Netherlands Enterprise Agency

Archaeological Assessment (Phase II)

Hollandse Kust (west) Wind Farm Zone

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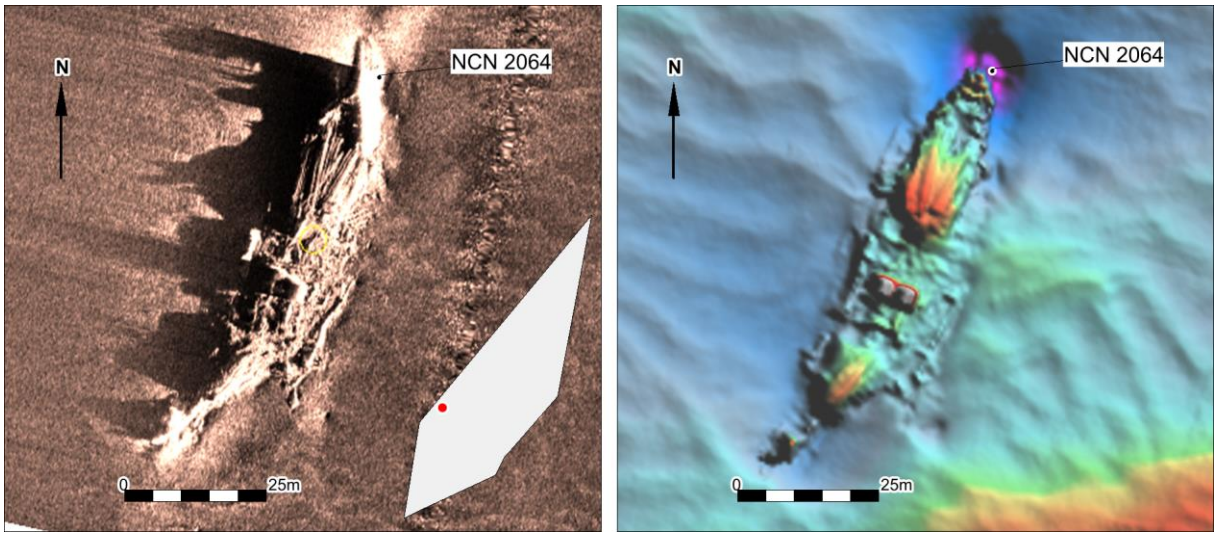
Periplus Archeomare

Hollandse Kust (west)

An archaeological assessment
Of geophysical survey results



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At the request of

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Periplus Archeomare Report 19A015-01
Hollandse Kust (west) – An archaeological assessment of geophysical survey results
Authors: R. van Lil S. van den Brenk and R.W. Cassée

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Table 1. Dutch archaeological periods

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

Table 2. Administrative details

Location:	North Sea	
Toponym Dutch:	Hollandse Kust (west)	
Chart:	1801-01	
Coordinates Geodetic datum: ETRS89 Projection: UTM31N	Centre	E 584 230 - N 5 834 717
	IA_01	E 561228.0 - N 5855632.6
	IA_03	E 556460.6 - N 5830656.3
	IA_04	E 549868.2 - N 5822960.7
	IA_05	E 549138.1 - N 5822251.0
	IA_06	E 547864.6 - N 5819746.5
	IA_07	E 536954.7 - N 5814611.0
	IA_08	E 535232.6 - N 5813800.4
	IA_09	E 537288.5 - N 5826952.9
Depth (LAT):	20.0 to 34.6 meter, average 28.1 meter	
Surface investigation area Surface investigation area + 1km buffer	349 km^2 500.0 km^2	
Environment:	Tidal currents, salt water	
Area use:	Shipping , fishing, oil and gas industry	
Area administrator:	Rijkswaterstaat Zee en Delta	
Competent authority	Rijkswaterstaat Zee en Delta	
Advising body	Dutch Cultural Heritage Agency	
ARCHIS-research report (CIS-code):	4697697100	
Periplus-project reference:	19A015-01	
Period	April – September 2019	

Samenvatting (Abstract in Dutch)

In opdracht van RVO.nl heeft Periplus Archeomare een archeologische analyse uitgevoerd van de resultaten van de geofysische onderzoeken voor het toekomstige windpark Hollandse Kust (west).

Op de locatie voor het toekomstige windpark is een gebied met een oppervlakte van 402 km^2 opgenomen met *sidescan sonar, magnetometer, multibeam echolood en profilering subbottom profiler*. De grote hoeveelheid onderzoeksgegevens is geanalyseerd om een archeologische beoordeling uit te voeren.

Scheeps- en vliegtuigwrakken

De analyse van de geofysische onderzoeksresultaten vormt, na het bureauonderzoek, de tweede stap in het archeologische proces. Uit het bureauonderzoek is gebleken dat er binnen de begrenzing van het onderzoeksgebied van het geplande windpark in totaal 39 objecten, waarvan (maximaal) 23 wrakken, bekend waren. 19 van deze wrakken zijn mogelijk van archeologische waarde.

15 bekende objecten, waarvan 10 wrakken, zijn gevonden tijdens de geofysische survey.

- 7 wrakken, die mogelijk van archeologische waarde zijn;
- 3 wrakken, die vermoedelijk niet van archeologische waarde zijn;
- 4 wellheads;
- 1 antropogeen object, dat vermoedelijk niet van archeologische waarde is.

24 bekende objecten, waarvan 13 wrakken, zijn niet gevonden tijdens de geophysische survey.

- alle bekende objecten (inclusief de wrakken), die niet zijn aangetroffen binnen het onderzochte gebied zijn waarschijnlijk afgedekt door sediment ten gevolge van migrerende zandduinen;
- 12 van de 13 niet gevonden wrakken, zijn mogelijk van archeologische waarde;
- 5 van de 12 potentieel archeologische wrakken liggen buiten het onderzochte gebied;
- 1 van de niet gevonden wrakken is niet van archeologische waarde.

Bekende Objecten	Archeologische Verwachting		Totaal
	Ja	Nee	
Gevonden	7	8	15
Niet gevonden	12*	12	24
Totaal	19	20	39

* 5 van deze wrakken liggen buiten het onderzochte gebied; de 7 andere mogelijk archeologische wrakken liggen binnen het onderzoeksgebied, maar zijn vermoedelijk afgedekt door sediment.

Naast de 15 gevonden objecten zijn 405 *sidescan sonar* contacten gerapporteerd. De analyse van deze contacten heeft geresulteerd in de selectie van 8 locaties waar 10 contacten zijn aangetroffen die, op basis van hun afmetingen en voorkomen, mogelijk van archeologische waarde zijn.

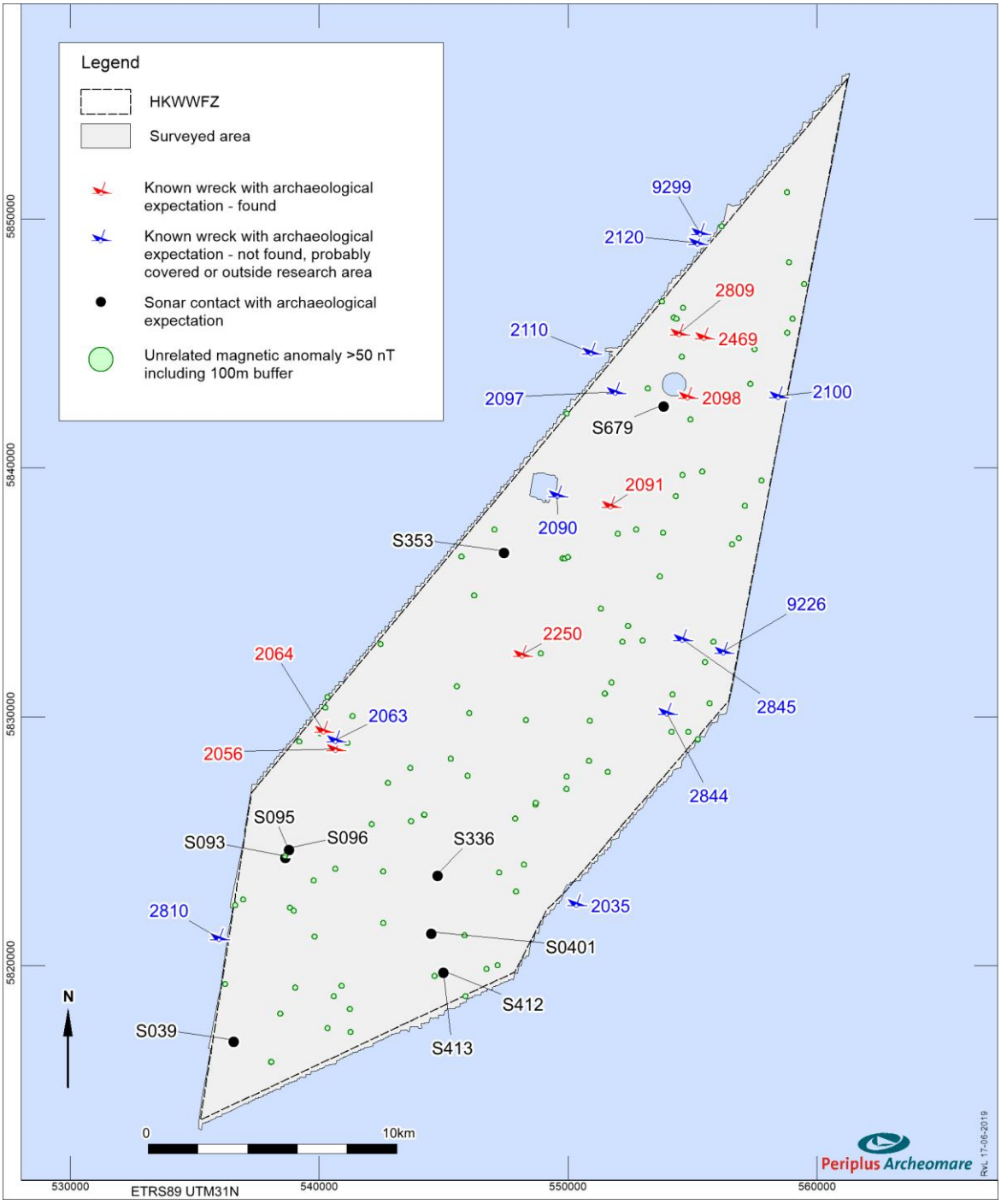
De objecten met een archeologische verwachting zijn samengevat in de volgende tabel.

Nr/	ETRS89 UTM31N		Afmetingen (m)			Beschrijving	Classificatie
NCN	Easting	Northing	L	B	H		
S_0039	536556	5817013	4.7	2.4	0.3	langgerekt tot rechthoekig object met een harde reflectie	mogelijk wrak
S_0093	538628	5824408	5.6	2.9	0.0	sferisch object temidden van een slijpgeul 13 x 11 m met een magnetische anomalie van 118 nT	mogelijk wrak
S_0095	538755	5824686	3.8	0.8	0.4	twee langgerekt objecten	mogelijke wraklocatie
S_0096	538786	5824717	2.6	1.1	0.9		
S_0336	544748	5823694	28.5	5.3	0.2	sterk reflectieve ontsluiting	mogelijk begraven wrak
S_0353	547417	5836653	7.2	6.8	0.7	sterk reflectieve ontsluiting	mogelijk begraven wrak
S_0401	544499	5821369	33.8	9.4	0.4	contouren met van een schip	begraven wrak
S_0412	544989	5819800	3.5	5.8	0.7	cluster van contacten	mogelijke wraklocatie
S_0413	544995	5819792	4.6	4.1	1.2		
S_0679	553839	5842543	7.2	1.0	0.4	lineair object temidden van een cluster van contacten	mogelijk begraven wrak
NCN2056	540645	5828700	63.0	9.6	3.0	wrak DHY 2247. Duikteam Zeester: Biaritz, vergaan 1940	wrak Biaritz
NCN2064	540162	5829452	87.0	20.0	3.4	wrak DHY 2256. Duikteam Zeester: SS Paris, vergaan 1939	wrak SS Paris
NCN2091	551689	5838477	28.0	9.0	1.8	verspreide wrakdelen DHY 2284	wrak
NCN2098	554783	5842860	0.0	0.0	0.0	wrak DHY 2292. Duikteam Zeester: Boezemwrak dicht bin platform	geen zichtbare contacten, zandduin, mag. anomalie; 2031 nT
NCN2250	548149	5832487	31.0	10.0	1.1	wrak DHY 2468. Onbekend wrak gerapporteerd in 1984	wreck
NCN2469	555444	5845242	29.0	8.0	3.4	wrakresten	wreck, partly buried
NCN2809	554440	5845409	28.0	7.0	0.4	wrak DHY 3427. Onbekend wrak gerapporteerd met *sidescan sonar* 1997	mogelijk wrak

De 22 vondstlocaties omvatten 8 ‘nieuwe’ locaties waar met *sidescan sonar* resten zijn aangetroffen en 14 bekende NCN-wrakken, waarvan er 7 tijdens de survey zijn gevonden en 7 (vermoedelijk) zijn afgedekt door sediment.

In totaal zijn 2450 magnetische anomalieën waargenomen. 674 van deze anomalieën kunnen gerelateerd worden aan bekende pijpleidingen of kabels. 10 anomalieën kunnen gerelateerd worden aan objecten die met *sidescan sonar* ontsloten aan de zeebodem zijn waargenomen.

1750 magnetische anomalieën kunnen niet worden gerelateerd aan bekende pijpleidingen en kabels of zichtbare objecten op het oppervlak van de zeebodem. De anomalieën worden veroorzaakt door onbekende ijzerhoudende objecten in de zeebodem, die zijn afgedekt door sediment. 107 van deze objecten zijn gemeten als magnetische anomalie met een uitslag van 50 nT of meer. Een overzicht van alle objecten en anomalieën wordt gepresenteerd op de volgende pagina.



Prehistorische resten

Het grootste deel van het *pleistocene* landschap lijkt te zijn geërodeerd tijdens de vroeg-*holocene* mariene transgressie en de ontwikkeling van een getijdengebied. Door de erosie is de gaafheid van eventuele prehistorische nederzettingen op deze locaties aangetast. Locaal kunnen *pleistocene* landschappen en de (eventueel) hierin besloten prehistorische resten intact bewaard zijn gebleven.

Tot de gebieden met archeologische potentie worden gerekend:

- de oevers van beekdalen en dekzandduinen en -ruggen van de Formatie van Boxtel langs de randen van het glaciale dal, vooral als deze gebieden zijn afgedekt door veen en/of humeuze klei;

- gestuwde afzettingen langs de rand van het glaciale dal;
- kleine bekkens die zijn opgevuld met afzettingen van het Brown Bank Laagpakket.

De fysieke kwaliteit, die wordt gevormd door de gaafheid en conservering van de prehistorische resten, wordt vooral bepaald door de mate waarin archeologische niveaus door erosie zijn aangetast.

De seismische interpretatie van de lithostratigrafische eenheden en de aard van de laaggrenzen (erosief of intact) is gebaseerd op de geologische data die van het gebied bekend zijn en 'expert judgement'. De seismische interpretatie dient getoetst te worden door een combinatie van sonderingen en boringen, zodat een goed beeld wordt gekregen van de opeenvolgende geologische lagen die daadwerkelijk in het gebied aanwezig zijn, en de intactheid van de laaggrenzen, zodat de ontwikkeling en intactheid van de opeengestapelde prehistorische landschappen en het archeologisch potentieel nader kan worden gespecificeerd.

Aanbevelingen

Scheeps- en vliegtuigwrakken
Zolang de archeologische waarde van de resten die op 22 locaties zijn aangetroffen niet is vastgesteld, wordt geadviseerd geen bodemverstorende activiteiten uit te voeren binnen een zone van 100 m rondom deze locaties. Dit geldt ook voor het aanleggen van kabelsleuven en verankeringen van werkschepen.

De bufferzone van 100 meter is een norm die van toepassing is op de bescherming van cultureel erfgoed. Deze afstand kan worden verkleind als kan worden onderbouwd dat de toegepaste verstoring geen effect heeft op het archeologisch object. Als bijvoorbeeld geen verankering wordt gebruikt tijdens het leggen van de kabels, kan de bufferzone worden verkleind. Reductie van de afstand moet worden goedgekeurd door Rijkswaterstaat (RWS). Rijkswaterstaat is de handhavende instantie, handelend in opdracht van het ministerie van Economische Zaken en Klimaat. De Rijksdienst voor het Cultureel Erfgoed (RCE) treedt op als adviseur van Rijkswaterstaat.

Met betrekking tot deze begraven objecten uit het magnetometeronderzoek wordt geadviseerd om deze locaties, inclusief een bufferzone van 100 meter, te vermijden tijdens het installeren van windturbines en de kabels. De aard van de objecten die de magnetische anomalieën veroorzaken is onbekend. Dit betekent dat afgezien van mogelijke archeologische objecten ook andere type objecten kunnen worden aangetroffen, waaronder niet-gesprongen explosieven, ankers, stukken kettingen en kabels, puin, enzovoort.

Als het niet mogelijk is om de gerapporteerde *magnetometer*locaties te vermijden, is aanvullend onderzoek nodig om de feitelijke archeologische waarde van de objecten te bepalen. Indien een UXO onderzoek wordt uitgevoerd binnen 100 meter van de locaties, wordt aanbevolen om dit onderzoek archeologisch te begeleiden. Afhankelijk van de uitkomst van het UXO-onderzoek kan worden besloten of aanvullend onderzoek (bijvoorbeeld door middel van ROV of duikonderzoek) nodig is. Als het UXO-onderzoek aangeeft dat het object geen archeologische waarde heeft, kan de locatie worden geschrapt.

prehistorie

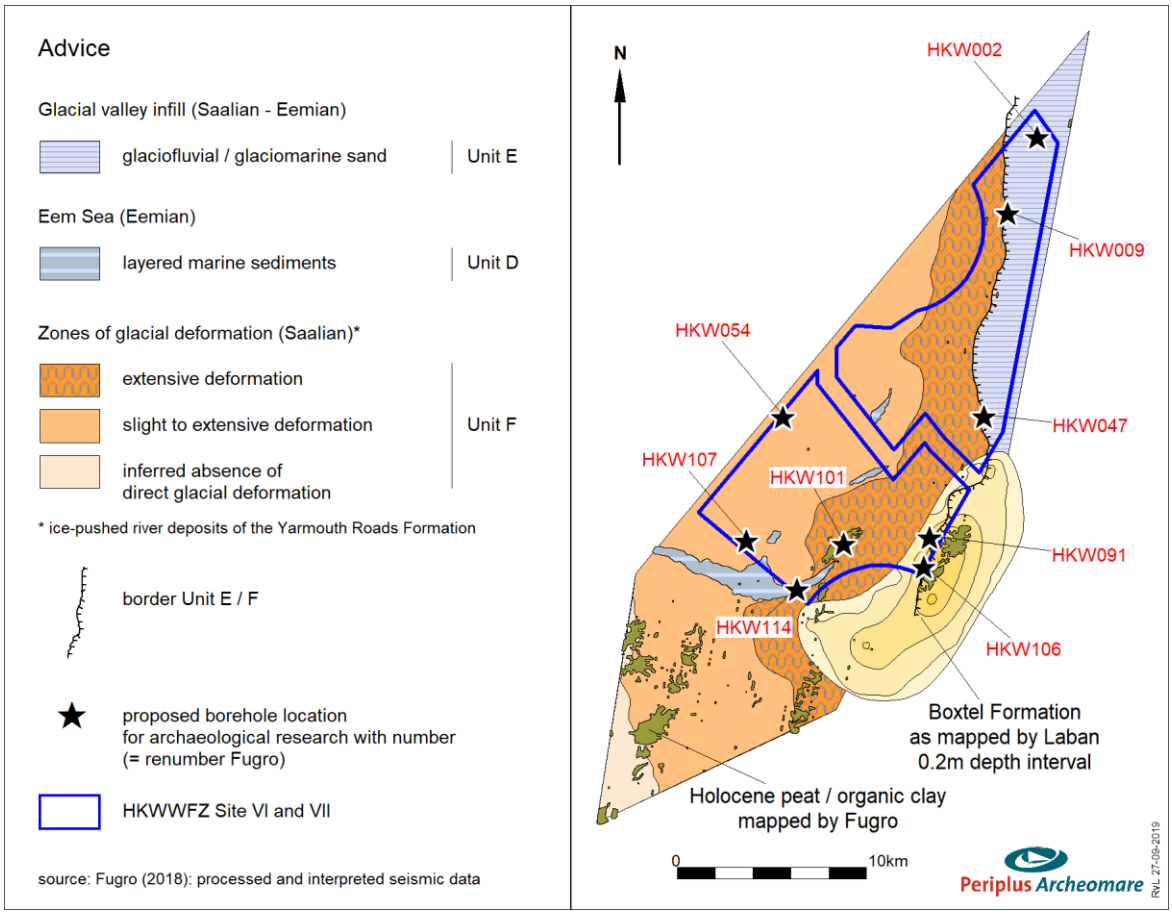
Op basis van de resultaten en conclusies van het huidige onderzoek adviseren wij om nader archeologisch onderzoek uit te voeren dat specifiek gericht is op de genese en intactheid van paleolandschappen in de HKWWFZ. Dit onderzoek omvat een inventariserend veldonderzoek door middel van boringen en sonderingen conform de Kwaliteitsnorm Nederlandse Archeologie Waterbodems (KNA-WB rev. 4.1). Wij stellen voor om de boringen en sonderingen die volgens planning worden uitgevoerd voor het vervaardigen van een geologisch model en fysische eigenschappen van de aanwezige sedimenten te gebruiken voor het geo-archeologische onderzoek.

Het onderzoek richt zich in eerste instantie op de boorkernen die worden bemonsterd op negen locaties (zie onderstaande afbeelding). De monsters die op deze locaties worden genomen leveren naar verwachting de informatie die nodig is om de geogenese van het gebied en de intactheid van de afgedekte paleolandschappen vast te stellen. Het is niet ondenkbaar dat tijdens de analyse van de kernen vragen naar voren komen die enkel kunnen worden beantwoord door analyse van kernen die geen deel uitmaken van de nu voorgestelde negen locaties. Het is daarom van belang dat alle boorkernen die tijdens geotechnische campagne worden bemonsters beschikbaar zijn voor het geo-archeologische onderzoek.

De intacte monsters dienen te worden onderzocht door een *(senior) prospector waterbodems* en beschreven conform de Standaard Boorbeschrijvingsmethode (SBB). Monsters worden geselecteerd en gestabiliseerd voor analyses door specialisten op het gebied van C-14 datering, micromorfologisch onderzoek, pollen analyse, macro-resten van planten en dieren, mollusken, et cetera om inzicht te krijgen in de ontwikkeling van het landschappen in de tijd en de mate waarin deze landschappen bewaard zijn gebleven.

Conform de Kwaliteitsnorm Nederlandse Archeologie (KNA waterbodems, versie 4.1) dient voor dit booronderzoek een Programma van Eisen (PvE) en/of Plan van Aanpak (PvA) te worden opgesteld. In het PvE/PvA worden de doelstelling, de onderzoeksstrategie en -methodiek, de kaders en praktische invulling van het onderzoek vastgelegd, zodat het proces voorspoedig verloopt en meervoudig gebruik van op uniforme wijze verkregen data wordt bewerkstelligd. Geadviseerd wordt om dit PvE/PvA ter goedkeuring voor te leggen aan de Bevoegde Overheid en de RCE.

Na uitvoering van het booronderzoek kan tijdens de aanleg van het windpark data worden ingewonnen die - uit archeologisch oogpunt - op detailniveau waardevolle informatie opleveren. Het kan zeer zinvol zijn om deze informatie nader archeologisch te onderzoeken. Het verdient aanbeveling om de mogelijkheden hiertoe in samenspraak met de RCE te onderzoeken, op het moment dat de plannen zijn uitgewerkt.


Advice
Glacial valley infill (Saalian - Eemian)
glaciofluvial / glaciomarine sand
Unit E
Eem Sea (Eemian)
layered marine sediments
Unit D
Zones of glacial deformation (Saalian)*
extensive deformation
slight to extensive deformation
inferred absence of direct glacial deformation
Unit F
* ice-pushed river deposits of the Yarmouth Roads Formation
border Unit E / F
proposed borehole location for archaeological research with number (= renumber Fugro)
HKWWFZ Site VI and VII
source: Fugro (2018): processed and interpreted seismic data
N
HKW002
HKW009
HKW054
HKW047
HKW107
HKW101
HKW091
HKW114
HKW106
Boxtel Formation as mapped by Laban 0.2m depth interval
Holocene peat / organic clay mapped by Fugro
0
10km
Periplus Archeomare
RvL 27-09-2019

Renumber	PPA	Easting	Northing	Z mLAT
HKW002	mogelijke (*holocene*) Echteld geul van 1.1-7.4m diepte	558511	5850094	27.7
HKW009	Naast de rand van het glaciale dal. Interessant dateringsprofiel volgens RVO/FUGRO	556935	5846086	28.8
HKW047	Saalien glaciaal dal; opvulling = Saalien, Eemien, Holoceen?; dicht bij de rand (28m); onderliggende glaciaal gedeformeerde afzettingen	555680	5835338	26.6
HKW054	kleine *holocene* geulinsnijding	545071	5835320	28.2
HKW091*	binnen Laban Boxtel Fm 0.4m; naast rand van glaciaal dal (220m); geen veen gekarteerd	552817	5828953	29.5
HKW101	Mogelijk Brown Bank Laagpakket; rand van *holocene* geulopvulling met veen en/of organische klei	548290	5828597	27.0
HKW106	Binnen Laban Boxtel Fm 0.6m; op rand van glaciaal dal (70m); geen veen gekarteerd	552522	5827385	29.1
HKW107	Glaciaal gedeformeerde afzettingen; gelaagde opgevulde depressive (Bruine Bank Lp)	543126	5828766	29.5
HKW114	Eem Fm (<10m) Bruine Bank LP (circa 3m) Naaldwijk Fm (?) Bligh Bank Lp (5-10m)	545801	5826218	27.6

*Opmerking: Geadviseerd wordt om deze locatie op te schuiven naar 553226E; 5828876N om de *holocene* laag veen of humeuze klei mee te nemen in het monster en een dunne laag van de opvulling van het glaciale dal; dit punt is op de kruizing van de seismische lijnen 2D545 and 2X598

Samenvattend wordt geconcludeerd dat de eigenaar van het windpark rekening dient te houden met:

- 14 bekende NCN wrakken van mogelijk archeologische waarde, die zijn gevonden op de zeebodem (7) of zijn afgedekt zijn door sediment (7);
- 8 nieuwe locaties waar resten van mogelijk archeologische waarde zijn gevonden op de zeebodem;
- 107 afgedekte ijzerhoudende resten van mogelijk archeologische waarde (magnetische anomalieën > 50 nT);
- 9 voorgestelde boorlocaties waar kernen worden bemonsterd om de aanwezigheid, gaafheid en conservering van de opeengestapelde prehistorische landschappen te beoordelen.

Er wordt geadviseerd om binnnen zone van 100m rond de 129 locaties waar archeologische resten kunnen voorkomen geen bodemverstorende activeiten uit te voeren.

Tijdens de aanleg van het windmolenpark kunnen archeologische resten aan het licht komen die volledig begraven waren of niet als een archeologisch object zijn herkend tijdens het geofysisch onderzoek. We raden daarom passieve archeologisch begeleiding aan op basis van een goedgekeurd Programma van Eisen. Passief betekent dat een archeoloog niet tijdens de uitvoering van het werk aanwezig is, maar altijd op afroep beschikbaar. Hierdoor kunnen vertragingen tijdens de werkzaamheden voorkomen worden wanneer onverwacht archeologische vondsten gedaan worden. Eventuele vondsten dienen gemeld te worden aan het bevoegd gezag. Deze meldingsplicht voor archeologische vondsten dient in het bestek of Plan van Aanpak van het werk te worden opgenomen.

Het bevoegd gezag is de Minister van Economische Zaken en Klimaat op grond van de Wet windenergie op zee. Rijkswaterstaat (RWS) is door de Minister van Economische Zaken en Klimaat gemandateerd om het toezicht op grond van die wet uit te voeren. De Rijksdienst voor Cultureel Erfgoed (RCE) zal door RWS geconsulteerd worden ten aanzien van archeologische aspecten.

Summary

RVO.nl has contracted Periplus Archeomare B.V. to conduct an Archaeological assessment of geophysical survey results of the Wind Farm Zone (WFZ) Hollandse Kust (west) (HKW).

A large quantity of survey data (*sidescan sonar, magnetometer, multibeam echosounder* and *subbottom profiling*) recorded within the wind farm zone covering a total area of 402 km^2 have been analyzed in order to conduct an archaeological assessment.

Ship wrecks and remains of WWII aircraft

The current analysis of geophysical survey results is the second and step in the archaeological assessment, following the desk study. The desk study has shown that within the boundary of the wind farm site a total of 39 objects including (a maximum of) 23 wrecks are known from database sources. 19 of those wreck sites are considered to be of potential archaeological interest.

15 known objects including 10 wrecks have been found during the geophysical survey.

- 7 of the wrecks found are of possible archaeological value;
- 3 of the wrecks found are considered to be of no archeological value;
- 4 wellheads;
- 1 man-made object considered to be of no archaeological value.

24 known objects including 13 wrecks have not been found during the geophysical survey.

- all known objects (including the wrecks) which have not been found witing the survey area have probably become covered with sediment due to the migration of sand waves;
- 12 of the 13 wrecks which have not been found are of possible archaeological value;
- 5 of the 12 wrecks of possible archaeological value are probably located outside the area of investigation;
- 1 of the wrecks which has not been found are considered to be of no archeological value.

Known Objects	Archaeological Expectation		Total
	Yes	No	
Found	7	8	15
Not Found	12*	12	24
Total	19	20	39

* 5 of these wrecks are probably situated outside the area of investigation; the other 7 wrecks of possible archaeological value are presumably located inside the area of investigation under a cover of sediment.

Apart from the 15 known objects found, another 405 *sidescan sonar* contacts have been reported. The analysis of these contacts resulted in a final selection of 8 locations containing 10 unknown objects and structures which - based on their shapes and dimensions - may be of archaeological value.

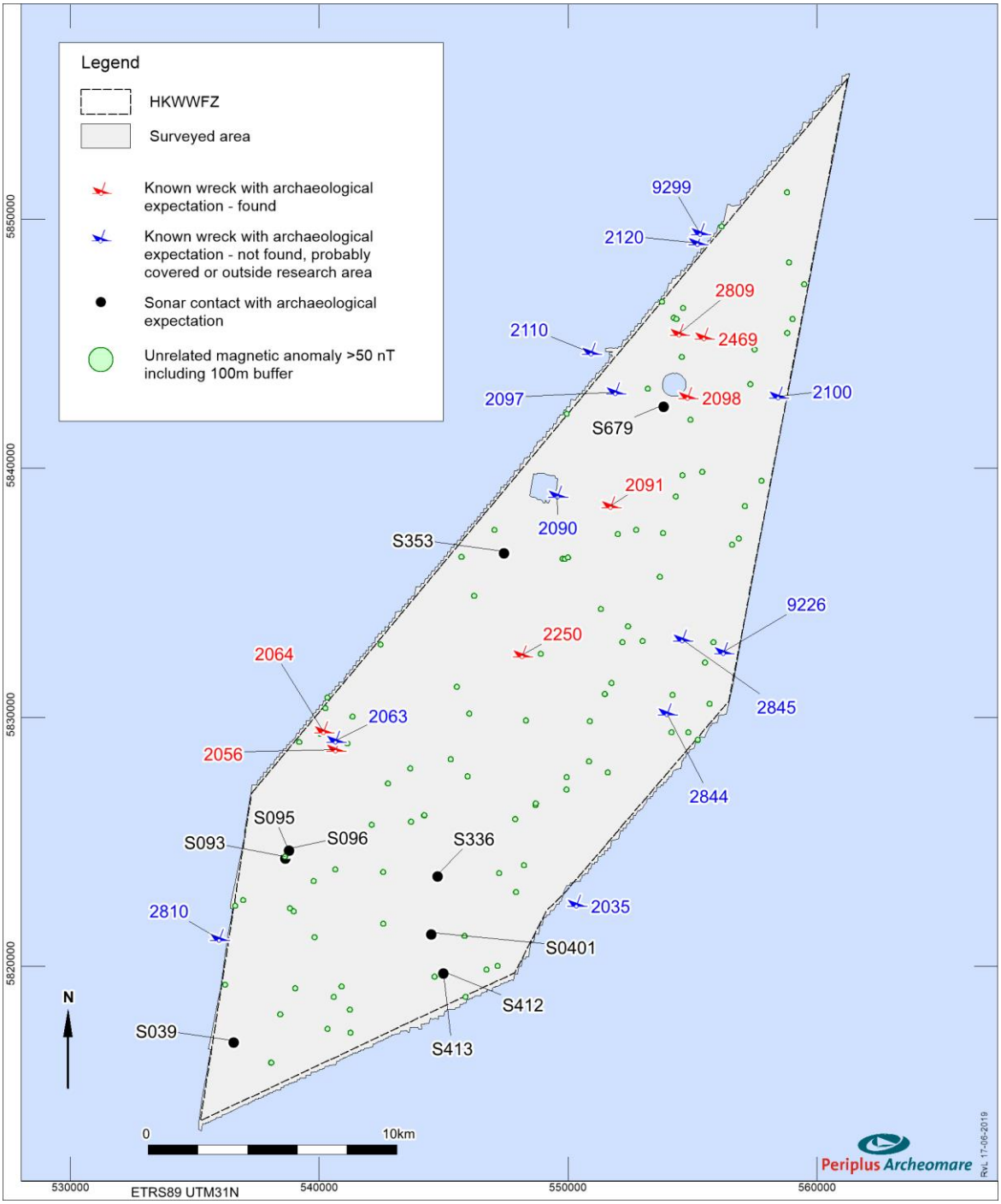
A summary of all found objects with a possible archaeological expectation is listed in the following table.

Nr/	ETRS89 UTM31N		Dimensions (m)				
NCN	Easting	Northing	L	W	H	Description	Classification
S_0039	536556	5817013	4.7	2.4	0.3	elongated to rectangular hard reflective object	Possible wreck
S_0093	538628	5824408	5.6	2.9	0.0	spherical object amidst a scour 13 x 11 m with 118 nT magnetic anomaly	Possible wreck
S_0095	538755	5824686	3.8	0.8	0.4	two elongated objects	Possible wreck site
S_0096	538786	5824717	2.6	1.1	0.9		
S_0336	544748	5823694	28.5	5.3	0.2	high reflective exposure	Possible buried wreck
S_0353	547417	5836653	7.2	6.8	0.7	high reflective exposure	Possible buried wreck
S_0401	544499	5821369	33.8	9.4	0.4	contours of a ship-like object	Buried ship wreck
S_0412	544989	5819800	3.5	5.8	0.7	cluster of contacts	Possible wreck site
S_0413	544995	5819792	4.6	4.1	1.2		
S_0679	553839	5842543	7.2	1.0	0.4	linear contact amidst cluster of contacts	Possible buried wreck
NCN2056	540645	5828700	63.0	9.6	3.0	Wreck DHY 2247. Duikteam Zeester: Biaritz, sunk 1940	Wreck Biaritz
NCN2064	540162	5829452	87.0	20.0	3.4	Wreck DHY 2256. Duikteam Zeester: SS Paris, sunk 1939	Wreck SS Paris
NCN2091	551689	5838477	28.0	9.0	1.8	Distributed remains of wreck DHY 2284	Wreck
NCN2098	554783	5842860	0.0	0.0	0.0	Wreck DHY 2292. Duikteam Zeester: Boezemwrak close to platform	No visible contacts, sandwave, mag. anomaly 2031 nT
NCN2250	548149	5832487	31.0	10.0	1.1	Wreck DHY 2468. Unknown wreck reported 1984	Wreck
NCN2469	555444	5845242	29.0	8.0	3.4	Wreck debris	Wreck, partly buried
NCN2809	554440	5845409	28.0	7.0	0.4	Wreck DHY 3427. Unknown wreck reported with sonar 1997	Possible wreck

Magnetic anomalies

A total of 2450 magnetic anomalies have been observed. 674 of these anomalies can be related to known pipelines or cables. 10 anomalies can be related to *sidescan sonar* contacts.

A total of 1750 magnetic anomalies cannot be related to known pipelines and cables, or visible objects at the seabed surface. The anomalies are related to unknown ferrous objects buried in the seabed, covered by sediments. 107 of these anomalies have an amplitude of 50 nT or more. An overview is presented in the figure below.



Prehistoric remains

Major part of the *Pleistocene* landscapes appear to have eroded during the Early *Holocene* marine ingression and development of an intertital area, thus affecting the integrity of possible prehistoric settlements. Locally the geological units defined as potential containers of prehistoric remains might have been preserved intact.

Areas of potential archaeological interest are:

- the shores of small streams and aeolian dunes of the Boxtel Formation proximate to the valley, especially if those areas are cover by peat or clay;
- ice-pushed deposits along within zone bordering the glacial valley edge;
- small basin infills of the Brown Bank Member.

The physical quality, that is the integrity and preservation of prehistoric remains is highly dependent on the extent to which archaeological levels have been affected by erosion. The interpretation of lithostratigraphic units and the character of the layer boundaries (erosive versus non-erosive) from the seismic data is based on the geological data available and expert judgement. The seismic interpretation shall be ground-truthed by a combination of cone penetration tests and borehole sampling. The actual geological sequences present in the area and the integrity of layer bounderies will be verified, thus offering a tool to further for prehistoric landcapes and specify and test the archaeological potential.

Recommendations

As long as the value of the 22 sites of potential archaeological interest has not been determined, it is advised not to conduct seabed disturbing activities within an area of 100 meters around these sites. This advice also applies to cable trenching and anchorages of work vessels. The 22 sites included 8 locations with newly found exposed objects and 14 known NCN wreck sites (7 found and 7 presumably buried).

Concerning the buried ferrous objects, it is advised to avoid these locations including a buffer zone of 100 meters areas whilst installing wind turbines and the various inner field and export cables. It should be stressed that the origin of the magnetic anomalies is unknown and apart from possible archaeological remains any type of man-made objects can be encountered including unexploded ammunition, anchors, pieces of chains and cables, debris, etcetera.

The buffer zone of 100 meters is a standard that applies to the protection of cultural heritage, this distance may be reduced if it can be substantiated that the applied disturbance has no effect on the archaeological object. For example, when no anchoring is used during cable lay operations the buffer zone can be decreased. Reduction of the distance has to be approved by Rijkswaterstaat (RWS). Rijkswaterstaat is the enforcing authority, acting on behalf of the Ministry of Economic Affairs and Climate Policy. The Cultural Heritage Agency of the Netherlands (RCE) acts as an advisor to Rijkswaterstaat.

If it is not feasible to avoid the reported *magnetometer* locations, additional research is required in order to determine the actual archaeological value of the reported locations. It is advised that the UXO research within 100 meter of the *magnetometer* anomalies are carried out under archaeological supervision. Depending on the outcome of the UXO research it can be decided if additional research (for instance by means of ROV or dive investigations) is needed. If the UXO research indicates that the object has no archaeological value, the location can be omitted.

Prehistory

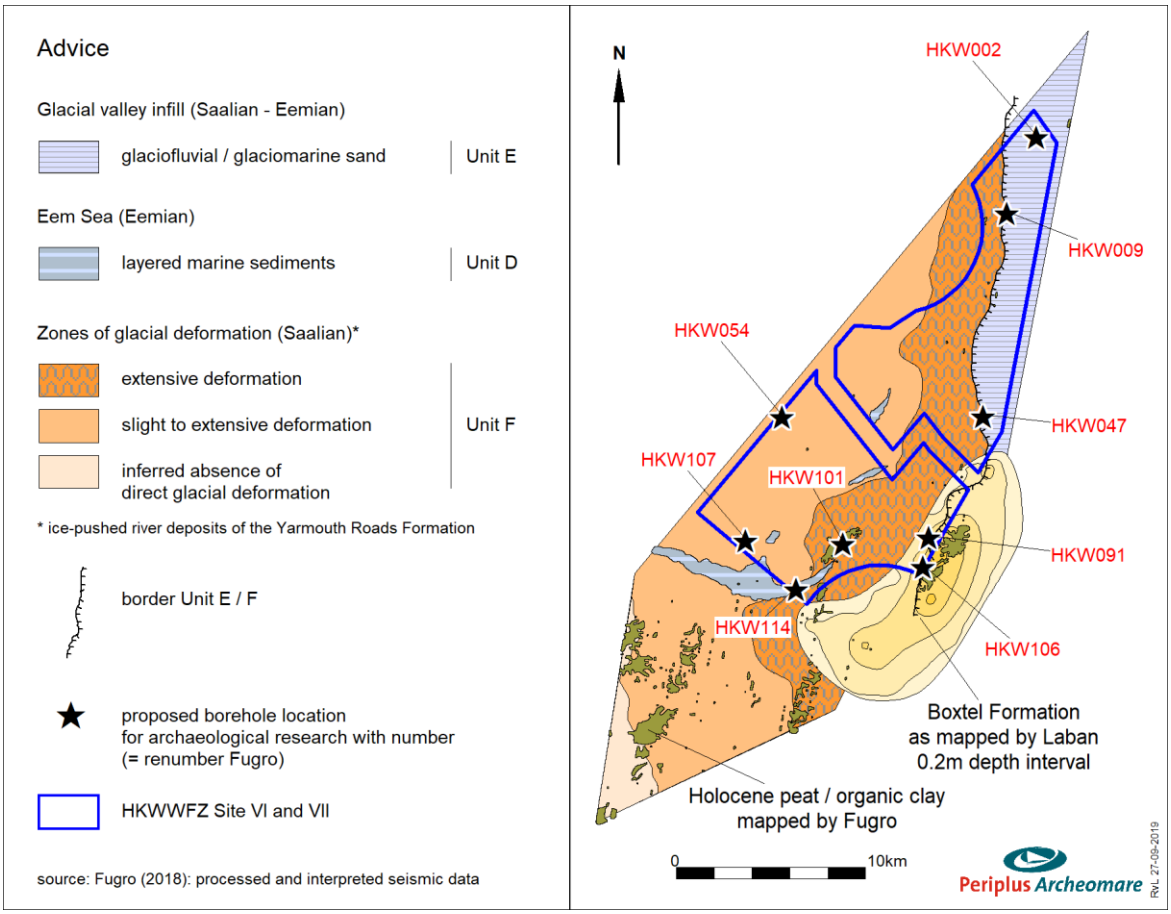
Based on the results and conclusions of the current research, we recommend to conduct further archaeological research that focuses on the genesis and integrity of paleo landscapes in the HKWWFZ. This research comprises an inventory of field research by means of borehole sampling and cone pentration tests (CPT's) in accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1). A geotechnical campaign is carries out to generate a geological model of the subsurface of the windfarm and to determine the physical properties of the sediment layers present. We advise to use the borehole samples and CPT-graphs for geo-archaeological research.

The research primarily focuses on the borehole samples collected at nine locations (see figure below). The samples taken at these locations are expected to provide the information needed to determine the geogenesis of the area and the integrity of the covered paleo landscapes. It is not inconceivable that during the analysis of the sediment samples questions will arise that can only be answered by analyzing borehole samples from other locations. It is therefore important that the samples of all borehole locations in the HKWWFZ are available for geo-archaeological research.

The intact samples must be examined by a (senior) prospector and described in accordance with the *Standaard Boorbeschrijvingsmethode* (SBB). Samples are selected and stabilized to be analyzed by specialists in the field of C-14 dating, micromorphological research, pollen analysis, macro-remains of plants and animals, molluscs, et cetera to gain insight into the development of landscapes over time and the extent to which these paleolandscapes have been preserved.

In accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1), a Program of Requirements (PvE) and / or Plan of Action (PvA) must be drawn up. The PvE/PvA includes the objective, the research strategy and methodology, the frameworks and the practical implementation of the research, so that the process runs smoothly and multiple use of the data acquired in a uniform manner is achieved. It is advised to submit this PvE / PvA for approval to the Competent Authorities and the RCE.

After completion of the inventory field research, during the construction of the wind farm, data can be collected that - from an archaeological point of view - provide valuable information at a detailed level. It can be very useful to investigate this information further from an archeological point of view. It is advised to investigate the possibilities for this in consultation with the RCE, once the plans have been worked out.


Advice
Glacial valley infill (Saalian - Eemian)
glaciofluvial / glaciomarine sand
Unit E
Eem Sea (Eemian)
layered marine sediments
Unit D
Zones of glacial deformation (Saalian)*
extensive deformation
slight to extensive deformation
inferred absence of direct glacial deformation
Unit F
* ice-pushed river deposits of the Yarmouth Roads Formation
border Unit E / F
proposed borehole location for archaeological research with number (= renumber Fugro)
HKWWFZ Site VI and VII
source: Fugro (2018): processed and interpreted seismic data
N
HKW002
HKW009
HKW054
HKW047
HKW107
HKW101
HKW091
HKW114
HKW106
Boxtel Formation as mapped by Laban 0.2m depth interval
Holocene peat / organic clay mapped by Fugro
0
10km
Periplus Archeomare
RvL 27-09-2019

Renumber	PPA	Easting	Northing	Z mLAT
HKW002	possible Echteld (*Holocene*) channel feature from 1.1-7.4m depth.	558511	5850094	27.7
HKW009	proximate to glacial valley edge. interesting age dating profile according to RVO/FUGRO	556935	5846086	28.8
HKW047	Saalian valley; infill = Saalian, Eemian, *Holocene*?; proximate to edge (28m); underlying ice-pushed deposits	555680	5835338	26.6
HKW054	small *Holocene* channel incission	545071	5835320	28.2
HKW091*	within Laban bx 0.4m; near valley edge (220m); no peat mapped	552817	5828953	29.5
HKW101	possible brb; edge of *Holocene* channel infill; peat and/or organic clay	548290	5828597	27.0
HKW106	within Laban bx 0.6m; at valley edge (70m); no peat mapped	552522	5827385	29.1
HKW107	instead of PPA proposed location no 5; ice-pushed deposits; layered infill depression with brb (10m)	543126	5828766	29.5
HKW114	ee (<10m) brb (appr. 3m) na (?) brb (5-10m)	545801	5826218	27.6

*Note: It is advised to move this location to 553226E; 5828876N to include *Holocene* peat/organic clay and thin layer of glacial valley infill; this location is at the cross point of 2D545 and 2X598

Short summary

In summary it is concluded that the windpark owner shall take into account:

- 14 known NCN wrecks of possible archaeological value found exposed at the seabed (7) or (possibly) covered by sediments (7);
- 8 new sites with remains of possible archaeological value found exposed at the seabed;
- 107 buried iron-bearing objects of possible archaeological value (magnetic anomalies > 50 nT);
- 9 proposed borehole sampling locations to investigate the presence, integrity and preservation of stacked prehistoric landscapes.

Short Recommendation

It is adviced to maintain a 100m zone as Area to be Avoided around the 129 locations of possible archaeological interest.

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

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1 Introduction

1.1 Location

RVO.nl has contracted Periplus Archeomare B.V. to conduct an Archaeological assessment of geophysical survey results of the Wind Farm Zone (WFZ) Hollandse Kust (west) (HKW).

The area of investigation (349 km^2) is located in the North Sea, 51 km off the coast of Petten. Within the HKWWFZ two interim sites have been designated: Site VI (90 km^2) and Site VII (87 km^2).

Figure 1. Location map of area of investigation

1.2 Background[1]

The Netherlands has formulated ambitious objectives for reducing CO2 emissions, and related to that, producing sustainable energy. The 2013 Energy Agreement for Sustainable Growth contains major steps in realizing these objectives. The following Energy Report, Energy Dialogue and Energy Agenda form the

[1] Source: C.J.R. van der Hout, 2019: Conceptnotitie reikwijdte en detailniveau kavels VI en VII windenergiegebied Hollandse Kust (west).

basis for the longer term energy policy, towards 2050. Offshore wind energy plays a prominent role in this policy.

The Offshore Wind Energy Act gives the government the option to designate sites for the development of wind farms at sea. In line with the policy intentions of the Road Map 2023 sites have been designated within the Offshore Wind Energy Zones Borssele, Hollandse Kust (zuid) and Hollandse Kust (noord). When commissioning wind farms within these sites the target of 4.5 gigawatts (GW) of wind energy from sea in 2023 as defined in the Energy agreement, is met.

The Road Map 2030 outlines, in line with the Energy Agenda, the further development of offshore wind energy for the period up to 2030. In line with the Road Map 2030 a target production of at least 49 TWh in 2030 has been defined in the draft Climate Agreement. The Road Map 2030 provides for a capacity of 6.1 GW up to and including 2030, in addition to the capacity of the existing wind farms (1 GW) and the wind farms that conform to the first road map by 2023 (3.5 GW). For this purpose new sites should be established in the coming years. The sites are set within the limits of the already designated as wind energy areas in the National Water Plan.[2] It concerns successively 1.4 GW in the area Hollandse Kust (west), 0.7 GW in the area North of the West Frisian Islands, and approximately 4 GW in the area IJmuiden Ver.

From October 2018 to February 2019 Fugro Neherlands Marine B.V. (Fugro) conducted a geophysical survey to improve the bathymetrical, morphological and geological understanding of the Wind Farm Sites at HKW. The geophysical results will be used together with the geotechnical results to create a ground model. The ground model will serve as the base for the design and installation requirements.[3]

In the Erfgoedwet[4] the protection of the archaeological heritage is embedded. Planned activities, such as the installation of a wind farm in the North Sea, may affect the archaeological values if present. If the remains are in jeopardy there is a statutory obligation to conduct archaeological research. In line with this obligation an archaeological desk study has been carried out.

An archaeological desk study is the first step in the so-called *AMZ* cycle (Archeologische Monumenten Zorg). The *AMZ* cycle includes a description of procedures for subsequent phases of archaeological research to be performed in order to ensure the protection of archaeological heritage in the Netherlands.

The second phase of the *AMZ* cycle is an inventory archaeological field study. As a rule this field study comprises a geophysical survey of the sea bed. The survey executed by Fugro was not primarily set to provide data to be used in the course of archaeological research. However, a scan of the survey data acquired, prove these data to be fit for an archaeological assessment.

The separate phases of the AMZ-cycle are embedded in the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1). This standard dictates a mandatory workflow for archaeologists. A detailed description of the different phases of archaeological research is included in appendix 4.

[2] National Water Plan 2016 – 2021.

[3] Nieboer 2016.

[4] De Erfgoedwet became effective on the 1st of July 2016.

1.3 Results desk study[5]

In October 2018 an archaeological desk study has resulted in specific information on the archaeological remains which are to be expected within the HKW WFZ. The results of the desk study will discussed below.

The study has shown that (remains of) ship wrecks, WWII plane wrecks and prehistoric remains are to be expected in the area.

Shipwrecks

A (maximum) total of 23 shipwrecks is known in the area (see figure 2). It is possible that some of these object entries are duplicates. Six ship wrecks and a submarine have been identified. Four of the ship wrecks are recent and have no archaeological value, two ship wrecks and the submarine do have an archaeological value. For the other sixteen wreck reportings, 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 of the wrecks and assess whether undiscovered shipwrecks are present.

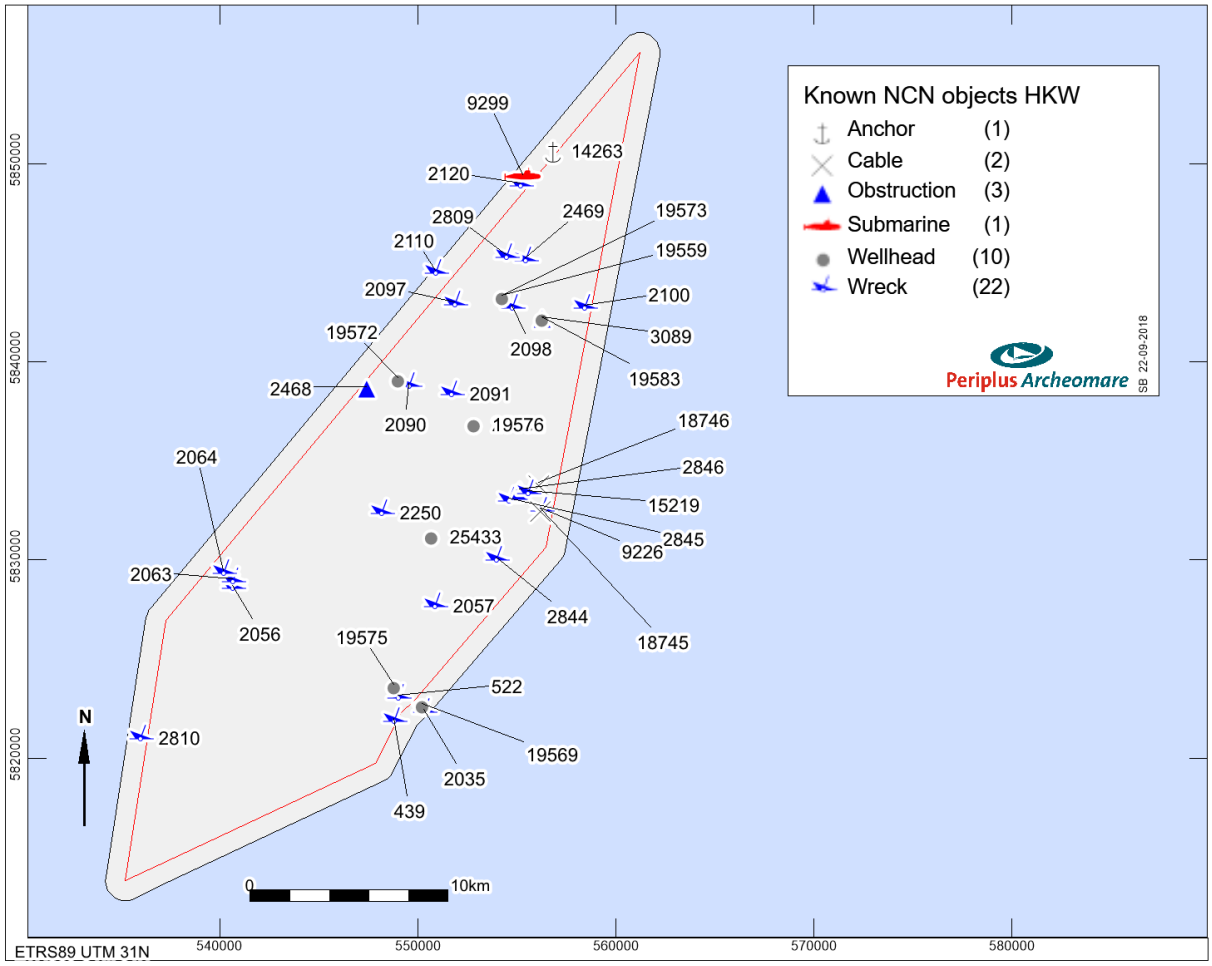

Figure 2. Overview of known objects and contacts in the area of investigation[6]

[5] Van den Brenk 2018.

[6] Van den Brenk 2018.

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 regularly by fishermen or during sand extraction. In the vicinity of the area of investigation, no locations of plane wrecks are known, but it is quite possible to expect plane wrecks within the area of investigation.

Prehistory

Locally *in situ* remains of prehistoric camp sites might be present. Remains of *in situ* Paleolithic and Early Mesolithic camp sites are expected within the context of the following lithostratigraphic units:

Boxtel Formation (Late Paleolithic and Mesolithic)

Late Paleolithic and Mesolithic camp sites and inhumations can occur in the cover sand dunes and ridges (top of Wierden Member and embedded Usselo Bed), and along the valleys of small streams (Singraven Member). The covering Basal Peat Bed and Velsen Bed can contain well-preserved lost objects, intentional depots and dumps.

Brown Bank Member

Remains of Neanderthal camp sites can be expected along the shores of fresh water lakes and beaches of lagoons which developed at the transition from Eemian to Weichselian. The sediments (clay and sand) are part of the Brown Bank Member. Within the peat of the covering Woudenberg Formation well-preserved lost objects, intentional depots and dumps can be encountered.

Ice-pushed ridge

The ice-pushed river sands of the Yarmouth Roads Formation can contain reworked flint artefacts from Lower and Middle Paleolithic times. At the top of the ice-pushed ridge in situ remains of camp sites and inhumations of Neanderthal and Late Paleolithic and Mesolithic hunters and gatherers can be expected. The ice-pushed ridge pre-dates the above-mentioned Eemian, Weichselian and Early *Holocene* deposits.

All archaeological levels of interest are located under a < 1 meter to 17 meter cover of *Holocene* deposits of the Bligh Bank Member possibly preceded by the Naaldwijk Formation.

At this stage little is known about the integrity of the *Pleistocene* landscape. By means of subbottom profiling the occurrence of geological units (both horizontal as vertical) and archaeological levels herein can be mapped. The character of layer boundaries (erosive or non-erosive) can be interpreted. 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. This applies to all the above mentioned archaeological levels (Ice-pushed ridge, Brown Bank Member and Boxtel Formation). At this stage focus should therefore not be put on tracing prehistoric camp sites but on a pragmatic employment of geophysical techniques in order to obtain a better insight in (the integrity of) the *Pleistocene* landscape. The insights gained shall be used to a) refine the archaeological expectancy model and b) allocate areas with a high expectancy for *in situ* prehistoric remains.

The lithostratigraphic units in which and the depth below the seabed at which archaeological remains are to be expected is summarized in the table below.

Formation	Member / Bed	Lithology	Age	Arch. Expectancy*	Period
Southern Bight	Bligh bank	sand	Holocene	I, IV	Historical periods
Naaldwijk	Wormer	clay and sand		I	
	Velsen	humic clay	Early Holocene	II	Mesolithic
Nieuwkoop	Basal Peat	peat		II	
Boxtel	Singraven	sand, loam, clay and peat	Weichselian and Early Holocene	II and III	Late Paleolithic and Mesolithic
	Wierden	fine sand		III	
Woudenberg		peat	Eemian and Early Weichselian	II	Middle Paleolithic
Eem	Brown Bank	humic clay and silt	Eemian and Early Weichselian	II and III	Middle Paleolithic
		sand and clay	Eemian	IV	
Yarmouth Roads (ice-pushed)		sand and clay	Pre-Saalian and Saalian (ice-push event)	II, III and IV	Early Paleolithic to Mesolithic
Drente	Uitdam	sand, silt and clay	Saalian	II and III	Middle Paleolithic
	Schaarsbergen	sand		II	
	Gieten	gravelly clay, loam, and sand with cobbles and boulders		III	

Table 3. Classification of archaeological expectancy

In 2016, Deltares published a map describing the archaeological expectancy for prehistoric remains and settlements in the Dutch EEZ[7]. The expectancy within the HKW sites matches the results from the desk study.

[7] Vonhögen – Peeters 2016.

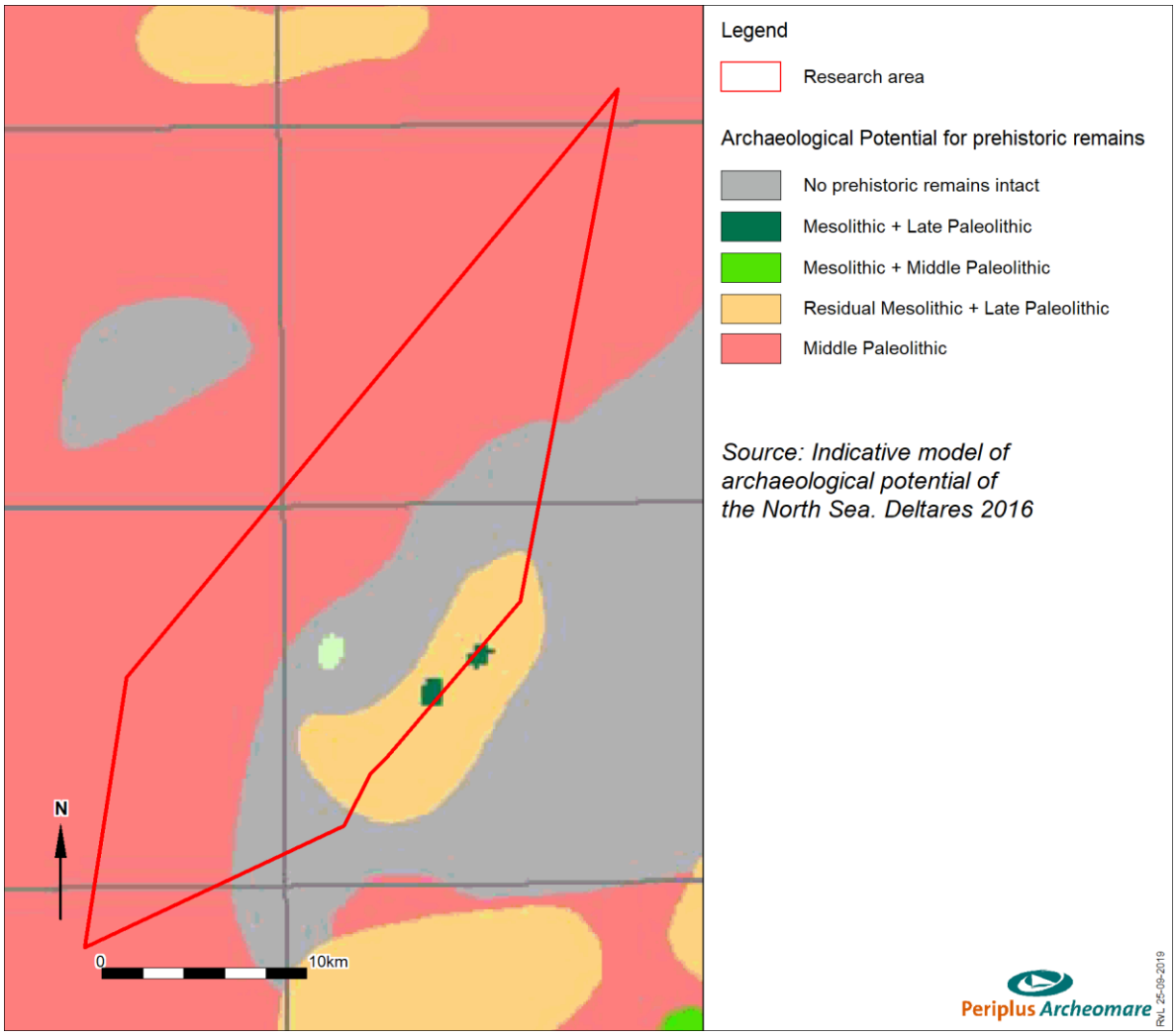

Figure 3. Archaeological potential for prehistoric remains (Deltares 2016)

1.4 Objective

The purpose of the archaeological assessment is to test the desk study based expectancy for archaeological remains in the area. The expectancy covers remains of shipping related objects (wrecks), airplanes from World War II and prehistoric settlements.

The goals set for this assessment are:

- To determine the historical or archaeological value of contacts found in the geophysical survey;
- The validate the locations of known wrecks;
- Assess the prehistoric landscape based on the seismic data.

1.5 Research questions

For the inventory archaeological field study, the following research questions have been defined in the Program of Requirements: [8]

primary question:

Are any archaeological remains present within the Area of Interest and to what extent are these remains traceable?

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

Are there any phenomena visible on the seabed?

If so:

What is the description of these phenomena?

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

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

What classification can be attached?

If these phenomena can be classified as archaeological:

Is it possible to interpret the nature of the archaeological objects?

If these phenomena can be identified as natural:

What is the nature of these natural phenomena?

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

If so:

How can these zones be interpreted?

General:

What is the relation between the observed objects and the topography of the seabed? Based on this relationship can risk-prone areas be marked selectively? Risk-prone areas are areas where the probability of archaeological remains is considered to be high. The risk involves both the degradation

[8] Van den Brenk and van Lil, 2018.

of archaeological remains by the development of the wind farm as the risks in terms of costs, progress and image of the wind energy project itself because of the presence of archaeological remains and the measures to be taken accordingly.

If no acoustic phenomena can be observed:

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

With respect to subbottom profiler- and sampling:

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

If so:

*Can the expected buried Pleistocene units / landscapes be identified in the seismic data?**

What is the depth of the Pleistocene landscapes with respect to the present seabed?

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

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

If so:

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

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

If so:

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

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

Additional questions have been formulated after consultation with RvO.nl, the Cultural Heritage Agency and the Ministry of Economic Affairs and Climate Policy. Those question are not included in the Program of Requirements.

The following questions have been asked:

Can Early Holocene clayey and peaty deposits be distinghuished as separate unit(s) in the seismic data?

If so:

What is the seismic character, thickness and spacial distribution of the Early Holocene unit(s)?

Can the Wormer Member, Velsen Bed and/or the Basal Peat Bed be identified?

Is the top of the underlying Pleistocene sequence intact?

If so:

In which part(s) of the area is the top of the pleistocene sequence expected to be intact?

Do the seismic profiles show indicatations for the presence of ice-pushed ridges?

If so:

What is the seismic character and spacial distribution of the ice-pushed ridge(s)?

Is the top of the ice-pushed ridge(s) intact?

If so:

In which part of the area is the top of the ice-pushed ridge(s) expected to be intact?

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2 Methodology

2.1 Introduction

As part of the installation of wind farm related infrastructure (monopiles, cables, power station, etc.) a geophysical survey has been carried out by Fugro. The objectives and the general outcome of the survey activities including the minimum technical, functional and procedural requirements are described in the survey report.[9]

The following methods have been deployed:

- sidescan sonar (Edgetech 4200-FS dual frequency 520-573 Khz. / 115-130 Khz.
- single beam echo sounder (SBES)
- A Geometrics G-882 magnetometer (MAG)
- multibeam echo sounder (Kongsberg EM2040 hull mounted MBES 400 kHz.)
- sub-bottom profiler; pinger TR-1075, 7 kHz. (SBP)
- ultra high resolution seismic; sparker (UHR)

The results of the survey and geotechnical activities have been recorded in reports, listings, drawings and images. The input for the archaeological assessment consists of the deliverables listed in table 4.

SSS	- XTF-files of all side scan records - event listings containing all contacts observed - geotiffs of all contacts listed
MAG	- event listings containing all anomalies observed
MBES	- validated *multibeam* XYZ point cloud dataset (grid 25x25cm)
SBP/UHR	- representative subbottom profiles
Report	- survey reports

Table 4. Data used for the archaeological assessment

2.2 Geophysical survey

The geophysical survey was carried out by two vessels, MV Fugro Pioneer, from 10 October 2018 to 16 February 2019, and MV Fugro Frontier, from 22 October 2018 to 17 February 2019.

The MV Fugro Frontier was used for all the shallow geophysical operations, acquiring data using Sidescan Sonar (SSS), Magnetometer (MAG), Multi Beam Echo Sounder (MBES), Sub-Bottom Profiler (SBP), Single Channel Seismic (SCS). The MV Fugro Pioneer carried out the ultra-high resolution Multi Channel Seismic (MCS) acquisition.

For all lines the *multibeam*, *sidescan sonar*, *subbottom profiler* and magnetometer were used simultaneously with a line spacing of 100 m and cross lines 2000m. Multichannel seismic survey UHR data were acquired with a line spacing of 400 m for the main lines and cross lines.

[9] Fugro April 2019

2.3 Known objects

Fugro has summarized the *sidescan sonar* contacts and *magnetometer* anomalies encountered within the survey area in detailed event listings. From different databases the occurrence of objects within the area is known, as described in the desk study[10]. The contacts included in the survey event listings are compared with the database objects in the area. For this comparison four different datasets are used:

- The Hydrographic Service database (hereafter referred to as Nlhono database);
- The Rijkswaterstaat SonarReg database (hereafter referred to SR database);
- The Dutch Cultural Heritage Agency database ARCHIS;
- The Dutch Nationaal Contact Nummer database (hereafter referred to as NCN);

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 SonarReg 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).

The NCN database contains all basic information (E, N and description) of the Nlhono, SR and Archis databases. More detailed information is gathered through the other datasets.

In addition to ship wrecks information on contacts referred to as 'foul' or 'obstruction' is included. From these objects the origin is not always known, but information on the location, dimensions and other valuable information is listed. Besides the databases other sources containing information on wrecks and historic finds are consulted for comparison with the survey results.

All known data is combined and plotted in a GIS. In this way an overview is made of the areas in which archaeological remains are present or to be expected. The known contacts are a reference framework for the assessment of data recorded during the route survey.

[10] Van den Brenk et al, 2018

2.4 Archaeological assessment of survey data

The geophysical and hydrographic survey techniques employed include *sidescan sonar* (SSS), *magnetometer* (MAG), *multibeam* (MBES), subbottom profiling (SBP) and ultra-high resolution multi channel seismic (MCS). The natures of those methods differ, with coherent strengths and weaknesses.

Table 5 provides a summary of the objective(s) the methods employed and the nature of those methods in terms of seabed penetration and coverage. Data are cross-correlated because the methods are complementary. E.g. *multibeam* data can aid in the interpretation of a *sidescan sonar* contact by providing information on its height with respect to the surrounding seabed, the occurrence of scouring next to the contact, and the accuracy and precision of the object. CPT's and borehole data can aid in the determination of geological units from seismic strata.

Method	**Objective**	**Seabed**		**Accuracy and Precision**	**Cross Correlation**
		Penetration	**Coverage**		
SSS	Identification of outcropping objects; seabed classification	No	Full	High	MBES / MAG
MBES	Charting of seabed morphology; identification of scours	No	Full	Very high	SSS
MAG	Identification of magnetic anomalies induced by ferromagnetic objects	Yes*1	Full*2	Accuracy = high Precision = poor*3	SSS
SBP/UHR	Identification of seismic strata and buried objects such as pipelines, cables and boulders	Yes	No Profile data beneath sailed line	High	BH/VC/CPT*4 MAG
BH/VC	Determination physical properties of sediments and lithostratigraphy	Yes, up to 60 to 80m beneath the seabed	No Point location	High	CPT/ SBP/UHR
CPT	Determination of physical properties of sediments and lithostratigraphy	Yes, up to 50 to 80 m beneath the seabed	No Point location	High	BH/VC/ SBP/UHR

Table 5. Characteristics of geophysical and geotechnical methods employed

*1 detection dependent on size of the ferromagnetic object, depth of burial, height of *magnetometer* above the seabed and distance cross course

*2 distant and/or deeply buried objects can be missed.

*3 precision: perpendicular to ship heading = ½ * spacing of sailed lines
parallel to ship heading = appr. 1m

*4 interpretation of geology through correlation of seismic data with BH/VC/CPT-data

With *sidescan sonar* all objects and structures on the seabed can be made visible. Seabed sediment of different composition can be distinguished by their characteristic reflection. *Multibeam* images reveal the morphology of the seabed. Large objects and scouring can be mapped. Smaller objects, like thin cables, or flat objects lying on the seabed often are impossible to identify in *multibeam* images.

The strength of *sidescan sonar* resides in the ability to visualize differences in reflectivity of seabed sediments and exposed objects. Variations in seabed composition cannot be observed in *multibeam* data, unless those variations are accompanied by morphological changes. This also applies for objects which are barely elevated above the seabed. Another strength of *sidescan sonar* is full coverage is accomplished with a limited of survey lines. A limitation of *sidescan sonar* buried objects cannot be found with this technique.

The strength of *multibeam* lies in the high accuracy and high precision images of the seabed morphology the technique provides. Sand waves and current ripples can clearly be observed in *sidescan sonar* data, but can the height of those sedimentary structures can far better be established by means of *multibeam*. However buried objects generally cannot not be traced with *multibeam*, scours caused by shallowly buried objects can lead to the identification of buried objects.

In this study *sidescan sonar* and *multibeam* data were combined in the identification of objects which are of potential archaeological interest. The listing of potential archeological objects is considered to be complete as far as it concerns exposed objects, although the presence of buried non-ferro-magnetic archaeological objects or objects which erroneously have been labeled as non-archaeological, can never be fully excluded.

Magnetometer contacts are identified by the presence of ferro-metalic objects which induce an anomaly in the earth magnetic field. These objects can be buried or lying on the seabed. Unlike *sidescan sonar* and *multibeam* the contacts are tagged at the sailed survey line. The actual object can be located at both sides of the survey line. Given the 100 meter spacing of the run lines the precision perpendicular to the line is in the order of 50 meter. The precision parallel to the run line is in the order of one meter.

The strength of a *magnetometer* lies in its ability to trace buried objects, if those objects are ferro-magnetic. The technique provides a strong tool in mapping continuous linear structures like buried cables and pipelines. Also an indication of the presence and distribution of isolated ferro-magnetic objects in a area of investigation is obtained.

An important limitation of the *magnetometer* is the poor precision of the positions of the objects found. An object has to be boxed in by sailing additional lines with a *magnetometer* to pinpoint the location of the object. Further, the measured amplitude of a magnetic anomaly is dependent on the interaction of different parameters, such as the size of the object, the depth of burial, the height of the *magnetometer* above the seabed and the distance cross course. Because of this it is very hard to establish the size of the object which caused the anomaly. Thirdly buried objects cannot be seen. Therefore it is not possible to identify the nature of the buried object.

The listing of *magnetometer* anomalies is expected to be complete as far as it concerns large ferro-magnetic objects. As the line spacing employed is 100 meter it cannot be excluded that especially small distant buried objects have been missed.

Fugro processed their survey data and produced detailed event listings of the *sidescan sonar* and *magnetometer* contacts encountered within the survey areas. Alike the known objects the locations of the contacts are plotted in a GIS.

In the course of this archaeological assessment a selection is made based on the dimensions of the reported contacts. All contacts have been assessed, and the fraction of contacts larger than or equal to four (4) meter is looked into in more detail, because these objects are considered to be more likely to be related to wreck sites than the smaller contacts. This choice is based on best professional judgment and not prescribed by legislation or the KNA. Purpose of this analysis is to identify contacts that could reflect potential archaeological sites.

This is done by analyses of:

- *sidescan sonar* images included in the survey reports;
- raw *sidescan sonar* data (XTF-files);
- raw *multibeam*-data (xyz-files);
- values of magnetic anomalies reported in the survey reports;
- comparison of *sidescan sonar* and *magnetometer* contacts;

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

The *sidescan sonar* images are scanned in order to define potential archaeological sites. A selection of contacts was made of contacts to be studied in detail. The interpretation and selection of *sidescan sonar* contacts is based on best professional judgment. If desired or needed the exact nature of the contacts observed can be established with certainty through the execution of additional research by means of a ROV or divers in a following phase.

Fugro has acquired and processed shallow seismic data using a sub-bottom profiler (SBP), a single channel sparker (SPK) and an ultra-high resolution multi-channel sparker (UHR). The processing involved an analysis of seismic profiles which had a line spacing of 100 m for the main lines and 2000 m for the cross lines. Observed seismic strata have been digitized and – based on known geological data from the area – lithostratigraphic units have been identified. The base of each lithostratigraphic unit has been interpolated into a grid. The results have been summarized and reported. In addition to the identification and occurrence of lithostratigraphic units seismic anomalies which are expected to reflect potential hazardous phenomena have been identified.

2.5 Data Analysis

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

For the cross-reference we have assumed that all present possible contacts and anomalies have been reported and described by the survey contractor. Only the raw data is used, when available, to verify the description of found objects and anomalies as reported.

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

Besides the objects detected from the *sidescan sonar* survey also the *magnetometer* contacts were plotted on the high resolution *multibeam* grid. For the *magnetometer* contacts that corresponded with the *sidescan sonar* contacts within 50 meters of each other, these contacts were considered to be related. When at the position of the *magnetometer* anomaly no visible object was recognized the size of the anomaly was leading. If the magnetic anomaly of a contact is more than 50 nT (nano-Tesla) then it is stated that the contact could possibly be of archaeological value. All the *magnetometer* contacts above 50 nT but within 25 meter of the existing cable and pipeline routes are exempt for further investigation. It has to be stressed that within this assessment no distinction can be made between anomalies related to possible archaeological objects or anomalies related to (for example) unexploded ordinance (UXO's).

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

The interpreted seismic data have been assessed in order to test the archaeological expectation with respect to remains of prehistoric settlements in the area. The archaeological desk study has resulted in the identification of lithostratigraphic units which could contain archaeological levels. The grids produced by Fugro have been used to get an insight both the lateral and vertical distribution of the lithostratigraphic units and the expected archeological levels herein. Thus testing the desk study based archaeological expectation. An important factor included in the assessment is the integrity of layer boundaries, because erosion by natural processes poses a significant threat to archaeological levels. Based on the assessment, zones within the wind farm zone which are expected to contain archaeological remains are mapped and presented. The results are reviewed in the context of the activities planned in order to predict possible influence on the potential archaeological remains.

The analysis was executed in May and June 2019 by R. van Lil and S. van den Brenk (both KNA senior prospector). The investigation is carried out according to specifications set up within the Dutch Quality Standard for Archaeology (*KNA Waterbodems 4.1; protocol 4103*).

2.6 Used Sources

The following sources were used for the analysis:

- Survey data Fugro, original survey data and reported interpretations;
- Archaeological desk study Periplus (18A031-01);
- ARCHIS database Cultural Heritage Agency;
- Archeomare Database;
- Nlhono database Hydrographic Service of the Royal Netherlands Navy;
- Wrecksite.eu;
- Database, Nationaal Contact Nummer (NCN).

For a complete list of used sources and literature see the reference list at page 85.

Italic written words are explained in the glossary at page 84.

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3 Results

3.1 Seabed bathymetry and morphology

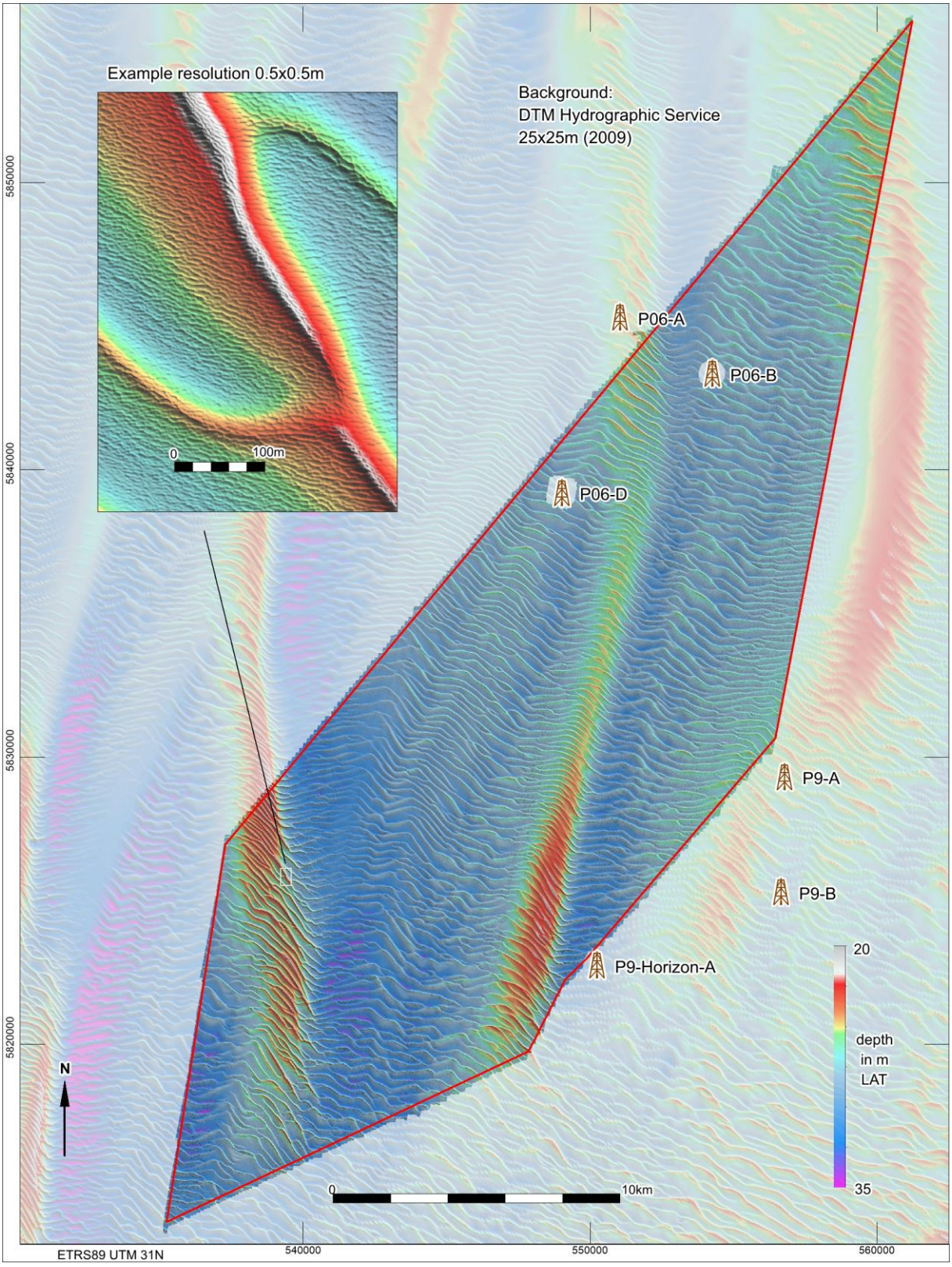


Figure 4. Bathymetry based on the multibeam recordings (source data: Fugro 2019)

Based on the 2019 survey data the water depth within the HKW WFZ varies from 19.1 to 34.4 m, with an average of 28.3m LAT.

Seabed

The seabed is characterized by a complex pattern of bedforms of various orders. Those bedforms include very large ridges[11], sand dunes, megaripples and small ripples. The sand banks are some 2 tot 2.5 km wide and stretch more or less north - south. The sand banks are separated by low-lying areas. The difference in height between the troughs and crests of the sand banks is up to 10 m. The distance between the crests of the two major sand ridges in the HKWWFZ is 10 km.

The sand dunes crests stretch northwest - southeast. The sand dune crests display an undulating pattern inflicted by the ridges and valleys they are superposed on. The wavelength of the sand dunes is varies. The approximate average wavelength ranges from 250 m to 350 m dependent on the ridge or trough they developed on; the height of the dunes ranges from 1 m to 6 m.

Superimposed on the major sand dunes, megaripples with an average wavelength of 15 m are present. The height of the megaripples range from 0.3 m to 0.7 m. Alike the sand dunes the megaripple crests stretch northwest - southeast. The megaripples have not developed on all of the sand dunes.

Each of the morphological features in the area has its typical migration rate. The position of the north-south oriented sand banks are fairly stable. Van der Meulen et al. (2004) reported a migration rate for sand dunes of over 20 m/year near the island of Texel, with typical migration rates decreasing southwards to a stationary (0 – 3 m/year) field near the entrance of the Rotterdam Harbour. Deltares studied the migration rate of sand dunes in the Offshore Wind Farm Prinses Amalia and concluded that the dunes in this area migrate some 4 m/year.[12]

In order to assess the migration rate of sand dunes in the HKWWFZ Fugro compared the *multibeam* data which had been acquired 22 days apart. Within this short period of time a sand dune had migrated 4 m and the shape of the sand dune had altered. The mobility of the seabed of the HKWWFZ appears to be significantly higher than the Offshore Wind Farm Prinses Amalia.

As stated before the megaripples have not been observed in all parts of the area. Fugro has shown that megaripples can evolve from weak developed only 0.1 m high ripples into well-developed and straight-crested megaripples of 0.3 m in height. This morphological change has been observed over a period of only 36 days.

The high mobility of the seabed sediments in the area impart major implications to the prospection of archaeological remains in the area. Especially wrecks remains might be covered by a layer of sandy seabed sediments, because of which the remains are not exposed at the seabed and cannot be traced with *sidescan sonar*. Remains can become exposed at a later stage due to the ongoing migration of the sand dunes.

[11] Hereafter the term 'sand bank' will be used as Fugro did in their survey report P904162, Volume 3.

[12] Fugro survey report P904162, Volume 3.

3.2 Known objects: As Found positions versus database positions

Based on the desk study 39 objects are known within the HKWWFZ. These objects include a (maximum) total of 23 ship wrecks. It is possible that some of these object entries are duplicates (for example: a submarine is listed twice). This is due to differences and overlaps of the different databases.

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

The outcome of this comparison can be:

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

An overview of the As Found- versus Not Found known objects is presented in the next figure.

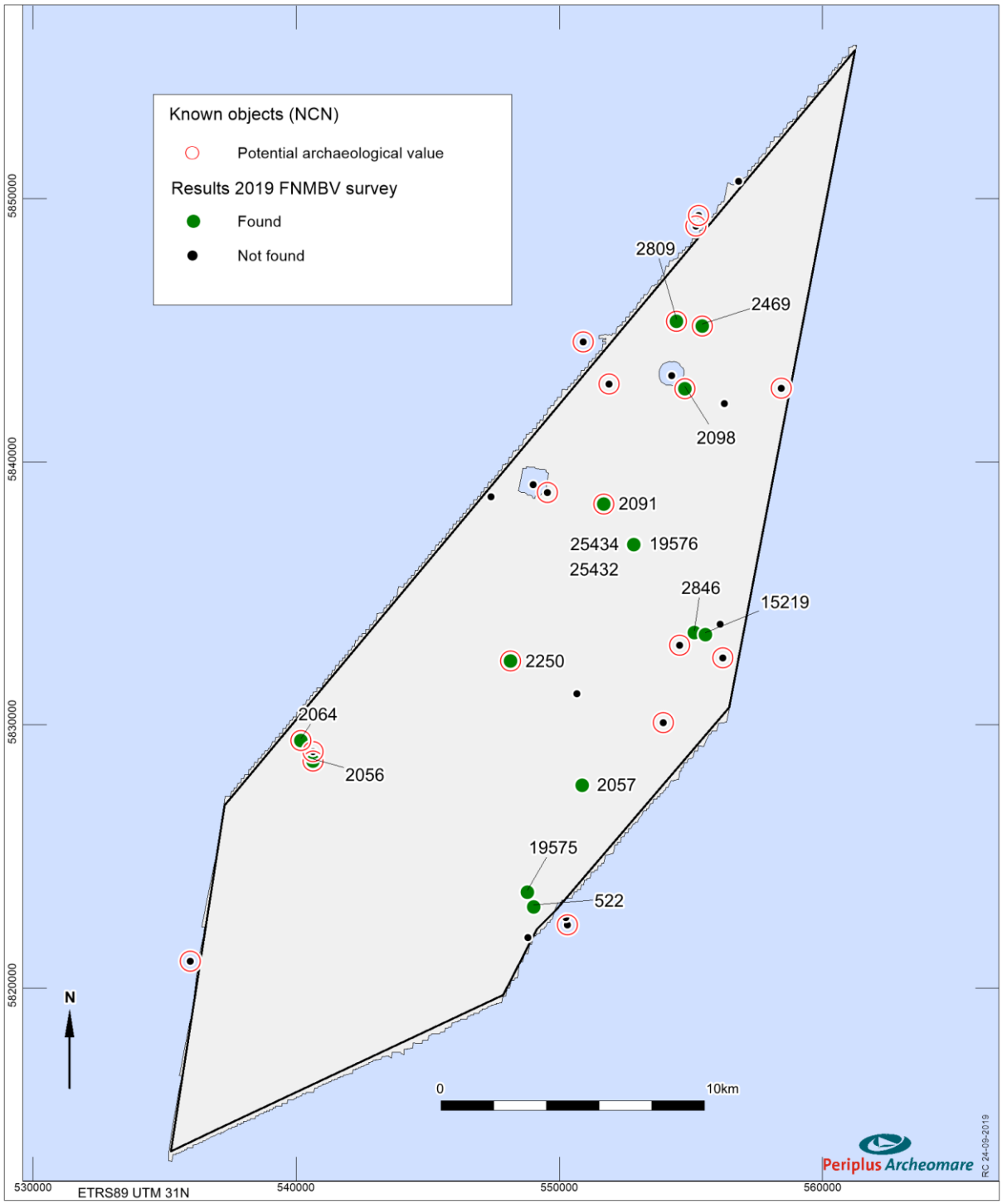


Figure 5. Known objects found or not found during the survey

The detailed results are discussed in the next paragraphs.

NCN found

A total of 15 out of 39 known NCN objects have been found during the survey:

- 10 ship wrecks (23 known)
- 1 obstruction (3 known)
- 4 wellheads (10 known)
- 0 cables (2 known)
- 0 anchors (1 known)

The NCN objects were found by *sidescan sonar/multibeam echosounder* (13) and *magnetometer* (2).

A total of 7 out of the 10 known ship wrecks found are considered to be of possible archaeological value.

	As found				Arch.	Descr.
NCN	**Easting**	**Northing**	**Type_contact**	**Original description**	**Exp.**	**Found**
522	549023	5823155	Wreck	Wreck DHY 522. Duikteam Zeester: Wreck of coastvessel, sunk 1980, standing right up, superstructure is gone, close by platform	No	Wreck
2056	540645	5828700	Wreck	Wreck DHY 2247. Duikteam Zeester: Biaritz, sunk 1940	Yes	Wreck
2057	550864	5827799	Wreck	Wreck DHY 2248. Duikteam Zeester: Wreck Dutch fishingtrawler Stellendam 4, sunk 1969	No	Wreck
2064	540162	5829452	Wreck	Wreck DHY 2256. Duikteam Zeester: SS Paris, sunk 1939	Yes	Wreck
2091	551689	5838477	Wreck	Distributed remains of wreck DHY 2284	Yes	Wreck
2098	554783	5842860	Wreck	Wreck DHY 2292. Duikteam Zeester: Boezemwrak close to platform	Yes	No visible contacts sandwave, large mag. Anomaly 2031 nT
2250	548149	5832487	Wreck	Wreck DHY 2468. Unknown wreck reported 1984	Yes	Wreck
2469	555444	5845242	Wreck	Wreck debris	Yes	Wreck, partly buried
2809	554440	5845409	Wreck	Wreck DHY 3427. Unknown wreck reported with sonar 1997	Yes	Possible wreck
2846	555126	5833574	Obstruction	Manmade object. RWS ROV images available	No	Debris
15219	555515	5833543	Wreck	Norwegian cargo vessel Nordfrakt, sunk 25-10-1992, dimensions 76x12x2m. RWS SR 11968	No	No contacts visible, sandwave, small mag. Anomaly (14nT)
19575	548747	5823697	Wellhead	Wellhead P09-02	No	Wellhead
19576	552785	5836996	Wellhead	Wellhead P06-S-01, same location as NCN 25432	No	Wellhead
25432	552778	5836997	Wellhead	Wellhead P06-S-01	No	Wellhead
25434	552782	5836998	Wellhead	Wellhead P06-10	No	Wellhead

Table 6. Listing of known objects found during the survey

The seven wreck sites of possible archaeological interest are discussed below.

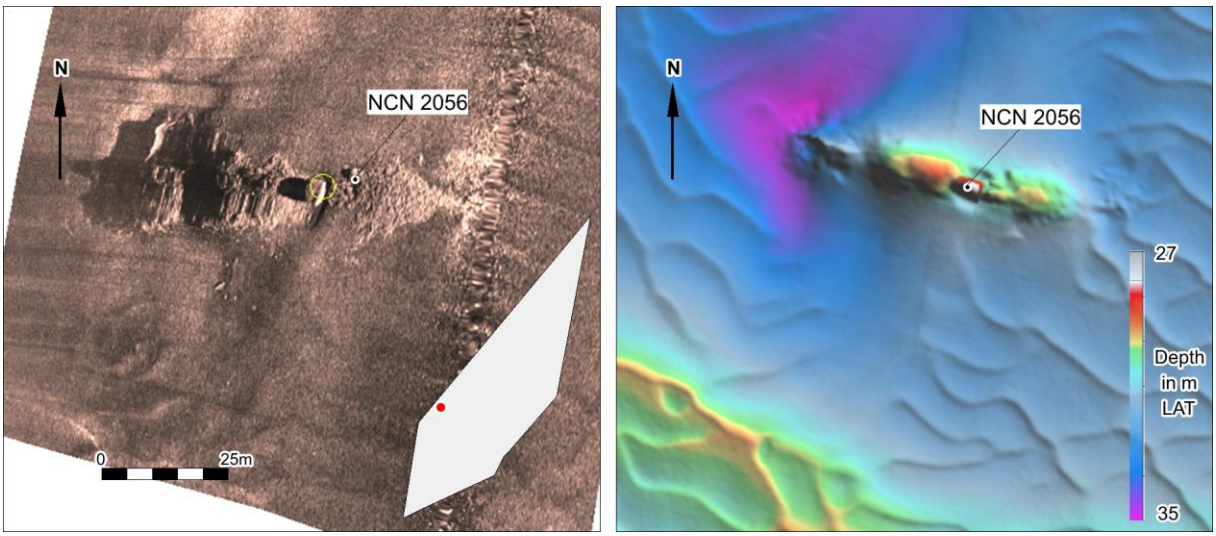


Figure 6. Sidescan sonar and multibeam image of NCN 2056

NCN 2056 has been identified by the Duikteam Zeester as the wreck of the Biaritz. This was a passenger/cargo vessel built for the Fred Olsen line in 1922. It sunk in 1940 because it run over a sea mine or was hit by a torpedo from the German submarine U-14 (there are multiple sources that claimed that one of these caused the ship to sink). The original dimensions (77.9 x 12.1 x 5.2 m) do not completely agree with the visual dimensions on the *multibeam* image (63 x 9.6 x 3.0m), but parts of the wreck may be covered with sediment.

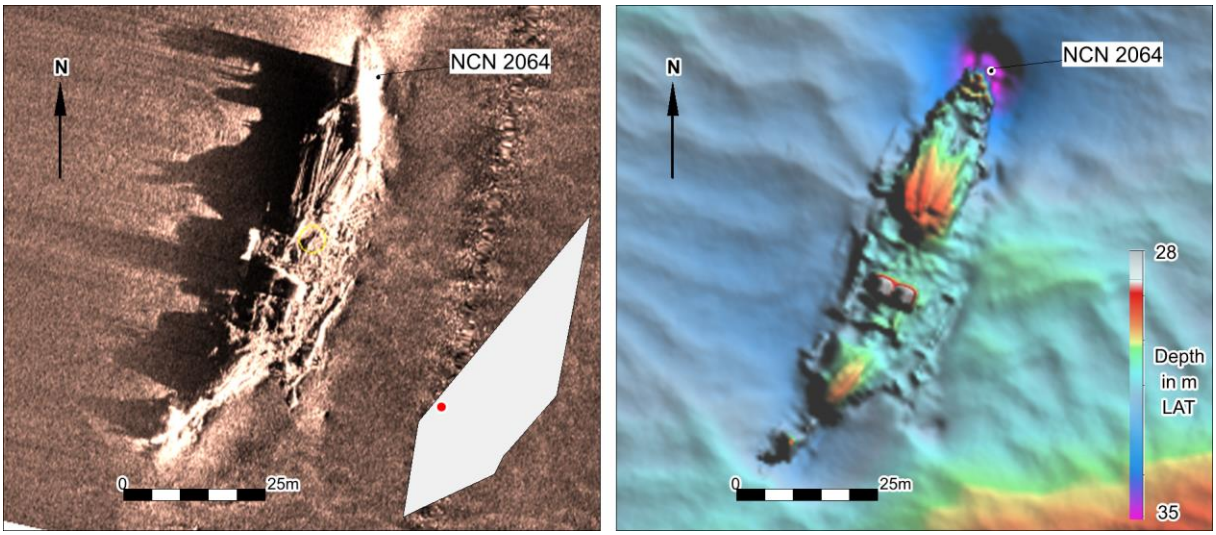


Figure 7. Sidescan sonar and multibeam image of NCN 2064

NCN 2064 represents the site of a which has been identified by the Duikteam Zeester as the wreck of the SS Paris, Fred Olsen line , built in 1922, sunk in 1939 by a mine. The dimensions of the visible part of the wreck are 87 x 20 x 3.4 m.

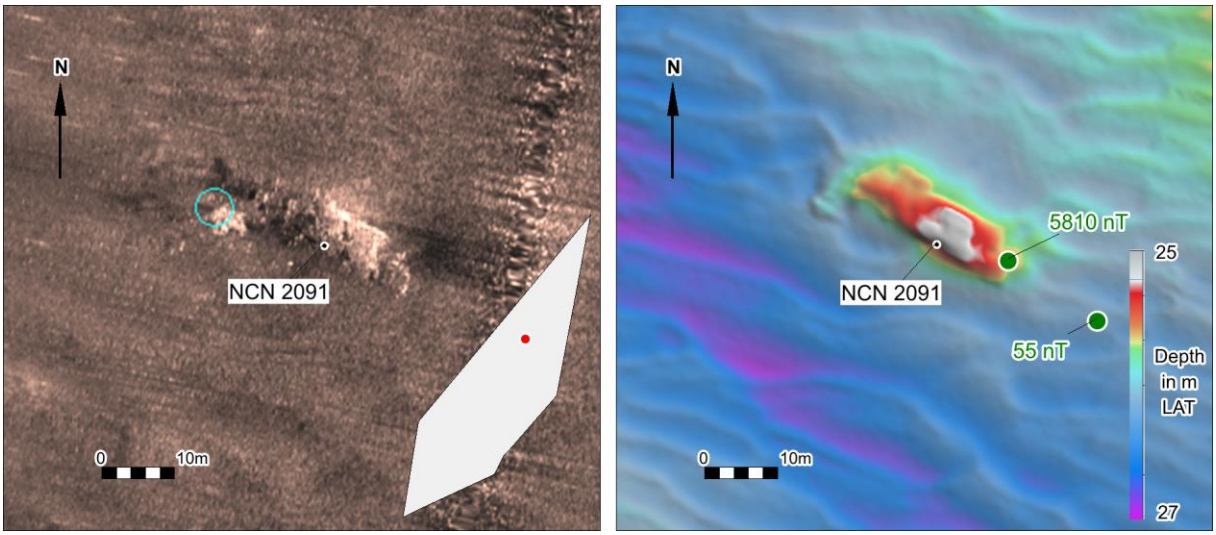


Figure 8. Sidescan sonar and multibeam image of NCN 2091

NCN 2091 are the remains an unknown ship wreck. The wreck dimensions are 28 x 9 x 1.8 m. The wreck remains have induced a magnetic anomaly of 5810 nT and a smaller anomaly of 55 nT.

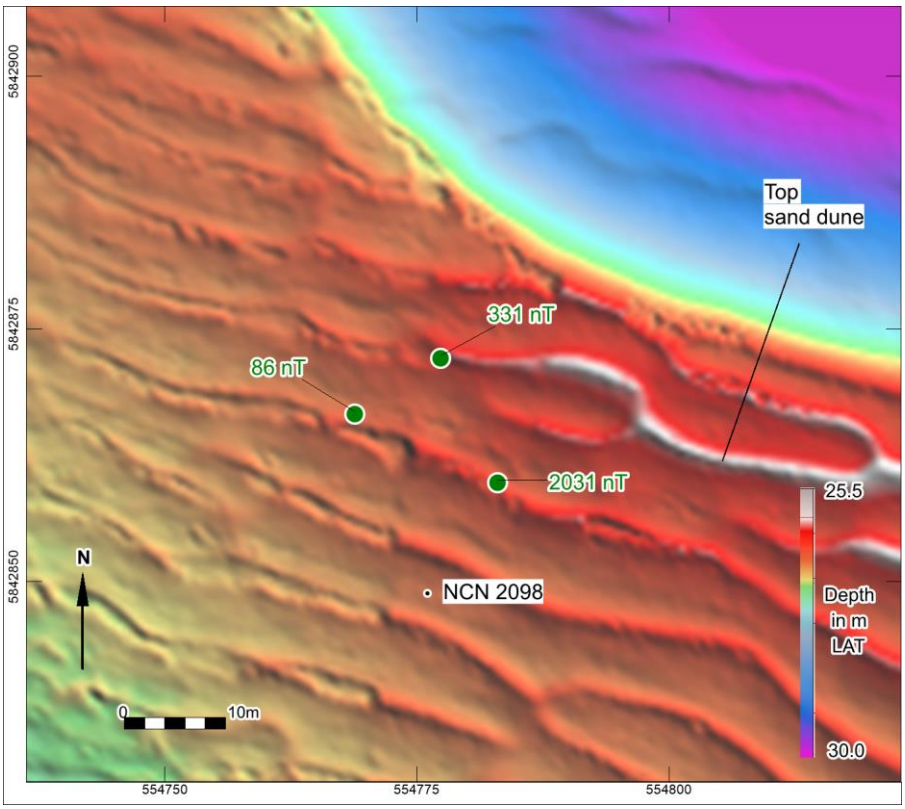


Figure 9. Sidescan sonar and multibeam image of NCN 2098

NCN 2098 presumably is fully covered by a sand dune. The remains of this wreck, which is registered in the database as “Boezemwrak”, have been picked up the *magnetometer* on different survey lines.

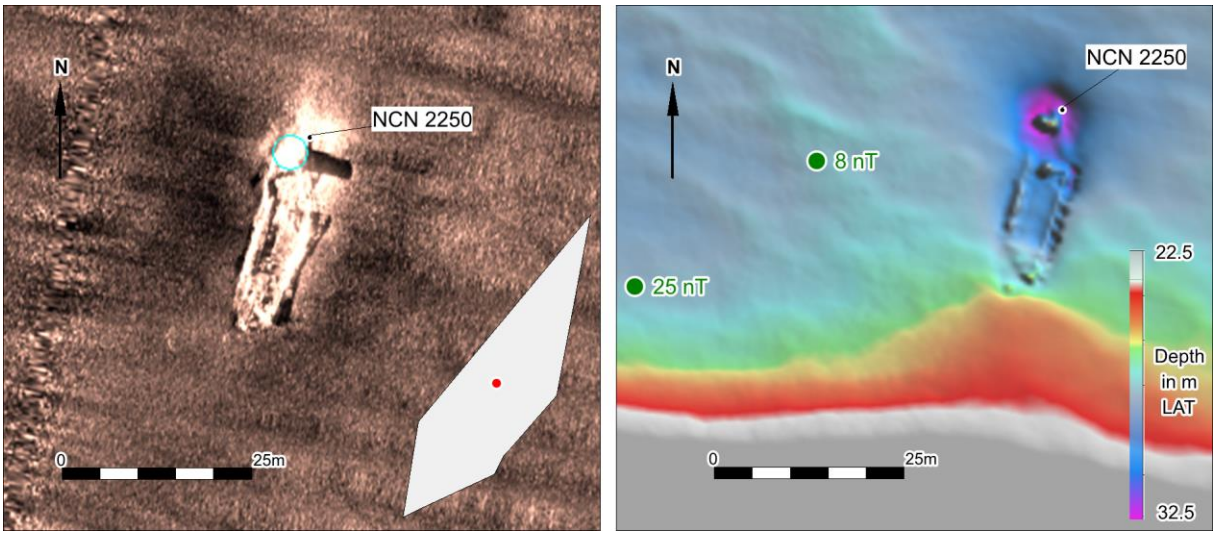


Figure 10. Sidescan sonar and multibeam image of NCN 2250

NCN 2250 are the remains an unknown ship wreck. The wreck dimensions are 31 x 10 x 1.1 m. Two magnetic anomalies of 25 nT and 8 nT.

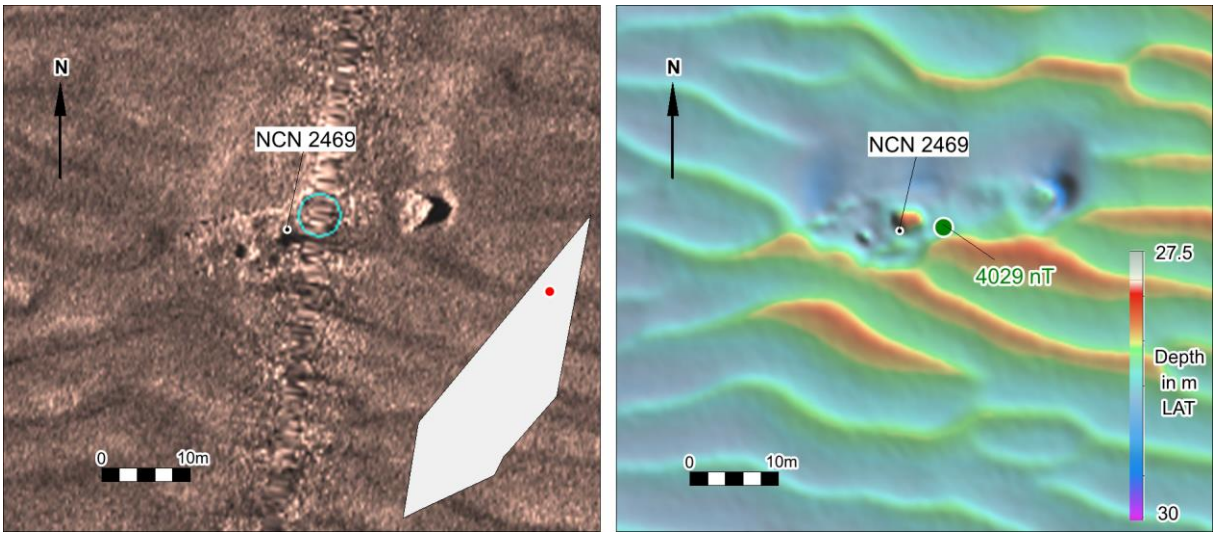


Figure 11. Sidescan sonar and multibeam image of NCN 2469

NCN 2469 is an unknown ship wreck. The wreck is nearly completely embedded in the seabed. The dimensions are 29 x 8 x 3.4 m. The wreck remains have induced a magnetic anomaly of 4029 nT.

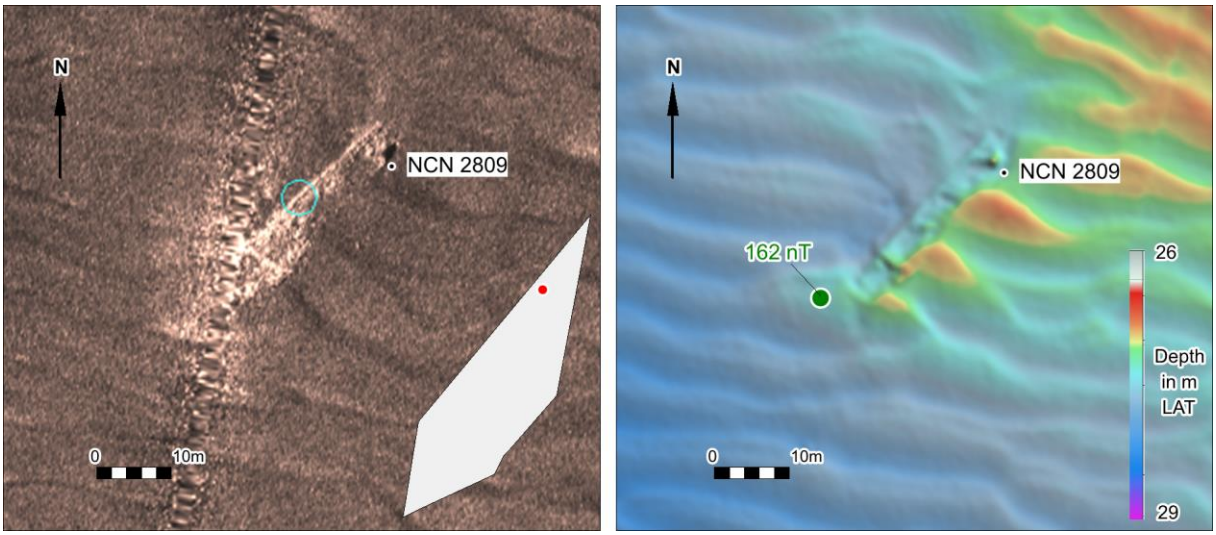


Figure 12. Sidescan sonar and multibeam image of NCN 2809

NCN 2809 is an unknown ship wreck. This wreck also is nearly completely embedded in the seabed. The dimensions are 28 x 7 x 0.4 m. The wreck remains have induced a magnetic anomaly of 162 nT. The wreck has also been identified as a reflection hyperbola in de *subbottom profiler* data.

NCN with an archaeological expectation – not found

A total of 24 out of 39 known NCN objects have not been found during the survey.

A total of 13 out of those 24 objects are ship wrecks.

A total of 12 out of those 13 ship wrecks are of possible archaeological value.

NCN	Easting	Northing	R95	Description	Results survey
2035	550310	5822477	500	Wreck DHY 2221. Unknown small wreck found 1959, not confirmed since	Outside area
2063	540648	5829062	20	Wreck DHY 2255, Unknown wreck found 1970	No visible contacts; No anomalies
2090	549558	5838909	1000	Wreck DHY 2283. Unknown wreck found 1946	No visible contacts; No anomalies; sandwave
2097	551880	5843043	500	Wreck DHY 2291 Unknown wreck found 1961	No visible contacts; No anomalies; sandwave
2100	558429	5842871	1000	Wreck DHY 2294. Mast reported 1898, not confirmed since	No visible contacts; No anomalies
2110	550906	5844640	1000	Wreck DHY 2304. Wreck reported 1946, not confimed since	Outside area
2120	555194	5849035	25	Wreck DHY 2315. Duikteam Zeester: Submarine Doris	Outside area
2810	535978	5821107	50	Distributed remains of wreck	Outside area
2844	553958	5830158	50	Wreck DHY 3498	No visible contacts; No anomalies; sandwave
2845	554572	5833117	50	Wreck DHY 3500. Wreck debris reported 2014	No visible contacts; No anomalies
9226	556213	5832620	5	Wooden wreckremains, discovered in 2002. ARCHIS wng 47163	No visible contacts; No anomalies; sandwave
9299	555298	5849442	1	French submarine Doris, sunk mei 1940, cannon salvaged in 2003. ARCHIS wng 48181	Outside area

Table 7. NCN contacts with an archaeological expectation – not found

Five objects have not been found because they are likely to be located outside the surveyed area and have therefore not been found. Three known wrecks which are expected to be located inside the survey area have a position accuracy of 500 or 1000 meters. The positions are therefore not reliable. The remaining four wrecks may not exist anymore, or are they are covered by sediment due to the migration of the sand waves. Moreover, also the know wrecks with inaccurate positions might have been covered by sediment.

Summary of known objects

The desk study has shown that a total of 39 contacts are known within the research area of the HKWWFZ.[13] The known contacts consist of ship wrecks (23), wellheads (10), unidentified obstructions (3), lost cables or chains (2), and an anchor (1). For 19 wrecks the archaeological value has not been determined.

15 known objects including 10 wrecks have been found during the geophysical survey.

- 7 of the wrecks found are of possible archaeological value.
- 3 of the wrecks found are considered to be of no archeological value.

24 known objects including 13 wrecks have not been found during the geophysical survey.

- all known objects (including the wrecks) have probably become covered with sediment due to the migration of sand waves;
- 12 of the 13 wrecks which have not been found are of possible archaeological value;
- 5 of the 12 wrecks of possible archaeological value are probably located outside the area of investigation;
- 1 of the wrecks which has not been found are considered to be of no archeological value.

Known Objects	Archaeological Expectation		Total
	Yes	No	
Found	7	8	15
Not Found	12*	12	24
Total	19	20	39

Table 8. Summary of known objects

* 5 of these wrecks are probably situated outside the area of investigation; the other 7 wrecks of possible archaeological value are presumably located inside the area of investigation under a cover of sediment.

[13] Research Area = HKWWFZ + 1km bufferzone.

3.3 Sidescan sonar

Fugro has identified 405 *sidescan sonar* contacts within the HKWWFZ zone. The classification of the contacts is listed below.

Classification	Total
Boulder	225
Debris	109
Depression	21
Linear Debris	38
Wreck (more than 1 contact per wreck possible)	12
Total	**405**

Table 9. Sidescan sonar contacts identified in the HKWWFZ

All contacts which match known objects have been discussed in the previous paragraph. The remaining *sidescan sonar* contact and images have been scanned and checked for the presence of potential archaeological contacts. This is done by analyses of:

- *Sidescan sonar* images included in the survey reports;
- Raw *sidescan sonar* data (XTF-files);
- Raw *multibeam*-data (xyz-files) ;
- Comparison of *sidescan sonar* and *magnetometer* contacts.

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

All contacts larger than four meter are examined in detail, because these objects are considered to be more likely to be related to wreck sites than the smaller contacts. This choice is based on best professional judgment and not prescribed by legislation or the KNA. Purpose of this analysis is to identify contacts that could reflect potential archaeological sites. This selection of large contacts comprises a total of 51 contacts. Contacts identified by Fugro as pipelines and cables are not included in this selection. For a complete listing of the result of this examination is referred to Appendix 3. A summary of the outcome of the detailed inspection of selected contacts is presented in the table below.

Interpretation Periplus	Total
Boulder	7
Debris	15
Depression	5
Linear Debris	13
Wreck	11
Total	**51**

Table 10. Results of the assessment of selected sidescan sonar contacts

The majority of the reviewed contacts has been classified as natural phenomena (sedimentary features).

7 of the 51 contacts represent wreck remains or could not be identified, but might represent archaeological objects because of their dimensions. In addition another 3 contacts smaller than 4 m were identified to be of potential archaeological interest resulting in 10 possible archeological objects which are listed in table 11.

Nr	Easting	Northing	L(m)	W(m)	H(m)	Description_PPA	Classification_PPA
S_0039	536556	5817013	4.7	2.4	0.3	elongated to rectangular hard reflective object	Possible wreck
S_0093	538628	5824408	5.6	2.9	0.0	spherical object amidst a scour 13 x 11 m with 118 nT magnetic anomaly	Possible wreck
S_0095	538755	5824686	3.8	0.8	0.4	two elongated objects	Possible wreck site
S_0096	538786	5824717	2.6	1.1	0.9		
S_0336	544748	5823694	28.5	5.3	0.2	high reflective exposure	Possible buried wreck
S_0353	547417	5836653	7.2	6.8	0.7	high reflective exposure	Possible buried wreck
S_0401	544499	5821369	33.8	9.4	0.4	contours of a ship-like object	Buried ship wreck
S_0412	544989	5819800	3.5	5.8	0.7	cluster of contacts	Possible wreck site
S_0413	544995	5819792	4.6	4.1	1.2		
S_0679	553839	5842543	7.2	1.0	0.4	linear contact amidst cluster of contacts	Possible buried wreck

Table 11. Summary of the archaeological assessment of the sidescan sonar records.

The wreck locations registered in the NCN database have been discussed in section 3.2. The results with examples of the ten unknown objects are discussed below.

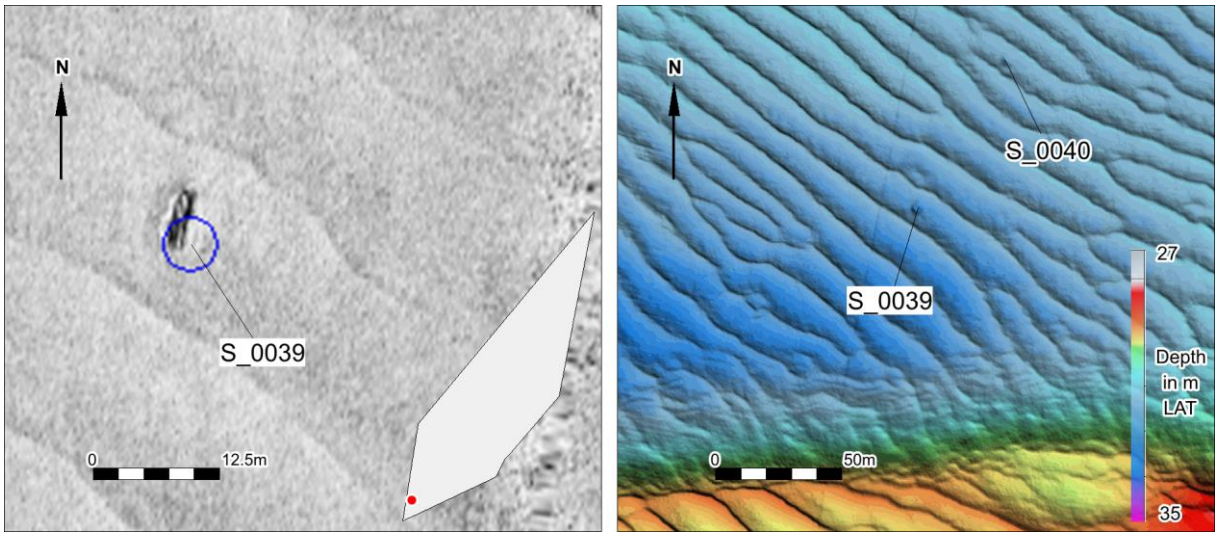


Figure 13. Sidescan sonar image (left) an multibeam image (right) of contact S_0039

Contact S_0039 appears on the sonar images as an elongated to rectangular hard reflective object. The 4.7 x 2.4 x 0.3 m object is found amidst a shallow 6 x 6 m scour. The scour is 0.2 to 0.3 m deep. The object could be part of a larger buried structure. No magnetic anomalies have been observed at the location. Because the structure cannot be identified it might be of potential archaeological interest.

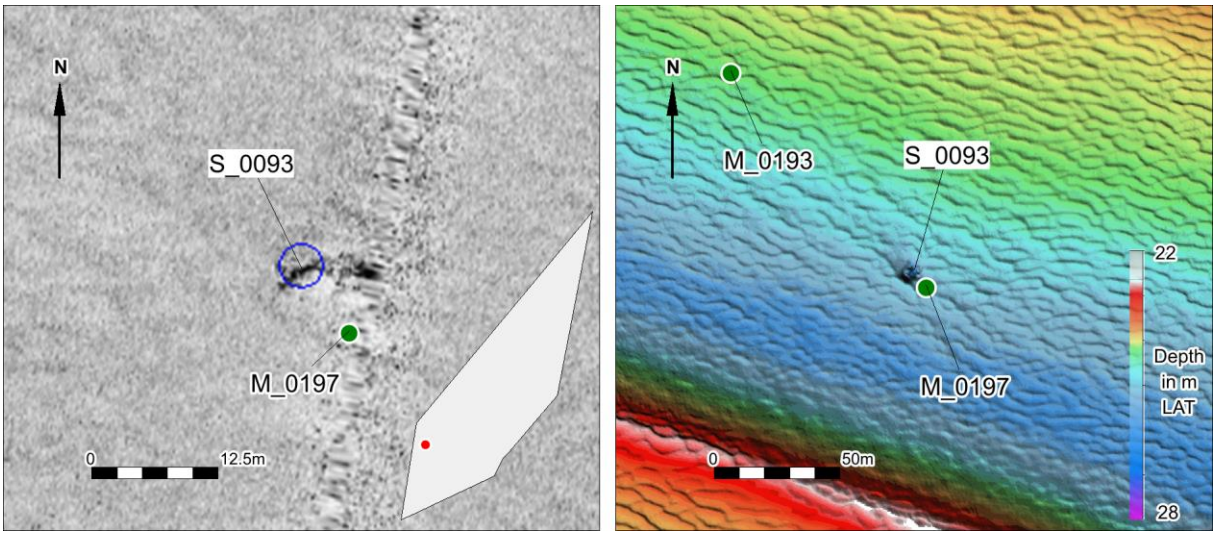


Figure 14. Sidescan sonar image (left) an multibeam image (right) of contact S_0093

Sonar contact S_0093 is classified by Fugro as a boulder with dimensions 5.6 x 2.9 x 0 m. The *multibeam* image shows that the object is located amidst a scour 13 x 11 m. The object height with respect to the surrounding scour is 0.4 to 0.5 m. A magnetic anomaly (118 nT) has been observed within a few meters from the object. Because the object cannot be identified it might be of potential archaeological interest.

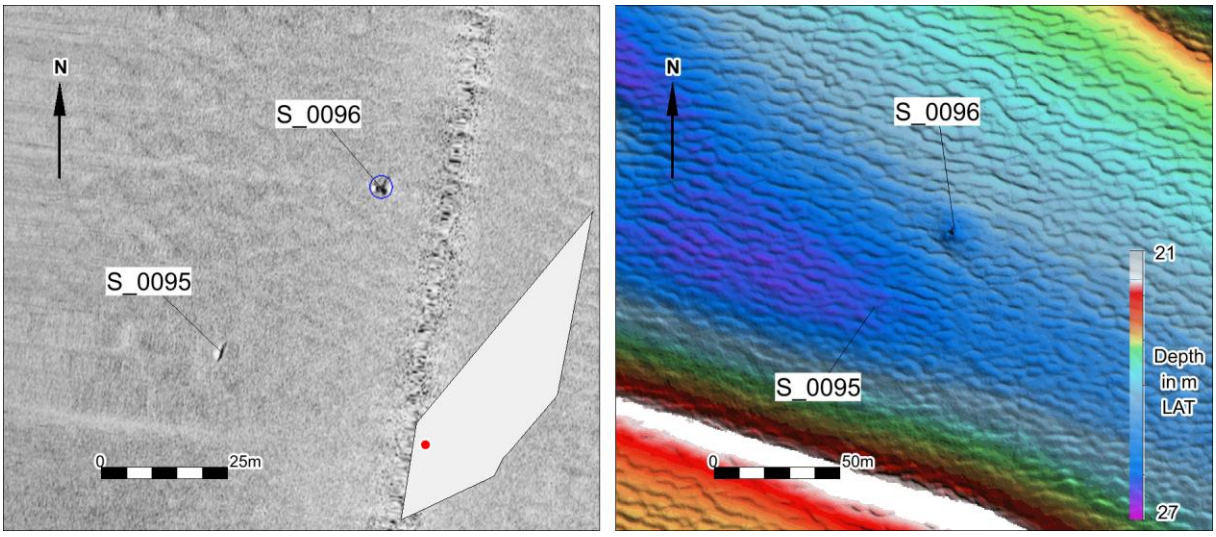


Figure 15. Sidescan sonar image (left) an multibeam image (right) of contacts S_0095/S_0096

Sonar contacts S_0095 and S_0096 have been classified by Fugro as debris. The dimensions of the contacts are 3.8 x 0.8 x 0.4 m (S_0095) and 2.6 x 1.1 x 0.9 m (S_0096). The *multibeam* image shows that both objects have resulted in a slight seabed disturbances. It is unknown if the objects are related. No magnetic anomalies have been observed at the location. Because the objects cannot be identified the site is considered to be of potential archaeological interest.

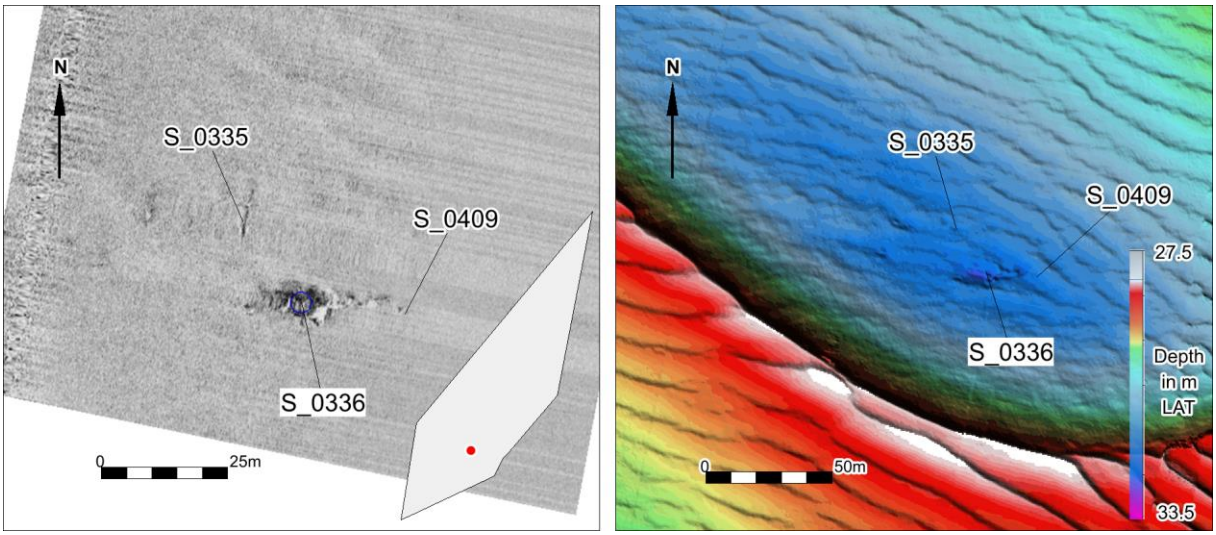


Figure 16. Sidescan sonar image (left) an multibeam image (right) of contact S_0336

Sonar contact S_0336 is a high reflective exposure amidst a sandy seabed with weakly developed mega ripples. The contact has been described by Fugro as 'debris, possible buried structure or wreck'. The dimensions are 29 x 5 x 0.2 m. The elevation above the seabed is a few decimeters maximum. Part of the unknown object or structure could be buried under a layer of sediment. The *multibeam* image does appear to vaguely show the contact to extent to the west. Within 25 meters from S_0336 two smaller contacts have been identified, which indeed could indicate that the site is not limited to the exposed part listed as contact S_0336.

The buried object and coherent smaller *sidescan sonar* contacts have been interpreted as a possible wreck site, which can be of archaeological value.

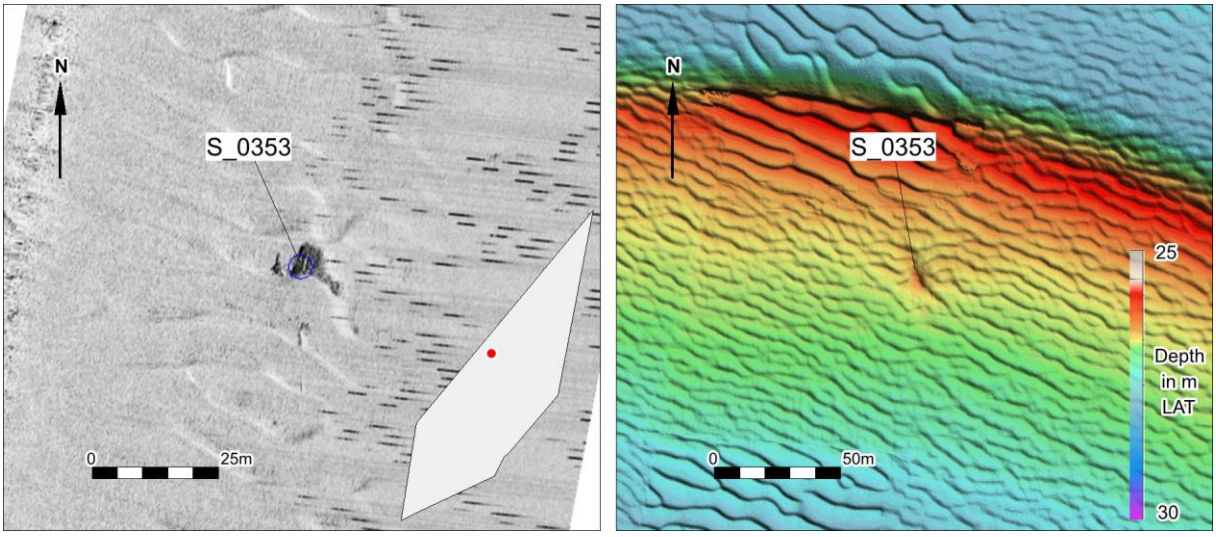


Figure 17. Sidescan sonar image (left) an multibeam image (right) of contact S_0353

Alike sonar contact S_0336 contact S_0353 is a high reflective exposure amidst a sandy seabed. The contact is located at the slope of a sand dune. The contact has been interpreted as 'debris' by Fugro.
Part of object or structure is likely to be buried under a layer of sand. The dimensions of the exposed parts are 7.2 x 6.8 x 0.7 m. The reported height of 0.7 m does not show on the *sidescan sonar* image, but can be measured in the *multibeam* data with respect to the dune slope. No magnetic anomalie has been

measured at this location. The object or structure has not been identified and could therefore be of archaeological value.

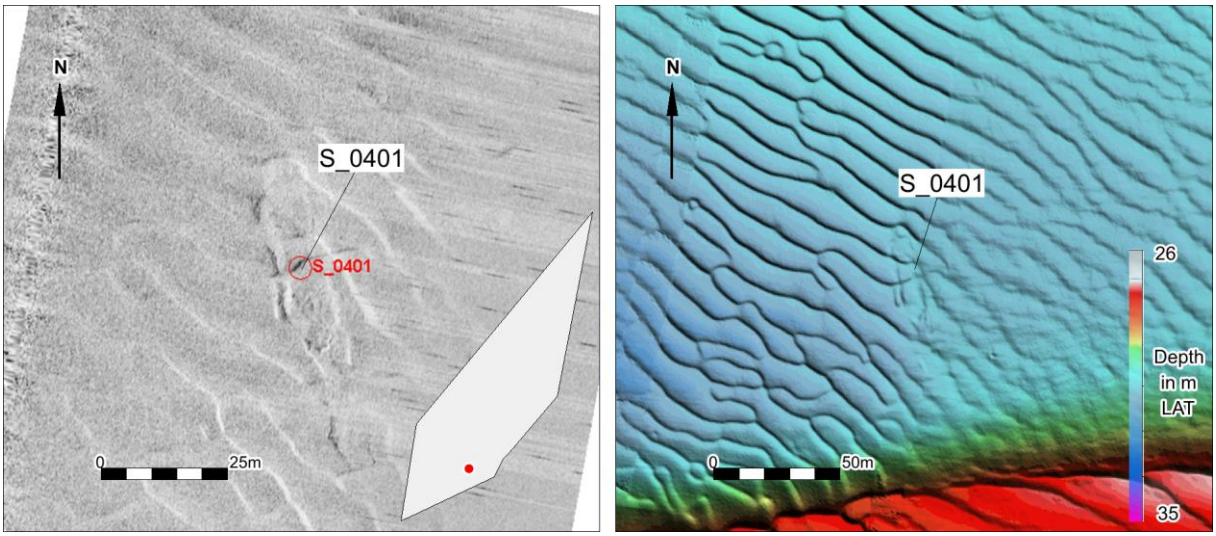


Figure 18. Sidescan sonar image (left) an multibeam image (right) of contact S_0401

Both the sidescan sonar and *multibeam* image display the contours of an object which is likely to be a ship wreck. The dimensions are 34 x 9 x 0.4 m. The possible wreck is almost fully embedded in the surrounding seabed. No magnetic anomalies have been found in the viscinity of the contact. The contact has been interpreted as a wreck of possible archeological value.

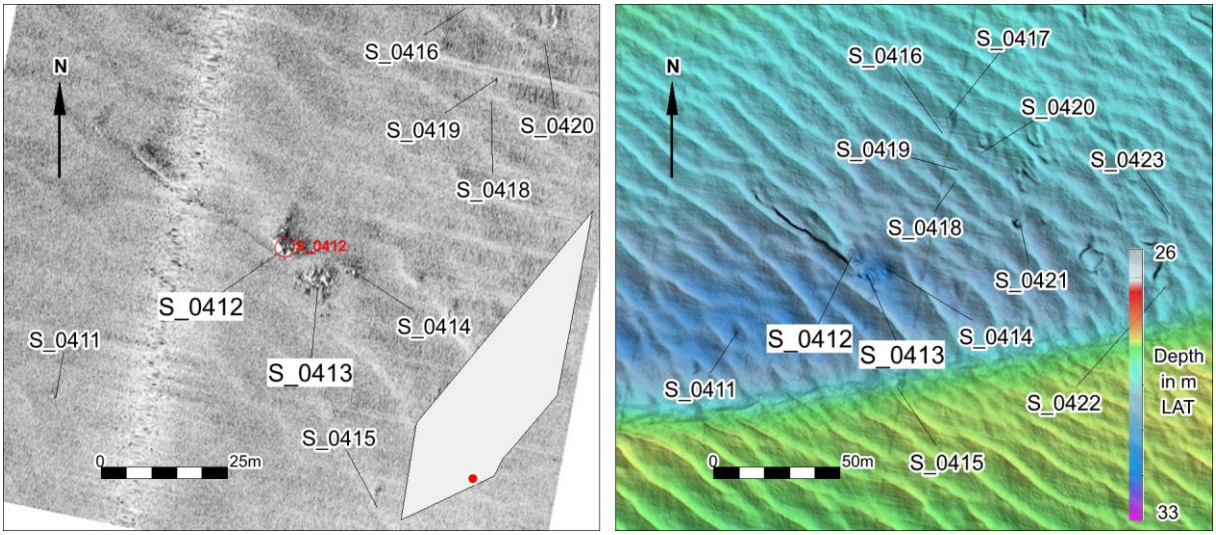


Figure 19. Sidescan sonar image (left) an multibeam image (right) of contact S_0412/S_0413

The *sidescan sonar* contacts S_0412 and S_0413 are part of a cluster of 11 *sidescan sonar* contacts. The contacts have been interpreted by Fugro as debris; the dimensions of the contacts are 3.5 x 5.8 x 0.7 m (S_0412) and 4.6 x 4.1 x 1.2 m (S_0413). The 11 surrounding contacts range in size from less than 1 m to 3.7 m and have been interpreted as debris (4), linear debris (2) and boulders (5). The interpreted boulders could indicate that the ice-pushed deposits of the Yarmouth Roads Formation are exposed at the seabed. The boulders would in that case most likely be transported by glaciers. Figure 19 also shows linear contacts of which two have been interpreted as debris. The linear contacts might relate to outcrops of clay, loam or peat at the seabed. No magnetic anomalies have been found in the viscinity of the *sidescan sonar* contacts. If the contacts reflect boulders and outcrops of geological layers of different composition

than the surrounding seabed the origin would be natural. The interpretation however is uncertain, because of which we cannot exclude the presence of remains of archaeological value at this location.

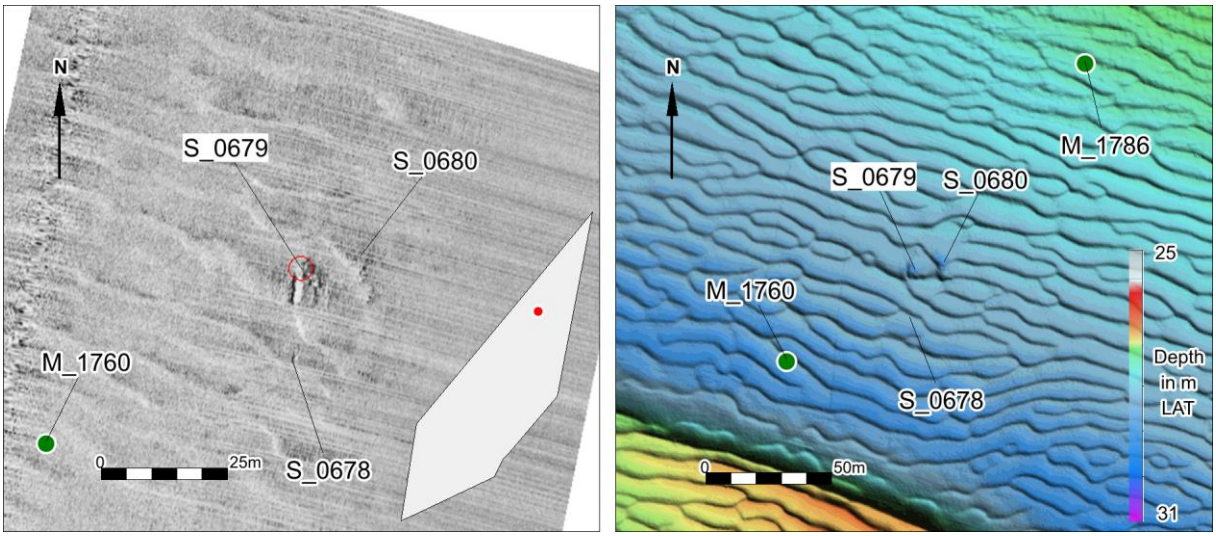


Figure 20. Sidescan sonar image (left) an multibeam image (right) of contact S_0679

Sidescan sonar contact S_0679 has been interpreted by Fugro as linear debris. The contact dimensions are 7.2 x 1.0 x 0.4 m. Next to contact S_0679, that is within 12 m, two contacts have been found. These contacts have been interpreted as boulder. The dimensions of contact S_0680 are 2 x 0.8 x 0 m. The *multibeam* image shows scours at the S_0679 and S_0680. The three contacts could be related and part of a buried object or structure.

Magnetic anomalies have been measured on two survey lines at a distance of 66 m (M_1760; 28 nT dipole) and 100 m (M_1786; 20 nT monopole) from S_0679. The anomalies have not been found at the shortest distance from the sonar contacts on the survey line. The anomalies are therefore probably not induced by to the observed *sidescan sonar* contacts, albeit that if the *sidescan sonar* contacts reflect a buried ship, an isolated anchor in the proximaty of such a wreck could result in the magnetic anomalies identified.

Summary of side scan sonar contacts

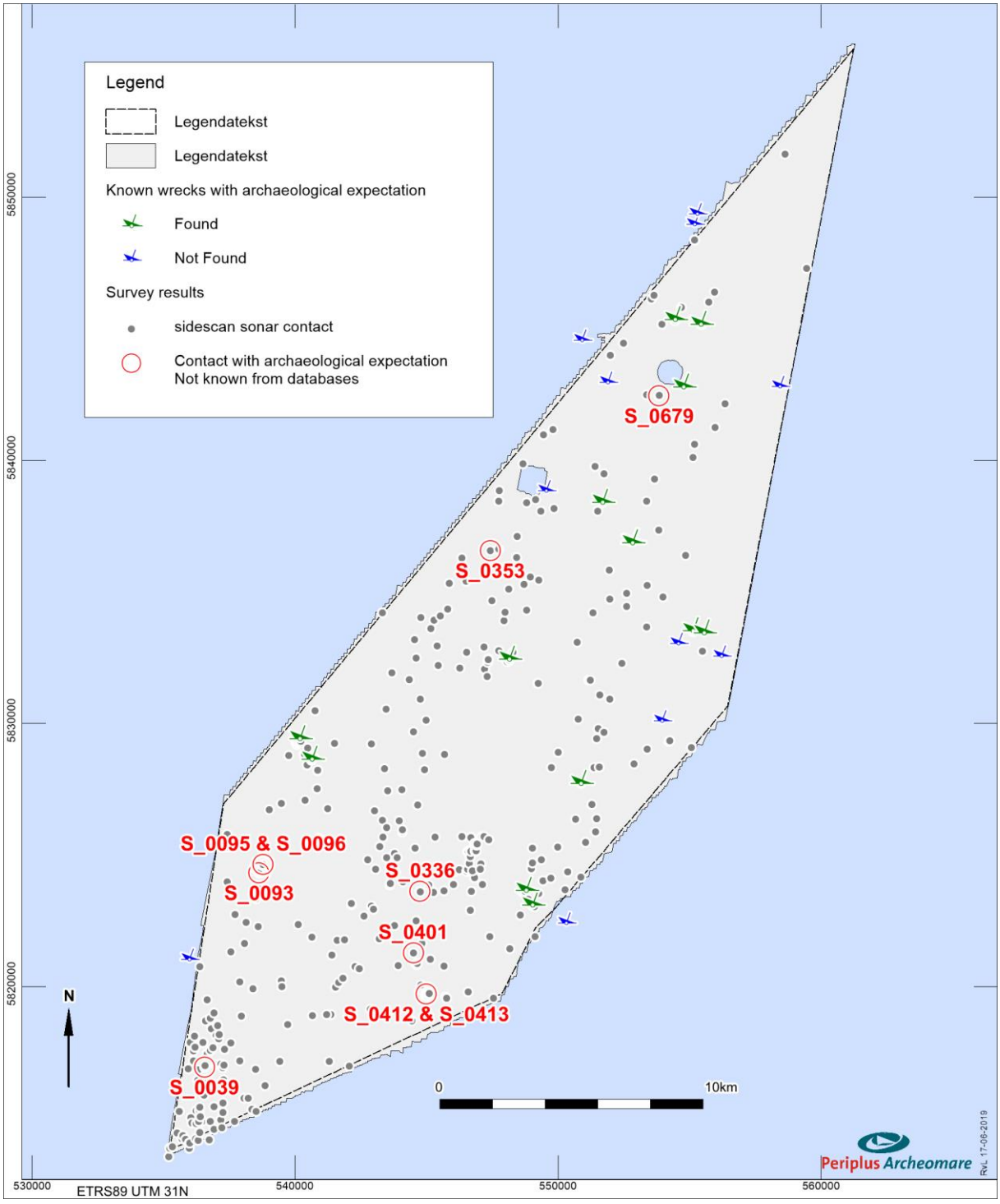


Figure 21. Overview of the sidescan sonar contacts with an archaeological expectation

3.4 Multibeam

Apart from the *multibeam* images discussed in the previous sections no *multibeam*-features have been observed which are interpreted to reflect the presence of archaeological objects or structures.

3.5 Magnetometer

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

A total of 2450 magnetic anomalies have been observed within the area of investigation. A classification is listed in the table below.

Classification	**Total**
Unknown	1635
Pipeline	445
Cable	229
Unknown linear feature	115
Wreck	13
Possible buoy	6
Subsea structure	4
Pipeline crossing	2
Platform	1
Total	**2450**

Table 12. Classification of the magnetic anomalies

Ten anomalies are related to exposed objects detected by *sidescan sonar*. These anomalies correlate with the positions of known ship wrecks.

A total of 1750 magnetic anomalies cannot be related to known pipelines and cables, or visible objects at the seabed surface. They are related to unknown ferrous objects buried in the seabed, covered by sediments. 107 of these anomalies have an amplitude of 50 nT or more. An overview is presented in the figure below.

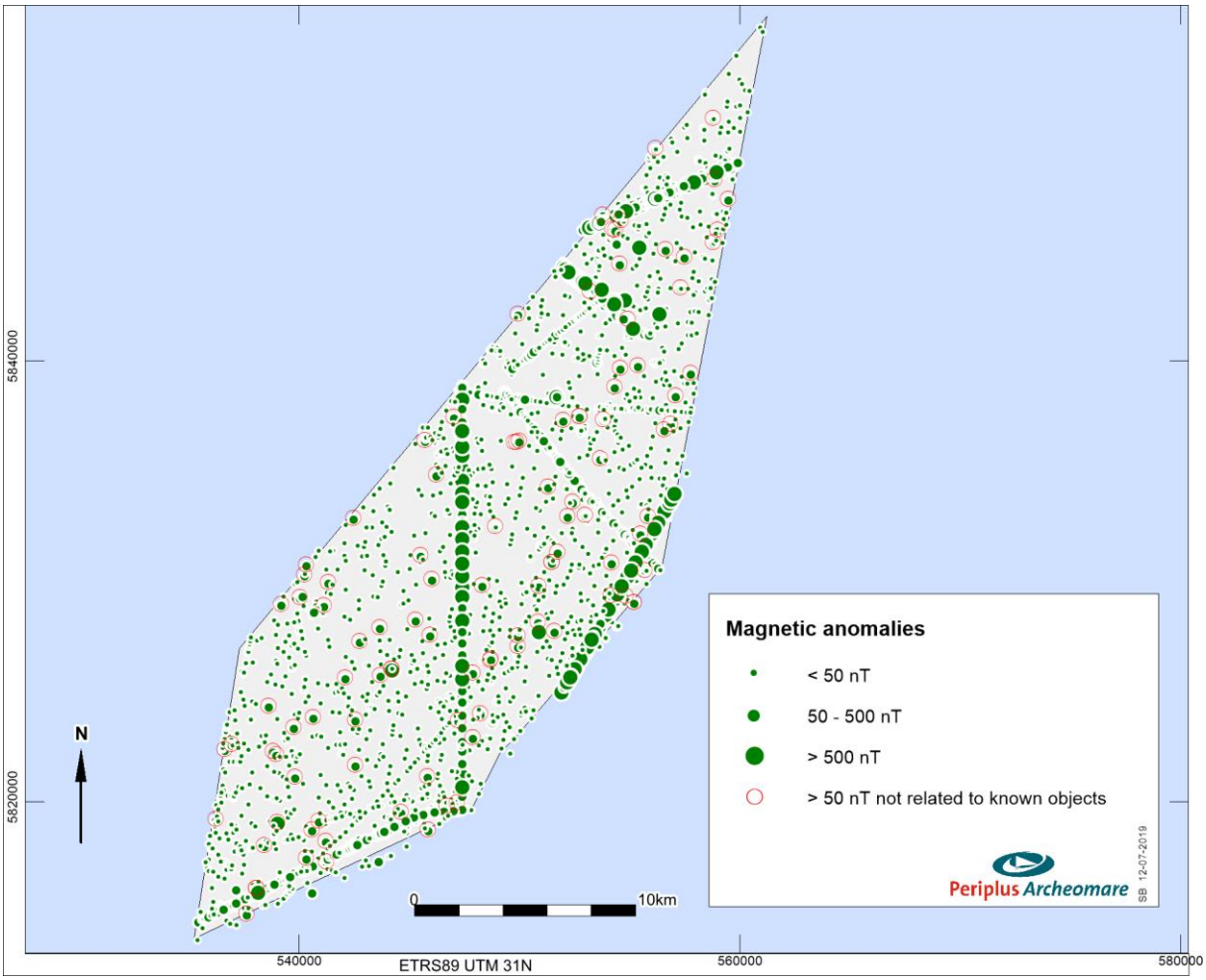


Figure 22. Overview of the magnetic anomalies

The clear lineations of magnetic contacts in the figure above represent the present cables and pipelines in the area.

3.6 Subbottom data

The archaeological desk study has indicated that the combined thickness of the *Holocene* sequence is expected to range from 0 to 18 meters in the area.[14] The variations in thickness are partly due to the occurrence of morphological features such as sand ridges and sand waves. The expected *Holocene* units include the Bligh Bank Member, the Velsen Bed (Naaldwijk Formation) and/or the Basal Peat Bed.

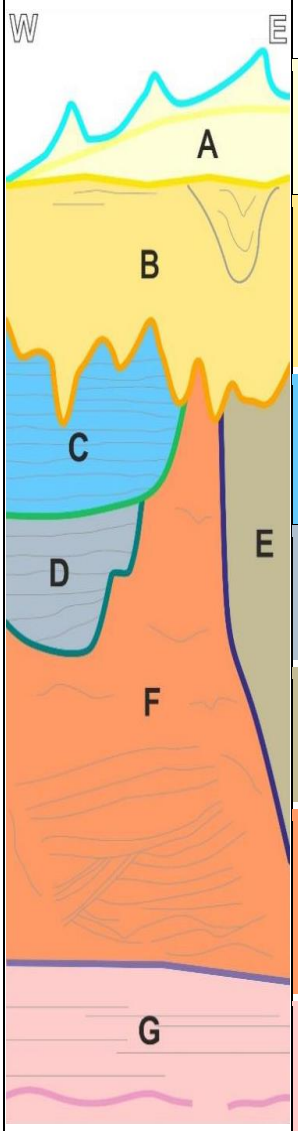
Schematic Log	Seismic Unit	Reflector		Depth Base [m BSF]	Geometry of Base	Deposition Environment	Formation (Member)	Age
		Top	Base					
								
	A	Seafloor	H02	<1 to 14	Flat to slightly undulating	Shallow marine	(Bligh Bank)	Holocene MIS 1
	B	H02	H05	1 to 18	Erosion surface	Intertidal to coastal	Naaldwijk	Holocene MIS 1 MIS 4 - 2?
	C	H05	H10	2 to 23	Horizontal to sub-horizontal	Brackish marine	Eem (Brown Bank)	LatePleistocene MIS 5 - 4
	D	H05 or H10	H15	5 to 36	Erosion surface	Shallow marine	Eemian	Late Pleistocene MIS 5
	E	H02 or H05	H20	3 to >35	Erosion surface	Glacio-fluvial to marine	Valley infill	Post-Saalian MIS 5 - 1
	F	H05 or H10 or H15	H25	7 to 51	Undulating erosion surface	Fluvial	Yarmouth Roads	Early to Middle Pleistocene MIS 62 - 13
	G	H25	N/A	N/A	Not visible	Fluvio - deltaic	Winterton Shoal	Early to Middle Pleistocene MIS 62 - 22

Table 13. Overview of the interpreted seismic Units[15]

[14] Brenk 2018.

[15] From: FUGRO Report P904162 (rev. 1 Draft), 2019.

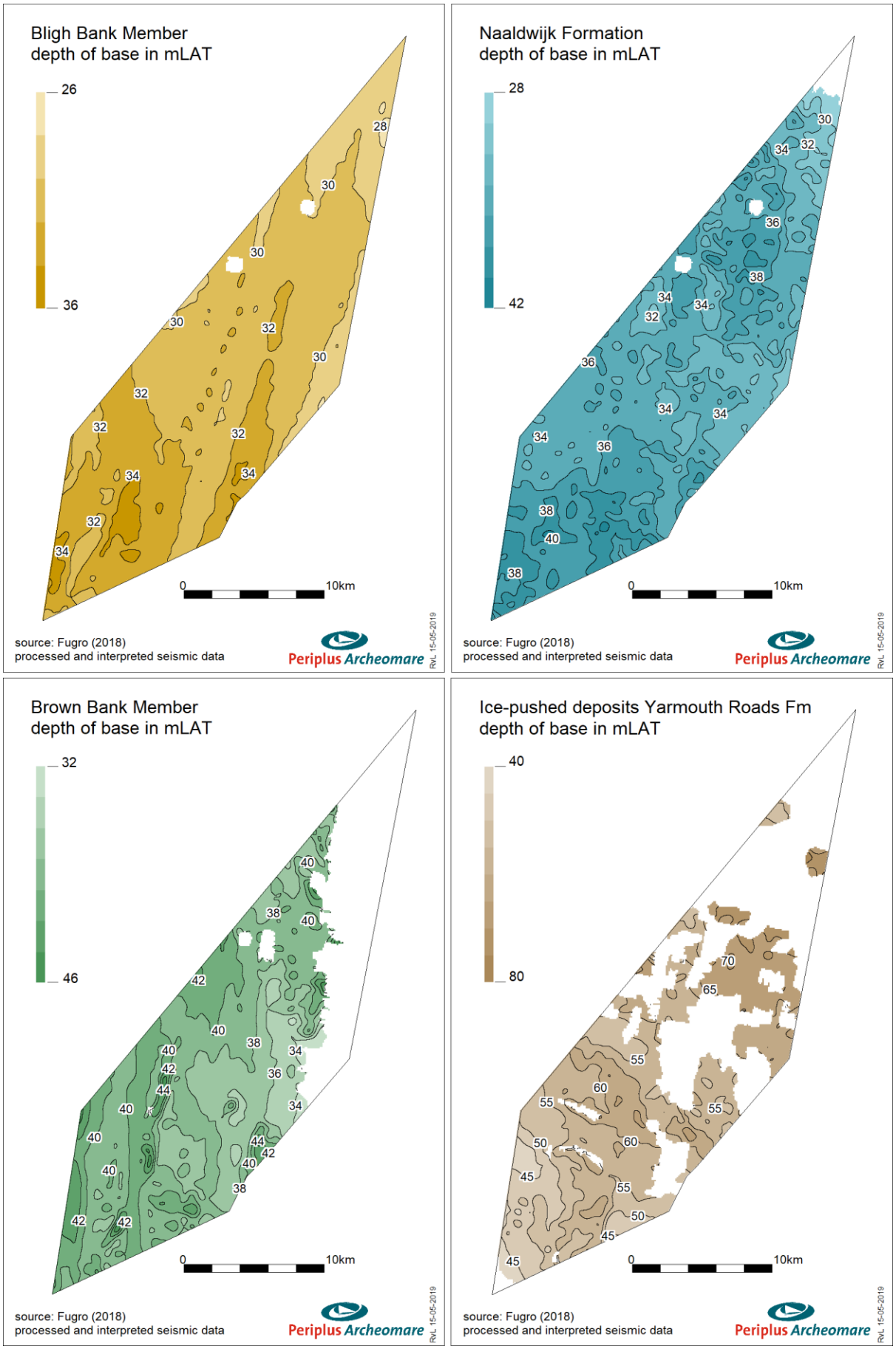


Figure 23. Geological units in the HKWWFZ - depth of the base of the units in mLAT

The expected units indeed have been found during the geophysical survey. The base of Naaldwijk Formation has been found up to 18m bsb at locations where large early *Holocene* tidal channels have incised underlying *Pleistocene* units.

Figure 23 (above) shows the interpreted seismic units identified in the HKWWFZ. The data provided by FUGRO include the bases of the units. The base of unit F has not been observed in all parts of the area, because the base of this unit is beneath the penetration depth of the seismic data. In fact unit F is present in all parts of the area including the white spots in figure 23 where the base was not observed.

Unit F consists Yarmouth Roads river deposits which were pushed upward by Saalian glaciers. The river deposits display internal deformation structures because of the glacier-induced thrusting and folding. The southward migrating glaciers reached their maximum during the Late Saalian. The edge of the glacier is marked by the border of the ice-pushed deposits of unit F from the glaciofluvial/(glacio)marine deposits of unit E.

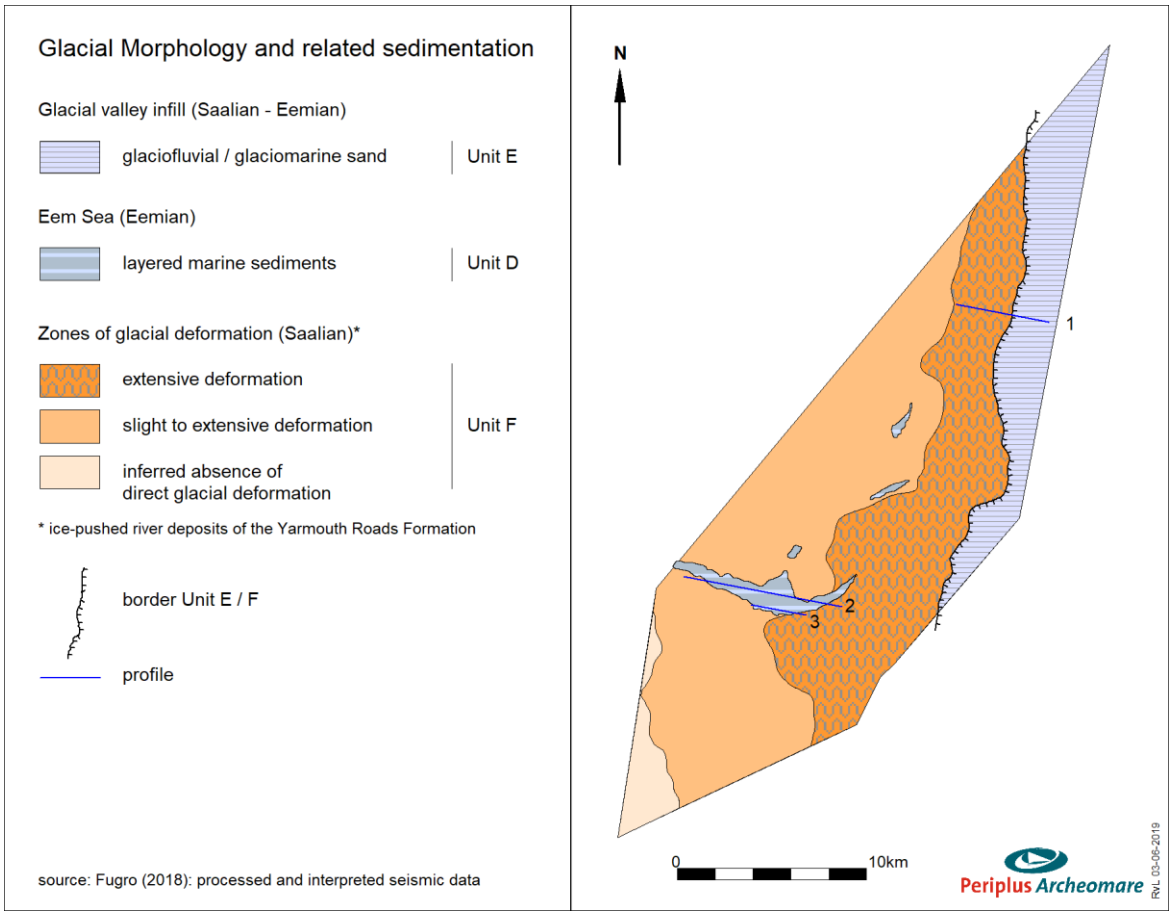


Figure 24. Subcropping glacial landforms

At the onset to the Eemian interglacial period the glaciers melted leading to the development of proglacial lakes. The glacial valleys were filled with meltwater deposits. Fugro has not named the lithostratigraphic unit those deposits are part of. Based on the assumption that the glacial valley has been formed during the Saalian can be concluded that the valley infill is post-Saalian. Fugro suggests that the valley infill may consist of Eemian and/or *Holocene* deposits. Unit E could therefore consist of marine sand of the Eem Formation or the Naaldwijk Formation. However, in our opinion another possible origin of Unit

E can be found in the development of sandrs or kame terrasses in front of, next to, and partly under the glacier. Those Late Saalian glaciofluvial sands are part of the Schaarsbergen Member within the Drente Formation.

The transition between the subcropping ice-pushed deposits and the glaciofluvial valley-infill is shown in plan view (figure 24 above) and profile (figure 25 below). The different degrees of deformation are also indicated in figure 24. The most extensive deformation is found next to the glacial valley; little or no deformation is observed in the eastern part of the area. From the seismic data the layer boundary between Unit E and Unit F has been interpreted to be erosive. Unit E has a striking uniform internal acoustic character.

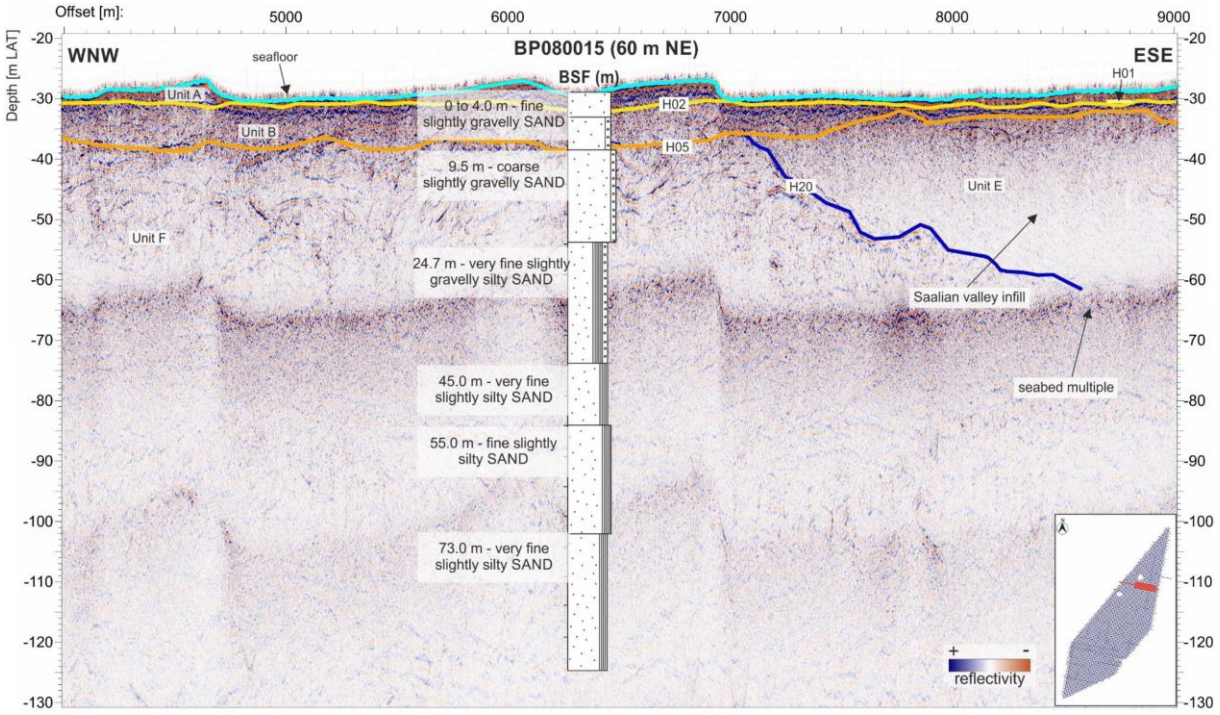


Figure 25. Profile 1 - Transition from Ice pushed deposits (Unit F) to glacial valle infill (Unit E)

East of the glacial valley edge amidst the glacially deformed sediments of Unit F a concave shaped basin-like feature is found which is filled with a pronouncedly layered sequence of sediments. The sediments have been interpreted as shallow-marine, tidal, medium to high energy environment deposits of the Eem Formation (Unit D). The occurrence of the subcropping marine deposits of the Eem Formation is shown in plan view (figure 24) and profile (figure 26 and figure 27).

Borehole sample BP080031 shows that the infill consists of alternating layers of clay, silt and fine sand. The base of the Eem Formation has been found at depths varying from 5 to 36m bsb (=35 to 66m LAT) and has been interpreted to be erosive. The identification of the base might in places might have been troublesome due to the interference of the seabed multiple around -60m LAT. The genesis of the basin-like feature is not known. It is however considered likely that this feature has a glacial origin, either being abraded by a relatively small ice-lobe or formed by the incision of melt water resulting a tunnel valley like phenomenon. During the Eemian interglacial periode the valley was filled in with shallow-marine deposits. The occurrence of the Eem Formation in the HKWWFZ is, according to the interpretation of the seismic records, limited to the at the time isolated low-lying areas shown in figure 24.

The occurrence of the Brown Bank Member (Unit C) on the other hand is widespread throughout the area (see figure 23). The unit has been identified west of the glacial valley covering the glacially deformed river sediments of the Yarmouth Roads Formation and the shallow marine deposits of the Eem Formation. The Brown Bank Member consists of lagoonal and lacustrine clay, silt and sand. The sequence represents the regression which occurred at the Eemian to Weichselien transition. In general the sequence tends to be thinning upward becoming more clayey and humic towards the top, whereby the clays at the top have been deposited in a brackish to fresh water environment.

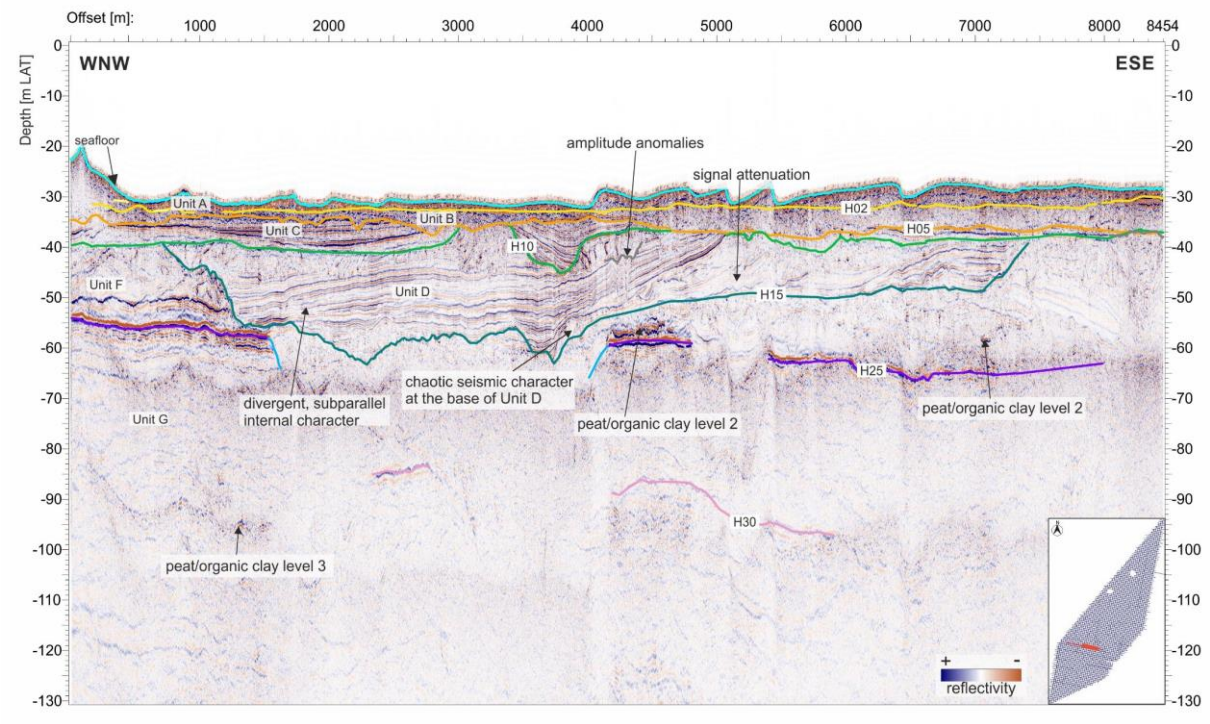


Figure 26. Profile 2 - Occurrence of the Eem Formation (Unit D)

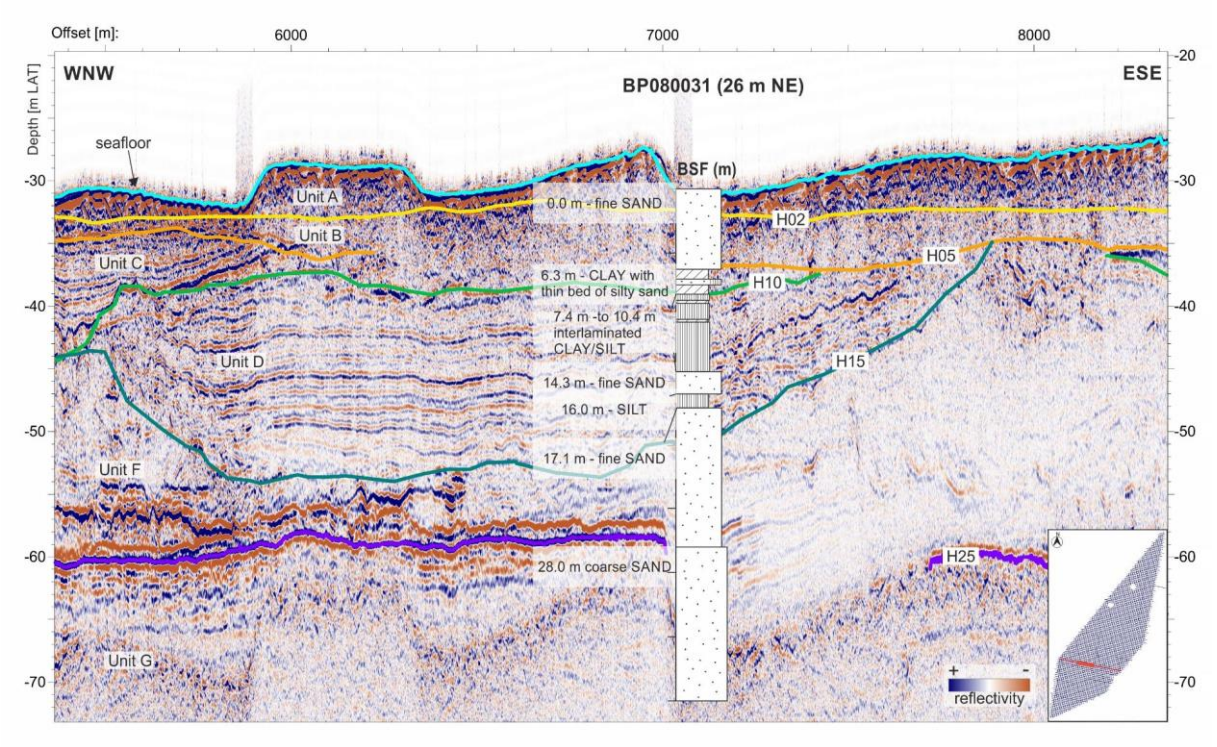


Figure 27. Profile 3 - Occurrence of the Eem Formation (Unit D) with DINO borehole BP080031

The Naaldwijk Formation (Unit B) has been mapped throughout the whole HKWWFZ area except from the a small corner in the north. An overview of the depth at which the base of the unit was found within the boundaries of the HKWFZ is shown in table 14. The Naaldwijk Formation (Unit B) covers the Brown bank Member (Unit D), the ice-pushed deposits of the Yarmouth Roads Formation (Unit F) and de glacial valley infill (Unit E). Seismic reflector H05 at the base of Unit B has been interpretated by Fugro as an unconformity. This means that the development of an intertidal and coastal environment lead to widespread erosion of the (at the time) outcropping units. Indeed limited relief is seen at the top surface of the ice-pushed deposits of the Yarmouth Roads Formation (Unit F) in figure 25. Erosion during the Early *Holocene* marine ingression presumably contributed to abration of the glacial relief. The top of the Brown Bank Member (Unit C) has also eroded, especially in places where tidal channels have developed.

Base of Naaldwijk Fm	depth bsb (m)
Minimum	2.2
Maximum	16.2
Average	6.9
Mode	6.4

Table 14. Depth of the base of the Naaldwijk Formation (m bsb)

In places the pre-*Holocene* units could have been protected from erosion due to the presence of an Early *Holocene* layer of peat and/or organic clay. Occurrences of possible peat and organic clay have been mapped and described in the geohazard section of the Fugro survey report. Peat occurs at different stratigraphic levels within Unit B (Level 1), Unit F (Level 2) and Unit G (Level 3).

The rise in temperature and increasing precipitation in the Early *Holocene* caused the then arid North Sea area to become vegetated. Peat and organic clay were deposited due to the ongoing rise of groundwater levels upward grading into laminated shell bearing intertidal and coastal deposits of the Naaldwijk Formation (Unit B). The Early *Holocene* deposits of peat and humic clay have been separately classified as the Basal Peat Bed (Nieuwkoop Formation) and Velsen Bed (Naaldwijk Formation).

Fugro has described Level 1 as follows: 'Seismic anomalies in the form of thin (<1 m) intervals of parallel, high-amplitude reflectors were locally observed on the SBP data at the interface between Unit A and Unit B. These anomalies are interpreted as possible peat and/or organic clay deposits.'

If Level 1 were to reflect the Basal Peat Bed and/or Velsen Bed the stratigraphic level does not seem to fit. Fugro identified Level 1 at the interface between Unit A (interpretation = Bligh Bank Member) and Unit B (interpretation = Naaldwijk Formation). The Basal Peat Bed and Velsen Bed are to be expected the base of Unit B, at the interface with the underlying units (Units C, D, F and possibly E).

Possible explantions for this apparent discrepancy are:

a) Local occurrences of terrestrial Pleistocene to Early *Holocene* deposits of the Boxtel Formation could be part of the seismic Unit B. The internal seismic character of Unit B has been described as 'variable from high amplitude reflections to semi-transparent and chaotic'. Because of this the Boxtel Formation might have been hard to distinghuish from the Naaldwijk Formation.
b) Unit E and Unit F have a similar seismic character as Unit B, which can make it difficult to distinghuish the units from one another in areas where the Unit B is underlain by Unit E or F.

From an archaeological perspective it is important to know which paleolandscape is covered by the *Holocene* layers of peat and/or organic clay:

a) the *Pleistocene* landscape consisting of ice-pushed deposits (Unit F)
b) the Boxtel Formation (not identified in this survey), which can consist of:
    - aeolean sands;
    - small-scale fluvial deposits (loam, clay, peat);
    - mass-transported slope material originating from the ice-pushed ridges;
c) the *Holocene* intertidal and shallow marine deposits of the Naaldwijk Formation (Unit B).

Figure 29 shows the theorethical occurrences of the Boxtel Formation as mapped by Laban. The occurrences of peat and/or organic clay and the position of the glacial valley edge as mapped by Fugro have been projected on top of the mapped Boxtel Formation. The Boxtel Formation has not been identified by Fugro in the seismic data. The reason for this can be that the unit actually is not present (as Fugro conludes), or the unit is present but sediment layers are very thin, or the unit is reasonably thick but seismic signature of the unit resembles the seismic signal of other units.

In prehistoric times the glacial valley edge could have attracted hunters and gatherers because of the favourable landscape setting. The valley edge provided good locations to install camps, fresh water streams and lakes, opportunities for fishing and hunting large mammels, and a large variation in flora.

To date we know little of the timing and geogenesis of the glacial valley infill (Unit E). If the infill took place during and directly after retreat of the Saalian glaciers the top of unit F is not expected to contain

Late Paleolithic and Mesolithic remains, at least not within the infille valley area. If the sediment infill took place during the *Holocene*, the top of the underlying ice-pushed *Pleistocene* deposits (Unit F) could contain Middle and Late Paleolithic and Mesolithic remains. The Boxtel Formation, if present, could contain Late Paleolithic and Mesolithic remains.

Especially in places where *Pleistocene* units are covered by peat remains might have been preserved *in situ*, because Early *Holocene* peat and organic clay could protect the underlying soils from erosion. Level 1 peat and organic clay predominantly occurs in the southern part of the HKWWFZ. They occurrences appear to be small, but in fact the patch labeled 'Peat / Organic Clay Level 1' in figure 29 covers an area over 1 square kilometer. DINO boreholes that plot within or very close to the shallow peat occurrences of Level 1 indeed contain organic clay (BP090058) and peat (BP090064), thus confirming Fugro's interpretation of the seismic interpretation.

Peat is also found at deeper levels within Unit F and Unit G. The peat occurences within Unit F comprise glacially deformed peat inclusion which originate from the Yarmouth Roads Formation.

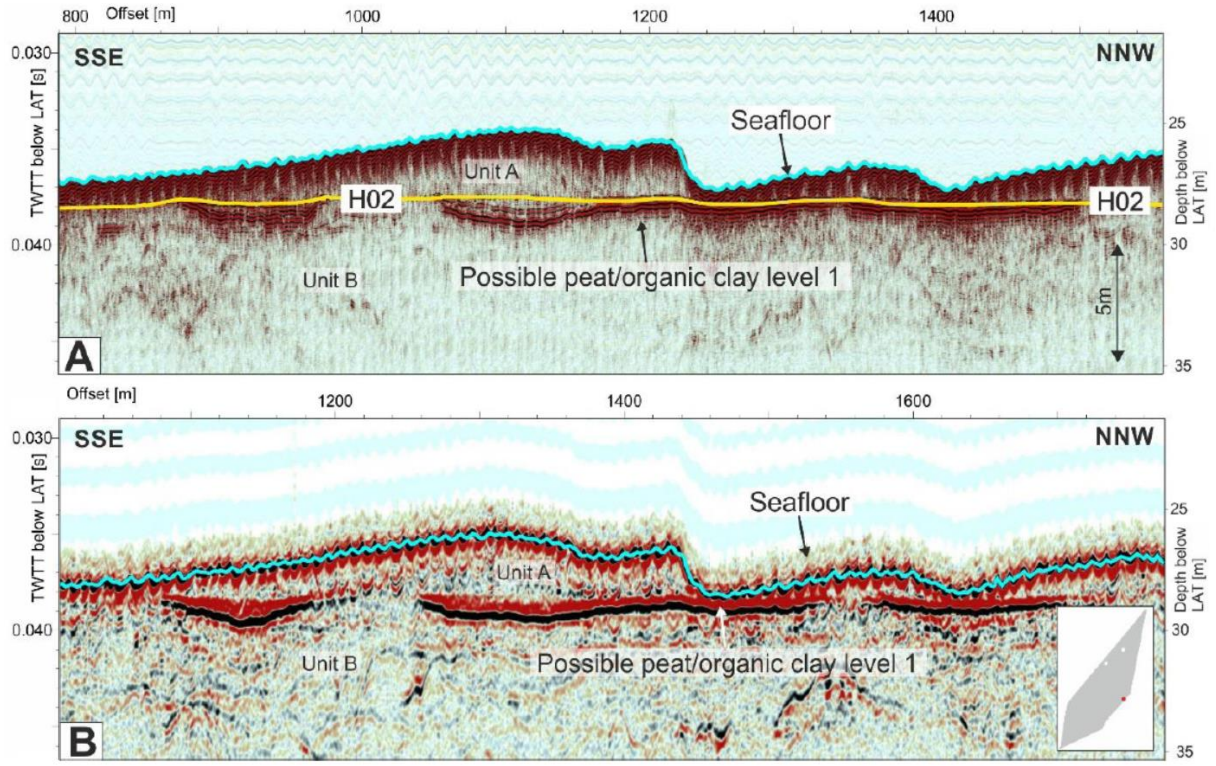


Figure 28. Level 1 peat or organic clay observed in survey lines SBP 1D185 / MCS UHR 2D548

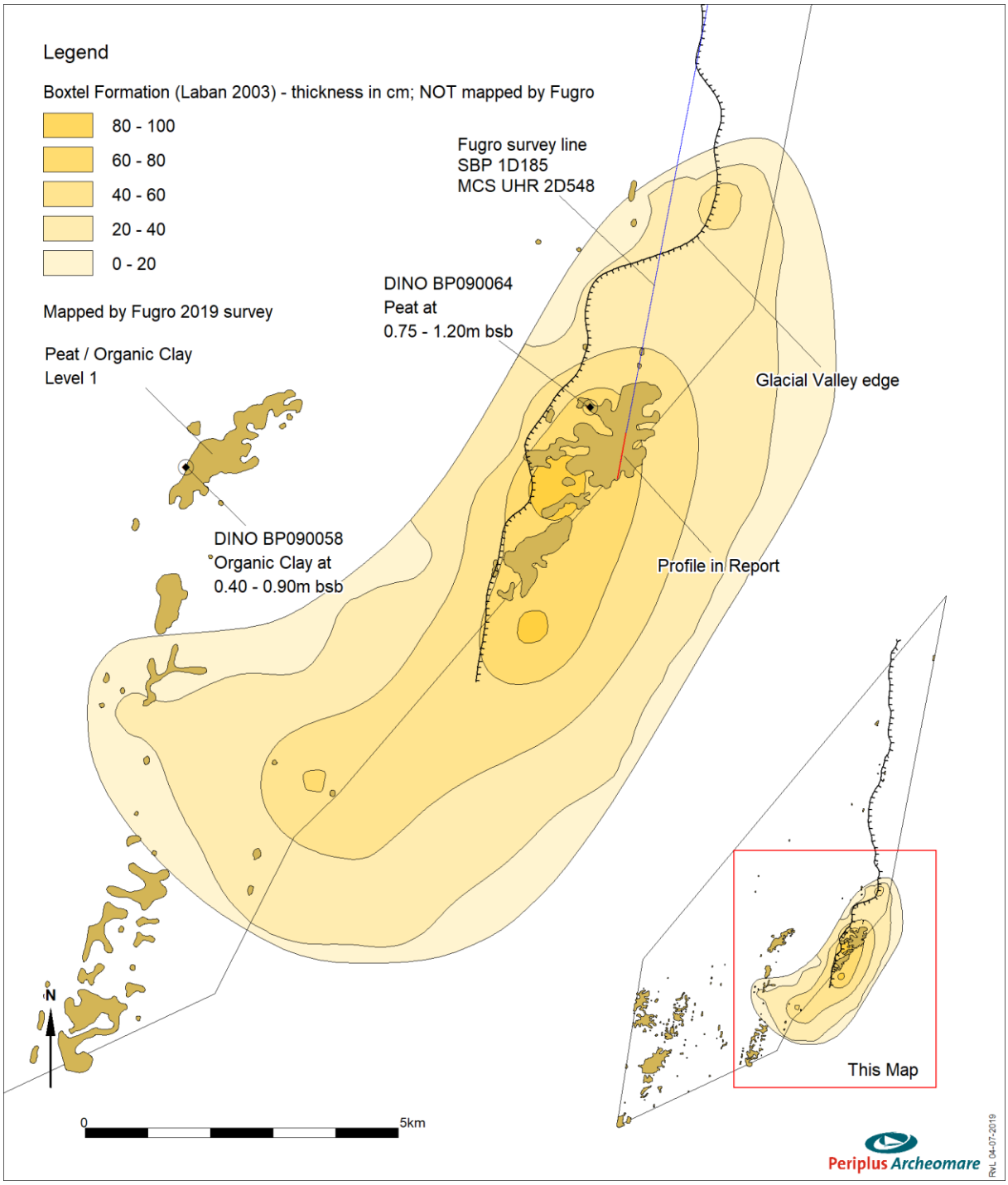
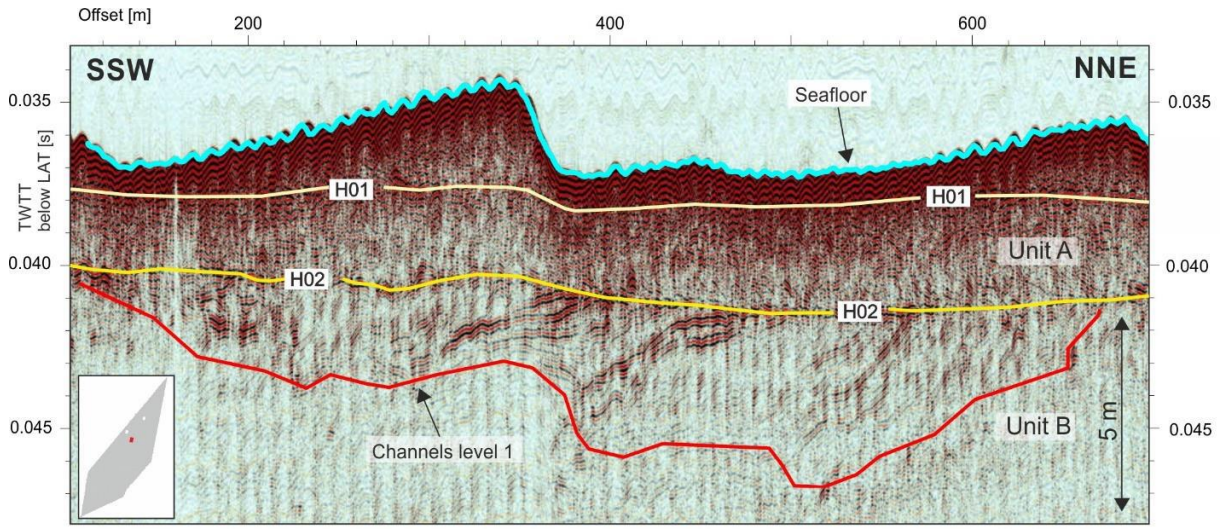


Figure 29. Expected occurrence of Boxtel Formation (Laban 2003) and As Found Level 1 peat/organic clay subcrops


Offset [m]
200
400
600
SSW
NNE
0.035
0.040
0.045
TWTT
below LAT [s]
Seafloor
H01
H01
H02
H02
Unit A
Unit B
Channels level 1
5 m

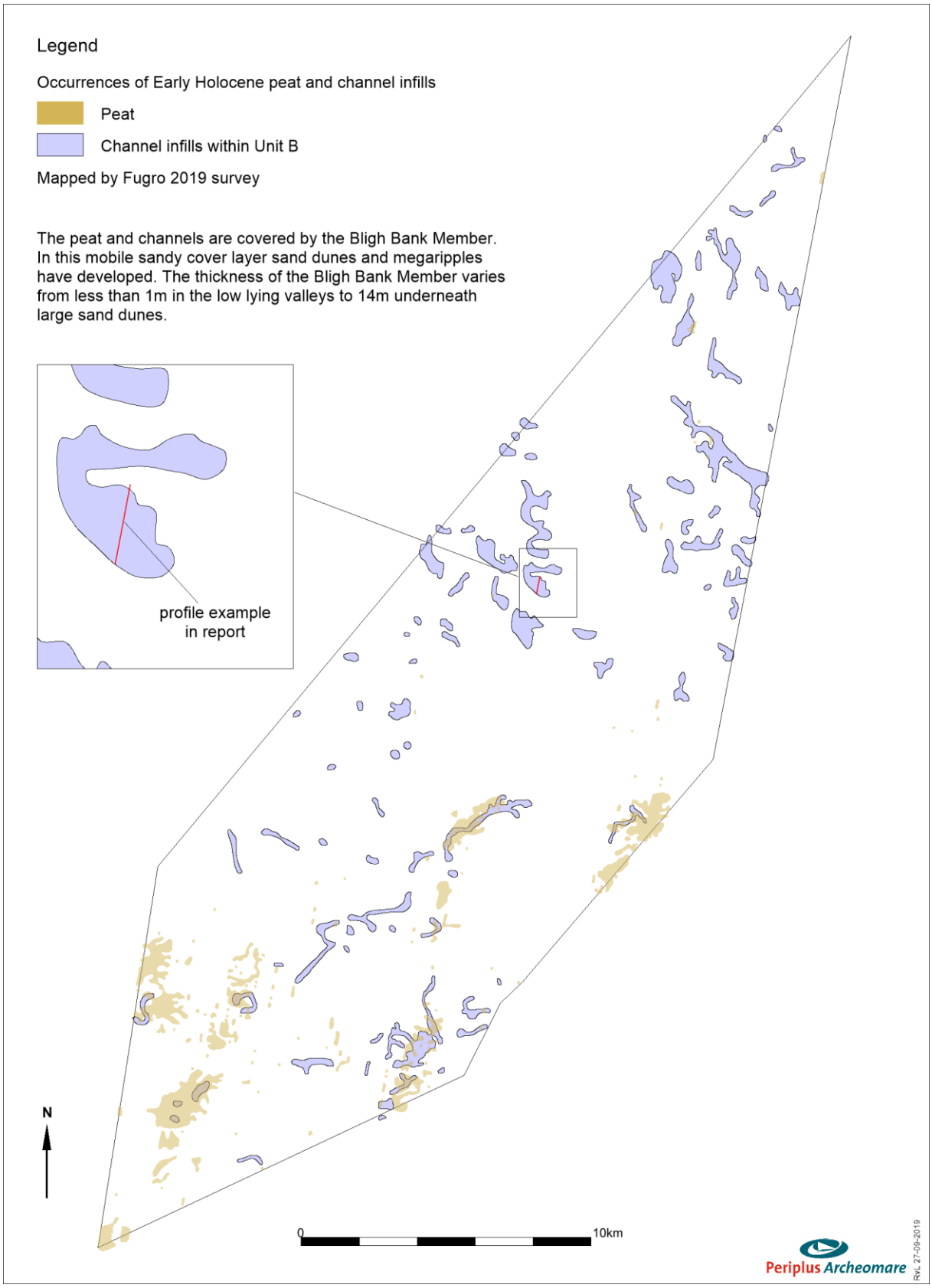


Figure 30. Occurrences of Early Holocene peat and channel infills

The figure on the next page shows the interpreted geolological profile through the WFZ from southwest to northeast.

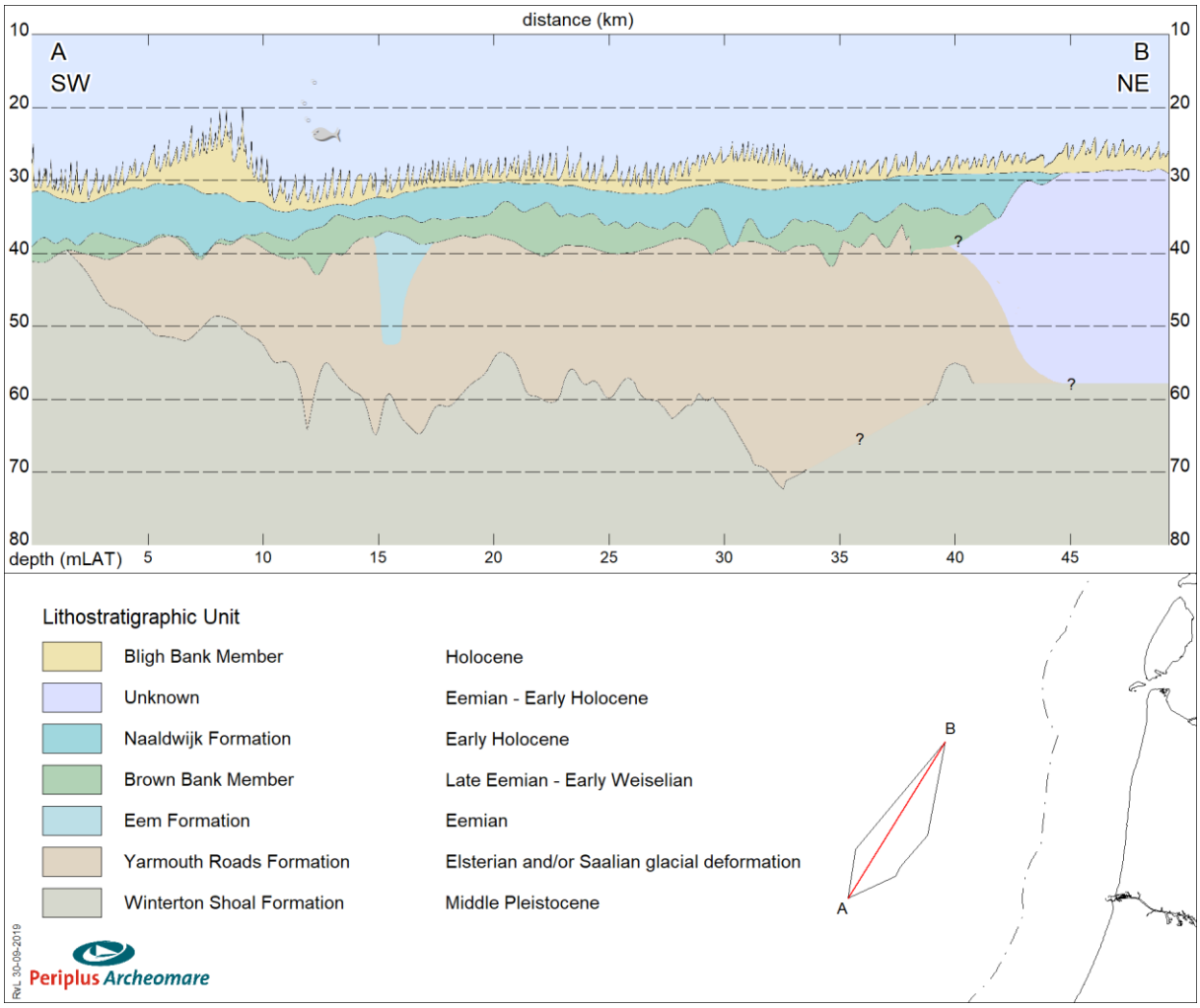


Figure 31. An interpreted geolological profile from southwest to northeast.

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4 Synthesis

For this investigation different research questions are defined in the Program of Requirements.[16]
Based on the results of de data analysis the research questions are answered.

Primary question:

Are any archaeological remains present within the Area of Interest and to what extent are these remains traceable?

Yes. An archaeological expectation is assigned to a total of 22 locations within the HKWWFZ.
7 known objects and 8 new sites have been found during this survey campaign.
7 known wrecks with an archaeological expectaction have not been found, presumably because they are covered with sediment.
5 known wrecks have not been found because their location is outside the research area.

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

Are there any phenomena visible on the seabed?

Yes. A total of 405 contacts visible at the surface are reported with *sidescan sonar* and *multibeam*.

A total of 1750 magnetic anomalies cannot be related to known pipelines and cables, or visible objects at the seabed surface. They are related to unknown ferrous objects buried in the seabed, covered by sediments. 107 of these anomalies have an amplitude of 50 nT and more.

General	**Total**
Sidescan sonar contacts	405
Magnetometer contacts	2450
Overlap sonar *magnetometer*	10
Unidentified *magnetometer* > 50nT	107

Table 15. Summary of all contacts

If so:

What is the description of these phenomena?

Fugro has identified 405 *sidescan sonar* contacts within the HKWWFZ zone. The classification of the contacts is listed below.

Classification	**Total**
Boulder	225
Debris	109
Depression	21
Linear Debris	38
Wreck	12
Total	**405**

Table 16. Sidescan sonar contacts identified in the HKW WFZ

[16] Van Lil and van den Brenk, 2017.

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

None of the assessed contacts smaller than 4 meter has been interpreted as potential archaeological object or structure. After reviewing a selection of 51 contacts larger than four meters in more detail, a number of contacts can be interpreted as natural phenomena such as sedimentary features. A summary is listed in the table below.

Interpretation Periplus	Total
Boulder	7
Debris	15
Depression	5
Linear Debris	13
Wreck	11
Total	**51**

Table 17. Results of the assessment of selected sidescan sonar contacts

Eight of the unknown objects were assigned with an archaeological expectation.

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

What classification can be attached?

The man-made phenomena consist of (remains of) shipwrecks, an exposed pipeline and loose pieces of cables and chains, which were lost or dumped at sea.

If these phenomena can be classified as archaeological:

Is it possible to interpret the nature of the archaeological objects?

An archaeological expectation is assigned to 10 sidescan sonar contacts found at 8 locations; a summary is listed below.

Nr	Easting	Northing	L(m)	W(m)	H(m)	Description_PPA	Classification_PPA
S_0039	536556	5817013	4.7	2.4	0.3	elongated to rectangular hard reflective object	Possible wreck
S_0093	538628	5824408	5.6	2.9	0.0	spherical object amidst a scour 13 x 11 m with 118 nT magnetic anomaly	Possible wreck
S_0095	538755	5824686	3.8	0.8	0.4	two elongated objects	Possible wreck site
S_0096	538786	5824717	2.6	1.1	0.9		
S_0336	544748	5823694	28.5	5.3	0.2	high reflective exposure	Possible buried wreck
S_0353	547417	5836653	7.2	6.8	0.7	high reflective exposure	Possible buried wreck
S_0401	544499	5821369	33.8	9.4	0.4	contours of a ship-like object	Buried ship wreck
S_0412	544989	5819800	3.5	5.8	0.7	cluster of contacts	Possible wreck site
S_0413	544995	5819792	4.6	4.1	1.2		
S_0679	553839	5842543	7.2	1.0	0.4	linear contact amidst cluster of contacts	Possible buried wreck

Table 18. Summary of objects from sonar and multibeam with a possible archaeological value

The resolution of the data is not high enough to discuss details about the found objects with an archaeological expectation. In case operations are planned within 100 meters of the objects, or in

case indirect consequences such as scouring because of the installation of infrastructure are to be foreseen within 100 meters of the objects, the developer is legally obliged to carry out additional research, e.g. by means of an ROV or divers, to determine the archaeological value.

If these phenomena can be identified as natural:

What is the nature of these natural phenomena?

The phenomena interpreted as natural consist of sedimentary features.

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

The seabed is characterized by a complex pattern of bedforms of various orders. Those bedforms include very large ridges, sand dunes, megaripples and small ripples. The sand banks are some 2 tot 2.5 km wide and stretch more or less north - south. The sand banks are separated by low-lying areas. The difference in height between the troughs and crests of the sand banks is up to 10 m. The distance between the crests of the two major sand ridges in the HKWWFZ is 10 km.

Each of the morphological features in the area has its typical migration rate. The position of the north-south oriented sand banks are fairly stable. Van der Meulen et al. (2004) reported a migration rate for sand dunes of over 20 m/year near the island of Texel, with typical migration rates decreasing southwards to a stationary (0 – 3 m/year) field near the entrance of the Rotterdam Harbour. Deltares studied the migration rate of sand dunes in the Offshore Wind Farm Prinses Amalia and concluded that the dunes in this area migrate some 4 m/year.

In order to assess the migration rate of sand dunes in the HKWWFZ Fugro compared the *multibeam* data which had been acquired 22 days apart. Within this short period of time a sand dune had migrated 4 m and the shape of the sand dune had altered. The mobility of the seabed of the HKWWFZ appears to be significantly higher than the Offshore Wind Farm Prinses Amalia.

If so:

How can these zones be interpreted?

See the answer to the previous question

General:

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

Larger objects like ship wrecks show clear scouring at the north and northwestern side caused by the dominant currents in a northerly direction.

If no acoustic phenomena can be observed:

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

This question is given the results of the investigation not applicable.

With respect to subbottom profiler- and sampling:

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

Yes, the acquired seismic data set is of high qualitity which is fit to map the stacked sequence of *Pleistocene* landscapes.

If so:

Can the expected buried Pleistocene units / landscapes be identified in the seismic data?

Yes, the expected buried *Pleistocene* units / landscapes have been identified in the seismic data. It should be noted however, that the actual presence of the interpreted lithostratigraphic units including the character of layer boundaries (erosive vs non-erosive) needs to be tested by means of borehole sampling.

What is the depth of the Pleistocene landscapes with respect to the present seabed?

The top of the *Pleistocene* sequence is found at depths varying from 2.2 m to 16.2 m below the seabed. The largest values coincide with the large north-south orientated sand ridges. The average and mode depths are 6.9 m and 6.4 m below the seabed.

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

Based on the seismic profiles the boundary between the top of the *Pleistocene* landscape and the covering *Holocene* deposits appears to be erosive in many locations within the HKWWFZ. However, local occurrences of (an) intact *Pleistocene* landscape(s) are likely to be present. Those areas include the areas where peat or (organic) clay has been mapped in the top sections of the seismic profiles. Also glacial depressions which gradually have been infilled with clayey material could show an intact *Pleistocene* landscape.

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

Remains of prehistoric settlements are to be expected in the context of the now covered deposits of:

a) the edge of the glacial valley,
b) the shore deposits of lagoons and lakes found along the rims of the Brown Bank Member,
c) the top of the cover sand and stream deposits of the Boxtel Formation

The change of finding in situ remains is enhanced in area where the abovementioned archaeological levels are covered by peat or clay which could have protected the underlying archaeological levels from erosion.

If so:

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

The top of the *Pleistocene* landscape has been mapped by means of the current *subbottom profiler* survey. The depth of installation of the infield and export cables is currently not known. Once known, it is adviced to substract the burial depth of the cables from the top *Pleistocene* map to obtain an overview of the location where the expected remains might be affected and where the cable installation does not reach the archaeological levels.

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

Yes, a concentration of diffraction hyperbola have been observed in the mobile top layer of the Bligh Bank Member in the southeastern part of the area. The hyperbola are probably related to natural inclusions in the sediments, like boulders, gravel layer or shell beds.

If so:

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

No, neither on the *multibeam* data nor on the sidescan sonar images are any of those phenomena visible indicating that the presumed objects are buried.

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

No, there are no indications that those objects are of archeological value. The objects possibly could hinder the installation of infrastructure.

Additional questions have been formulated after consultation with RvO.nl, the Cultural Heritage Agency and the Ministry of Economic Affairs and Climate affairs. Those question are not included in the Program of Requirements.

The following questions have been asked:

Can Early Holocene clayey and peaty deposits be distinghuished as separate unit(s) in the seismic data?

Yes, Fugro has mapped occurrences of Early *Holocene* ('possible') deposits of peat and organic clay as Level 1. The possible peat and/or organic clay layers have been found at the interface of the Naaldwijk Formation and the Bligh Bank Member. This stratigraphic level does not comply with the expected occurrence of the Basal Peat Bed and/or Velsen Bed at the base of the Naaldwijk Formation covering the underlying *Pleistocene* landscape. A possible explanation could be that the seismic Unit B which has been interpreted as Naaldwijk Formation by Fugro also includes the Boxtel Formation. The Boxtel Formation has not been identified by Fugro. Unit B has a 'variable internal seismic character' which can make it difficult to distinghuish Unit B from Unit E or Unit which have a 'similar seismic character'. Therefore the Saalian ice-pused deposits of the Yarmouth Roads Formation (Unit F) could in places have been interpreted and labeled as Unit F. In that case the peat and/or organic clay covers the late *Pleistocene* landscape.

If so:

What is the seismic character, thickness and spacial distribution of the Early Holocene unit(s)?

The 'Level 1' possible peat and/or organic clay beds have been identified as a intervals of thin (< 1m) high amplitude reflectors in the *subbottom profiler* data. The combined area in which possible peat and/or organic clay has been identified is over 13 square kilometer. The subcrops are predoninamtly found in the southern part of the HKWWFZ.

Can the Wormer Member, Velsen Bed and/or the Basal Peat Bed be identified?

The occurrences of (possible) peat and/or organic clay are expected to comprise the Basal Peat Bed and Velsen Bed. The Naaldwijk Formation comprises the Wormer Member.

Is the top of the underlying Pleistocene sequence intact?

This question cannot be answered based on the data available. The analysis of borehole samples can clarify the integrity of the *Pleistocene* landscapes covered by peat.

If so:

In which part(s) of the area is the top of the Pleistocene sequence expected to be intact?

For now, we presume that the peat-covered *Pleistocene* landscape is intact until proven differently.

Do the seismic profiles show indicatations for the presence of ice-pushed ridges?

Yes, glacially deformed deposits have been found in major part of the area.

If so:

What is the seismic character and spacial distribution of the ice-pushed ridge(s)?

Glacially deformed sediments characterized by 'chaotic internal seismic reflections, inclined shear planes, faulting, acoustic masking, deformed layers and generally large variability of the seismic signal within short distance.' The deformed sediments are found west of the glacial valley edge which has been mapped by Fugro. The degree of deformation diminishes towards the west.

Is the top of the ice-pushed ridge(s) intact?

The intial ice-pushed ridge appears to have largely been abraded due to the marine ingression and development of an intertidal environment in Early *Holocene* times. The deposits of the Yarmouth Roads Formation (Unit F) which were thrusted into the HKWWFZ are unconformably overlain by the Naaldwijk Formation, the boundary between the units in most places being erosive.

If so:

In which part of the area is the top of the ice-pushed ridge(s) expected to be intact?

Part of the ridge flanks are expected to be intact albeit that those flanks might be covered by slope material which moved down the valley edge by a process called gelifluction and small streams. Also in areas where the ice-pushed deposits are covered the Boxtel Formation and/or Early *Holocene* peat and organic clay the the top of the unit possibly has been preserved intact.

5 Summary and recommendations

A large quantity of survey data (*sidescan sonar, magnetometer, multibeam echosounder* and *subbottom profiling*) recorded within the wind farm zone covering a total area of 402 km^2 have been analyzed in order to conduct an archaeological assessment.

Ship wrecks and remains of WWII aircraft

The current analysis of geophysical survey results is the second and step in the archaeological assessment, following the desk study. The desk study has shown that within the boundary of the wind farm site a total of 39 objects including (a maximum of) 23 wrecks are known from database sources. 19 of those wreck sites are considered to be of potential archaeological interest.

15 known objects including 10 wrecks have been found during the geophysical survey.

- 7 of the wrecks found are of possible archaeological value;
- 3 of the wrecks found are considered to be of no archeological value;
- 4 wellheads;
- 1 man-made object considered to be of no archaeological value.

24 known objects including 13 wrecks have not been found during the geophysical survey.

- all known objects (including the wrecks) which have not been found witing the survey area have probably become covered with sediment due to the migration of sand waves;
- 12 of the 13 wrecks which have not been found are of possible archaeological value;
- 5 of the 12 wrecks of possible archaeological value are probably located outside the area of investigation;
- 1 of the wrecks which has not been found are considered to be of no archeological value.

Known Objects	Archaeological Expectation		Total
	Yes	No	
Found	7	8	15
Not Found	12*	12	24
Total	19	20	39

* 5 of these wrecks are probably situated outside the area of investigation; the other 7 wrecks of possible archaeological value are presumably located inside the area of investigation under a cover of sediment.

Apart from the 15 known objects found, another 405 *sidescan sonar* contacts have been reported. The analysis of these contacts resulted in a final selection of 8 locations containing 10 unknown objects and structures which - based on their shapes and dimensions - may be of archaeological value.

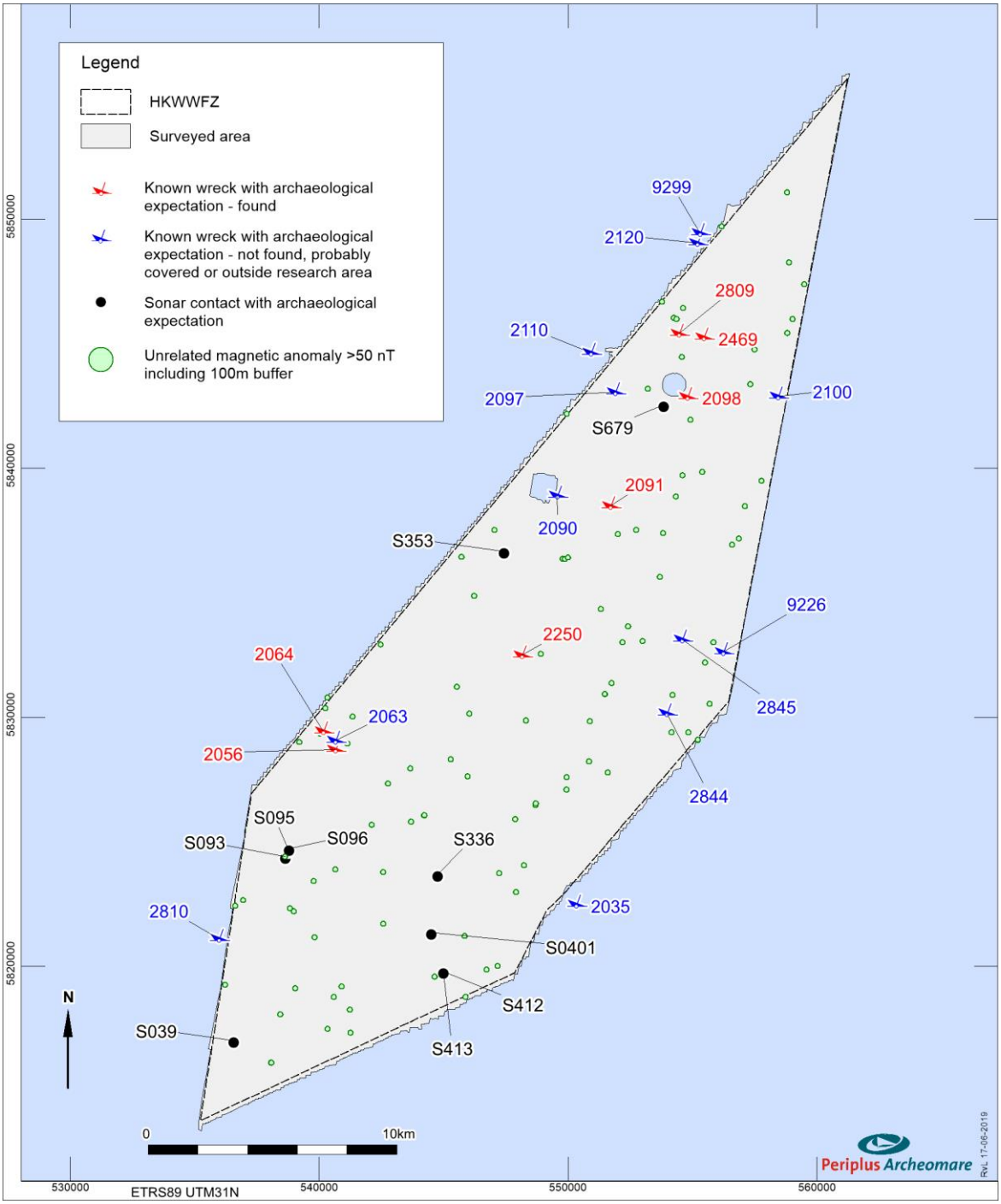
A summary of all found objects with a possible archaeological expectation is listed in the following table.

Nr/	ETRS89 UTM31N		Dimensions (m)				
NCN	Easting	Northing	L	W	H	Description	Classification
S_0039	536556	5817013	4.7	2.4	0.3	elongated to rectangular hard reflective object	Possible wreck
S_0093	538628	5824408	5.6	2.9	0.0	spherical object amidst a scour 13 x 11 m with 118 nT magnetic anomaly	Possible wreck
S_0095	538755	5824686	3.8	0.8	0.4	two elongated objects	Possible wreck site
S_0096	538786	5824717	2.6	1.1	0.9		
S_0336	544748	5823694	28.5	5.3	0.2	high reflective exposure	Possible buried wreck
S_0353	547417	5836653	7.2	6.8	0.7	high reflective exposure	Possible buried wreck
S_0401	544499	5821369	33.8	9.4	0.4	contours of a ship-like object	Buried ship wreck
S_0412	544989	5819800	3.5	5.8	0.7	cluster of contacts	Possible wreck site
S_0413	544995	5819792	4.6	4.1	1.2		
S_0679	553839	5842543	7.2	1.0	0.4	linear contact amidst cluster of contacts	Possible buried wreck
NCN2056	540645	5828700	63.0	9.6	3.0	Wreck DHY 2247. Duikteam Zeester: Biaritz, sunk 1940	Wreck Biaritz
NCN2064	540162	5829452	87.0	20.0	3.4	Wreck DHY 2256. Duikteam Zeester: SS Paris, sunk 1939	Wreck SS Paris
NCN2091	551689	5838477	28.0	9.0	1.8	Distributed remains of wreck DHY 2284	Wreck
NCN2098	554783	5842860	0.0	0.0	0.0	Wreck DHY 2292. Duikteam Zeester: Boezemwrak close to platform	No visible contacts, sandwave, mag. anomaly 2031 nT
NCN2250	548149	5832487	31.0	10.0	1.1	Wreck DHY 2468. Unknown wreck reported 1984	Wreck
NCN2469	555444	5845242	29.0	8.0	3.4	Wreck debris	Wreck, partly buried
NCN2809	554440	5845409	28.0	7.0	0.4	Wreck DHY 3427. Unknown wreck reported with sonar 1997	Possible wreck

Magnetic anomalies

A total of 2450 magnetic anomalies have been observed. 674 of these anomalies can be related to known pipelines or cables. 10 anomalies can be related to *sidescan sonar* contacts.

A total of 1750 magnetic anomalies cannot be related to known pipelines and cables, or visible objects at the seabed surface. The anomalies are related to unknown ferrous objects buried in the seabed, covered by sediments. 107 of these anomalies have an amplitude of 50 nT or more. An overview is presented in the figure below.



Prehistoric remains

Major part of the *Pleistocene* landscapes appear to have eroded during the Early *Holocene* marine ingression and development of an intertital area, thus affecting the integrity of possible prehistoric settlements. Locally the geological units defined as potential containers of prehistoric remains might have been preserved intact.

Areas of potential archaeological interest are:

- the shores of small streams and aeolian dunes of the Boxtel Formation proximate to the valley, especially if those areas are cover by peat or clay;
- ice-pushed deposits along within zone bordering the glacial valley edge;
- small basin infills of the Brown Bank Member.

The physical quality, that is the integrity and preservation of prehistoric remains is highly dependent on the extent to which archaeological levels have been affected by erosion. The interpretation of lithostratigraphic units and the character of the layer boundaries (erosive versus non-erosive) from the seismic data is based on the geological data available and expert judgement. The seismic interpretation shall be ground-truthed by a combination of cone penetration tests and borehole sampling. The actual geological sequences present in the area and the integrity of layer bounderies will be verified, thus offering a tool to further for prehistoric landcapes and specify and test the archaeological potential.

Recommendations

Ship wrecks and WWII aircraft remains

As long as the value of the 22 sites of potential archaeological interest has not been determined, it is advised not to conduct seabed disturbing activities within an area of 100 meters around these sites. This advice also applies to cable trenching and anchorages of work vessels. The 22 sites included 8 locations with newly found exposed objects and 14 known NCN wreck sites (7 found and 7 presumably buried).

Concerning the buried ferrous objects, it is advised to avoid these locations including a buffer zone of 100 meters areas whilst installing wind turbines and the various inner field and export cables. It should be stressed that the origin of the magnetic anomalies is unknown and apart from possible archaeological remains any type of man-made objects can be encountered including unexploded ammunition, anchors, pieces of chains and cables, debris, etcetera.

The buffer zone of 100 meters is a standard that applies to the protection of cultural heritage, this distance may be reduced if it can be substantiated that the applied disturbance has no effect on the archaeological object. For example, when no anchoring is used during cable lay operations the buffer zone can be decreased. Reduction of the distance has to be approved by Rijkswaterstaat (RWS). Rijkswaterstaat is the enforcing authority, acting on behalf of the Ministry of Economic Affairs and Climate Policy. The Cultural Heritage Agency of the Netherlands (RCE) acts as an advisor to Rijkswaterstaat.

If it is not feasible to avoid the reported *magnetometer* locations, additional research is required in order to determine the actual archaeological value of the reported locations. It is advised that the UXO research within 100 meter of the *magnetometer* anomalies are carried out under archaeological supervision.

Depending on the outcome of the UXO research it can be decided if additional research (for instance by means of ROV or dive investigations) is needed. If the UXO research indicates that the object has no archaeological value, the location can be omitted.

Prehistory

Based on the results and conclusions of the current research, we recommend to conduct further archaeological research that focuses on the genesis and integrity of paleo landscapes in the HKWWFZ. This research comprises an inventory of field research by means of borehole sampling and cone pentration tests (CPT's) in accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1). A geotechnical campaign is carried out to generate a geological model of the subsurface of the windfarm and to determine the physical properties of the sediment layers present. We advise to use the borehole samples and CPT-graphs for geo-archaeological research.

The research primarily focuses on the borehole samples collected at nine locations (see figure below). The samples taken at these locations are expected to provide the information needed to determine the geogenesis of the area and the integrity of the covered paleo landscapes. It is not inconceivable that during the analysis of the sediment samples questions will arise that can only be answered by analyzing borehole samples from other locations. It is therefore important that the samples of all borehole locations in the HKWWFZ are available for geo-archaeological research.

The intact samples must be examined by a (senior) prospector and described in accordance with the *Standaard Boorbeschrijvingsmethode* (SBB). Samples are selected and stabilized to be analyzed by specialists in the field of C-14 dating, micromorphological research, pollen analysis, macro-remains of plants and animals, molluscs, et cetera to gain insight into the development of landscapes over time and the extent to which these paleolandscapes have been preserved.

In accordance with the Dutch Quality Standard for Archaeology (KNA Waterbodems 4.1), a Program of Requirements (PvE) and / or Plan of Action (PvA) must be drawn up. The PvE/PvA includes the objective, the research strategy and methodology, the frameworks and the practical implementation of the research, so that the process runs smoothly and multiple use of the data acquired in a uniform manner is achieved. It is advised to submit this PvE / PvA for approval to the Competent Authorities and the RCE.

After completion of the inventory field research, during the construction of the wind farm, data can be collected that - from an archaeological point of view - provide valuable information at a detailed level. It can be very useful to investigate this information further from an archeological point of view. It is advised to investigate the possibilities for this in consultation with the RCE, once the plans have been worked out.

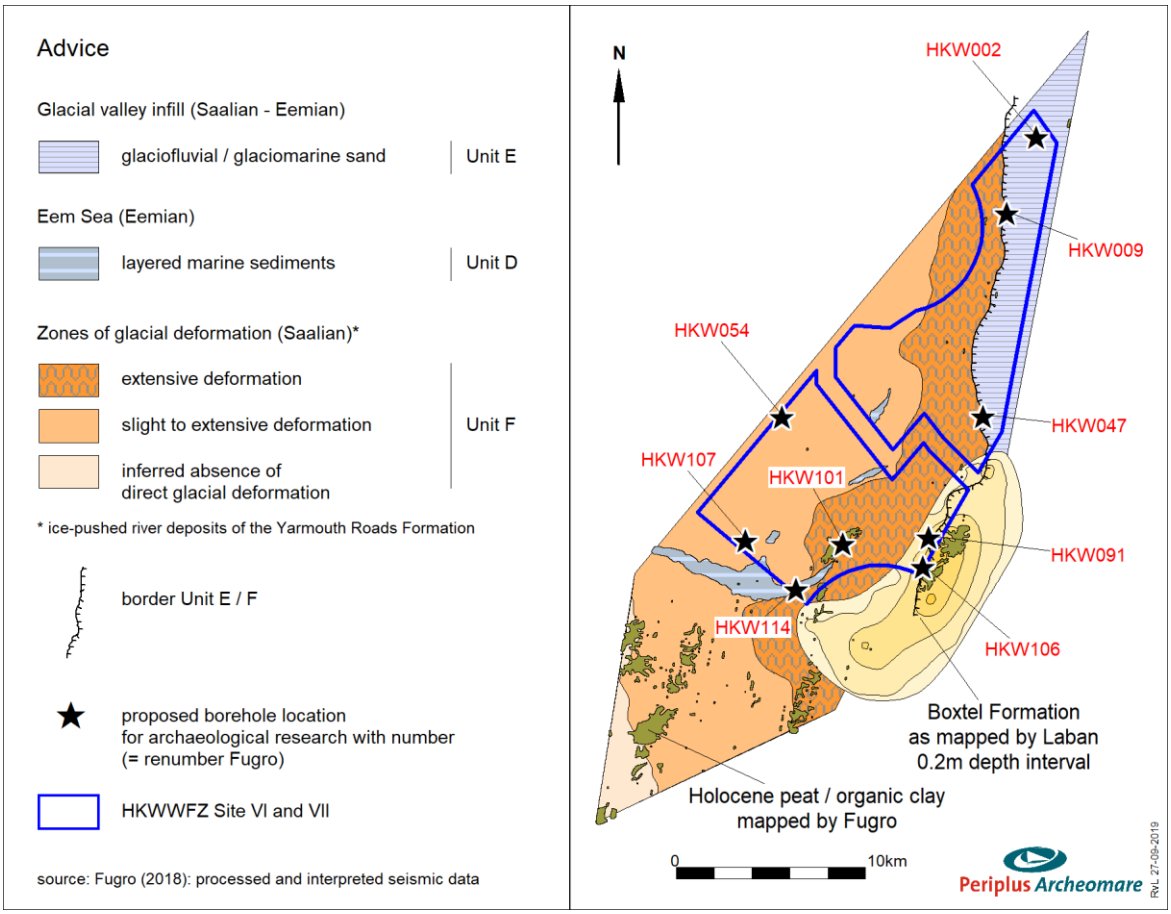


Figure 32. Proposed borehole sample locations for archaeological research

Renumber	PPA	Easting	Northing	Z mLAT
HKW002	possible Echteld (*Holocene*) channel feature from 1.1-7.4m depth.	558511	5850094	27.7
HKW009	proximate to glacial valley edge. interesting age dating profile according to RVO/FUGRO	556935	5846086	28.8
HKW047	Saalian valley; infill = Saalian, Eemian, *Holocene*?; proximate to edge (28m); underlying ice-pushed deposits	555680	5835338	26.6
HKW054	small *Holocene* channel incission	545071	5835320	28.2
HKW091*	within Laban bx 0.4m; near valley edge (220m); no peat mapped	552817	5828953	29.5
HKW101	possible brb; edge of *Holocene* channel infill; peat and/or organic clay	548290	5828597	27.0
HKW106	within Laban bx 0.6m; at valley edge (70m); no peat mapped	552522	5827385	29.1
HKW107	instead of PPA proposed location no 5; ice-pushed deposits; layered infill depression with brb (10m)	543126	5828766	29.5
HKW114	ee (<10m) brb (appr. 3m) na (?) brb (5-10m)	545801	5826218	27.6

*Note: It is advised to move this location to 553226E; 5828876N to include *Holocene* peat/organic clay and thin layer of glacial valley infill; this location is at the cross point of 2D545 and 2X598

Short summary

In summary it is concluded that the windpark owner shall take into account:

- 14 known NCN wrecks of possible archaeological value found exposed at the seabed (7) or (possibly) covered by sediments (7);
- 8 new sites with remains of possible archaeological value found exposed at the seabed;
- 107 buried iron-bearing objects of possible archaeological value (magnetic anomalies > 50 nT);
- 9 proposed borehole sampling locations to investigate the presence, integrity and preservation of stacked prehistoric landscapes.

Short Recommendation

It is adviced to maintain a 100m zone as Area to be Avoided around the 129 locations of possible archaeological interest.

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

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Glossary and abbreviations

Terminology	Description
AMZ	Archeologische Monumenten Zorg, a description of procedures to ensure the protection of National archaeological Cultural Heritage
CPT	Cone penetration test
Eemian	Warm period (interglacial) between Saalian and Weichselian from 130.000 to 115.000 years ago
Erratic	An (glacial) erratic is a piece of rock that differs from the size and type of rock native to the area in which it rests. These rocks are carried by glacial ice, often over distances of hundreds of kilometres. Erratics can range in size from pebbles to large boulders.
Ferrous	Material which is magnetic or can be magnetized, and well known types are iron and nickel
Glacial	Ice-age
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
Interglacial	Warm period in between two ice-ages
KNA	Kwaliteitsnorm Nederlandse Archeologie = Dutch Quality Standard for Archaeological Research
Magnetometer	Methodology to measure deviations from the earth's magnetic field (caused by the presence of ferro-magnetic = ferrous objects)
Multibeam	Acoustic instrument that uses different bundles or beams to measure the depth in order to create a detailed topographic model
Pleistocene	Geological era that began about 2 million years ago. The era of the ice ages but also moderately warm periods. The *Pleistocene* ends with the beginning of the *Holocene*
PvE	Program of Requirements (Dutch: Programma van Eisen)
RCE	Ministry of Cultural Heritage (Dutch: Rijksdienst voor het Cultureel Erfgoed)
ROV	Remotely Operated Vehicle
Saalian	Second last Ice age (glacial) from 240.000 to 130.000 years ago
Sidescan sonar	Acoustic instrument that registers the amplitude 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
Weichselian	Last Ice Age (glacial) from 115.000 to 12.000 years ago

References

Literature

- Arlar, L. and E. van den Berg, 2018. UXO desk study Unexploded Ordnance Site data Hollandse Kust (west) Wind Farm Zone (HKWWFZ). REAS Euro reference 73065/RO-180140 version 3.0 (final report)
- Backes, F. and Yeo, R., 2017. Hollandse Kust (noord) Windfarm Zone Survey 2017, Dutch Continental Shelf, North Sea GH216 Field Report Volume 1 of 1 revision 2.
- Busschers, F.S., C.W. Dubelaar, J. Stafleu en D. Maljers, 2010: Lithological and sand grain-size variability in the three-dimensional GeoTOP model of Zuid-Holland, Delft.
- De Bruin, R., Forzoni, A., de Kleine, M., de Lange, G., Mesdag, C. and Vermaas, T., 2015. Geological study Hollandse Kust (zuid) Wind Farm Zone. Deltares rapport 1221136-000-BGS-0006.
- De Mulder, E. e.a., 2003: De ondergrond van Nederland, Groningen.
- De Wolff, R., 2017. Site Studies Wind Farm Zone Hollandse Kust (noord). Scope of Work Geophysical Survey
- Deeben, J., D.P. Hallewas & Th.J. Maarleveld, 2002: Predictive modelling in Archaeological Heritage Management of the Netherlands: the Indicative Map of Archaeological Values (2nd Generation), Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek 45, 9-56.
- Forzoni, A., T. Vermaas, C. Mesdag, M. Hijma, G. de Lange en M. de Kleine, 2017. Geological study Hollandse Kust (noord) Wind Farm Zone. Deltares project 11200513-002 reference 11200513-002-BGS-0001.
- Fugro, 2019. Geophysical Results Report Hollandse Kust (West) Wind Farm Zone Survey 2018, Zone Survey 2018 Dutch Continental Shelf, North Sea. Fugro Document No.: P904162, volume 3 of 3.
- Gaffney, V.L., K. Thomson en S. Fitch, 2005: The Archaeology and geomorphology of the North Sea, Kirkwall.
- Hessing, W.A.M., 2005: Het Nederlandse kustgebied, in: Bechert, T en W.J.H. Willems (red.), De Romeinse rijksgrens tussen Moezel en Noordzeekust, 89-102.
- Hijma, M., 2009: From river valley to estuary, The early-mid holocene transgression of the Rhine-Meuse valley, The Netherlands, Netherlands Geographical Studies 389, Utrecht.
- Huizer, J. en H.J.T. Weerts, 2003: Formatie van Maassluis, In: Lithostratigrafische Nomenclator van de Ondiepe Ondergrond, Geologische Dienst Nederland (DINOloket).
- IMAGO projectgroep, 2003: Eindrapportage IMAGO: Samenvatting en conclusies, RDIJ rapport 2003-13a.
- Kramer, E. e.a., 2003 (red.): Koningen van de Noordzee, 250-850, Leeuwarden / Nijmegen.
- Louwe Kooijmans, L.P., 1970-1971. Mesolithic Bone and Antler Implements from the North Sea and from the Netherlands.- Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek, 20-21: 69-70.
- Maarleveld, Th. J. en E.J. van Ginkel, 1990: Archeologie onder water, het verleden van een varend volk, Amsterdam.
- Maarleveld, TH.J. 1998: Archaeological heritage management in Dutch waters: exploratory studies, Almere.
- Nieboer, R., Marchetti, M. end Taliana, D., 2016. Geophysical Site Investigation Survey Dutch Continental Shelf, North Sea. Hollandse Kust (zuid) Wind Farm Development Zone Wind Farm Site I. Fugro Report No.: GH176-R1S.
- Nieboer, R., Marchetti, M. end Taliana, D., 2016. Geophysical Site Investigation Survey Dutch Continental Shelf, North Sea. Hollandse Kust (zuid) Wind Farm Development Zone Wind Farm Site II. Fugro Report No.: GH176-R02.

- Reikwijdte en Detailniveau Transmissiesyteem wind op zee Hollandse Kust (zuid), 2015.
- Rieu, R., van Heteren, S., van der Spek, J.F., and de Boer, P.L., 2005: Development and preservation of a Mid-holocene Tidal-Channel Network Offshore the Western Netherlands. Journal of Sedimentary Research, 75-3, p 409-419.
- Rijsdijk, K.F, S. Passchier, H.J.T. Weerts, C. Laban, R.J.W. van Leeuwen & J.H.J. Ebbing, 2005: Revised Upper Cenozoic stratigraphy of the Dutch sector of the North Sea Basin: towards an integrated lithostratigraphic, seismostratigraphic and allostratigraphic approach. Netherlands Journal of Geoscience 84-2, p 129-146.
- Sier, M.M.; Cohen, K.M.; Kooistra, L.; Kubiak-Martens, L.; Moree, J.M.; Niekus, M.; Peeters, J.H.M.; Schiltmans, D.E.A.; Verbaas, A.; Verbruggen, F.; Vos, P.C.en Zeiler, J.T., Utrecht 2014. Twenty metres deep! The Mesolithic period at the site Yangtze Harbour in the Rotterdam Maasvlakte, the Netherlands. Early Holocene landscape development and habitation.
- Thal, J., Socko, L., Feldmann, S, Brock, J. P. (2018). Geological Desk Study for the Hollandse Kust (west) Wind Farm Zone. Arcadis Nederland B.V. and Geo-Engineering.org GmbH, 180017. Netherlands Enterprise Agency. (RVO.nl).
- Van den Brenk, S. and van Lil, R., 2018. Program of requirements Hollandse Kust (west) Wind Farm Zone – Archaeological field survey (geophysical stage).
- Van den Brenk, S. en van Mierlo, B.E.J.M., 2006. Archeologische assesment Maasvlakte II. Periplus Archeomare rapport 06A001.
- Van den Brenk, S., van Lil, R. en Cassee, R, 2018. Archaeological desk study Hollandse Kust (west). Periplus Archeomare rapport 18A031-01.
- Verhart, L., 2005: Een verdronken land. Mesolithische vondsten uit de Noordzee, in: Louwe Kooijmans, L.P. e.a. (red.), de Prehistorie van Nederland, 157-160.
- Vonhögen-Peeters, L.M., van Heteren, S. and Peeters, J.H.M., 2016. Indicatief model van het archeologisch potentieel van de Noordzeebodem. Deltares rapport 1209133-000.

Atlases and Maps

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

Sources from the Internet

- Dienst der Hydrografie (www.hydro.nl)
- Dutch Federation of Aviation Archaeology (www.nfla.nl)
- Geologische Dienst Nederland – Data Informatie Nederlandse Ondergrond (www.dinoloket.nl)
- Noordzeeloket (www.noordzeeloket.nl)
- North sea paleolandscapes, University of Birmingham (http://www.iaa.bham.ac.uk)
- Olie en Gasportaal (www.nlog.nl)
- Stichting Aircraft recovery Group 40-45 (http://www.arg1940-1945.nl)
- Stichting Infrastructuur Kwaliteitsborging Bodembeheer (SIKB.nl)

Various sources

- Archis III, archeologische database Rijksdienst voor het Cultureel Erfgoed
- KNA Waterbodems 4.1
- Nationaal Contactnummer Nederland (NCN)
- SonarReg92, objectendatabase Rijkswaterstaat Noordzee en Delta

Appendix 1. Summary of contacts and known objects

General	Total
Side scan sonar contacts	405
Magnetometer contacts	2450
Overlap sonar magnetometer	10
Unidentified magnetometer contacts (total)	1750
Unidentified magnetometer contacts > 50nT	107

Objects with an archaeological expectation within HKWWFZ	Total
Known objects with an archaeological expectation found	7
Known object covered with sediments	7
New object exposed at seabed, found by SSS	8
Unidentified magnetometer contacts > 50nT	107
Total	**129**

Objects with an archaeological expectation within HKWWFZ

Nr/	ETRS89 UTM31N		Dimensions (m)				
NCN	Easting	Northing	L	W	H	Description	Classification
S_0039	536556	5817013	4.7	2.4	0.3	elongated to rectangular hard reflective object	Possible wreck
S_0093	538628	5824408	5.6	2.9	0.0	spherical object amidst a scour 13 x 11 m with 118 nT magnetic anomaly	Possible wreck
S_0095	538755	5824686	3.8	0.8	0.4	two elongated objects	Possible wreck site
S_0096	538786	5824717	2.6	1.1	0.9		
S_0336	544748	5823694	28.5	5.3	0.2	high reflective exposure	Possible buried wreck
S_0353	547417	5836653	7.2	6.8	0.7	high reflective exposure	Possible buried wreck
S_0401	544499	5821369	33.8	9.4	0.4	contours of a ship-like object	Buried ship wreck
S_0412	544989	5819800	3.5	5.8	0.7	cluster of contacts	Possible wreck site
S_0413	544995	5819792	4.6	4.1	1.2		
S_0679	553839	5842543	7.2	1.0	0.4	linear contact amidst cluster of contacts	Possible buried wreck
NCN2056	540645	5828700	63.0	9.6	3.0	Wreck DHY 2247. Duikteam Zeester: Biaritz, sunk 1940	Wreck Biaritz
NCN2064	540162	5829452	87.0	20.0	3.4	Wreck DHY 2256. Duikteam Zeester: SS Paris, sunk 1939	Wreck SS Paris
NCN2091	551689	5838477	28.0	9.0	1.8	Distributed remains of wreck DHY 2284	Wreck
NCN2098	554783	5842860	0.0	0.0	0.0	Wreck DHY 2292. Duikteam Zeester: Boezemwrak close to platform	No visible contacts, sandwave, mag. anomaly 2031 nT
NCN2250	548149	5832487	31.0	10.0	1.1	Wreck DHY 2468. Unknown wreck reported 1984	Wreck
NCN2469	555444	5845242	29.0	8.0	3.4	Wreck debris	Wreck, partly buried
NCN2809	554440	5845409	28.0	7.0	0.4	Wreck DHY 3427. Unknown wreck reported with sonar 1997	Possible wreck
NCN2063	540648	5829062	-	-	-	Wreck DHY 2255, Unknown wreck found 1970	No visible contacts May be covered
NCN2090	549558	5838909	-	-	-	Wreck DHY 2283. Unknown wreck found 1946	No visible contacts May be covered
NCN2097	551880	5843043	-	-	-	Wreck DHY 2291 Unknown wreck found 1961	No visible contacts May be covered
NCN2100	558429	5842871	-	-	-	Wreck DHY 2294. Mast reported 1898, not confirmed since	No visible contacts May be covered
NCN2844	553958	5830158	-	-	-	Wreck DHY 3498	No visible contacts May be covered
NCN2845	554572	5833117	-	-	-	Wreck DHY 3500. Wreck debris reported 2014	No visible contacts May be covered
NCN9226	556213	5832620	-	-	-	Wooden wreckremains, discovered in 2002.	No visible contacts May be covered

Appendix 2. Listing of unidentified magnetic anomalies

> 50 nT and not related to known objects or *sidescan sonar* contacts

	ETRS89 UTM31N		Anomaly				
Id	Easting	Northing	Amplitude	Type	Width	Line	Classification
M_0031	536229	5819259	282.2	Dipole	27.3	1A004	Unknown
M_0060	536633	5822430	74.1	Dipole	49.1	1A002	Unknown
M_0087	536955	5822654	76.1	Dipole	67.2	1A005	Unknown
M_0140	537629	5814965	50.1	Dipole	32.7	1A026	Unknown
M_0168	538075	5816129	56.4	Complex	64.6	1A028a	Unknown
M_0169	538087	5816136	76.5	Complex	53.5	1A028	Unknown
M_0185	538445	5818071	50.2	Dipole	28.3	1A028a	Unknown
M_0197	538633	5824401	117.9	Positive monopole	52.1	1A018	Unknown
M_0204	538833	5822329	58.9	Dipole	43	1A024	Unknown
M_0219	538986	5822208	79.4	Dipole	40.1	1X206	Unknown
M_0226	539047	5819118	1191.9	Dipole	33.1	1A032a	Unknown
M_0233	539209	5829003	69.7	Negative monopole	21.7	1A015	Unknown
M_0290	539787	5823417	88.2	Dipole	63.6	1A031	Unknown
M_0296	539822	5821164	81.6	Negative monopole	37.6	1A036	Unknown
M_0313	540057	5829326	130	Complex	171	1A023	Unknown
M_0331	540259	5830359	104.5	Dipole	40.6	1A023	Unknown
M_0337	540338	5830792	70.6	Dipole	23.9	1A023	Unknown
M_0338	540346	5817488	69.9	Negative monopole	14.7	1A048a	Unknown
M_0356	540596	5818770	101.3	Negative monopole	53.6	1A048a	Unknown
M_0360	540653	5823892	56.8	Dipole	39.8	1A039	Unknown
M_0393	541141	5828941	56.3	Dipole	39	1A034	Unknown
M_0402	541241	5818256	283.7	Dipole	30.8	1A055	Unknown
M_0405	541266	5817334	103.9	Positive monopole	34.9	1A057	Unknown
M_0413	541348	5830019	50.1	Positive monopole	42.3	1A034	Unknown
M_0468	542118	5825679	96.1	Positive monopole	37.7	1A050	Unknown
M_0493	542475	5832918	50.6	Positive monopole	33	1A040	Unknown
M_0497	542575	5823780	62.7	Positive monopole	22.8	1A058	Unknown
M_0498	542578	5821711	57.8	Dipole	29	1B062	Unknown
M_0513	542768	5827335	125.3	Dipole	48.6	1A053b	Unknown
M_0579	543667	5827944	66.9	Dipole	41.7	1B061	Unknown
M_0583	543697	5825803	50.6	Positive monopole	27	1B065	Unknown
M_0631	544221	5826060	1364.9	Positive monopole	125.8	1B070	Unknown
M_0632	544228	5826059	8968.3	Positive monopole	152.3	1B070infb	Unknown
M_0633	544232	5826063	4244.5	Complex	72.9	1B070infa	Unknown
M_0664	544643	5819585	114.1	Dipole	41.6	1B086	Unknown
M_0712	545293	5828310	55.8	Positive monopole	18.2	1B076	Unknown
M_0727	545537	5831218	120.6	Dipole	17.3	1B073	Unknown
M_0747	545724	5836432	70.5	Dipole	24	1B065	Unknown
M_0765	545851	5821216	121.5	Dipole	31.1	1B095	Unknown
M_0768	545886	5818770	103.2	Dipole	45.1	1C110	Unknown
M_0775	545967	5827624	55.6	Complex	197.5	1B084	Unknown
M_0781	546038	5830145	52.9	Dipole	29.5	1B080	Unknown
M_0799	546233	5834870	65.9	Dipole	17.5	1B073	Unknown
M_0861	546725	5819870	97.4	Dipole	41.4	1C116	Unknown
M_0904	547046	5837513	79.6	Positive monopole	48.3	1B076	Unknown
M_0919	547171	5820013	68.4	Dipole	27.9	1C120	Unknown
M_0925	547239	5823738	120	Dipole	37.8	1C114	Unknown
M_1035	547881	5825908	246.7	Negative monopole	54.5	1C116	Unknown
M_1037	547909	5822979	73.9	Complex	167.8	1C122	Unknown

Id	ETRS89 UTM31N		Anomaly			Line	Classification
	Easting	Northing	Amplitude	Type	Width		
M_1068	548232	5824052	111.1	Dipole	41.3	1C123b	Unknown
M_1075	548315	5829869	56.4	Negative monopole	28	1C113	Unknown
M_1113	548694	5826473	159.9	Dipole	35.1	1C123b	Unknown
M_1116	548708	5826535	113.9	Dipole	38.4	1C123b	Unknown
M_1140	548910	5832541	71.1	Dipole	33.4	1C114	Unknown
M_1223	549781	5836360	265.8	Negative monopole	26	1C115	Unknown
M_1236	549876	5836350	391.3	Negative monopole	36.2	1C116	Unknown
M_1244	549939	5827092	86.3	Dipole	37.6	1C134a	Unknown
M_1245	549943	5827592	70.4	Negative monopole	52.4	1C133a	Unknown
M_1247	549949	5842179	64.5	Dipole	38.1	1B101	Unknown
M_1252	549999	5836411	85.1	Negative monopole	45.9	1X214	Unknown
M_1337	550847	5828221	166.2	Dipole	47.9	1C141	Unknown
M_1341	550883	5829837	52.2	Positive monopole	26.7	1C138	Unknown
M_1392	551321	5834340	92.5	Positive monopole	27	1C134a	Unknown
M_1405	551477	5830930	77.3	Complex	30.8	1C142a	Unknown
M_1407	551483	5830926	127.8	Dipole	61.8	1C142b	Unknown
M_1419	551601	5827779	72.8	Dipole	77.5	1C149	Unknown
M_1439	551752	5831372	61.2	Dipole	66.9	1C144	Unknown
M_1465	552003	5837348	107.6	Positive monopole	22.2	1C135_cont.	Unknown
M_1492	552185	5833004	99.6	Complex	47	1C145a	Unknown
M_1536	552412	5833646	79.1	Complex	55.5	1C146a	Unknown
M_1575	552739	5837522	163	Dipole	41.9	1C142a	Unknown
M_1576	552740	5837522	148.1	Dipole	44.8	1C142b	Unknown
M_1617	552995	5833058	96.3	Dipole	30.6	1C153c	Unknown
M_1651	553211	5843184	137.6	Dipole	52.6	1C136a	Unknown
M_1749	553687	5835632	65.8	Dipole	30.8	1D165b	Unknown
M_1758	553782	5846675	111.4	Dipole	27.5	1C135_cont.	Unknown
M_1765	553820	5837386	73	Positive monopole	28.5	1C153c	Unknown
M_1826	554162	5829393	50.1	Dipole	14.8	1D181b	Unknown
M_1834	554201	5830893	213.1	Dipole	76.7	1D179	Unknown
M_1857	554330	5838860	79.6	Complex	81.4	1D165a	Unknown
M_1892	554572	5844458	58.8	Negative monopole	46.9	1C158a	Unknown
M_1895	554599	5839710	70.6	Negative monopole	48.5	1D166	Unknown
M_1899	554621	5846424	52.6	Dipole	44.9	1C161	Unknown
M_1934	554836	5829392	83.9	Positive monopole	47	1X211	Unknown
M_1950	554920	5841940	76.9	Dipole	52.1	1D165a	Unknown
M_1983	555212	5829091	102	Complex	84.5	1D192a	Unknown
M_1984	555213	5829086	77.7	Complex	86.8	1D192	Unknown
M_2013	555394	5839849	62.6	Dipole	42	1D174a	Unknown
M_2037	555505	5832192	67.3	Negative monopole	38.3	1D189a	Unknown
M_2094	555843	5833007	60.7	Negative monopole	49	1D191b	Unknown
M_2144	556173	5849701	52	Dipole	36.8	1C153a	Unknown
M_2201	556593	5836926	163.8	Negative monopole	53.4	1D191b	Unknown
M_2209	556640	5845104	85.5	Dipole	41.4	1D176	Unknown
M_2239	556865	5837172	54.8	Dipole	61.2	1D193a	Unknown
M_2263	557105	5838473	108	Positive monopole	50.3	1D193a	Unknown
M_2279	557325	5843366	104.7	Dipole	35.4	1D186a	Unknown
M_2294	557492	5844762	127.3	Dipole	54.1	1D185a	Unknown
M_2311	557775	5839492	357.6	Dipole	62.6	1D198a	Unknown
M_2377	558797	5851070	88	Positive monopole	31.9	1D186a	Unknown
M_2379	558807	5845424	82.4	Dipole	55.4	1D197a	Unknown
M_2385	558877	5848256	124.2	Dipole	43.5	1D192a	Unknown
M_2394	559019	5845986	167.1	Dipole	44.3	1D198a	Unknown

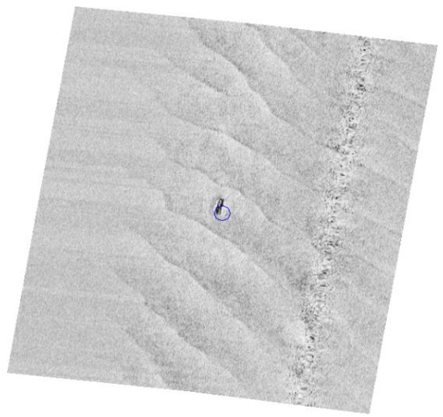
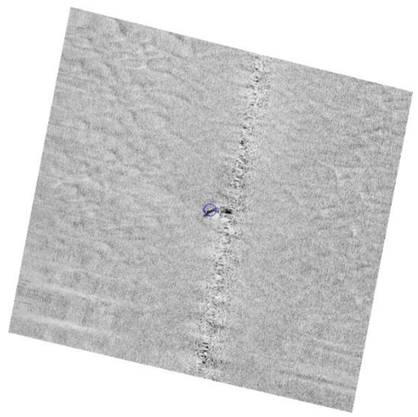
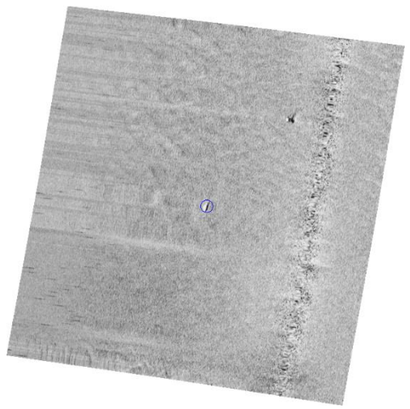
Id	ETRS89 UTM31N		Anomaly			Line	Classification
	Easting	Northing	Amplitude	Type	Width		
M_2423	559486	5847380	213.7	Dipole	28.8	1D200a	Unknown
M_2060	555689	5830536	60.4	Dipole	33	1D194	Assoc. with unknown linear feature 1
M_1842	554250	5846031	106.5	Dipole	38	1C141	Assoc. with unknown linear feature 3
M_1865	554359	5845984	54.5	Dipole	41.9	1C163	Assoc. with unknown linear feature 3
M_0382	540905	5819187	60.9	Dipole	46.2	1A050b	Assoc. with unknown linear feature 4

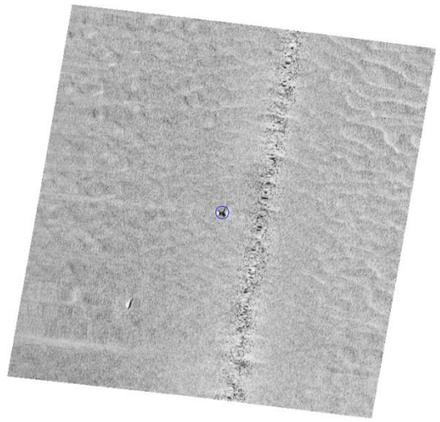
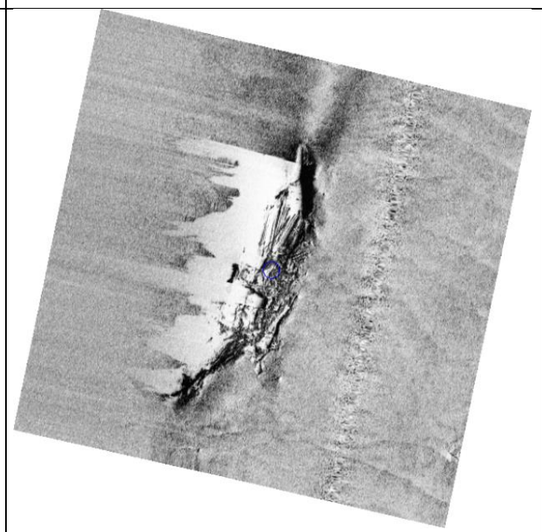
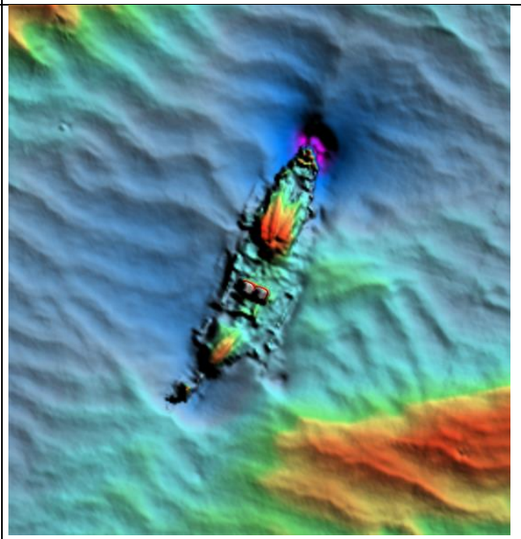
Appendix 3. Listing of selected side scan sonar contacts

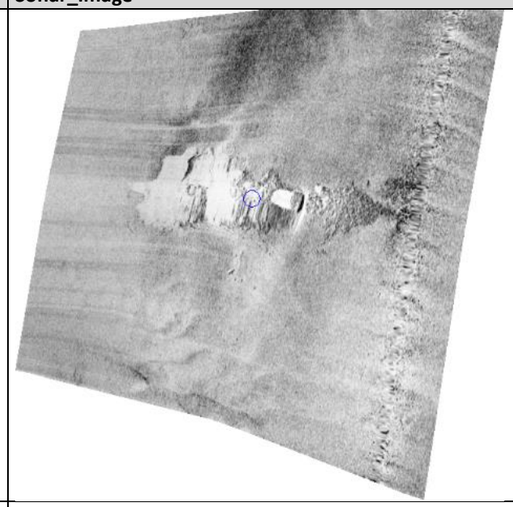
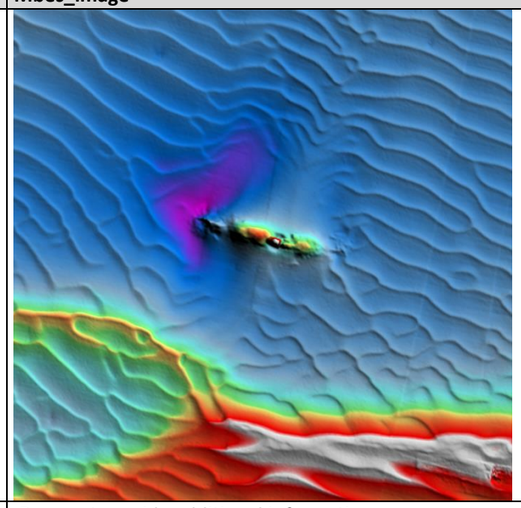
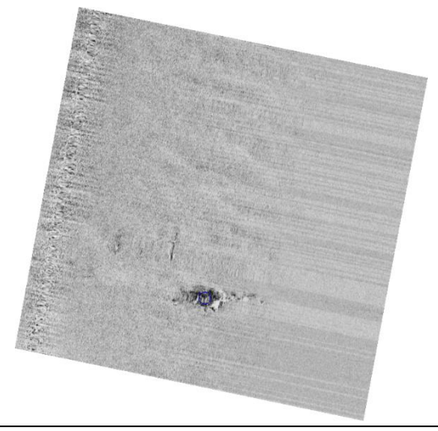
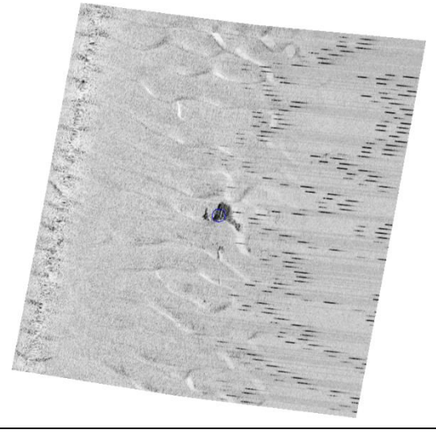
The table on the next pages contains a selection of 27 out of a total of 405 *sidescan sonar* contacts with a possible archaeological expectation, based on the comparison with known objects (NCN), their size (larger than four meters) and characteristics.

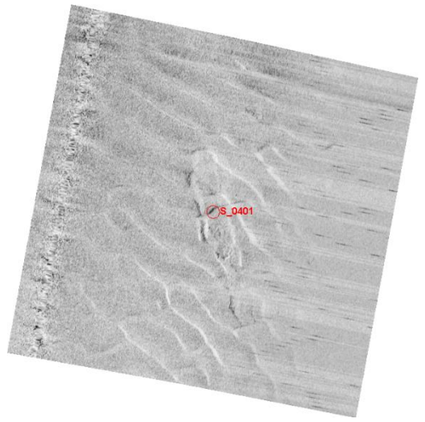
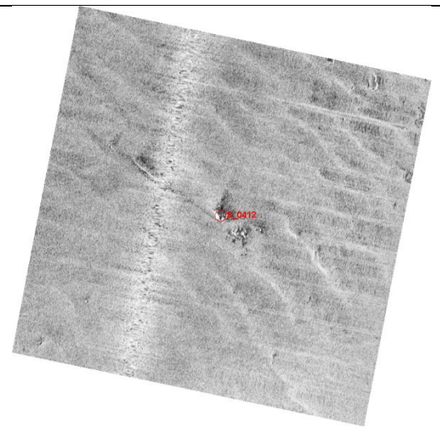
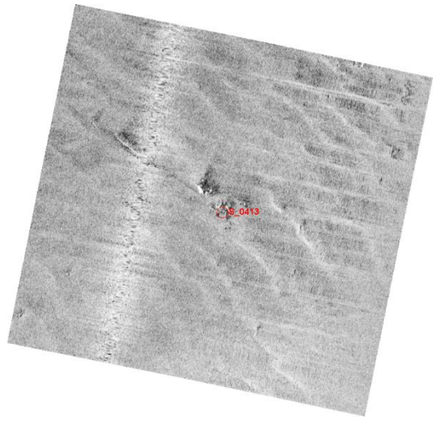
After reviewing, an archaeological expectation has been assigned to 10 newly found objects at 8 locations and 15 objects found at 7 known NCN wreck sites. These are marked with a light red colour, presented in the table at the end of this appendix.

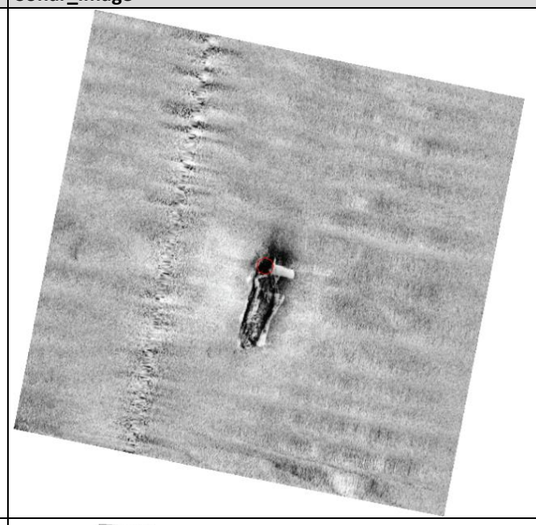
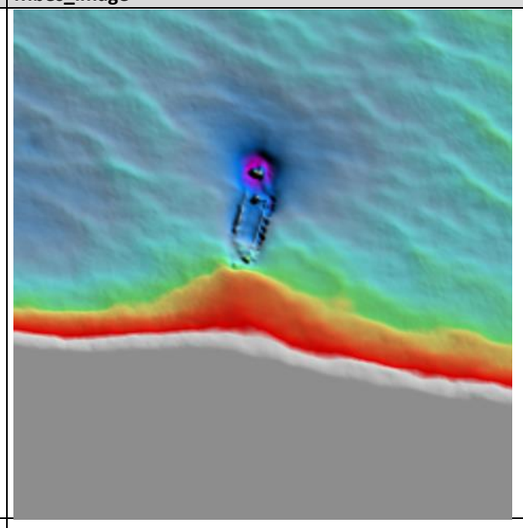
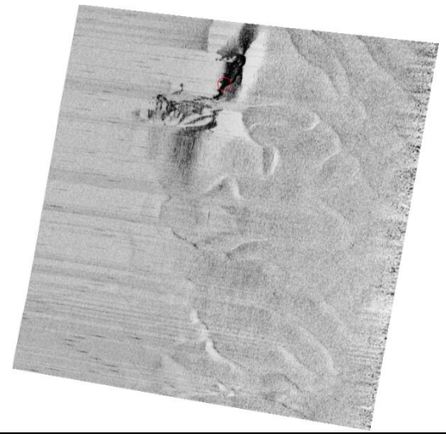
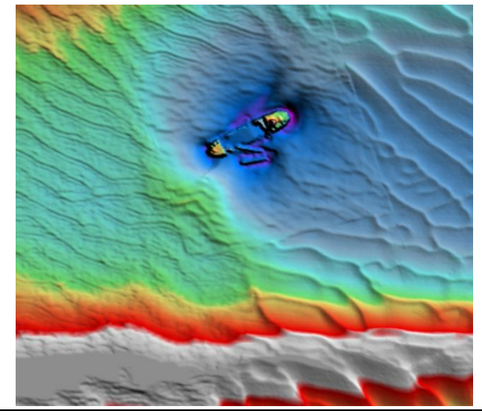
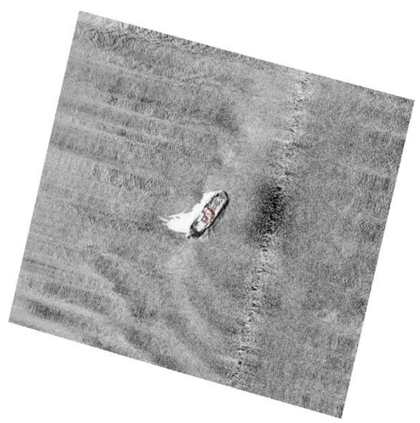
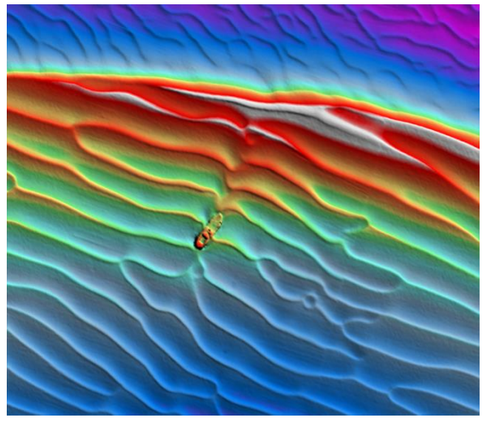
Nr	Easting	Northing	L(m)	W(m)	H(m)	Description_PPA	Classification_PPA
S_0039	536556	5817013	4.7	2.4	0.3	elongated to rectangular hard reflective object	Possible wreck
S_0093	538628	5824408	5.6	2.9	0.0	spherical object amidst a scour 13 x 11 m with 118 nT magnetic anomaly	Possible wreck
S_0095	538755	5824686	3.8	0.8	0.4	two elongated objects	Possible wreck site
S_0096	538786	5824717	2.6	1.1	0.9		
S_0336	544748	5823694	28.5	5.3	0.2	high reflective exposure	Possible buried wreck
S_0353	547417	5836653	7.2	6.8	0.7	high reflective exposure	Possible buried wreck
S_0401	544499	5821369	33.8	9.4	0.4	contours of a ship-like object	Buried ship wreck
S_0412	544989	5819800	3.5	5.8	0.7	cluster of contacts	Possible wreck site
S_0413	544995	5819792	4.6	4.1	1.2		
S_0679	553839	5842543	7.2	1.0	0.4	linear contact amidst cluster of contacts	Possible buried wreck
S_0109	540104	5829487	3.77	2.03	0.29	Wreck Debris, height from MBES.	NCN 2064 wreck site
S_0111	540141	5829393	1.31	0.43	0.07	Wreck Debris, height from MBES.	
S_0112	540162	5829452	86.58	19.85	3.4	Wreck DHY 2256. Duikteam Zeester: SS Paris, sunk 1939- large magnetic anomaly nearby (M_0322)	
S_0113	540213	5829397	3.28	0.54	0.37	Wreck Debris	
S_0121	540625	5828686	2.01	1.15	0.3	Wreck Debris	NCN 2056 wreck site
S_0122	540631	5828702	76.58	15.55	3.3	Wreck DHY 2247. Duikteam Zeester: Paaswrak 1 close to the Brown bank, identified as the Biaritz, sumk 1940 - large magnetic anomaly nearby (M_0363)	
S_0123	540645	5828700	4.46	3.81	2.31	Target within wreck DHY 2247 possible smoke stack - large magnetic anomaly nearby (M_0363)	
S_0478	548149	5832487	30.9	9.75	1.11	Wreck DHY 2468. Unknown wreck reported 1984 - strong magnetic anomalies nearby (M_1055, M_1057)	NCN 2250 wreck site
S_0479	548150	5832496	2.95	2.96	2.26	Wreck DHY 2468. Unknown wreck reported 1984 - strong magnetic anomalies nearby (M_1055, M_1057)	
S_0657	551674	5838482	4.07	3.42	0.3	Part of wreck DHY 2284	NCN 2091 wreck site
S_0658	551689	5838477	27.67	9.2	1.85	Distributed remains of wreck DHY 2284	
S_0682	554440	5845409	28.16	7.05	0.4	Wreck DHY 3427. Unknown wreck first seen in 1997	NCN 2809 wreck site
S_0683	554448	5845403	1.31	0.56	0.78	within 5m of wreck DH3427	
S_0711	555135	5833591	2.37	1.19	0.58	Marked as an obstruction. Inside large depression. stretched on SSS. Next to similar target.	NCN 2846 wreck site
S_0715	555444	5845242	29.4	7.69	3.35	Uncharted wreck	NCN 2469 wreck site

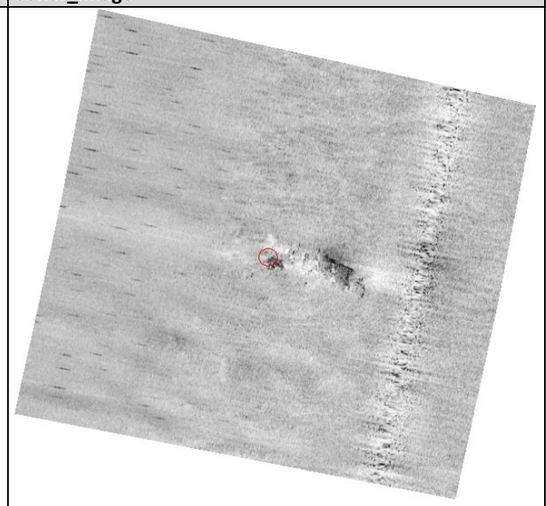
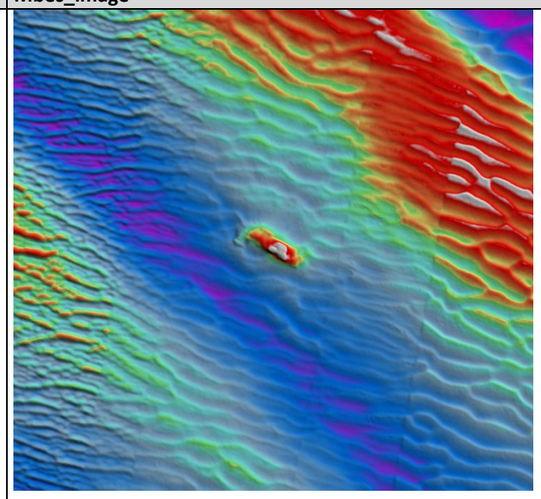
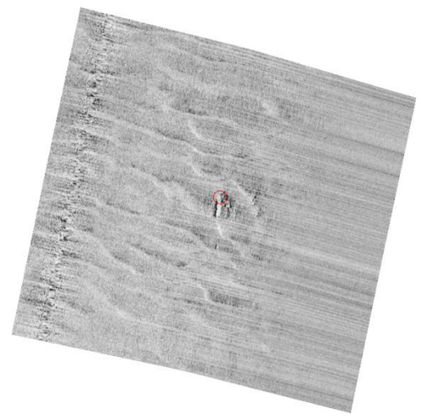
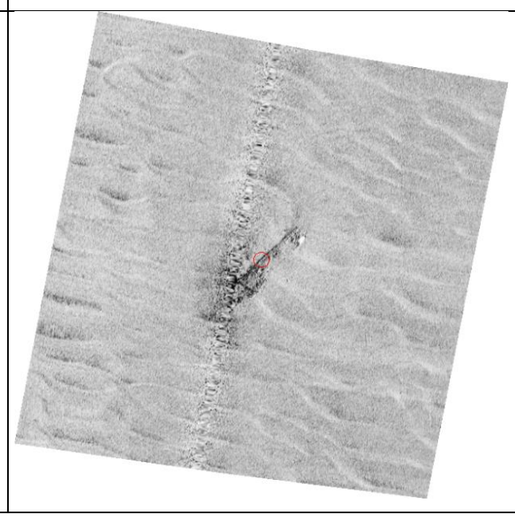
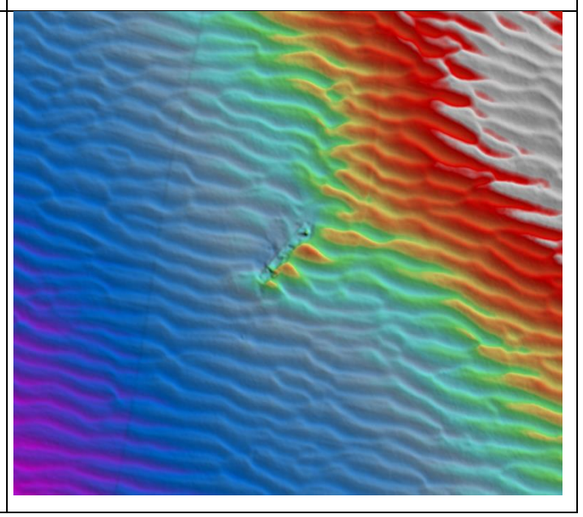
	ETYRS89 UTM31N		Dimensions						
Sss_id	Easting	Northing	L (m)	W (m)	H (m)	Description PPA	NCN	Sonar_Image	Mbes_image
S_0039	536555.8	5817013	4.69	2.36	0.28	Elongated to rectangular hard reflective object, possible wreck			Does not provide additional information
S_0093	538628.4	5824408	5.61	2.91	0	spherical object amidst a scour 13 x 11 m with 118 nT magnetic anomaly			Does not provide additional information
S_0095	538754.6	5824686	3.8	0.77	0.37	two elongated objects, possible wreck site			Does not provide additional information

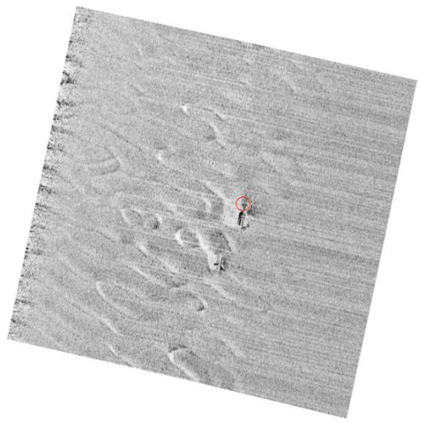
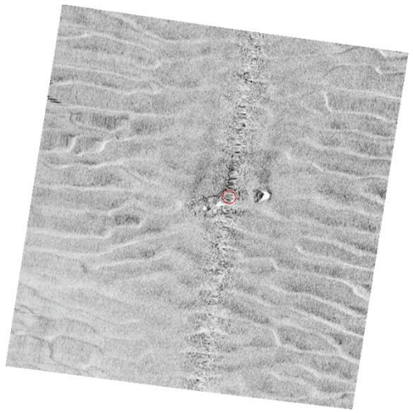
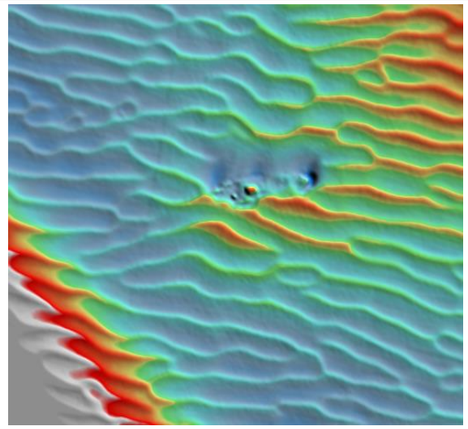
	ETYRS89 UTM31N		Dimensions						
Sss_id	Easting	Northing	L (m)	W (m)	H (m)	Description PPA	NCN	Sonar_Image	Mbes_image
S_0096	538786.3	5824717	2.62	1.09	0.85	two elongated objects, possible wreck site	2064		Does not provide additional information
S_0109	540103.6	5829487	3.77	2.03	0.29	Wreck Debris, height from MBES.			
S_0111	540140.8	5829393	1.31	0.43	0.07	Wreck Debris, height from MBES.			
S_0112	540161.5	5829452	86.58	19.85	3.4	Wreck DHY 2256. Duikteam Zeester: SS Paris, sunk 1939- large magnetic anomaly nearby (M_0322)			
S_0113	540213.2	5829397	3.28	0.54	0.37	Wreck Debris			

	ETYRS89 UTM31N		Dimensions						
Sss_id	Easting	Northing	L (m)	W (m)	H (m)	Description PPA	NCN	Sonar_Image	Mbes_image
S_0121	540625.3	5828686	2.01	1.15	0.3	Wreck Debris	2056		
S_0122	540630.5	5828702	76.58	15.55	3.3	Wreck DHY 2247. Duikteam Zeester: Paaswrak 1 close to the Brown bank, identified as the Biaritz, sumk 1940 - large magnetic anomaly nearby (M_0363)			
S_0123	540644.9	5828700	4.46	3.81	2.31	Target within wreck DHY 2247 possible smoke stack - large magnetic anomaly nearby (M_0363)			
S_0336	544748.4	5823694	28.51	5.25	0.21	High reflective exposure, possible buried structure or wreck. Mag amplitude of 4nT nearby			Does not provide additional information
S_0353	547417.1	5836653	7.15	6.8	0.74	High reflective exposure			Does not provide additional information

	ETYRS89 UTM31N		Dimensions						
Sss_id	Easting	Northing	L (m)	W (m)	H (m)	Description PPA	NCN	Sonar_Image	Mbes_image
S_0401	544498.7	5821369	33.81	9.4	0.37	Contours of a ship-like object, possible buried wreck.			Does not provide additional information
S_0412	544988.5	5819800	3.5	5.78	0.68	cluster of contacts, possible wreck site			Does not provide additional information
S_0413	544994.9	5819792	4.55	4.11	1.16	cluster of contacts, possible wreck site			Does not provide additional information

	ETYRS89 UTM31N		Dimensions						
Sss_id	Easting	Northing	L (m)	W (m)	H (m)	Description PPA	NCN	Sonar_Image	Mbes_image
S_0478	548148.5	5832487	30.9	9.75	1.11	Wreck DHY 2468. Unknown wreck reported 1984 - strong magnetic anomalies nearby (M_1055, M_1057)	2250		
S_0479	548149.5	5832496	2.95	2.96	2.26	Wreck DHY 2468. Unknown wreck reported 1984 - strong magnetic anomalies nearby (M_1055, M_1057)			
S_0618	549023.3	5823155	23.22	10.7	3.52	Wreck DHY 522. Duikteam Zeester: Wreck of coastvessel sunk 1980 standing right up superstructure is gone close by platform This wreck has no archaeological value, but can cause an obstruction.	522		
S_0641	550863.7	5827799	23.79	6.2	3.14	Wreck DHY 2248. Duikteam Zeester: Wreck Dutch fishing trawler Stellendam 4 sunk 1969 (near M_1343, M_1342) This wreck has no archaeological value, but can cause an obstruction.	2057		

	ETYRS89 UTM31N		Dimensions						
Sss_id	Easting	Northing	L (m)	W (m)	H (m)	Description PPA	NCN	Sonar_Image	Mbes_image
S_0657	551674.2	5838482	4.07	3.42	0.3	Part of wreck DHY 2284	2091		
S_0658	551688.8	5838477	27.67	9.2	1.85	Distributed remains of wreck DHY 2284			
S_0679	553838.7	5842543	7.18	0.97	0.41	linear contact amidst cluster of contacts			Does not provide additional information
S_0682	554439.7	5845409	28.16	7.05	0.4	Wreck DHY 3427. Unknown wreck first seen in 1997	2809		
S_0683	554447.7	5845403	1.31	0.56	0.78	within 5m of wreck DH3427			

	ETYRS89 UTM31N		Dimensions					
Sss_id	Easting	Northing	L (m)	W (m)	H (m)	Description PPA	NCN	Sonar_Image	Mbes_image
S_0711	555134.9	5833591	2.37	1.19	0.58	Marked as an obstruction. Inside large depression. stretched on SSS. Next to similar target.	2846		Does not provide additional information
S_0715	555443.8	5845242	29.4	7.69	3.35	Uncharted wreck	2469		

Appendix 4. Phases of maritime archaeological research

The Dutch Quality Standard for Archaeology (KNA Waterbodems, version 4.1) describes all procedures and requirements for the archaeological research process. Below a brief description of the steps involved:

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

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

2. **Exploratory field research (opwaterfase)**

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

   IF potential archaeological objects are found, then the next phase (**3**) must be carried out.

   b. **Geotechnical survey**
   In order to reconstruct prehistoric landscapes and refine and test the archaeological expectation related to those landscapes a geotechnical survey can be carried out. A geotechnical survey comprises penetration tests (CPT's) and/or bottom sampling (*vibrocore*, Acqualock, Begemann, grab sampling, etcetera). The sample strategy and sample locations are based on the geological constellation of the area and interpreted subbottom profiling data. The requirements of the survey shall be listed in a program of requirements which must be approved by the competent authorities.

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

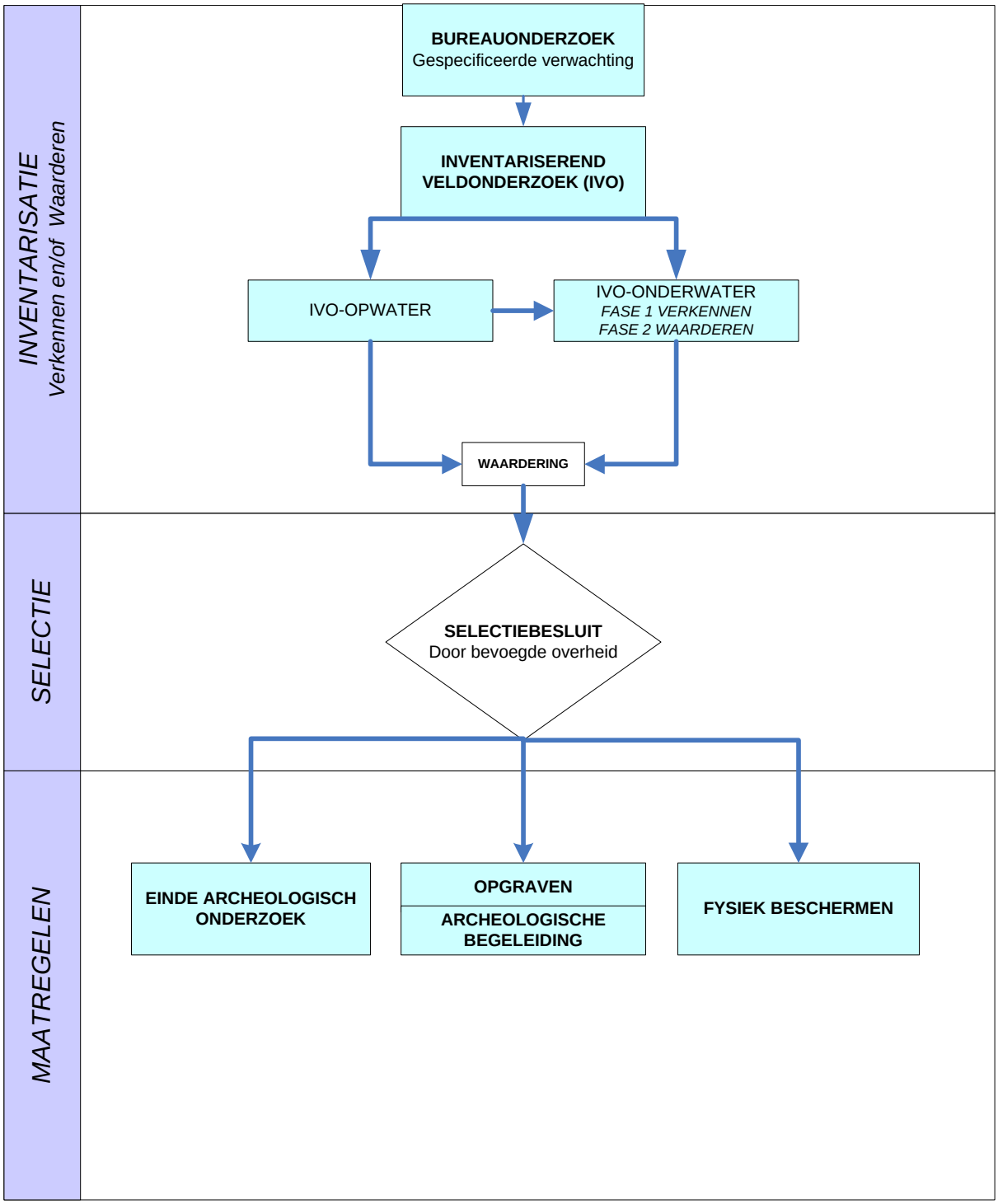
are two possibilities: either the remains can be preserved in situ (adjustment of plans) or the next phase will be conducted:

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 archaeological objects. The figure on the next page shows these moments schematically.

Schematic overview KNA Waterbodems version 4.1

(AMZ cycle in Dutch)



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The information in this document is valid at the time of publishing (see month/year). Updates will be published on the website https://offshorewind.rvo.nl/ at the relevant sitemap, General Information, submap Revision Log and Q & A. In the Revision Log is indicated which versions are the latest and what the changes are in relation to previous versions. The documents can be found at the relevant sites, indicated in the List of all reports and deliverables.

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