A15, B10 Stage 2+ Investigations
WP2 - Geophysical Survey

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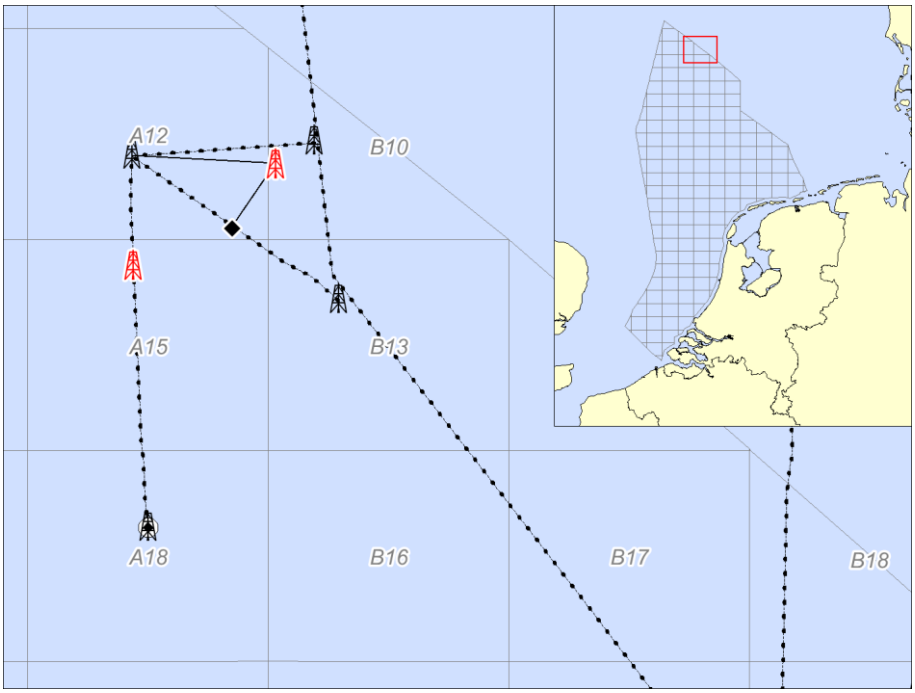
Field development B10-block, North Sea

An archaeological assessment

Of

Geophysical survey results



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Colophon

Periplus Archeomare Report 19A024-02
Field development B10-block, North Sea - An archaeological assessment of geophysical survey results

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Content

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

Table 2. Administrative details of the research area

Location:	North Sea		
Toponym:	Field development B10-blocks		
Chart:	Hydrografie 1801-1		
Coordinates (ED50 UTM31N)	Location	Easting [m]	Northing [m]
	A12-CPP	551404	6139695
	B10 proposed platform	563967	6139165
	Tie-in proposed	560266	6133619
Surface Area	17 km^2		
Environment:	Tidal currents, saltwater		
Area use:	Shipping lane, fishing,		
Area administrator:	Rijkswaterstaat Zee en Delta		
Enforcing authority:	Rijkswaterstaat Zee en Delta		
Enforcing authority contact:	R. Duijts		
Enforcing authority advisory body:	Rijksdienst voor het Cultureel Erfgoed		
Enforcing authority advisor:	Mrs. M. Snoek, mr. J. Opdebeeck, mr. B.J. Smit		
ARCHIS-research report (CIS-code):	4761401100		
Periplus project reference:	19A024-02		
Period of execution:	January - February 2020		
Archive:	Periplus Archeomare BV, Amsterdam		

Samenvatting (Dutch)

Periplus Archeomare heeft in opdracht van Fugro een archeologisch assessment van geofysische data uitgevoerd in verband met de geplande ontwikkeling van een boorlocatie in het B10 blok en de hieraan gerelateerde installatie van één *umbilical* en een pijpleiding in de zeebodem.

Het onderzoek heeft uitgewezen dat zes objecten gevonden zijn met *side scan sonar*. Geen van deze objecten heeft een archeologische waarde.

Ook zijn 69 magnetische anomalieën aangetroffen.

- 36 anomalieën kunnen gerelateerd worden aan de reeds bestaande infrastructuur, bestaande uit pijpleidingen (35) en een wellhead B10-03 (1);
- 2 anomalieën zijn gerelateerd aan een object welk met de *side scan* sonar is gevonden. Het object genaamd A15_A12_SSS_0001 is geïnterpreteerd als puin.
- 31 anomalieën kunnen niet gerelateerd worden aan bekende infrastructuur of zichtbare objecten op de zeebodem. These anomalieën worden veroorzaakt door onbekende ijzerhoudende objecten welke verborgen zijn in de zeebodem.

Geen van deze magnetische anomalieën heeft een archeologische waarde.

Prehistorie
Op basis van de seismische data kan worden geconcludeerd, dat in het onderzochte gebied de *pleistocene* en vroeg *holocene* landschappen zich op meer dan 10 m onder de zeebodem bevinden. Het is niet bekend of, en zo ja, in hoeverre de prehistorische landschappen en hieraan gerelateerde archeologische resten intact bewaard zijn gebleven.

De installatie van de pijpleiding, de *umbilical* en het exploratieplatform vormt geen bedreiging voor *in situ* prehistorische resten, omdat de archeologische niveaus ruim onder de maximale verstoringsdiepte liggen. De *conductor* zal door de prehistorische landschappen, en archeologische niveaus hierin besloten, worden geheid. De omvang van de bodemverstoring is echter beperkt. De kans dat prehistorische kampplaatsen worden aangetast door de installatie van de conductor wordt, gegeven de over het algemeen geringe omvang van laat-paleolithische en mesolithische kampplaatsen, klein geacht. Mitigerende maatregelen worden daarom niet nodig geacht. Wel wordt geadviseerd om de informatie die uit eventuele sonderingen en boormonsteranalyses naar voren komt te gebruiken voor het aanpassen en verfijnen van het huidige model van de archeologische potentie van het Noordzeegebied.

Tot slot kan nooit volledig worden uitgesloten dat tijdens de werkzaamheden archeologische resten aan het licht komen die begraven in de zeebodem lagen tijdens de survey of niet als archeologische resten zijn geïnterpreteerd. In overeenstemming met de Erfgoedwet dienen archeologische vondsten te worden gemeld aan de bevoegde overheid. Het verdient aanbeveling om deze meldingsplicht op te nemen in het bestek (Engels: *Scope of Work*) voor de werkzaamheden.

Summary

Fugro has contracted Periplus Archeomare B.V. to conduct an archaeological assessment of geophysical route and site survey data. The survey data have been collected in the course of a proposed well site development in the B10 block and the installation of an umbilical and one pipeline.

The assessment of geophysical survey data has proven that six contacts were encountered with *side scan sonar*. None of these contacts are considered to be of archaeological interest.

A total of 69 magnetic anomalies have been identified:

- 36 anomalies can be related to known infrastructure comprising pipelines (35) and wellhead B10-03 (1);
- 2 anomalies are related to an object found with side scan these are interpreted as debris and are related to *side scan sonar* contact A15_A12_SSS_0001 (2);
- 31 magnetic anomalies cannot be correlated with known infrastructure or visible objects at the seabed surface. Those anomalies are induced by unknown ferrous objects buried in the seabed. None of the objects have a peak to peak magnetic anomaly of over 50 nT.

None of these magnetic anomalies are considered to be of archaeological interest.

Prehistory
Base on the interpreted seismic data it can be concluded that the *Pleistocene* and Early *Holocene* landscapes are located at more than 10 m below the seabed throughout the research area. It is not known if those landscapes and possible archaeological remains contained herein have been preserved intact.

The installation of the pipeline, umbilical and jack-up rigs are not expected to affect *in situ* prehistoric remains, because the archaeological levels are located below the maximum depth of disturbance. The installation of the conductor will penetrate the prehistoric landscapes and potential in situ archaeological remains contained herein. However, the seabed disturbance is confined to a small area and the change that remains of prehistoric camp sites are affected by the installation of the conductor is, considering the generally small size of Late Palaeolithic and Mesolithic camp sites, small. Mitigating measures are therefore not considered necessary. It is advised to utilize the obtained data and information which is generated by the onsite borehole sample analysis for adjusting and fine-tuning the current expectancy model for the North Sea area.

Archaeological objects may be discovered which were completely buried or not recognized as an archaeological object during the geophysical survey. In accordance with the Heritage Act 2016 (Dutch: Erfgoedwet), it is required to report those findings to the competent authority. This notification must also be included in the scope of work.

1 Introduction

Fugro has contracted Periplus Archeomare B.V. to conduct an archaeological assessment of geophysical route and site survey data. The survey data have been collected in the course of a proposed well site development in the B10 block and the installation of an umbilical and one pipeline.

The area of investigation includes:

Platform location A12-CCP (Active)	1 sqkm site survey
Well site location B10 (Proposed)	1 sqkm site survey
B10 to A12-CPP Umbilical Route (Proposed)	600 m corridor route survey
B10 to Tie-in B13-A Pipeline Route (Proposed)	600 m corridor route survey

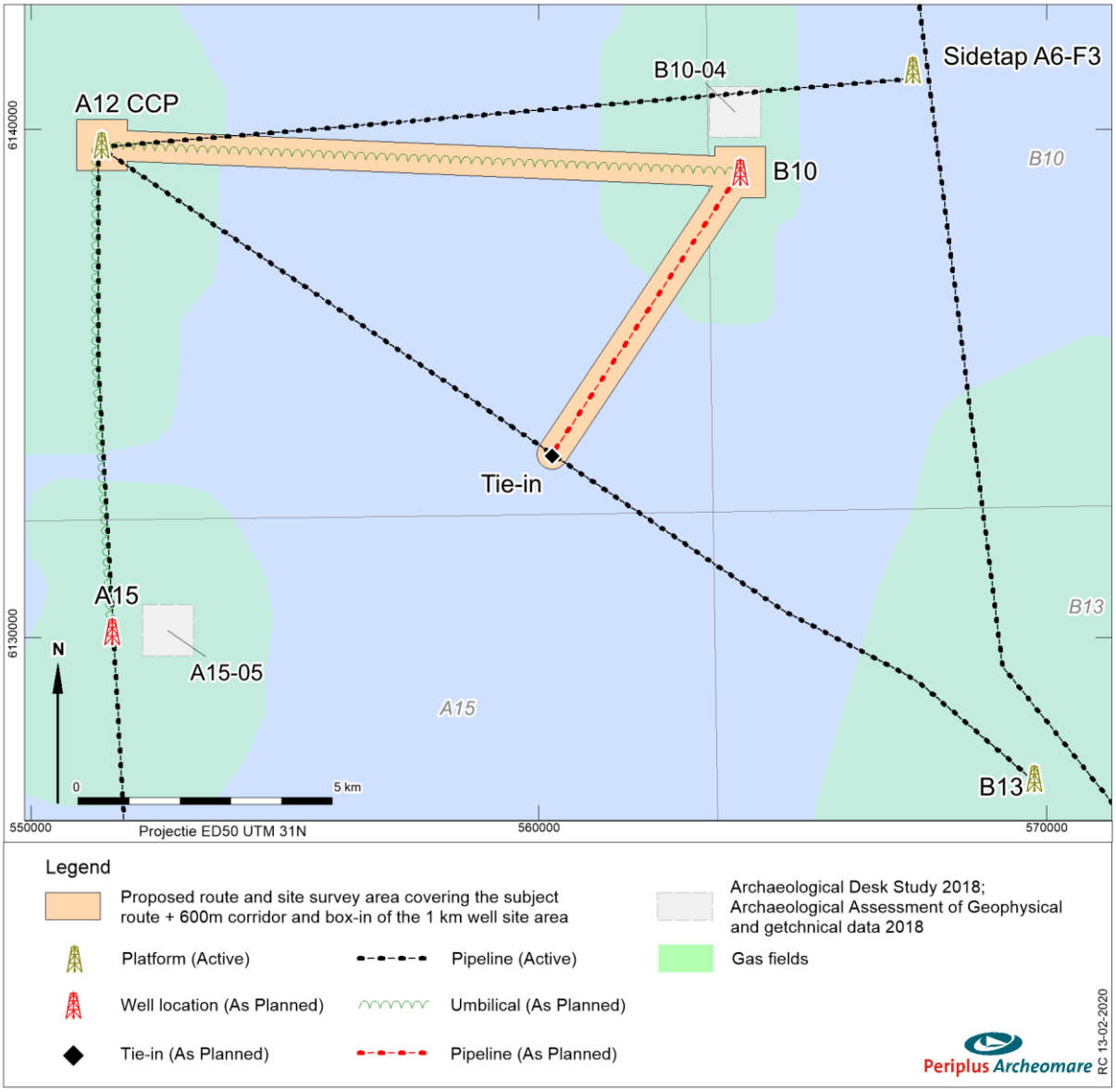

Figure 1. Location map of the research area

1.1 Background

Petrogas Netherlands B.V. intends to develop new fields in in the A- and B-blocks in the northern part of the Dutch North Sea. In the course of this development Petrogas plans to drill an appraisal well at the location B10. The future B10 facility will be remotely controlled from the Central Processing Platform A12-CPP. In order to do so a control umbilical is planned to be installed. A pipeline is planned to be installed for the transportation of the hydrocarbons produced at the B10 site to the Tie-In with the existing 16-inch gas pipeline from B13-A to A12-CPP.

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

The so-called *AMZ* cycle (Dutch: Archeologische Monumenten Zorg cyclus) consists of a series of procedures for the subsequent phases of archaeological research to be performed in order to ensure the protection of archaeological heritage in the Netherlands. 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 2.

The first step in the AMZ-cycle is an archaeological desk study. In 2018 two desk studies have been executed.[2,3] The first study covers a wide area of the A- and B-blocks; the second study zooms in at the then planned appraisal well sites A15-05 and B10-04 (refer to figure 1).

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 seabed. In accordance with the Dutch Quality Standard for Archaeological Research (Dutch: Kwaliteitsnorm Nederlandse Archeologie; KNA 4.1-waterbodems) an archaeological Program of Requirements was written for the inventory archaeological field study. Along with the technical Scope of Work, the preconditions and deliverables described in the archaeological Program of Requirements were used as input for the geophysical survey executed by Fugro. The survey data acquired prove therefore to be fit for an archaeological assessment.

Between 06 to 26 November 2019 Fugro conducted route and site surveys to gather sufficient information for drilling, platform and sea line engineering and installation.[4]

During this period a survey was also carried out for the proposed well site location A15 and the proposed umbilical route from A12-CPP to the proposed A15 site. The results of the archaeological assessment carried out for this proposed site and umbilical route are summarized in a separate report: 19A024-02. The survey results of the overlapping A12-CPP location are included in both reports.

[1] Dutch: Erfgoedwet.
[2] Van Lil 2018; report 18A021-01.
[3] Van Lil 2018; report 18A021-02.
[4] Fugro Reports 2019: P906247_GEOP_REP_B10 01 (Draft) and P906247_GEOP_REP_A15 01 (Draft).

1.2 Results desk study

The archaeological desk studies performed in August 2018 and September 2018 has resulted in specific information on the archaeological remains which are to be expected in the area. The desk study has shown that within the research areas ship and aircraft wrecks and, if the *Pleistocene* landscape is intact, in situ prehistoric remains can be expected.

Shipwrecks

Within the currently surveyed route from B10 proposed location to A12-CPP no ship wreck site is known (figure 2).

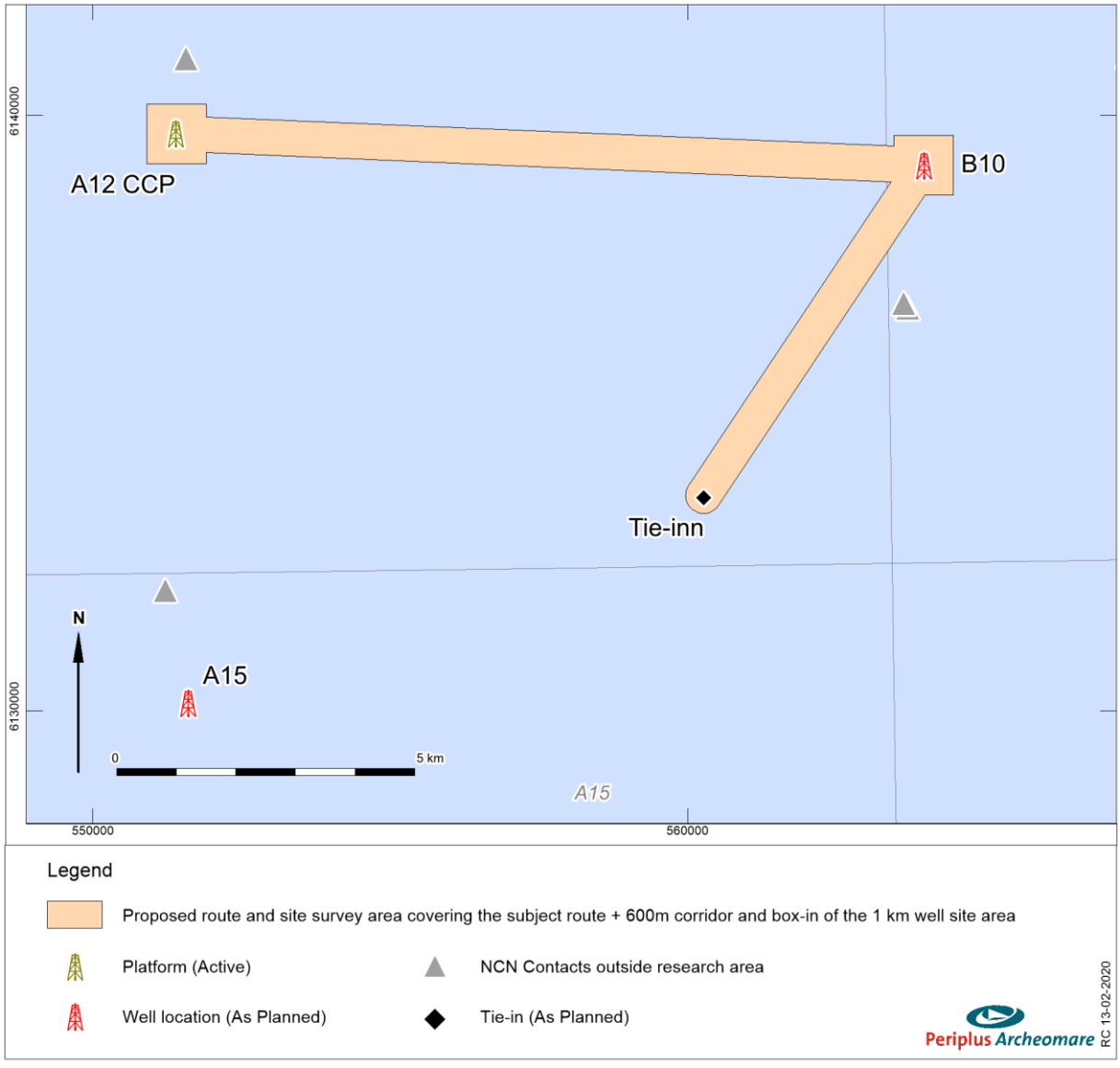

Figure 2. Overview of known objects and contacts in the research area

Plane wrecks

During World War II, many airplanes crashed into the North Sea. Sources are ambiguous about the number of aircraft still missing, but estimates indicate that it concerns at least hundreds.[5] Remains are found on a regular base by fishermen or during sand extraction.

Prehistory

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

Archaeological levels are formed by the top of the Dogger Bank Member and the entire sequence of the overlying Boxtel Formation. Especially in areas where those units have been covered by Early *Holocene* peat (Basal Peat Bed) or clay (Velsen Bed) well-preserved *in situ* remains of high integrity are to be expected.

The research area is located on a plateau, which in Early *Holocene* times bordered a large lake. Those transitions in the landscape attracted hunter-gatherers, because of the possibility the landscape offered to install camp sites at high grounds overviewing hunting grounds, the presence of nearby fresh water from the lake, the animals living in and foraging at the lake-site and variety in plant species available.

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

The top of the *Pleistocene* landscape is expected to occur at depths below the seabed ranging from less than 9m in near the Tie-In with the 16-ich gas pipeline from B13 to the A12-CPP to nearly 20m at the proposed B10 drill site.

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

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

[5] Nederlandse Federatie voor Luchtvaart Archeologie, NFLA.

1.3 Objective

The purpose of the archaeological assessment is to test the desk study-based likelihood of archaeological remains in the area. Included in this Likelihood are remains of shipping related objects (shipwrecks), aircraft from World War II and prehistoric remnants related to the drowned *Pleistocene* landscape.

The goals set for this assessment are:

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

1.4 Research questions

For the inventory archaeological field study, the following research questions have been defined in the program of Requirements:[6]

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 and to prioritize importance?

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?

[6] Van Lil, 2018.

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?[7]

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:

What is the depth of the Pleistocene landscape compared 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 side scan sonar, magnetometer and 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?

[7] Risk-prone areas are areas where the probability of archaeological remains is considered to be high. The risk involves both the degradation of archaeological remains by the installation of the pipeline 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.

2 Methodology

2.1 Introduction

As part of the planned activities pipeline and umbilical route surveys and platform box-in surveys have been carried out by Fugro.

Objective

The objective of the survey was to gather sufficient information for drilling, platform and pipeline engineering and installation in terms of:[8]

1. Meteorological and oceanographical Data
2. Geophysical & Geotechnical Surveys:
    a. Seabed topography
    b. Seabed and sub-seabed obstructions
    c. Seabed profile and sub-seabed layers
    d. Horizontal and vertical position of existing pipelines/cables crossing the pipeline route
    e. Seabed soil conditions
    f. Identify soils and foundation conditions at the proposed jack-up sites.
    g. Shallow gas prognosis
1. Environmental sampling
2. Archaeological survey
3. Debris surveys
4. Vessel Marine Assurance
5. Documentation

The survey shall provide the data in the selected corridor of the route required to design the proposed pipeline, umbilical and platform so that it can be safely installed. In addition, the survey shall provide the data required to safely drill the wells from a drill rig.

Survey equipment and operations

The survey was conducted by the MV Fugro Pioneer during the period 6 to 26 November 2019, using *multibeam* echo sounder (MBES), *side scan sonar* (SSS), *magnetometer* (MAG), *sub-bottom profiler* (SBP) and multichannel 2D-UHR seismic equipment.

- Bathymetry was acquired using a *multibeam* echo sounder at a frequency of 400 kHz with 400 beams;
- *Side scan sonar* data was acquired at frequencies of 100/600 kHz and a range of 75/100 m per channel;
- Sub-bottom profiler data was acquired for shallow seabed detail, operated at 8 kHz with a recording length of 55 ms, and with delay of 15 m / 20 m / 22 m;
- The *magnetometer* survey was performed at ten Hz sampling frequency, by piggybacking the sensor to the *side scan sonar*. The maximum altitude of the sensor did not exceed six meters from the seafloor, except the areas where client confession was given;

[8] Drost 2019; Scope of Work Geophysical & Geotechnical Surveys Stage 2+ Project – A15 & B10.

- Multi-channel seismic was acquired using an Ultra Hi-Res 48 channels streamer with 24 channels of one-meter group spacing and 24 channels of two meters group spacing combined with a two stacked 400 tips LW sparkers source to achieve a penetration of approximately 65 m;

Survey lines – proposed routes

A total of 43 survey lines were run along the proposed umbilical and pipeline routes, main lines with MBES, SSS, SBP, MAG, and crosslines with MBES and SBP.

Proposed Routes	Survey Lines		
	main	cross	total
B10 to A12-CPP umbilical	10	14	24
B10 to Tie-in pipeline	9	10	19
Survey corridor 600m			

Table 3. Survey lines along the proposed routes

The inner two wing lines were sailed at a distance of 50 meter from the centre line; the outer six wing lines (three on both sides) were sailed at a distance of 75 meter.

Survey lines – proposed platform location

A total of 30 survey lines were run at the proposed platform location B10, using MBES, SSS, SBP, MAG and multichannel 2D-UHR.

Proposed Platform Location	Survey Lines		
	main	cross	total
B10	15	15	30
Survey area 1.0 x 1.0 km			

Table 4. Survey lines at the proposed platform locations

The centre lines (1 main line + 1 cross line) and adjacent wing lines (8 main lines + 8 cross lines) were sailed with a spacing of 50 m. The outer wing lines (6 main lines + 6 cross lines) were sailed with a spacing of 100 m.

The results of the survey and geotechnical activities have been recorded in reports, listings, drawings and images.[9, 10]

[9] P906247_GEOP_REP_A15 01 | Geophysical Results Report, A15.
[10] P906247_GEOP_REP_B10 01 | Geophysical Results Report, B10.

2.2 Known objects

Fugro has summarized the *side scan 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. 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.

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.

2.3 Archaeological assessment of survey data

The geophysical and hydrographic survey techniques employed include *side scan sonar* (SSS), *magnetometer* (MAG), *multibeam* (MBES) and *subbottom profiling* (SBP). With *side scan sonar* all objects and structures larger than 0.3m in any dimension on the seabed can be made visible. Seabed sediments of different composition can be distinguished by their characteristic reflection and validated by core samples. *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.

Magnetometer contacts are identified by the presence of ferro-metallic objects which induce an anomaly in the earth magnetic field. These objects comprise both buried objects and objects which lie on the seabed. Unlike *side scan 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 50/75/100 meter spacing of the run lines the accuracy perpendicular to the line is in the order of 25/37.5/50 meter.
Fugro processed their survey data and produced detailed event listings of the *side scan sonar* contacts and magnetic anomalies encountered within the survey areas. Both the location of the known objects as well as 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 meter is looked at in more detail, because these objects are considered to be more likely to be related to wreck sites than the smaller contacts. This approach 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:

- *Side scan sonar* images included in the survey reports;
- *Side scan sonar* geotiffs (0.15m resolution);
- *Multibeam* geotiffs (0.30m resolution);
- Values of magnetic anomalies reported in the survey reports;
- Comparison of *side scan sonar* and *magnetometer* contacts;

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

The *side scan sonar* images are scanned in order to define potential archaeological sites. All contacts were studied in detail. The interpretation of *side scan 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). The processing involved an analysis of a seismic profile along the centre line of the proposed pipeline and umbilical routes. Observed seismic reflectors have been digitized and - based on known geological data from the area - lithostratigraphic units have been identified. The results have been summarized in a survey report including two site maps for the proposed B10 and B10 Tie-In locations and five overlapping alignment charts for the proposed umbilical route from B10 to A12-CPP (3), and proposed pipeline route from B10 to the Tie-In with the existing B13A to A12-CPP gas pipeline (2). In addition to the identification and occurrence of lithostratigraphic units, seismic anomalies - which are expected to reflect existing pipelines and potential hazardous phenomena - have been identified.

2.4 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 assumed that all present possible contacts and anomalies have been reported and described by the survey contractor. The raw data was only used, if 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 *side scan sonar* survey also the *magnetometer* contacts were plotted on the high resolution *multibeam* grid. *Magnetometer* contacts which were found within 25 meters of a *side scan sonar* contact were considered to be potentially related to this sonar contact. The correlation between the magnetic anomaly and side scan sonar contact was then assessed. 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) the contact is considered to be of potential archaeological interest. All the *magnetometer* contacts above 50 nT but within 25 meters 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 seismic profiles produced by Fugro have been used to get an insight in both the lateral and vertical distribution of the lithostratigraphic units and the expected archaeological 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 pipeline sections which are expected to contain archaeological remains are mapped and results are put in the context of the activities planned in order to predict of the activities might damage potential archaeological remains.

The analysis was executed in January 2020 by R. van Lil, S. van den Brenk (both KNA senior prospector) and R.W. Cassée (KNA maritime archaeologist in training). The investigation is carried out according to specifications set up within the Dutch Quality Standard for Archaeology (*KNA Waterbodems 4.1; protocol 4103*).

2.5 Used Sources

The following sources were used for the analysis:

- Survey data Fugro, original survey data and reported interpretations;
- Archaeological desk study Periplus Archeomare (18A021-01);
- Archaeological desk study Periplus Archeomare (18A021-02);
- ARCHIS database Cultural Heritage Agency;
- Archeomare Database;
- NLhono database Hydrographic Service of the Royal Netherlands Navy;
- Wrecksite.eu;
- Database, Nationaal Contact Nummer (NCN, Rijkswaterstaat Zee en Delta).

For a complete list of used sources and literature see the reference list at page 35.

Italic written words are explained in the glossary at page 34.

3 Results

3.1 Seabed bathymetry and morphology

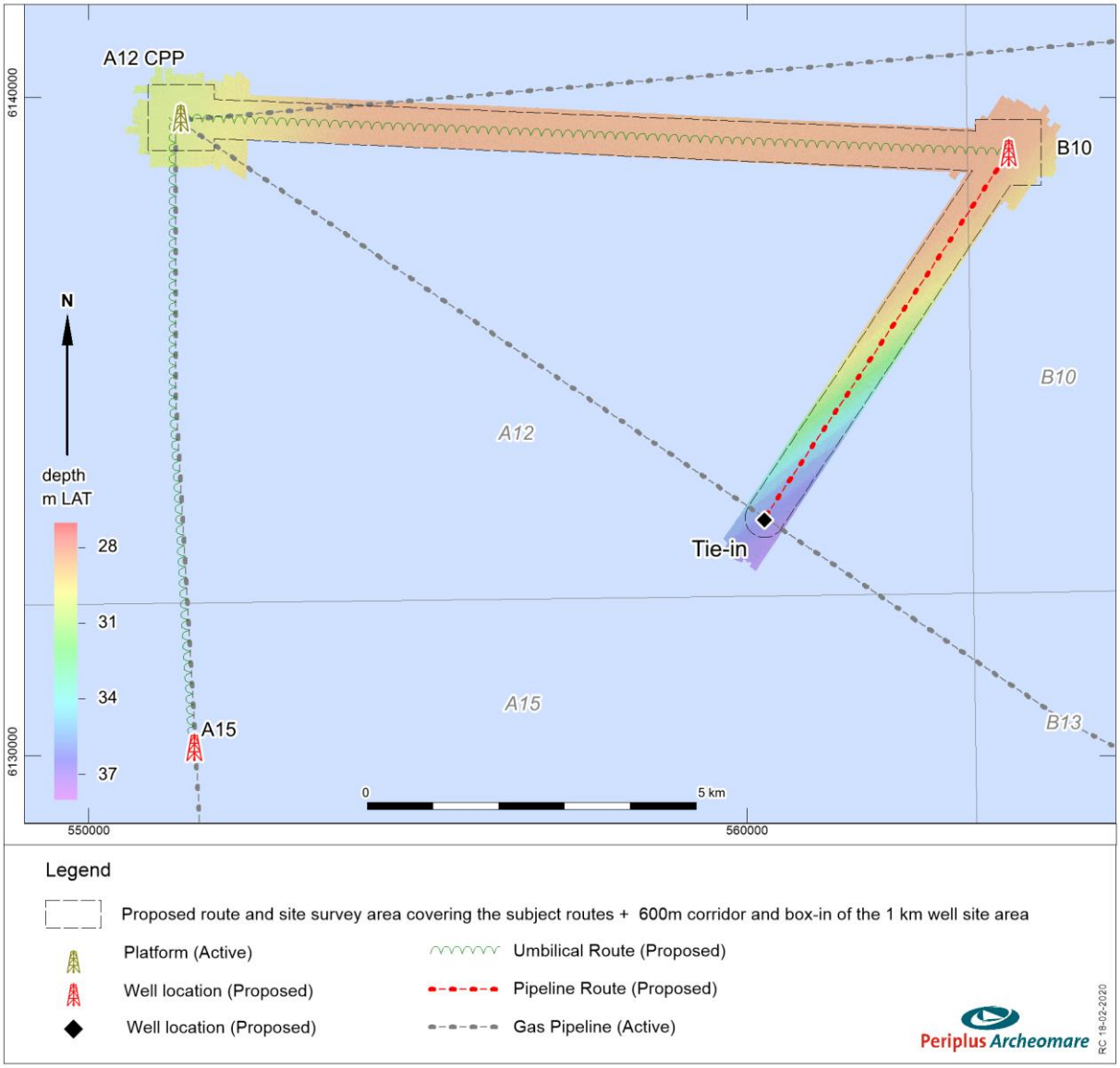

Figure 3. Bathymetry based on the multibeam recordings (source data: Fugro 2019)

The water depth in the survey area varies from 28.0 m in the area of the proposed B10 well site to 37.4 mLAT south of the Tie-In location.

Seabed

The seabed lacks visible sedimentary structures and is characterized by a very even surface. However, this even surface shows wide-spread scarring caused by the nets of fishing trawlers. The *multibeam* images do not show any signs of exposures of the existing pipelines. The rock berms which have been installed on these pipelines in the vicinity of the A12-CPP platform are clearly visible. Scouring around the platform is limited.

3.2 Known objects: As Found positions versus database positions

From database sources no object is known in the survey area (refer to section 1.3).

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 shipwreck 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 shipwreck is not in agreement with the database position of a known wreck;
- The As Found position of a contact is not in agreement with the position of a contact listed in the database and is therefore considered to be a new contact;
- A wreck listed in the database has not been found;
- A new wreck has been found.

3.3 Side scan sonar

Fugro has identified six *side scan sonar* contacts within survey area. The classification of the contacts is listed below.

Fugro Classification	**Total**
Debris	6
Total	**6**

Table 5. Side scan sonar contacts survey area

The six *side scan sonar* contact and images have been scanned and checked for the presence of potential archaeological contacts. This is done by analyses of:

- *Side scan sonar* images as delivered;
- 0.3m *multibeam* grid data (xyz-file);
- Comparison of *side scan sonar* and *magnetometer* contacts.

Apart from the survey data studied, the geological constellation and seabed morphology of the area are considered as outcrops of geological strata and sedimentary structures can lead to (apparent) anomalies in the *side scan sonar* record.

A summary of the outcome of the detailed inspection of the contacts is presented in table 6. Three contacts, A15_A12_SSS_0003/0004 and 0005, have a similar appearance on the both the side scan sonar and *multibeam* images. The spherical contacts are all located north of the A12-CPP platform have been interpreted as debris related to the drilling activities in the area. This also applies to the triangular contact A15_A12_SSS_0002 with a spherical elevated structure in its centre to the west of the platform.

Sonar contact A15_A12_SSS_0002 is interpreted as unknown debris, presumably related activities in the past. These activities include the installation of the A18-ALT1 to A12-CPP gas pipeline and the associated rock berm, and the drilling of borehole A12-01 (refer to figure 5).

Two magnetic anomalies found 10 m south and 14 m east of sonar contact possibly are induced by expected debris at the location of the sonar contact. The two magnetic anomaly values are alike: 632 nT (south) and 633 nT (east). Because of the size of the magnetic anomalies (over 600 nT), the distance of the anomalies to the rock dumped pipeline (32 m and 44 m), and the size and location of the magnetic anomalies found in relation to this pipeline, it is considered less likely that these anomalies are related to the A18-ALT1 to A12-CPP gas pipeline.

Target ID	Easting	Northing	Length	Width	Height	Description	Classification
A15_A12 SSS_0002	551280	6139687	3.8	1.1	0.5	Triangular contact with spherical elevated part in centre	Debris
A15_A12 SSS_0003	551179	6139928	2.2	1.2	0.0	Spherical medium reflective contact; no shadow; elevated contact on MBES	Debris
A15_A12 SSS_0004	551114	6140098	1.9	0.8	0.1	Spherical medium reflective contact; small shadow; elevated contact on MBES	Debris
A15_A12 SSS_0005	551355	6140064	1.8	0.8	0.1	Spherical medium reflective contact; small shadow; slightly elevated contact on MBES	Debris
B10_A12 SSS_0001	551379	6140049	1.4	0.8	0.2	Elongated contact; no shadow; not visible on MBES	Unknown*
B10_B13 SSS_0001	564052	6139411	1.9	0.4	0.4	Cigar-shaped contact with moderate reflection and clear shadow; not visible on MBES	Debris; Possible coiled fishing net

Table 6. Summary of the archaeological assessment of the side scan sonar records

* Interpreted by Fugro as possible clump weight for wave buoy.

The survey results of the A12-CPP site are contained both in this report as in the A15 report (19A024-01). An overview of the number of *side scan sonar* contacts assessed and contained in both reports is shown in Appendix 4.

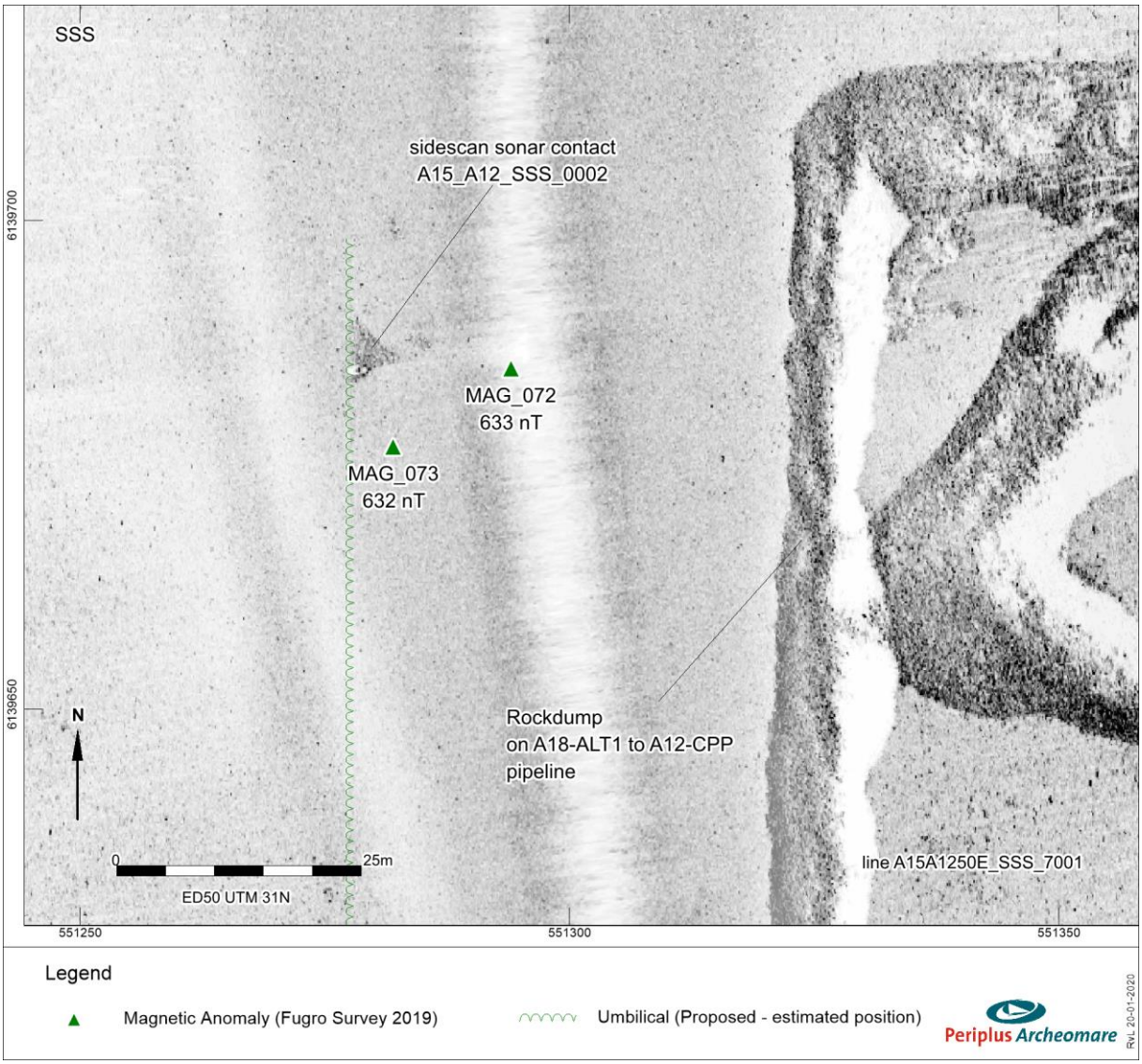

Figure 4. Side scan sonar image of Fugro target A15_A12_SSS_0002

3.4 Multibeam

All *side scan sonar* contacts have been correlated with *multibeam* images. Refer to the previous (side scan sonar) section for the results of this assessment. No *multibeam* contacts have been found other than the ones that also have been found with side scan sonar.

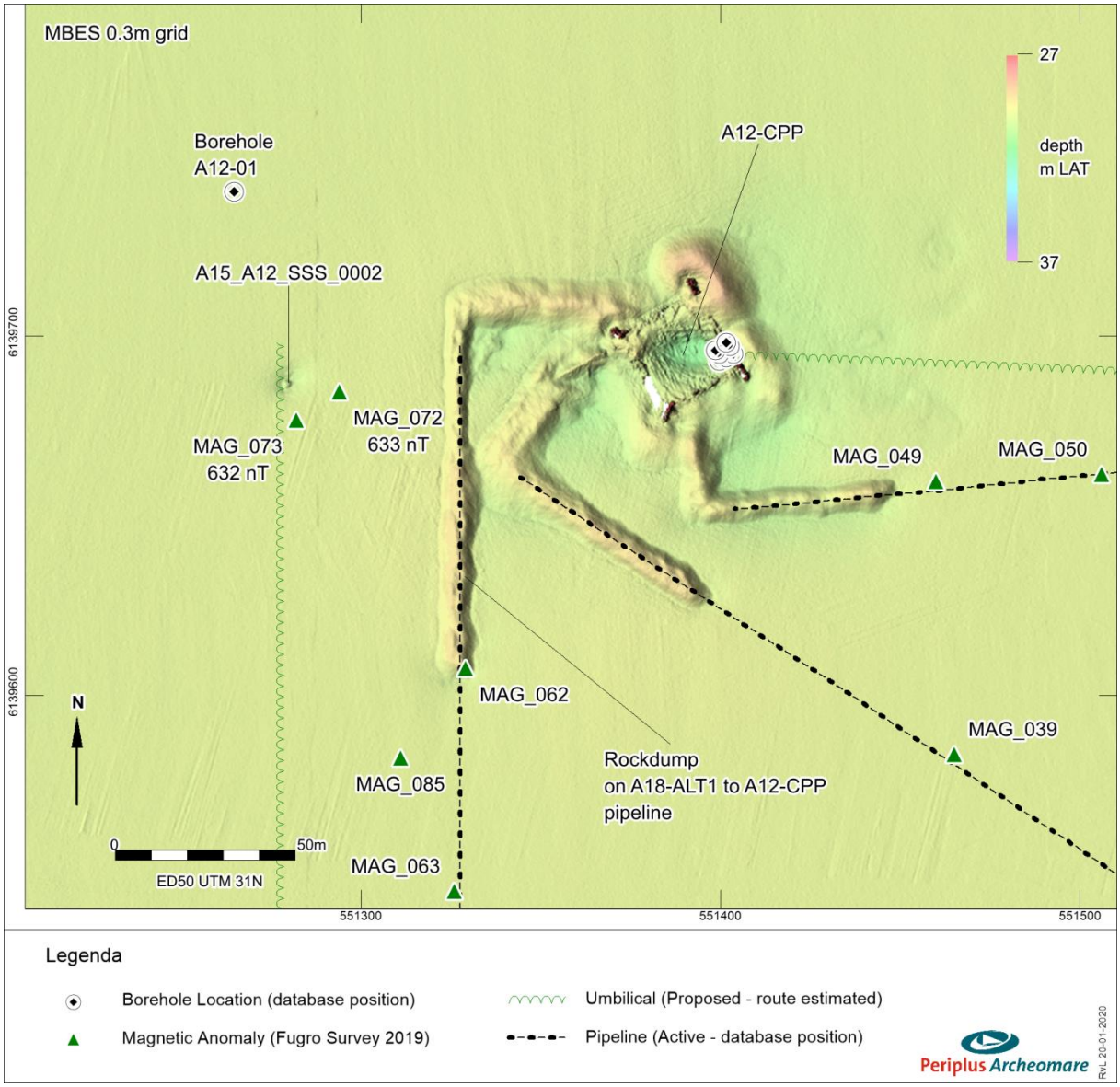

Figure 5. Multibeam image of Fugro target A15_A12_SSS_0002

3.5 Magnetometer

Besides the objects that are found exposed at the seabed there also are large *magnetometer* anomalies which have not been found on the *side scan sonar* or *multibeam* data. Although the nature of these objects is not known the anomalies could represent archaeological remains buried in the seabed, and therefore have to be taken into account within this assessment.

A total of 69 magnetic anomalies have been observed. A classification is listed in the table 7.

Classification		Number	Total
Magnetic anomalies related to infrastructure and objects known from database sources and found during the Fugro 2019 SSS survey	Pipelines	35	38
	Side scan sonar contact A15_A12_SSS_0002	2	
	Wellhead B10-03	1	
Magnetic anomalies induced by unknown ferrous objects			31
Total			**69**

Table 7. Classification of the magnetic anomalies

38 of these anomalies can be related to known and inferred pipelines (35), a wellhead (1), and debris found exposed at the seabed (2).

As discussed in the *side scan sonar* section 3.3 the two large magnetic anomalies which are related to debris found exposed at the seabed (side scan sonar contact A15_A12_SSS_0002) are also shown on a detailed map in figure 6. These two large anomalies of 632 nT and 633 nT indicate that the exposed debris contains a considerable amount of ferro-magnetic matter. The contacts do not correlate with known infrastructure, like borehole A12-01 which is located 63 m and 66 m north-northwest of these anomalies and 55 m north-northwest of side scan sonar contact A15_A12_SSS_0002. The debris found and listed as side scan sonar contact A15_A12_SSS_0002 and the magnetic anomalies MAG_071 and MAG_072 are not considered to be of archaeological interest.

31 anomalies cannot be related to known pipelines and cables, or visible objects at the seabed surface. They are related to unknown ferrous objects which have been covered by sediments. None of these anomalies have peak to peak amplitude of 50 nT.

The survey results of the A12-CPP site are contained both in this report as in the A15 report (19A024-01). An overview of the number of magnetic anomalies assessed and contained in both reports is shown in Appendix 4.

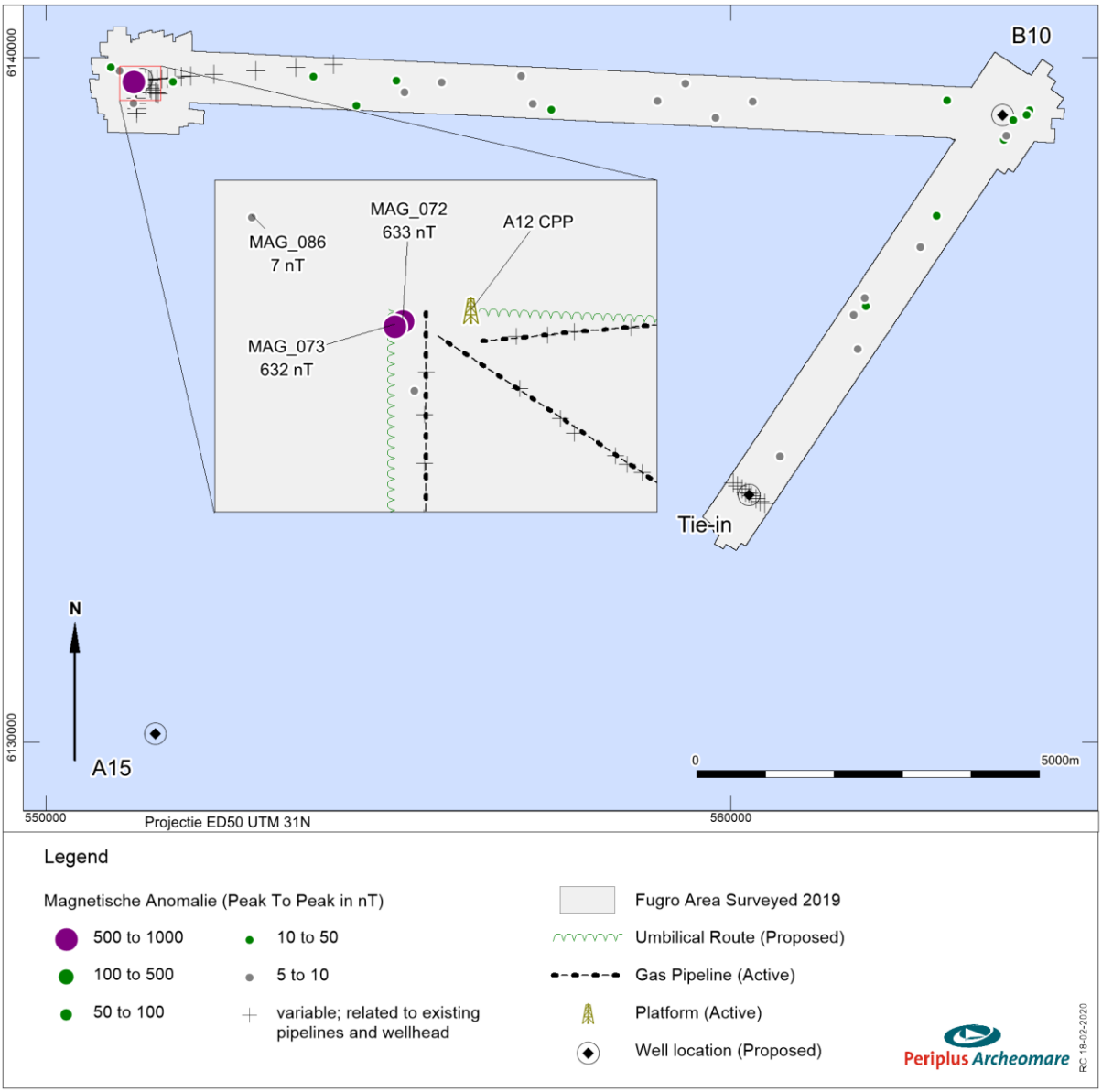

Figure 6. Overview of the magnetic anomalies

3.6 Subbottom data

Desk study expectancy

Based on the archaeological desk study the top of the subcropping *Pleistocene* sequence is expected to consist primarily of Late *Weichselian* glaciolacustrine clay of the Dogger Bank Member, locally overlain by terrestrial deposits of the Boxtel Formation. Especially in areas where those units have been covered by Early *Holocene* peat (Basal Peat Bed) or clay (Velsen Bed) well-preserved *in situ* prehistoric remains of high integrity are to be expected. An overview of the expected lithostratigraphy is shown in table 8.

The expected remains include Late Palaeolithic and Mesolithic camp sites, burials, lost or dumped objects such as flint and bone artefacts, hunting gear and canoes. Prehistoric camp sites in the context of sandy deposits of the Boxtel Formation are characterized by the scattered occurrence of flint artefacts and debris resulting from the production of flint tools accompanied by burnt seeds (hazel nuts), charcoal and

bone. The camp sites are generally small with few remains, though larger sites with a medium to high density of flint artefacts can occur in case a site has been used repeatedly and/or for a prolonged period of time.

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

Table 8. Old and new names of lithostratigraphic units in the area

According to the Sea Bed Sediments and *Holocene* Geology map the thickness of the *Holocene* sequence ranges from 5 to 20m.[11] At the A12-CPP platform location, the western and central part of the B10 to A12-CPP proposed umbilical route and at the location of the proposed Tie-In with the existing B13A to A12-CPP gas pipeline, the lower part of the *Holocene* sequence consists of the Elbow Formation, which includes the current units of the Wormer Member and Basal Peat Bed. The mapped thickness of the Elbow Formation is 1 to 5 m. At the proposed B10 platform location and the northern and central part of the B10 to Tie-in proposed pipeline route the Elbow Formation is absent according to Jeffery.

Subbottom profiling results

An overview of the seismostratigraphic units Fugro has identified at the proposed B10 site is shown in table 9.

Proposed B10 Platform Location

Age	Unit	Horizon	TWTT [s bLAT]	Depth [m BSF]	Description
Holocene	A	Seabed - H1	0.054 - 0.056	12.5-14.8	SAND to silty SAND and gravelly SANDS in the northern part (A12 to B10 pipeline and B10 area)
Pleistocene	B	H1 - H02	0.056-0.06	14-18	SAND to Gravelly SAND and SILT
	C	H02 - H04	0.057-0.075	15.2-30	CLAY with beds of SAND
	D	H04 - H05	0.063-0.078	21-34	
	E	H05 - H06	0.090-0.095	46.5-51.7	SAND to Gravelly SAND

Table 9. Seismostratigraphic units identified by Fugro

[11] Jeffery 1990.

Unit A consists of fine to medium sand with few shell fragments. Silty sands could be also occurring as well as gravelly sands within the top of the unit. The sands of Unit A have been deposited in an open marine setting and have been interpreted by Fugro as *Holocene* deposits of the Terschellingerbank Member within the Southern Bight Formation.

At the B10 site H01 defines the base of Unit A and H02 the base of Unit B. The base of unit A is found at an average depth of 14 m below the seafloor with variations between 12.5 m and 14.8 m. Unit B is observed to be a continuous 1- to 2-meter-thick layer between the H01 – H02 horizons. At the proposed A15 site Unit B has been described (and observed) as local palaeo-channel infill between the H01 – H02 horizons. Those small channel infills are also to be present at the proposed B10 site, but here the base of these channels is defined as H03.

Fugro has interpreted the lithostratigraphic sequence from the identified seismic units.[12] A summary of the interpreted geological setting is shown in table 10.
Unit B is found at 13 to 18 meters below the seafloor at the proposed B10 site. These depths are coherent with the depths at which the Boxtel Formation is expected to be present according to Fugro: 14 to 16 meters at the proposed B10 site.

The deposits of the Boxtel Formation include gravel sand, loam, clay and peat deposited along the banks of small streams during the Late Weichselian and Early *Holocene*. These small-scaled fluvial deposits are separately classified as the Singraven Member. Occurrences of fine-grained cover sand deposits might also be present. The cover sands are classified as the Wierden Member within the Boxtel Formation. It should however be noted that, apart from the B10 site, according to the Dogger Quaternary Geology map, the Boxtel Formation (formerly mapped as Twente Formation) is not subcropping along the proposed routes and at the proposed sites.[13]

Based on the desk study, the Elbow Formation - which comprised the current Basal Peat Bed, Velsen Bed and (part of) the Wormer Member - was expected to be present. The 1 to 5 m thick Elbow Formation has not been identified as a separate unit in the studied area. We consider it likely that the top of the former Elbow Formation is reflected by horizon H01. Possibly Unit B consists of Early *Holocene* fresh and brackish water tidal creek deposits and tidal flat deposits. Based on the available data it cannot be concluded if the Boxtel Formation, the former Elbow formation (current Wormer Member + Basal peat bed) or both units are present. The maximum vertical penetration of the *subbottom profiler* is approximately 16 m below seafloor. This depth coincides with the depth at which Unit B has been identified in the 2D-UHR seismic data. The Dogger Bank Member and deeper-seated units could not be identified in the *subbottom profiler* data as those units are located beyond the penetration depth of the *subbottom profiler*. The maximum recovery depth from vibrocores is 5.3m below seafloor. This means that, based on geotechnical data, it cannot be ascertained which units are present below the 5.3m. The analysis and interpretation of 2018 geotechnical data, however, provide some clues as will be discussed below.

[12] Refer to:
P906247_GEOP_REP_B10 01 | Geophysical Results Report, B10, Table 2.9, and
P906247_GEOP_REP_A15 01 | Geophysical Results Report, A15, Table 2.6.
[13] Jeffery 1991.

Unit	Description	Depth (m bsf)	Comments
Southern Bight / Terschellinger Bank	Fine to medium SAND, with few shell fragments. Silty sands could be also occurring as well as gravelly sands within the top of the unit.	Seabed to 14	open marine setting
Boxtel	Fine SAND, locally silty	14 - 16	periglacial setting; thin layers; presence at the site is uncertain
Dogger Bank	Stiff to very stiff CLAY, with layers and/or laminae of silt and very dense fine sand	16 - 30	glaciolacustrine and glaciomarine setting
Cleaver Bank	Very dense fine to coarse SAND and stiff to very stiff sandy CLAY, sometimes gravelly		glaciolacustrine setting; presence at the site is uncertain
Egmond Ground and Yarmouth Roads	Very dense SAND with thin to thick beds of CLAY, locally layers of laminated silt and clay, locally silty sand	> 50	marine / deltaic to fluvial setting; The boundary between formations is often difficult to distinguish on seismic data

Table 10. Lithostratigraphic units interpreted by Fugro

Geophysical and geotechnical data were gathered in 2018 at the then proposed B10-04 site (refer to figure 1 for approximate locations). From the datasets we concluded that the transition from the Pleistocene Doggerbank Member to the Holocene Wormer Member was found at 14.3 m below seabed at the B10-04 well site (refer to figure 7). This depth corresponds with the current Fugro data.

For B10-04 we further concluded that the Doggerbank Member in places is covered by tidal deposits of the Wormer Member, comprising laminated clays, silts and fine sands. Evidence for the presence of the Boxtel Formation had not been found, although based on the subbottom profiler and CPT-data the presence of this unit could not be excluded.

The interpretation of the 2018 geotechnical data differs somewhat from the current Fugro interpretation. In summary it can be concluded that the Late Weichselian and Early *Holocene* landscapes (which are considered to be of potential archaeological interest) are located below H01. This horizon has been found at depths over 10 meters below the seabed. From an archaeological point of view this is an important observation as levels of potential archaeological interest will not be jeopardized by the installation of the proposed pipeline and umbilical.

In the Executive Summary of the current Fugro route and site surveys report (2019) it is concluded that '*The seismostratigraphic units should be definitely validated by in-situ measurements and borehole description in order to create soil units for rig design and installation.'* From this borehole data analysis can be concluded which Early *Holocene* units are present at the proposed drill sites and if prehistoric landscapes and possible related archaeological remains have been preserved intact.

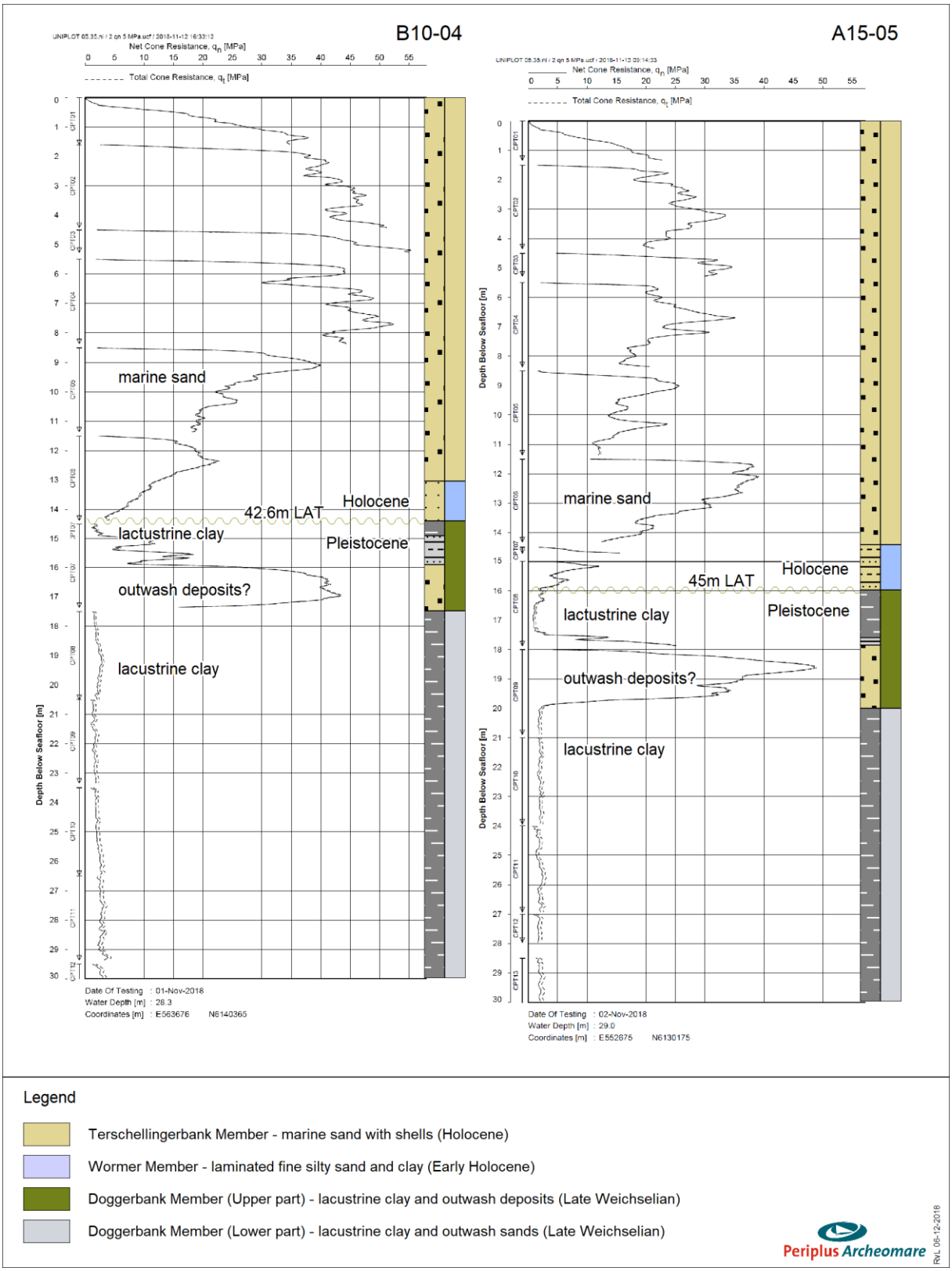

Figure 7. Interpretation of Cone Penetration Tests at the A15-05 and the B10-04 sites.[14]

[14] Uit van Lil, 2018

4 Synthesis

For this investigation different research questions are defined in the Program of Requirements.[15]
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?
Within the research corridor no archaeological remains have been found which is known from the NCN-database (NCN 2487).

with respect to *side scan sonar*, *magnetometer* and *multibeam* survey:
Are there any phenomena visible on the seabed?
Yes, a total of six *side scan sonar* contacts and 69 magnetic anomalies have been found during the survey.

If so:

What is the description of these phenomena?
The classification of the side scan sonar contacts is listed in the table below.

Fugro Classification	**Total**
Debris	6
Total	**6**

Table 11. Classification of the side scan sonar found

The classification of the magnetic anomalies is listed in the table below.

Classification		**Number**	**Total**
Magnetic anomalies related to infrastructure and objects known from database sources and found during the Fugro 2019 SSS survey	Pipelines	38	61
	Side scan sonar contact A15_A12_SSS_0002	2	
	Wellhead B10-03	1	
Magnetic anomalies induced by unknown ferrous objects			31
Total			**69**

Table 12. Classification of the magnetic anomalies found

Do these phenomena have a man-made or natural origin?
All side scan sonar contacts and magnetic anomalies have been interpreted to be man-made.

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

What classification can be attached?
The man-made objects found with side scan sonar include unknown debris (4), a possible fishing net (1), and a possible clump weight for wave buoy (1).

[15] Van Lil 2018.

38 magnetic anomalies are related to objects known from the database sources, including, known and inferred pipelines (35), a wellhead (1), and debris found exposed at the seabed found with side scan sonar (2).

If these phenomena can be classified as archaeological:

Is it possible to interpret the nature of the archaeological objects and to prioritize importance?

None of the debris items is considered to be of archaeological interest.

If these phenomena can be identified as natural:

What is the nature of these natural phenomena?

This question is not applicable.

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

The *multibeam* images show a flat seabed throughout the surveyed area. The absence of clear sedimentary structures is indicative of a low energy environment.

If so:

How can these zones be interpreted?

This question is not applicable.

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?

The seabed around the observed objects shows some scouring. The souring is observed at all sides of the objects.

Risk-prone areas are areas where the probability of archaeological remains is considered to be high. Based on the data studied no risk-prone areas can be designated.

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 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 top of the *Pleistocene* landscape could be mapped by means of the seismic data gathered. The *Pleistocene* to *Holocene* transition (= boundary between seismic Unit A and Unit B) is found at depths which coincide with the maximum penetration depth of the *subbottom profiler*. The top of the *Pleistocene* landscape has therefore primarily been mapped by means of the 2D-UHR seismic data.

If so:

What is the depth of the Pleistocene landscape compared to the present seabed?

Fugro has interpreted the seismic Unit B as lithostratigraphic unit of the Boxtel Formation. If this unit indeed reflects the Boxtel Formation, the top of the *Pleistocene* landscape lies at 14 to 16m below the seabed at site B10. The Boxtel Formation consists of small-scale fluvial deposits of the Singraven

Member where the palaeo-channel infills have been mapped, possibly accompanied by cover sand deposits of the where a continuous layer of sandy deposits occurs.

Jeffery has mapped the Elbow Formation and the subcropping *Pleistocene* units in the area.[16, 17]
The occurrence of both the Early *Holocene* and *Pleistocene* units in the research area has been summarized in table 13.

Geology		B10 site	
Formation	Epoch	Jeffery 1991	Fugro 2019
Elbow	Holocene	No	No
Boxtel	*Pleistocene*	Yes	Yes

Table 13. Geology: geological maps versus seismic survey results

From this table can be read that Elbow Formation has not been identified by Fugro.

From Pleistocene to Holocene deposits is the transition gradual or instantaneous (erosive)?
The current data do not provide sufficient information to conclude whether the transition from *Pleistocene* to *Holocene* deposits is erosive or non-erosive.

Can zones be identified where prehistoric settlement remains can be expected?
In places where the prehistoric landscape has been preserved intact in situ remains of Late Palaeolithic a Mesolithic camp sites are to be expected. Of special archaeological interest are the levees of small-scaled fluvial systems which are indicated in the seismic data along the edges of palaeo-channel infills.

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 installation of the pipeline and umbilical will not affect *in situ* prehistoric remains as the archaeological level for these remains are found in the Late *Pleistocene* and Early *Holocene* landscapes of which the deposits are situated at more than 10 m below the seabed. The installation of the pipeline and umbilical will certainly not reach that deep. At the drill sites jack-up rigs will be installed. Also, the spudding of the legs at the site and possible scouring of the seabed adjacent to the legs after installation will not affect the abovementioned archaeologic levels. The installation of the conductor will penetrate the prehistoric landscapes and potential in situ archaeological remains contained herein. However, the seabed disturbance is confined to a small area and the change that remains of prehistoric camp sites are affected by the installation of the conductor is, considering the generally small size of Late Palaeolithic and Mesolithic camp sites, small.

Are there any indications observed on the seismic profiles for the presence of buried (man-made) objects?
No.

[16] The Elbow Formation is an outdated name; currently the deposits of the Elbow Formation are referred to as the Basal Peat bed, the Velsen Bed and the Wormer Member.
[17] Jeffery 1991.

If so:

Based on the presence of buried objects and its correlation with side scan sonar, magnetometer en multibeam data can something be said about the nature of these buried objects?
Given the answer to the previous question this question is not applicable.

Are there any mitigating measures necessary to avoid disturbance of possible archaeological remains?
With respect to the *magnetometer* anomalies and *side scan sonar*, no mitigating measures are considered necessary.

With respect to the prehistoric camp sites related to the *Pleistocene* landscape no mitigating measures are considered necessary. It is advised to utilize the obtained data and information which comes forward from the onsite borehole sample analysis for adjusting and fine-tuning the current expectancy model for the North Sea area.

5 Summary and recommendations

A large quantity of survey data (*side scan sonar, magnetometer, multibeam echo sounder* and seismic) recorded within the route survey covering a total area of seventeen km^2 were analysed in order to conduct an archaeological assessment.

The current analysis of geophysical survey results is the second step in the archaeological assessment, following the desk study. The desk study has shown that no known objects within the survey corridor.

During the *side scan sonar* and *multibeam* survey six contacts were reported with *side scan sonar*. None of these contacts are considered to be of archaeological interest.

A total of 69 magnetic anomalies have been identified:

- 36 anomalies can be related to known infrastructure comprising pipelines (35) and wellhead B10-03 (1);
- 2 anomalies are related to object found with side scan these are interpreted as debris and are related to *side scan sonar* contact A15_A12_SSS_0001 (2);
- 31 magnetic anomalies cannot be correlated with known infrastructure or visible objects at the seabed surface. Those anomalies are induced by unknown ferrous objects buried in the seabed. Note of the object have a peak to peak magnetic anomaly over the 50 nT.

None of these magnetic anomalies are considered to be of archaeological interest.

Prehistory
From the interpreted seismic data can be concluded that the *Pleistocene* and Early *Holocene* landscapes are located at more than 10 m below the seabed throughout the research area. It is not known if those landscapes and possible archaeological remains contained herein have been preserved intact.

The installation of the pipeline, umbilical and jack-up rigs are not expected to affect *in situ* prehistoric remains, because the archaeological levels are located below the maximum depth of disturbance. The installation of the conductor will penetrate the prehistoric landscapes and potential in situ archaeological remains contained herein. However, the seabed disturbance is confined to a small area and the change that remains of prehistoric camp sites are affected by the installation of the conductor is, considering the generally small size of Late Palaeolithic and Mesolithic camp sites, small. Mitigating measures are therefore not considered necessary. It is advised to utilize the obtained data and information which comes forward from the onsite borehole sample analysis for adjusting and fine-tuning the current expectancy model for the North Sea area.

Archaeological objects may be discovered which were completely buried or not recognized as an archaeological object during the geophysical survey. In accordance with the Heritage Act 2016 (Dutch: Erfgoedwet), it is required to report those findings to the competent authority. This notification must also be included in the scope of work.

List of figures

List of tables

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
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
Holocene	Youngest geological epoch (from the last Ice Age, around 10,000 BC. To the present)
In situ	At the original location in the original condition
KNA	Kwaliteitsnorm Nederlandse Archeologie
Magnetometer	Methodology to measure deviations from the earth's magnetic field (caused by the presence of ferro-magnetic = ferrous objects)
Multibeam	Acoustic instrument that uses different bundles or beams to measure the depth in order to create a detailed topographic model
Pleistocene	Geological era that began about 2 million years ago. The era of the ice ages but also moderately warm periods. The *Pleistocene* ends with the beginning of the *Holocene*
PvE	Program of Requirements (Dutch: Programma van Eisen)
RCE	Ministry of Cultural Heritage (Dutch: Rijksdienst voor het Cultureel Erfgoed)
ROV	Remotely Operated Vehicle
Side scan 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.

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Appendix 1. Listing of all magnetic anomalies

Target ID	Easting	Northing	Offset	Kp	Peak To Peak	Fugro Comments	Fugro Report	PPA Comments
MAG_001	564120	6139118	160	107.06	12	Unknown MAG contact	B10	Unknown MAG object
MAG_002	563987	6138829	336	176.61	18	Unknown MAG contact	B10	Unknown MAG object
MAG_003	563606	6139879	801	333.18	21	Outside survey area	B10	MAG contact; possibly induced by B10-03 casing and wellhead
MAG_004	564362	6139264	407	75.92	19	Unknown MAG contact	B10	Unknown MAG object
MAG_005	564462	6138717	668	132.14	14	Outside survey area	B10	Unknown MAG object
MAG_027	560036	6133773	277	7.17	109	Pipeline B13A to A12 - CPP 16 inch	B10	Pipeline B13A to A12 - CPP 16 inch
MAG_028	560098	6133733	203	7.17	36	Pipeline B13A to A12 - CPP 16 inch	B10	Pipeline B13A to A12 - CPP 16 inch
MAG_029	560162	6133690	126	7.17	56	Pipeline B13A to A12 - CPP 16 inch	B10	Pipeline B13A to A12 - CPP 16 inch
MAG_030	561967	6136396	126	3.91	15	Unknown MAG contact	B10	Unknown MAG object
MAG_031	560216	6133637	52	7.18	81	Pipeline B13A to A12 - CPP 16 inch	B10	Pipeline B13A to A12 - CPP 16 inch
MAG_032	560266	6133620	0	7.17	144	Pipeline B13A to A12 - CPP 16 inch	B10	Pipeline B13A to A12 - CPP 16 inch
MAG_033	563000	6137719	2	2.24	23	Unknown MAG contact	B10	Unknown MAG object
MAG_034	560302	6133591	-46	7.17	77	Pipeline B13A to A12 - CPP 16 inch	B10	Pipeline B13A to A12 - CPP 16 inch
MAG_035	560369	6133549	-125	7.17	122	Pipeline B13A to A12 - CPP 16 inch	B10	Pipeline B13A to A12 - CPP 16 inch
MAG_036	560429	6133505	-198	7.17	99	Pipeline B13A to A12 - CPP 16 inch	B10	Pipeline B13A to A12 - CPP 16 inch
MAG_037	560497	6133477	-271	7.16	4	Pipeline B13A to A12 - CPP 16 inch	B10	Pipeline B13A to A12 - CPP 16 inch
MAG_038	564314	6139190	347	85.74	14	Unknown MAG contact	B10	Unknown MAG object
MAG_039	551465	6139584	188	9.964	101	Pipeline B13A to A12 - CPP 16 inch	A15 & B10	Pipeline B13A to A12 - CPP 16 inch
MAG_040	551524	6139540	248	9.919	168	Pipeline B13A to A12 - CPP 16 inch	A15 & B10	Pipeline B13A to A12 - CPP 16 inch
MAG_041	551545	6139519	269	9.897	133	Pipeline B13A to A12 - CPP 16 inch	A15 & B10	Pipeline B13A to A12 - CPP 16 inch
MAG_042	551605	6139486	-254	12.85	207	Pipeline B13A to A12 - CPP 16 inch	B10	Pipeline B13A to A12 - CPP 16 inch
MAG_043	551622	6139473	-266	12.83	105	Pipeline B13A to A12 - CPP 16 inch	B10	Pipeline B13A to A12 - CPP 16 inch
MAG_049	551460	6139660	183	10.04	457	Pipeline A12-CPP - B10 Side Tap 16 inch	A15 & B10	Pipeline A12-CPP - B10 Side Tap 16 inch
MAG_050	551506	6139662	229	10.042	142	Pipeline A12-CPP - B10 Side Tap 16 inch	A15 & B10	Pipeline A12-CPP - B10 Side Tap 16 inch
MAG_051	551545	6139667	269	10.047	197	Pipeline A12-CPP - B10 Side Tap 16 inch	A15 & B10	Pipeline A12-CPP - B10 Side Tap 16 inch
MAG_052	551628	6139673	-66	12.85	84	Pipeline A12-CPP - B10 Side Tap 16 inch	B10	Pipeline A12-CPP - B10 Side Tap 16 inch
MAG_053	551697	6139679	-55	12.78	149	Pipeline A12-CPP - B10 Side Tap 16 inch	B10	Pipeline A12-CPP - B10 Side Tap 16 inch

Target ID	Easting	Northing	Offset	Kp	Peak To Peak	Fugro Comments	Fugro Report	PPA Comments
MAG_054	551777	6139684	-46	12.7	470	Pipeline A12-CPP - B10 Side Tap 16 inch	B10	Pipeline A12-CPP - B10 Side Tap 16 inch
MAG_055	551887	6139694	-31	12.59	298	Pipeline A12-CPP - B10 Side Tap 16 inch	B10	Pipeline A12-CPP - B10 Side Tap 16 inch
MAG_056	551982	6139707	-14	12.5	97	Pipeline A12-CPP - B10 Side Tap 16 inch	B10	Pipeline A12-CPP - B10 Side Tap 16 inch
MAG_057	552116	6139717	3	12.36	1114	Pipeline A12-CPP - B10 Side Tap 16 inch. Centre of group of anomalies	B10	Pipeline A12-CPP - B10 Side Tap 16 inch
MAG_058	552458	6139745	46	12.02	265	Pipeline A12-CPP - B10 Side Tap 16 inch. Centre of group of anomalies	B10	Pipeline A12-CPP - B10 Side Tap 16 inch
MAG_059	553069	6139793	122	11.42	649	Pipeline A12-CPP - B10 Side Tap 16 inch. Centre of group of anomalies	B10	Pipeline A12-CPP - B10 Side Tap 16 inch
MAG_060	553653	6139843	200	10.83	733	Pipeline A12-CPP - B10 Side Tap 16 inch. Centre of group of anomalies	B10	Pipeline A12-CPP - B10 Side Tap 16 inch
MAG_061	554201	6139890	273	10.29	1102	Pipeline A12-CPP - B10 Side Tap 16 inch. Centre of group of anomalies	B10	Pipeline A12-CPP - B10 Side Tap 16 inch
MAG_062	551329	6139608	52	9.987	64	Pipeline A18-A to A12-CPP 12 inch	A15 & B10	Pipeline A18-A to A12-CPP 12 inch
MAG_063	551326	6139546	50	9.925	386	Pipeline A18-A to A12-CPP 12 inch	A15 & B10	Pipeline A18-A to A12-CPP 12 inch
MAG_064	551326	6139475	50	9.853	70	Pipeline A18-A to A12-CPP 12 inch	A15 & B10	Pipeline A18-A to A12-CPP 12 inch
MAG_065	551325	6139395	49	9.774	59	Pipeline A18-A to A12-CPP 12 inch	A15	Pipeline A18-A to A12-CPP 12 inch
MAG_066	551330	6139324	53	9.703	176	Pipeline A18-A to A12-CPP 12 inch	A15	Pipeline A18-A to A12-CPP 12 inch
MAG_067	551328	6139248	51	9.627	48	Pipeline A18-A to A12-CPP 12 inch	A15	Pipeline A18-A to A12-CPP 12 inch
MAG_068	551329	6139175	52	9.554	200	Pipeline A18-A to A12-CPP 12 inch	A15	Pipeline A18-A to A12-CPP 12 inch
MAG_072	551294	6139685	18	10.064	633	Pipeline A18-A to A12-CPP 12 inch	A15 & B10	SSS contact A15_A12_SSS_0002
MAG_073	551282	6139677	6	10.056	632	Pipeline A18-A to A12-CPP 12 inch	A15 & B10	SSS contact A15_A12_SSS_0002
MAG_084	551280	6139366	3	9.745	8	Unknown MAG contact	A15	Unknown MAG object
MAG_085	551311	6139583	35	9.962	6	Unknown MAG contact	A15 & B10	Unknown MAG object
MAG_086	551074	6139836	-204	10.214	7	Unknown MAG contact	A15 & B10	Unknown MAG object
MAG_087	559774	6139154	-205	4.69	7	Unknown MAG contact	B10	Unknown MAG object
MAG_088	557376	6139267	-203	7.09	16	Unknown MAG contact	B10	Unknown MAG object
MAG_089	557106	6139356	-127	7.36	6	Unknown MAG contact	B10	Unknown MAG object
MAG_090	560314	6139386	52	4.16	6	Unknown MAG contact	B10	Unknown MAG object

Target ID	Easting	Northing	Offset	Kp	Peak To Peak	Fugro Comments	Fugro Report	PPA Comments
MAG_091	558932	6139394	-4	5.54	5	Unknown MAG contact	B10	Unknown MAG object
MAG_092	551644	6139461	-275	12.82	88	Pipeline B13A to A12 - CPP 16 inch	B10	Pipeline B13A to A12 - CPP 16 inch
MAG_093	555233	6139526	-44	9.24	8	Unknown MAG contact	B10	Unknown MAG object
MAG_094	559333	6139652	272	5.15	6	Unknown MAG contact	B10	Unknown MAG object
MAG_095	555782	6139670	126	8.7	7	Unknown MAG contact	B10	Unknown MAG object
MAG_096	555118	6139698	123	9.36	16	Unknown MAG contact	B10	Unknown MAG object
MAG_097	550952	6139890	-326	10.266	25	Outside survey area	A15 & B10	Unknown MAG object
MAG_098	554536	6139330	-272	9.93	12	Unknown MAG contact	B10	Unknown MAG object
MAG_099	556935	6139765	273	7.55	6	Unknown MAG contact	B10	Unknown MAG object
MAG_100	563159	6139403	201	1.32	10	Unknown MAG contact	B10	Unknown MAG object
MAG_101	551855	6139677	-49	12.62	12	Unknown MAG contact	B10	Unknown MAG object
MAG_102	553905	6139752	120	10.58	11	Unknown MAG contact	B10	Unknown MAG object
MAG_103	564019	6138887	283	169.53	9	Unknown MAG contact	B10	Unknown MAG object
MAG_104	560718	6134208	-49	6.43	6	Unknown MAG contact	B10	Unknown MAG object
MAG_105	561851	6135772	-123	4.5	8	Unknown MAG contact	B10	Unknown MAG object
MAG_106	561790	6136274	206	4.11	8	Unknown MAG contact	B10	Unknown MAG object
MAG_107	561952	6136514	205	3.82	8	Unknown MAG contact	B10	Unknown MAG object
MAG_108	562762	6137261	-55	2.75	9	Unknown MAG contact	B10	Unknown MAG object

* Listing based on Fugro data; projection Easting and Northing: UTM31N ED50;

Appendix 2. Listing of assessed side scan sonar contacts

Target ID	Easting	Northing	User Class	Description	Height	Length	Width
A15_A12_SSS_0002	551280	6139687	debris	Possible buoy anchor	0.5	3.8	1.1
A15_A12_SSS_0004	551114	6140098	debris		0.2	1.9	0.8
B10_A12_SSS_0001	551379	6140049	debris	Possible Clump weight for wave buoy	0.2	1.4	0.8
A15_A12_SSS_0005	551355	6140064	debris		0.1	1.8	0.8
A15_A12_SSS_0003	551179	6139928	debris		0.0	2.2	1.2
B10_B13_SSS_0001	564052	6139411	debris		0.4	1.9	0.4

* Listing As given by Fugro; projection Easting and Northing: UTM31N ED50;

Appendix 3. Phases of maritime archaeological research

The care for cultural heritage is legally required according to Dutch law. In order to comply with the requirements, all procedures and requirements for the archaeological research process haven been incorporated in the Dutch Quality Standard for Archaeology (KNA waterbodems, version 4.1). 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)**
   In order to test the archaeological expectation, a geophysical survey is carried out. The type of survey depends on the type of expected objects, local geology and expected depth of the objects below the seafloor. In practice, the research usually consists of a *side scan sonar* survey, if necessary, supplemented with *multibeam* echosounder recordings, subbottom profiling and *magnetometer* measurements. The requirements of the survey are based on the desk study and should be included in a program of requirements which must be approved by the competent authorities.

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

3. **Exploratory field research (onderwaterfase verkennend)**
   The suspected sites are investigated by specialized divers in order to identify the objects. The requirements of the underwater research are included in a program of requirements which must be approved by the competent authorities.

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

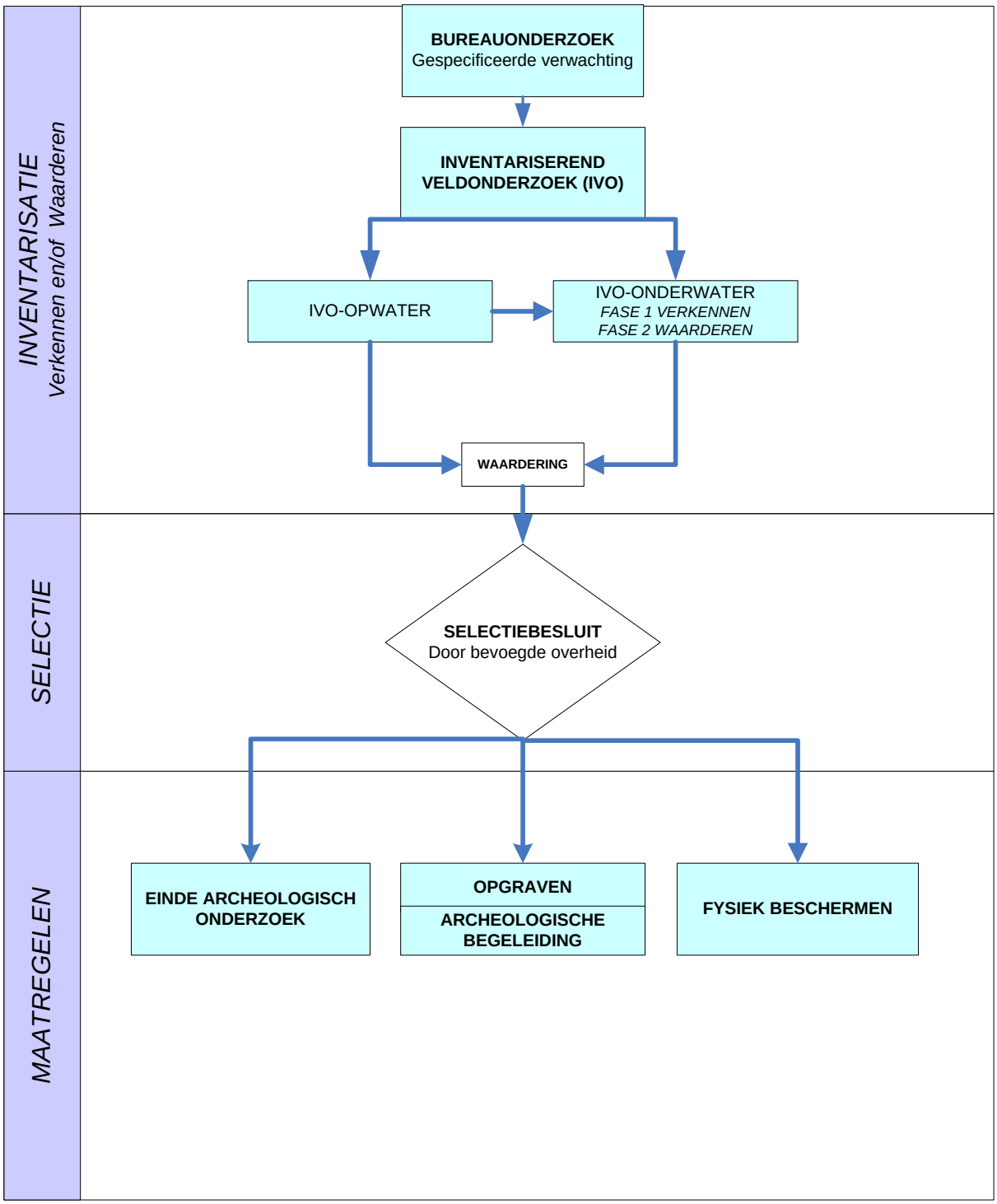
4. **Appreciative field research (onderwaterfase waarderend)**
   The archaeological remains at the site are thoroughly investigated and mapped by a specialized archaeological diving team and samples are collected for additional research. Then a decision will be made whether the archaeological remains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

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

The phases described above contain several 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)



Appendix 4. Reported contacts in 19A024-01 (A15) and 19A024-02 (B10)

	Side scan sonar		
	Found	Reported	
	Total number	19A024-01 (A15)	19A024-02 (B10)
B10	1	1	
A15	1		1
A12-CPP	5	5	5
Total	**7**	**6**	**6**

	Magnetic Anomalies		
	Found	Reported	
	Total number	19A024-01 (A15)	19A024-02 (B10)
B10	40	40	
A15	34		35
A12-CPP	29	29	29
Total	**103**	**69**	**64**