes	No
S0559	1.9	0.4	0	Unknown linear target	possible cable, partly buried; contact coherent with SO561	Yes	No
S0561	3.6	0.6	0.2	Unknown linear target	possible cable, partly buried; contact coherent with SO559	Yes	No
S0607	2.5	0.4	0.1	debris	no clear shadow; unknown elongated object	Yes	No

Data extracted from Fugro event listing						Archaeological Assessment	
Target	L(m)	W(m)	H(m)	Interpretation Fugro	Interpretation Periplus	Assessable?	Valuable
S0639	17.6	3.9	2.8	wreck 1723	wreck Alca Torda, sunk 1973; dimensions: L21.5m, W6.5m, H3.1m determined with MBES data	Yes	No
S0640	0.9	0.5	0.1	debris	unknown small object	Yes	No
S0660	1.8	0.4	0.3	debris	unknown small object	Yes	No
S0672	0.7	0.8	0.1	debris	set of small round objects; possibly man-made	Yes	No
S0771	6.7	1.1	0.4	debris	Two joint structures, partly buried in the seabed, probably man-made	Yes	No
S0791	2.1	0.5	0.2	debris	unknown small object	Yes	No
S0833	4	0.4	0.1	debris	unknown linear object	Yes	No

It turned out to be feasible to interpret the contacts in more detail, making it possible to exclude a number of contacts as of archaeological importance.

3.3 Wreck sites

From the desk study by Vestigia it was concluded that two wrecksites were known within the research areas WFSIII and IV: NLhono numbers 1703 and 1723, both located in WFS III.

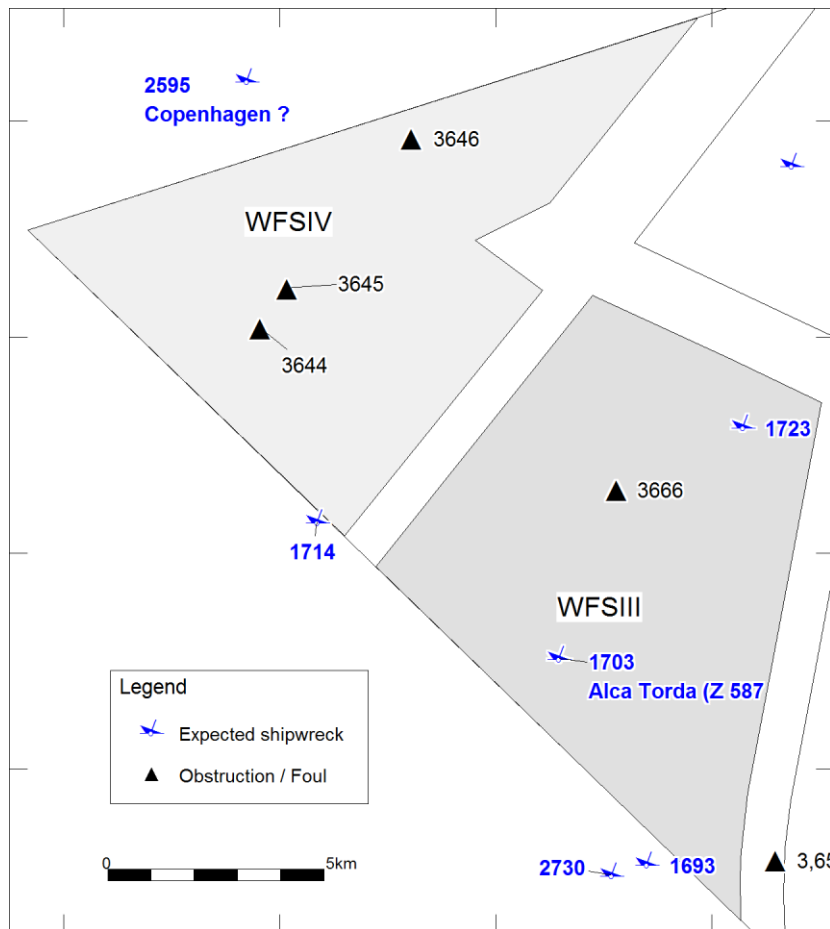


Figure 9. Overview of expected objects within the research areas

The Fugro report of WFSIII assumed that the NLhono locations 3644, 2645 and 3646 contained shipwrecks, while they are actually described by the Hydrographic Office as unknown objects causing possible obstructions.

Within the two research areas only one clear shipwreck was found by Fugro (location NLhono 1723). Additional research of historical data proved this to be the wreck of the 'Alca Torda'. The initial location of the 'Alca Torda' was placed 6.8 km to the south (NLhono 1723), with a position accuracy of 1 km. At this location, no evidence was found of a ship wreck. From the data and additional research it may be concluded the unknown wreck at location 1723 is actually the wreck of the 'Alca Torda', and there is no wreck at location 1703. It is recommended to pass this information to Rijkswaterstaat and the Hydrographic office.

The quality of the data set suffices for the identification of the ship wreck as such. The identification is supported by the integration of the different types of geophysical data available: SSS, MBES, MAGGY and SBP. The wreck is embedded in sandy sediments. The seabed is characterized by the presence of mega-ripples. Considerable scouring caused by tidal currents is observed both northeast as southwest of the wreck. In the surroundings side scan sonar contacts are observed which possibly are linked to the wreck site.

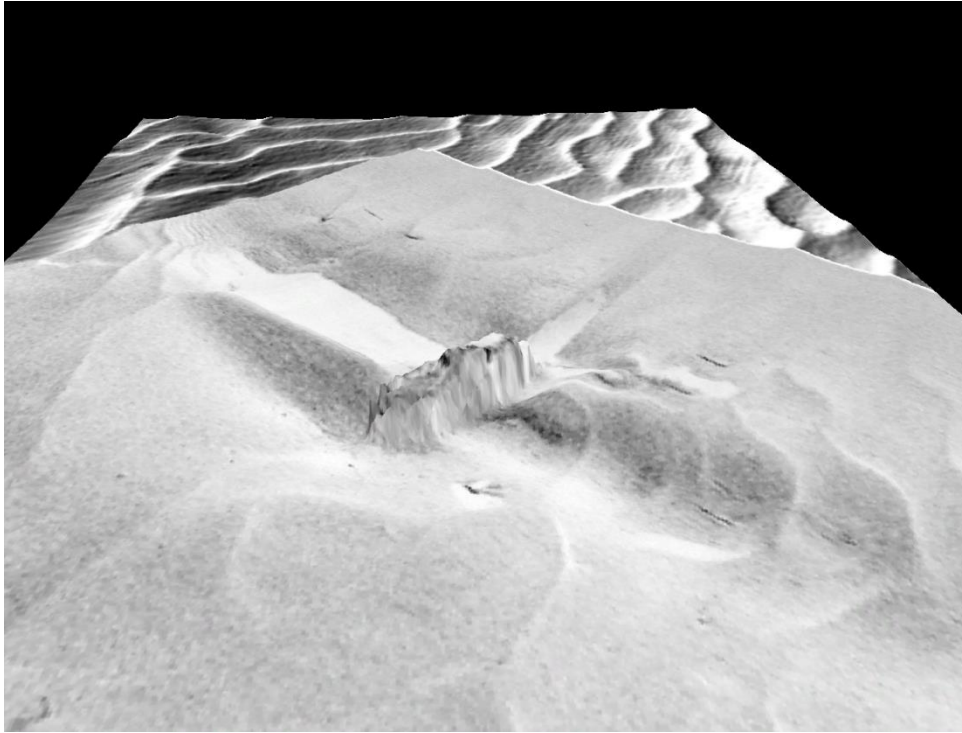


Figure 10. Side scan sonar image of the wreck draped over the multibeam model

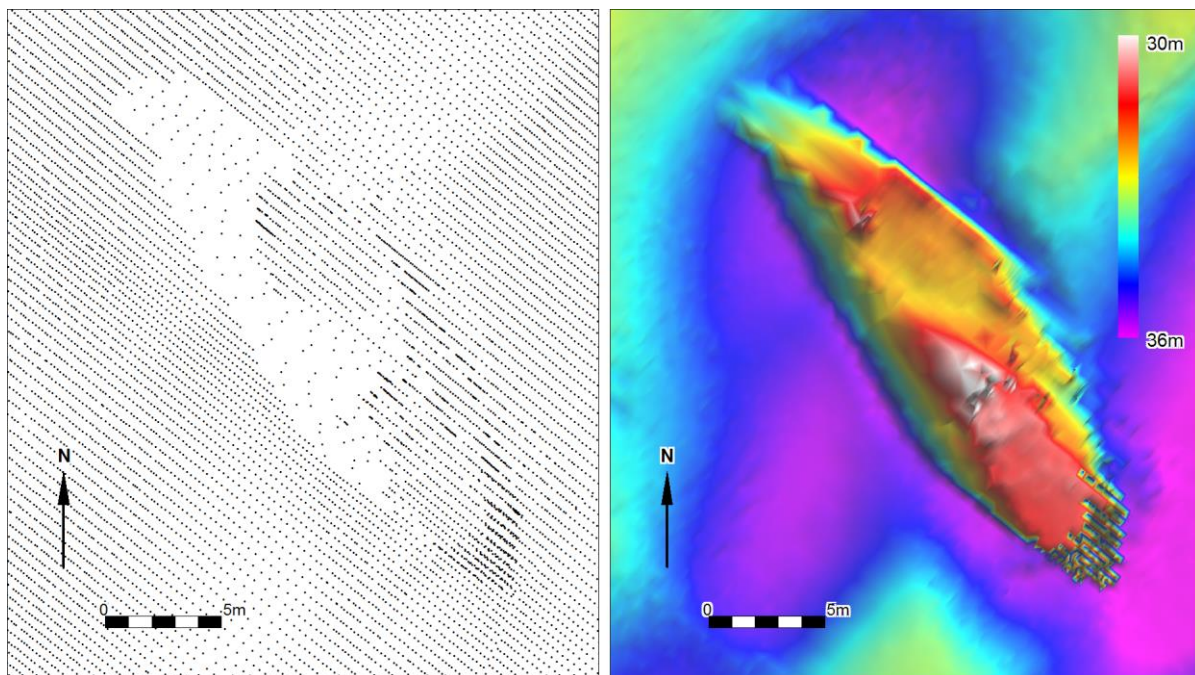


Figure 11. Raw multibeam soundings (left) and colour image of the multibeam data of the wreck Alca Torda

The raw multibeam data (with a data density of 11 points per square meter) supply slightly more details than the original gridded data (4 points per square meter) and is therefore useful for an archaeological assessment.



Figure 12. Photograph of the Alca Torda before sinking in 1973

Additional research within various databases provided additional and valuable information of the wreck. The wreck is identified as the Belgian kutter 'Alca Torda' which sunk in 1973. The database of the Hydrographic service placed the wreck at the incorrect location (1703 instead of 1723), which was adopted by the Desk study and Fugro.

The wreck is not considered to be of archaeological value. Therefore its presence will not - from an archaeological point of view - jeopardize the development of the wind farm.

3.4 Additional remarks

The assessment of the original survey reports concludes that a few assumptions were made which may lead to a improper archaeological assessment. Two examples are presented:

- a) The listing of known positions of wreck locations within area 3⁷ do not match the original coordinates from the GIS of the desk study. As a result, it was concluded that the As Found position of the wreck in area 3 is located 75m NE of the database location. However this is not the case. The As Found position corresponds perfectly with the theoretical position.
- b) In the survey report of area IV is stated that "Wreck 3644" was only detected by a possible magnetometer anomaly". This is not the our finding, because it was also detected by side scan sonar (sonar contact S0468). Furthermore, this is not a shipwreck, but listed as a "Foul" or obstacle in the database of the Hydrographic service. This is confirmed by the side scan sonar images, showing an (unknown) object with dimensions 3,0x1,1x1,0m

⁷Table 2.3 in report WFSIII

4 Conclusions and recommendations

Background

In 2015 two separate geophysical campaigns have been executed in the Borssele Wind Farm Zone (BWFZ) by Fugro Survey B.V. The areas of interest were investigated with geophysical and geotechnical techniques. The purpose of these investigations was to establish an accurate geological model and map possible obstructions in order to provide tendering parties with the information needed and assist future developers in their construction decisions.

The amount and quality of these geophysical and geotechnical data might suffice to identify possible archaeological objects and in the future mitigate the possible consequences of their presence in the Wind Farm Zone. The Dutch Cultural Heritage Agency and RVO.nl agreed to conduct a pilot project to investigate to what extent the already performed geophysical surveys would be a suitable source for the required archaeological phases of investigation.

Periplus was requested to conduct this pilot with the objective to assess whether it is feasible to:

- a) Exclude the archaeological value of detected objects based on a geophysical analysis of the survey data, and
- b) Map the locations of known wrecks in greater detail.

General conclusions

Overall

The quality and resolution of the geophysical data is sufficient for a first archaeological assessment of the observed contacts and described objects. The standard survey reports and interpretations from the survey contractor can be used as a base for an initial assessment; but additional analysis of the raw survey data around the suspected archaeological objects by a specialist is necessary.

With respect to the assessment and - if possible - identification of twenty (20) randomly chosen side scan sonar contacts the followings it is concluded:

As part of the assessment, 20 random sonar contacts and all contacts referring to possible wreck remains were picked from the total amount of contacts reported by Fugro in the areas (234 in WFSII, 649 in WFS IV). The raw data for these contacts (side scan sonar and multibeam) were analyzed in order to make a statement on the feasibility of an archaeological assessment. It turned out to be feasible to interpret the contacts in more detail, making it **possible to exclude all 20 contacts and the wreck as** of archaeological importance.

With respect to the wreck(s) identified the following is concluded:

1. Within the two research areas only one shipwreck was found by Fugro. This is consistent with the facts, because the base information from the desk study and wreck databases proved to be not in line with the findings (one supposed wreck is actually a "Foul", and another supposed wreck (nr 1703) does not exist (this wreck is actually located at nr 1723).
2. The quality of the data set is sufficient for the identification of the ship wreck as such. The identification is supported by the integration of the different types of geophysical data available: SSS, MBES, MAGGY and SBP.
3. The comparison of the survey results with information from various databases provided additional and valuable information of the wreck. The wreck is identified as the Belgian kotter 'Alca Torda' which sunk in 1973. The database of the Hydrographic service placed the wreck at a different location (1703 instead of 1723), which was adopted in the desk study of Vestigia and subsequently by Fugro.
4. The wreck is **not considered to be of archaeological value**. Therefore its presence will not - from an archaeological point of view - jeopardize the development of the wind farm.

With respect to the assessment of the parameters of the geophysical survey and the quality of the acquired dataset the followings is concluded:

1. The survey data collected by Fugro is complete, covering the entire research area with side scan sonar, high resolution multibeam, magnetometer and subbottom profiler. The data are of high quality and resolution. The (standard) survey report is fit for the primary purpose of describing detecting possible obstructions and geo-hazards.
2. The (standard) survey report contains insufficient information to answer the questions set for an archaeological assessment, because:
 - a) All objects and structures found are reported in a general way with short standard descriptions;
 - b) No reference is made to the possible archaeological value or the history of the objects based on available information from the desk study;
 - c) The quality of the sonar images within the report is poor; revealing no details.

ad. c) The side scan sonar data have been acquired by means of a Kongsberg EA 400/600 Sidescan. The working frequency of this sonar is 120 or 200 kHz which meets the minimum standard set for archaeological research for a research area of this size. The level of detail on sides can sonar images obtained with this sonar is less than when a high frequency side scan sonar is employed. For archeological investigations in smaller areas side scan sonar echo sounders with frequencies in the range of 450 - 900 kHz are used. However, concerning the relative large size of the investigated areas a detailed survey with these parameters is not feasible. The analysis of raw multibeam data can contribute to the interpretation of side scan sonar contacts observed, but - in most cases - will not resolve the relatively low level of detail obtained by the side scan sonar.

3. A few assumptions were detected in the survey reports which may lead to an incorrect archaeological assessment. Two examples are presented:
 - a) The listing of known positions of wreck locations within WFS III⁸ does not match the original coordinates from the GIS of the desk study. As a result, it was concluded that the As Found position of the wreck in WFS III is located 75m NE of the database location. However this is not the case. The As Found position corresponds perfectly with the theoretical position.
 - b) In the survey report of WFS IV is stated that "Wreck 3644" was only detected by a possible magnetometer anomaly". This is not the case, because it was also detected by side scan sonar (sonar contact S0468). Furthermore, this is not a shipwreck, but listed as a "Foul" or obstacle in the database of the Hydrographic service. This is confirmed by the side scan sonar images, showing an (unknown) object with dimensions 3,0x1,1x1,0m

Recommendations for the way forward

It is recommended to extend the archaeological assessment with an investigation of the remainder of the contacts detected during the Fugro and DEEP surveys. The initial interpretation from Fugro and DEEP can be used as a basis for a first selection of potential interesting contacts from an archaeological point of view. Subsequently, the raw side scan sonar- and multibeam data can be used to make a more detailed interpretation of these contacts.

The results can be used to prepare a formal report which complies with the requirements of the KNA. It is recommended to have this assessment executed by qualified personnel (prospector waterbodems). Before this assessment and the subsequent report can be completed an authorized Program of Requirements (Program van Eisen) has to be put in place.

Recommendations with respect to incorrect database information

The unknown wreck at NLhono location 1723 is actually the wreck of the 'Alca Torda', and we found no wreck at NLhono location 1703 to which the 'Alca Torda' wreck currently is assigned. It is recommended to pass this information to Rijkswaterstaat and the Hydrographic office.

⁸Table 2.3 in report WFSIII

List of figures

Figure 1. Overview of the research area – Site III and Site IV	8
Figure 2. Original description and interpretation from Fugro report of contact S0771	14
Figure 3. Raw waterfall sonar image of contact S0771	14
Figure 4. Gridded and raw multibeam data of contact S0771	15
Figure 5. 3D view of raw multibeam data of contact S0771	15
Figure 6. Original sonar image and description from Fugro report of contact S0222*	16
Figure 7. Raw waterfall sonar image of contact S0222	16
Figure 8. Raw multibeam data of contact S0222	17
Figure 9. Overview of expected objects within the research areas	19
Figure 10. Side scan sonar image of the wreck draped over the multibeam model	20
Figure 11. Raw multibeam soundings (left) and colour image of the multibeam data of the wreck Alca Torda	20
Figure 12. Photograph of the Alca Torda before sinking in 1973	21

List of tables

Table 1. Dutch archeological periods	2
Table 2. Administrative details	2
Table 3. Data of side scan sonar contact SO639 (wreck)	13

Glossary and abbreviations

Terminology	Description
<i>AMZ</i>	Archeologische Monumenten Zorg
<i>CPT</i>	Cone penetration test
<i>Ferrous</i>	Material which is magnetic or can be magnetized, and well known types are iron and nickel
<i>Holocene</i>	Youngest geological epoch (from the last Ice Age, around 10,000 BC. To the present)
<i>In situ</i>	At the original location in the original condition
<i>KNA</i>	Kwaliteitsnorm Nederlandse Archeologie
<i>Magnetometer</i>	Methodology to measure deviations from the earth's magnetic field (caused by the presence of ferro-magnetic = ferrous objects)
<i>Multibeam</i>	Acoustic instrument that uses different bundles or beams to measure the depth in order to create a detailed topographic model
<i>Pleistocene</i>	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
<i>PvE</i>	Programma van Eisen
<i>RCE</i>	Rijksdienst voor het Cultureel Erfgoed
<i>ROV</i>	Remotely Operated Vehicle
<i>Side scan sonar</i>	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
<i>Current ripples</i>	Asymmetrical wave pattern at the seabed caused by currents. The steep sides of the ripples are always on the downstream side.
<i>Subbottom profiler</i>	Acoustic system used to create seismic profiles of the subsurface.
<i>Trenching</i>	Construction of a trench for the purpose of burying a cable or pipeline
<i>Vibrocore</i>	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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- Maarleveld, Th.J. , Almere 1998: Archaeological heritage management in Dutch waters: exploratory studies.
- Visser, C.A., W.J. Weerheijm, R. Schrijvers en W.A.M. Hessing 2014. Borssele Wind Farm Zone, North Sea, the Netherlands. Archaeological desk study, risk assessment and recommendations. Vestigia report V1199.

Various sources

- Archis III, archeologische database Rijksdienst voor het Cultureel Erfgoed
- Databases Periplus Archeomare
- Wrecksite, www.wrecksite.eu
- 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)

