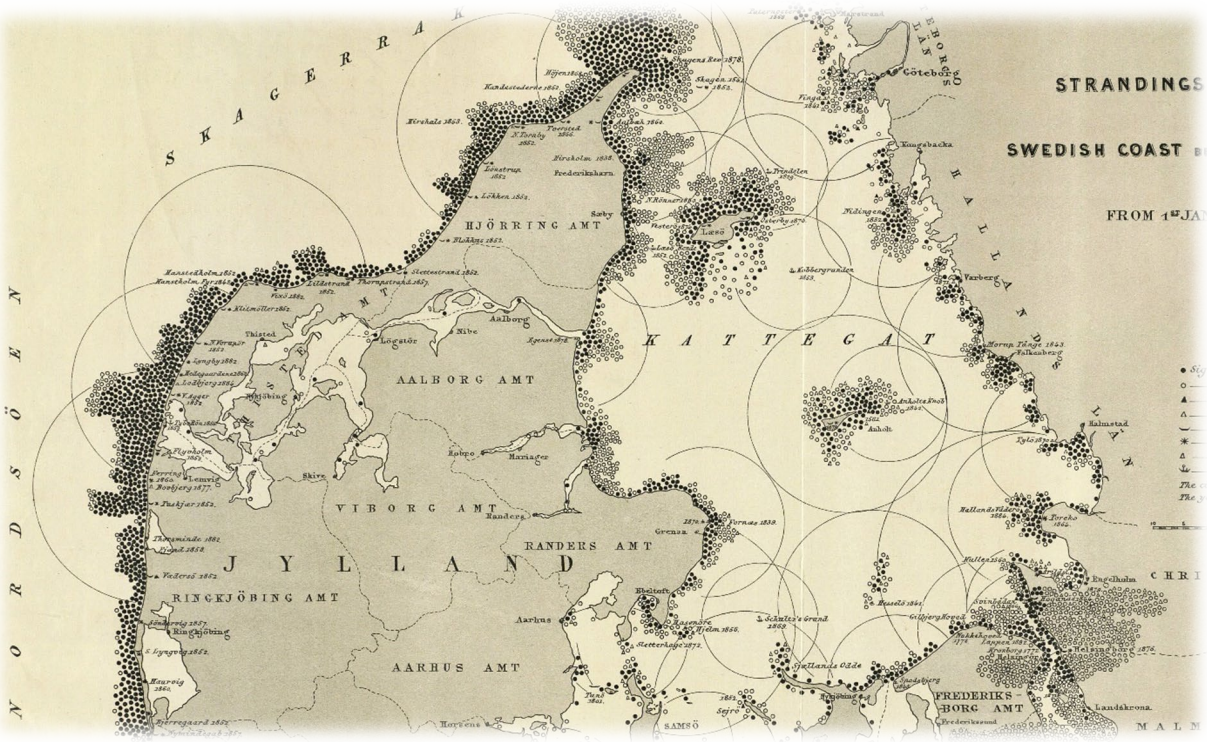
De Kulturhistoriske Museer

Holstebro Kommune

Thor offshore wind farm, North Sea

DKM 20.959 MAJ 2019-21 SLKS 19/04719

Archaeological analysis



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Marinarkæologi Jylland

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10 December 2019

Front page

Figure 1. (Hohlenberg, Chart showing the strandings on the coasts of Denmark and on the Swedish coast between Marstrand and Carlskrona during the period from 1st January 1858 to 31st December 1885, 1885). Source: Det Kongelige Bibliotek. Image used under https://creativecommons.org/licenses/by-nc-nd/3.0/

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Figure 2. Map showing the location of the Thor offshore wind farm marked with a red polygon. Scale 1:2 000 000

Abstract

In connection with construction of the offshore wind farm "Thor", Energinet asked the marine archaeological museums in the collaboration Marine Archeology Jutland (MAJ) to conduct an archaeological analysis of the proposed construction area in order to assess the extent to which the project will affect objects or areas protected by Section 28 of the Museum Act.

The archaeological analysis showed that there are potentially cultural-historical objects, wrecks and cultural remains in the form of Stone Age settlements in the affected area. The analysis further showed that in-depth studies are needed to locate and date them so that they are not damaged by construction work or are investigated and documented before it begins.

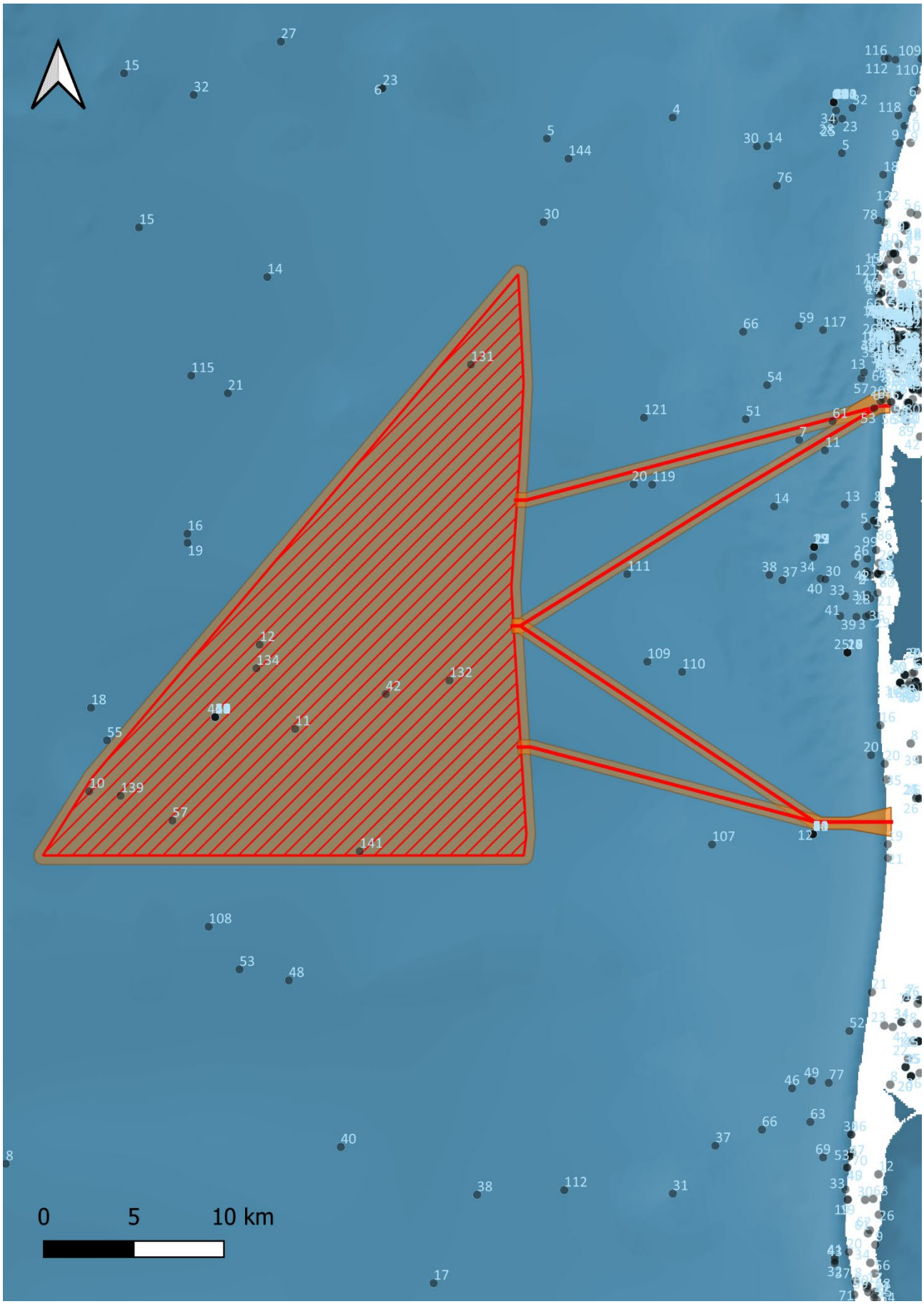

Figure 3. Map showing the proposed wind farm with a 500 meters buffer zone, plus all surrounding cultural heritage objects recorded in the "Fund og Fortidsminder database". Scale 1:300 000

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Abbreviations

DKM	De Kulturhistoriske Museer i Holstebro	*The Historical Museums of Holstebro*
Efs	Efterretninger for Søfarende	*Information for Seafarers*
FF	Fund og Fortidsminder (database)	*Database of Danish cultural heritage objects*
MAJ	Marinarkæologi Jylland	*Maritime Archaeology Jutland*
ROV	Undervandsrobot	*Remotely operated vehicle*
SKLS	Slots og Kulturstyrelsen	*Danish Agency for Culture and Palaces*
STM	Strandingsmuseum St. George	*Museum, Strandingsmuseum St. George*
UTM	Kortprojektion	*Universal Transverse Mercator*

Background

Energinet is planning a new offshore wind farm, Thor, in the North Sea outside Thorsminde off western Jutland. According to the application materials, construction will reach a depth of up to 70 meters into the seabed. The area of the offshore wind farm and cable corridors is approximately 516 km^2. Pr. Currently, there are four different cable corridors to examine.

The construction work, which is planned to be carried out in connection with the erection of the wind turbines, may conflict with marine archaeological interests. Furthermore, it must be presumed that anchoring and jacking-up of vessels used during construction work and in the event of any subsequent repairs can damage cultural heritage in the affected areas. This type of work

will be devastating to maritime archaeological objects such as shipwrecks, wreckage and Stone Age settlements.

Therefore, Energinet has asked the maritime archaeological museums in the collaboration Maritime Archeology Jutland (MAJ) to carry out an archaeological analysis of the proposed construction area to assess the extent to which the project will affect objects and areas protected by Section 28 of the Danish Museum Act.

Maritime Archeology Jutland has previously conducted an archival investigation of the area. The archival study was delivered in June 2019 and was based on an archaeological review of registered finds in the Agency for Culture and Palaces (SLKS) database, *Fund og Fortidsminder* (FF). Based on the design of the area and cable corridors at that time, there were 55 registrations in *Fund og Fortidsminder* within the project area. Of the 55 registrations, 36 were objects protected by the Museum Act while seven were registered as potentially protected.

Objectives

The archaeological analysis aims to assess the presence of ancient heritage such as settlements from the older Stone Age and also whether there are cultural-historical objects such as shipwrecks or fishing facilities within the planned study area.

Administrative and other data

Accountable museum:	Strandingsmuseet St. George
Museum contact:	Tine Verner Karlsen/Marie Jonsson
Report responsibility:	Marie Jonsson
Report finish date:	18 December 2019
Participating archaeologists:	Marie Jonsson, Claus Skriver, Peter Moe Astrup
Name of site:	Thor havvindmøllepark
Site and location number (FF):	400110c:152
MAJ collaboration case no.:	MAJ 2019-21
DKM case no.:	DKM 20.959
SLKSs case no.:	SLKS 19/04719
Approved budget incl. sales tax:	879,214.45 DKK
Date of approval of budget:	11 July 2019
Type of budget:	Archaeological analysis
Period of investigation:	August 2019
Date of project description	16 May 2019
Contractor name	Energinet
Contractor address	Tonne Kjærsvej 65, 7000 Fredericia
Contractor type	Private
Contractor CVR no.	39 31 50 41
Coordinates:	X416652 Y6243129
Geographic coordinate system:	Euref89 UTM zone 32N
Water depth:	0-35 m
Area of investigation:	516 km^2

Topography and bottom conditions

The current review is based on the areas shown in Figure 3. The area of the offshore wind farm is approximately 440 km^2. There are also four different cable corridors to be examined, they are between 20 and 25 kilometers long and each corridor has a width of one kilometer. An almost 80 km^2 area has thus been designated as the study area for the transmission cables. The total area for the wind farm and cable area is approximately 516 km^2, which is a little larger than the entire island of Falster (514 km^2). The bottom conditions are estimated to consist mostly of sand and boulders covered by layers of loose sediment of varying thicknesses. As the area extends all the way to shore, depths are between 0 and about 35 meters.

Geographic coordinate system

The report uses Euref89 UTM zone 32N, unless otherwise specified.

Methods

A revised and in-depth review of the previously mentioned objects in *Fund og Fortidsminder* was made. Other databases reviewed are: The Danish Maritime Authority's wreck register and vragguiden.dk. Enquiries were sent to local divers and fishermen in Thorsminde about their knowledge of shipwrecks or wreckage in the area. Relevant literature was reviewed in search of as yet unregistered remains.

To assess the potential for the occurrence of settlements from the older Stone Age, in collaboration with Rambøll, Energinet has prepared a “Geological Desk study” which briefly describes the geological conditions in the area. The archaeological analysis was prepared prior to the geo-archaeological analysis, which means that the archaeological analysis is based on relatively sparse information, with supporting data not yet incorporated. The archaeological analysis is primarily based on data available through the database *Fund og Fortidsminder*, as well as the geological data available through EMODnet - a digital portal for European marine data - and "Geological Desk Study" (Marstal & Petersen 2019). This gives a rough estimate of areas / depth intervals that may be of interest to the analysis, keeping in mind that the final designation of areas of interest is to be based on concrete, geophysical data in the geo-archaeological analysis.

Results

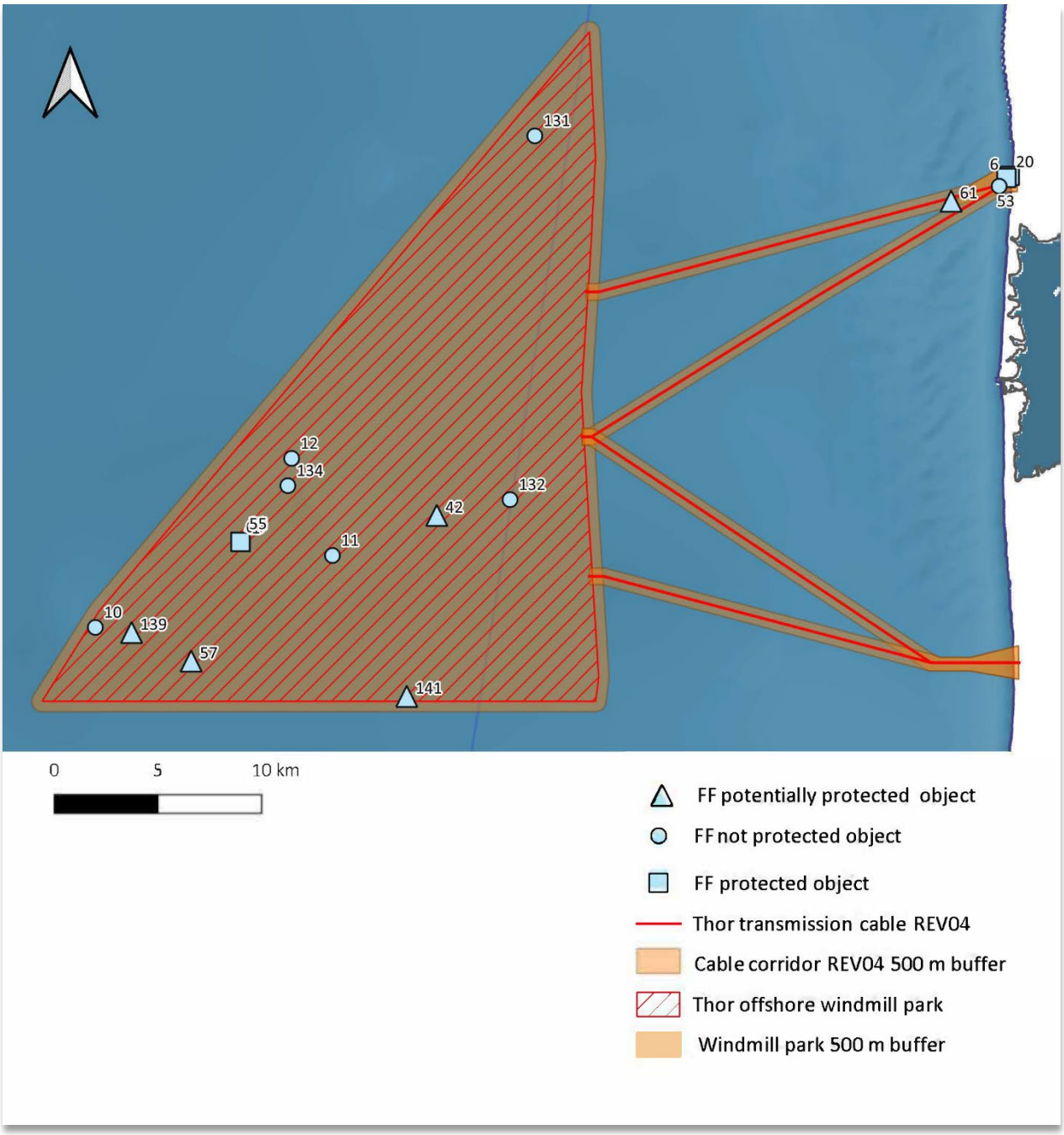

Figure 4. Map showing objects in Fund og Fortidsminder within the construction area. Scale 1:300 000

Cultural History Objects

There are a number of uncertainties associated with the objects originating from the North Sea registered in *Fund og Fortidsminder*. For many, for example, it is uncertain whether the specified position was recorded using a GPS. Furthermore, if a GPS was used, it is uncertain whether coordinates were plotted in WGS84 or, for example, ED50, which may cause a greater displacement of the recorded position. Finally, many of the sites in *Fund og Fortidsminder* are positioned by, for example, fishermen whose main purpose was not to record the exact location of

these sites. To compensate for these uncertainties, a 500 m buffer zone was added around the project area when conducting searches in *Fund og Fortidsminder*.

Positions are somewhat more reliable in the *Vragguidens* records. *Vragguiden*, the sports divers' wreck guide, is meant to guide divers to known wrecks and positions are most often recorded with GPS. Even more reliable are the Maritime Authority records. All of these are registered by GPS, since it is of great importance that the positions are correct.

Fund og Fortidsminder, *Vragguiden* and the Danish Maritime Authority's register

The extent of the study area means that three different water areas in *Fund og Fortidsminder* are to be considered; 400110c: *Nordsøen Ø (Thorsminde – Hvide Sande)*, 402102: *Husby (Bjerghuse - Stadil)* and 402103: *Fjaltring (Vrist – Bøvlingbjerg)*. With a 500 m safety distance around the wind farm and presently planned routes for transmission cables, there are 36 records of possible wrecks and objects in *Fund og Fortidsminder* (Appendix 1) (Figure 4).

If this data set is filtered for duplicates, recovered wrecks, wrecks younger than 100 years, (which is the age criterion for protection under the Museum Act) and wrecks only recorded by place name, seven cultural heritage objects remain - provided that none of these are duplicates. However, at first sight it does not appear that there are duplicates in the list below.

System no.	Area no.	Loc. no.	Type	Name	Wecking/ dating	Description	x	y
72440	402103	20	Single find		500 f.Kr.-1066 e.Kr.	Location lacks data.	445914,48	6257648,39
72499	402103	6	Single find		250000-3951 f.Kr.	Deer antler ax found on the beach.	445754,48	6257550,39
181007	400110c	42	Wreck		Unknown	Position of wreck with unknown wrecking year.	418294,69	6241286,57
181026	400110c	57	Wreck	JERRIQ ?	Unknown	Position of wreck registrered by fisherman. Unknown identity. Unknown wrecking year.	406451,79	6234266,58
181028	400110c	139	Wreck	BAUNTY ?	Unknown	Position of wreck registrered by fisherman. Unknown identity. Possible name *Bounty*. Unknown wrecking year.	403577,81	6235640,56
181030	400110c	141	Wreck	ANITA	Unknown	Position of wreck registrered by fisherman. Unknown wrecking year.	416844,73	6232563,62
181041	402103	61	Wreck	LIS		Position of wreck registrered by fisherman. Unknown wrecking year.	443091,48	6256431,42

Table 1. List of objects with a known position, that are protected or potentially protected by the Museum Act, within the construction area.

The first two objects on the list are single finds. One is a deer antler ax found on the beach in 1964 and imprecisely dated to the Stone Age, between the Mesolithic and the Neolithic Funnel Beaker

culture. The second single find is missing any data other than that it is an object from Iron Age. On the map they are shown as protected by the Museum Act. There are five wrecks with unknown dates of loss. They are potentially protected by the Museum Act since the date of sinking is unknown, no more can be said without further investigation.

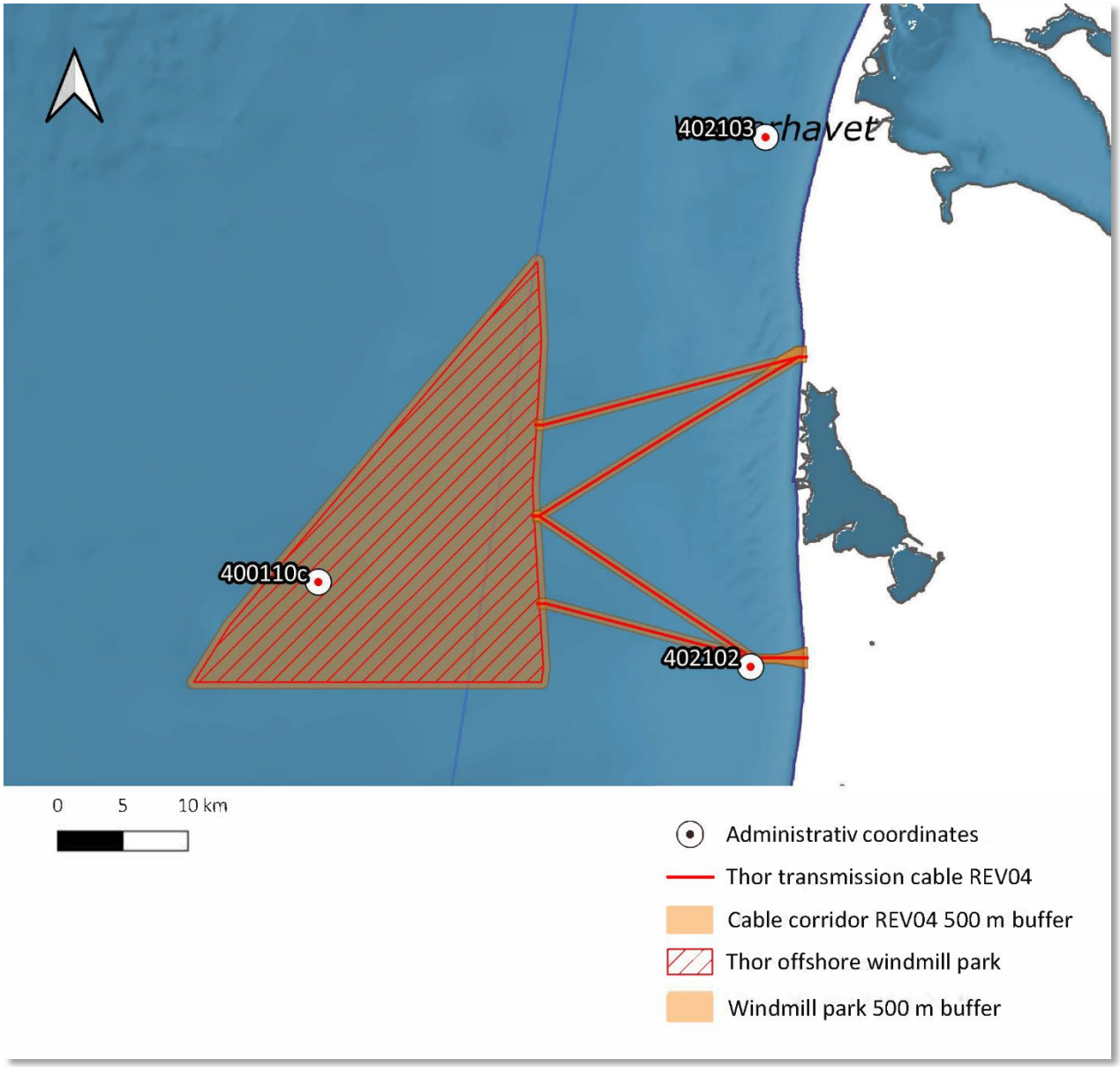

Figure 5. Map showing the three administrative coordinates discussed in the text. Scale 1:500 000

21 of the 36 enumerated records are located solely on the basis of place names in so-called "administrative coordinates", which in this case is a centroid of the water area 400110c: *Nordsøen Ø (Thorsminde-Hvide Sande)*. This position lies within the study area, which is why these wrecks appear in the above count. The other two areas, 402102: *Husby (Bjerghuse - Stadil)* 402103:

Fjaltring (Vrist – Bøvlingbjerg) also each has its own administrative coordinates, with 49 registrations mapped in area 402103 and 14 registrations in 402102. In contrast, these two positions are located outside the construction area and are therefore not included in this count. Figure 5 shows the three administrative coordinates.

Shipwrecks recorded at the administrative coordinates should be considered as being in the area even if the exact position of sinking is unknown. On the whole, older shipwreck information is subject to such uncertainty that it is difficult on this basis alone to indicate how many wrecks are in a given area. Appendix 1 shows the records at the three different administrative area points shaded in three different colors.

In the Danish Maritime Authority's wreck register; there are seven wrecks within the current construction area. Two of these are also included in the *Vragguiden*. None of them were lost more than 100 years ago and are thus not yet protected by the Museums Act. They are all registered in *Fund og Fortidsminder* as shown on the map in Figure 6.

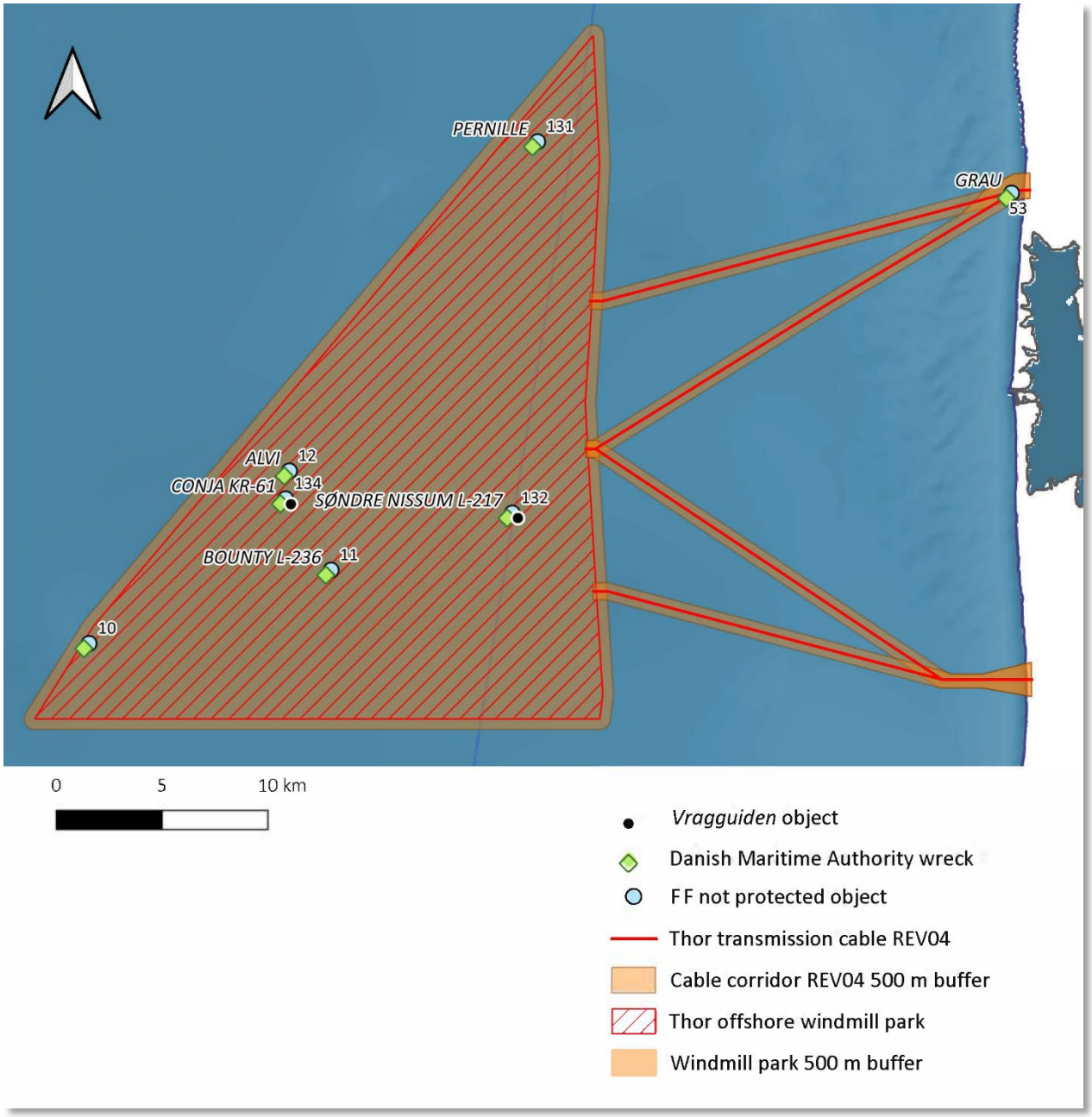

Figure 6. Map showing the objects registered in the Danish Maritime Authority wreck register, Vragguiden and Fund og Fortidsminder. Scale 1: 300 000

Other archives and oral information

In Norman Andersen's "*Skibsvrag ved Vestkysten*" (2000, pp. 9-10) there are descriptions of shipwrecks that occurred as early as the 1400s. The positions are very imprecise: "In 1422 a ship was lost at Bovbjerg, and again in 1472 a Hanseatic ship was lost on the west coast of Jutland." Further in the text, Bovbjerg appears repeatedly as a place of loss (ibid.). The little book "*Historien om Fjaltring og Trans*" contains some beachings, four of which occurred more than 100 years ago (Lisby Kjær, Olsen, & Villadsen, 2012, pp. 46-47). Some of them are also registered in *Fund og*

Fortidsminder. In,"*De nærer sig af vrag"*, the rescue service's activities along the coast south of Thorsminde are depicted (Tarbensen Christensen, 1995). A number of strandings are also described where rescues failed. An example is an attempt to rescue the schooner Neptune, which was stranded on Aug. 6, 1882. The rescue party was close to succeeding but the main mast fell, the ship lost contact with land and disappeared under the waves (Tarbensen Christensen, 1995, p. 128).

Attempts to obtain additional information from local divers or fishermen regarding wrecks or other objects in the construction area have not yet paid off.

Discussion

The fact that a large number of ships are wrecked in the current area is beyond doubt. A good picture of how many occurred can be seen in Hohlenberg's various maps of shipwrecks in the 19th century (see front page). For example, Figure 7 shows the wreckings that happened in October 1860. Most often, however, the exact location of a shipwreck is unknown. For the most part it is not more detailed than, as in the stories above, that a ship was lost at Bovbjerg.

For all sources in the *Fund og Fortidsminder*, both the identification and the location of the find are subject to uncertainty. This means that wrecks registered outside the area can be located inside it and vice versa. Furthermore, this means that it is not possible to simply write off different sources for the same wreck as duplicates. Where one source is based on contemporary loss data, the other may be based on observations made during fishing or diving. The wrecks in the latter category are often named from knowledge of the former, and in a water such as this it is quite possible that even very close records are not duplicates but actually two different wrecks. Finally, there may be wrecks that are so destroyed that they are actually scattered over several different sites.

Additionally, the sand that covers most of the bottom in the area is constantly moving and occasionally hiding, occasionally uncovering, the wrecks that are on the bottom. An example of this is the wreck of the *St. George*. In 1996, the wreck was uncovered and video documentation was made, while today it is covered in sand and cannot be seen.

All these uncertainties make it difficult to say where the wrecks that are registered to the administrative coordinates in *Fund og Fortidsminder* or are mentioned in the literature are actually located. Against this background, MAJ recommends Energinet that an archaeological survey of the

geophysical material be completed, which according to the applicant will be obtained as part of the planned seabed surveys.

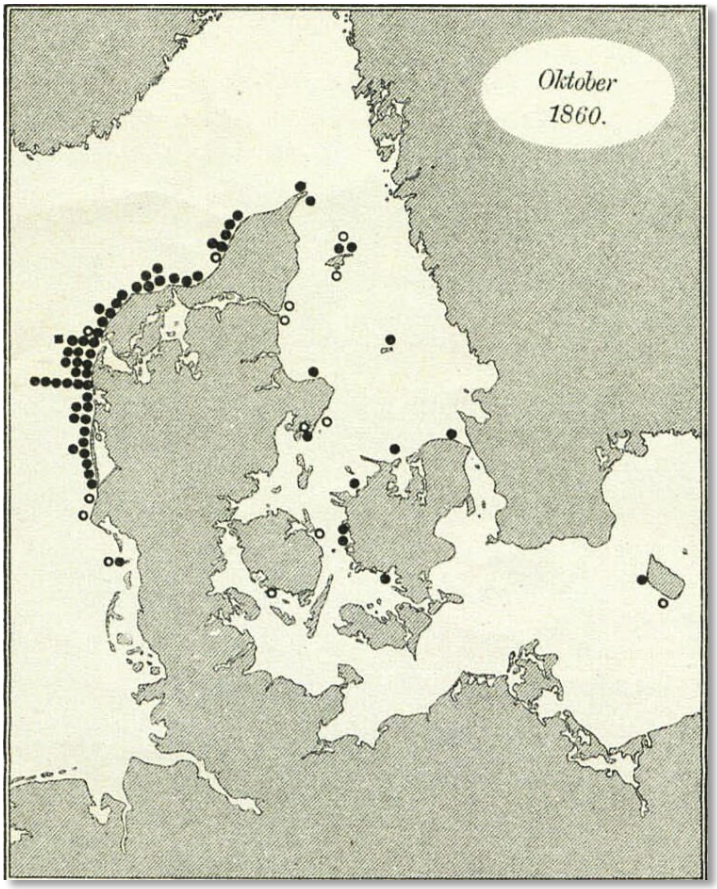

Figure 7. (Hohlenberg, 1883) Detail of maps showing the strandings that happened in the month of October 1860. Source: Det Kongelige Bibliotek. Image used at https://creativecommons.org/licenses/by-nc-nd/3.0/

Underwater Stone Age potential

Introduction

This section of the report aims to assess whether there are areas that could potentially accommodate Stone Age settlements within the proposed study area. Large parts of the current North Sea were exposed land throughout the Mesolithic due to lower water levels at the time. Within the proposed area, which covers approx. 800 km^2 (440 km^2 offshore wind farm area and 358 km^2 cable route area), there is only one record of archaeological material in the database *Fund og Fortidsminder* that is supposed to date from the Stone Age. According to this record, a fisherman found animal bones approx. 3 km southwest of Thorsminde. Occasionally, objects such as amber jewelry appear on the beach along the west coast of Jutland. These presumably originate from now submerged and eroded settlements or, for example, from sacrifices in prehistoric bogs

and the Stone Age sea. These findings do not indicate where the settlements were located precisely. Therefore, it is not possible to identify areas where construction work is particularly at risk of damaging an archaeological site. However, the individual findings indicate that the area was inhabited and that there is a real possibility of encountering archaeological sites that are protected by the Museum Act.

Several researchers have suggested that the shorelines contemporaneous with the Maglemose culture occupations in the proposed area must have been so exposed during prehistory that they were completely eroded away when they were engulfed by the sea. Nevertheless, drill samples as well as archaeological studies have shown intact stratigraphic layers in several areas (Verner Karlsen, Moe Astrup, & Skriver, 2019). Technically, these layers could contain archaeological finds like bone points, which have been found in large numbers in the North Sea and on the coast of Holland (Amkreutz & Spithoven, 2019).

In 2016, the energy company Vattenfall Vindkraft A / S was granted permission by the Danish Energy Agency to establish an offshore wind farm called *Vesterhav Syd* in the North Sea off Holmsland Klit, approximately 15 km south of the Thor Cable Area. Prior to construction of the wind turbines, an archaeological survey was carried out to assess if Mesolithic settlements could be located (Verner Karlsen, Moe Astrup, & Skriver, 2019). The feasibility study was done aboard the dredger vessel M / V Kronos that is owned by BG Stones A / S. The vessel moved to selected positions, lowered its "suction pipe" to the seabed and starting dredging. Sediment down to 2 meters below the sea floor, the depth specified for the construction work, was extracted. The sediments were sifted using a mesh size of 10 X 10 mm. In this way, the sediments were cleaned of sand and the residual material carried down into the open cargo space where archaeologists, with the help of shovels, examined the material in order to identify possible objects and settlement remains. After reviewing the material, the cargo was emptied and the vessel sailed to a new position where the same procedure was repeated. In this manner four spots were investigated. No archaeological findings were made during the study. However, discoveries of organic matter such as mud, peat, tree and branch fragments show that the area has potentially been accessible for settlement at some point during the older Stone Age. The study also shows that such layers may well have been preserved in the North Sea until the present. Therefore, the designation of the area on the basis of seismic profiles based on the geophysical material seems to be well-founded. The studies from *Vesterhav Syd* further show that the areas that are affected by

the Thor Project may well be of the same character, with preserved deposits of peat and other organic materials.

Topographic models

Normally, in an archaeological analysis based on the reconstructed landscape, topographic models (for example, the fishing site model) will be used to identify areas where people are particularly likely to have settled (Sørensen, 1996). However, it is thought that the available geological data from the area cannot be used to derive the most suitable topographic locations for habitats using the fishing site model. The main reason for this is that the seabed has been leveled to such an extent that determinations of these conditions must be made on the basis of a depth model which has been corrected for the thickness of the Holocene layers. If this is not done, the reconstructed coastline is instead stated as if the water were higher or lower than it actually was, depending on whether there has been erosion or accumulation of sediment. In addition, any settlements in the offshore wind farm area lie at sea depths of 23-35 m, which only includes settlements from a time so far back that it is unknown whether the fishing site model / location method works in practice.

Another reason why the topographic model is not considered to be a suitable tool for identifying prehistoric Stone Age settlements is that we still know very little about the area's original topography and environment. It is unknown whether the coastal area had the character of today's coastal stretches with large exposed beaches with large surf impacts and tidal differences (and with long straight stretches without bays and coves) or if it was more reminiscent of the environment / landscape that one finds today along the coasts of the inner Danish waters. A third possibility is that parts of this landscape were reminiscent of the Wadden Sea region, as it is known in the southwest of Denmark. Thus, there is a great need to increase our knowledge of the contemporary environment to be able to use a topographic model and thus assess which areas have the greatest archaeological potential.

The flat islands / meltwater plains in western Jutland are generally poor in archaeological material that can be traced back to the Mesolithic (compared to other parts of Denmark such as the western and southern Zealand lake basins). It is unclear whether we should expect the same distribution pattern in the North Sea as in western Jutland, or whether there were several settlements that were built with the coast easily accessible. More detailed landscape analysis is necessary to determine where to look and how to understand settlement during the Maglemose

period. A subsequent step may be to start actual searches for these sites to find out where they were located.

Depths / Coastal displacement curves

It is crucial to understand coastal development in a given region in order to target any marine archaeological studies. To aid this understanding, SLIPs (Sea-Level Index Points) can be used. SLIPs are data used to determine the water level (for further explanation see attached document with guidelines for 14C samples prepared for Energinet - Appendix 3). Unfortunately, establishing the prehistoric coastline in the construction area cannot be based on (SLIPs) derived from other parts of the North Sea due to differences in isostatic rebound, and from the proposed construction area there are so few SLIPs available that the relative sea level rise cannot be determined.

Isostatic- and eustatic curves used in Rambøll's geo-archaeological desk study is therefore based on SLIPs from the Great Belt area. It is unknown whether the pattern of isostatic uplift - as mapped by Mertz (1924) (Astrup, 2018) with the NV-SE-trending isobase course, continues into the North Sea, but these curves are used since better material is lacking. This is done knowing that it is problematic to use a coast-displacement curve that is based on data from another area. However, as can be seen from Figure 8, Rambøll has compared the available curves and here there seems to be good correspondence with the calculated position of the coastline (Astrup 2018) and the curve from the Great Belt area.

Developing a coastal displacement curve based on local North Sea data will be of great importance for the present study. Therefore, it is requested that a series of core samples be taken within the proposed construction area, samples which will provide relevant SLIPs. When the core samples are available, it will be necessary to select and date the most suitable sections so that they can be used in building coastal isostatic curves. In 2018, attempts were made to model land elevation differences for the whole of Southern Scandinavia (Astrup, 2018). The analyses clearly showed that the spread of SLIPs is crucial to the validity of the models and that the North Sea currently constitutes one of the areas with the least amount of data available. Therefore, SLIPs from the North Sea will be of great use in calculating isostatic movement going forward (see also the document with guidelines for 14C tests prepared for Energinet - Appendix 3).

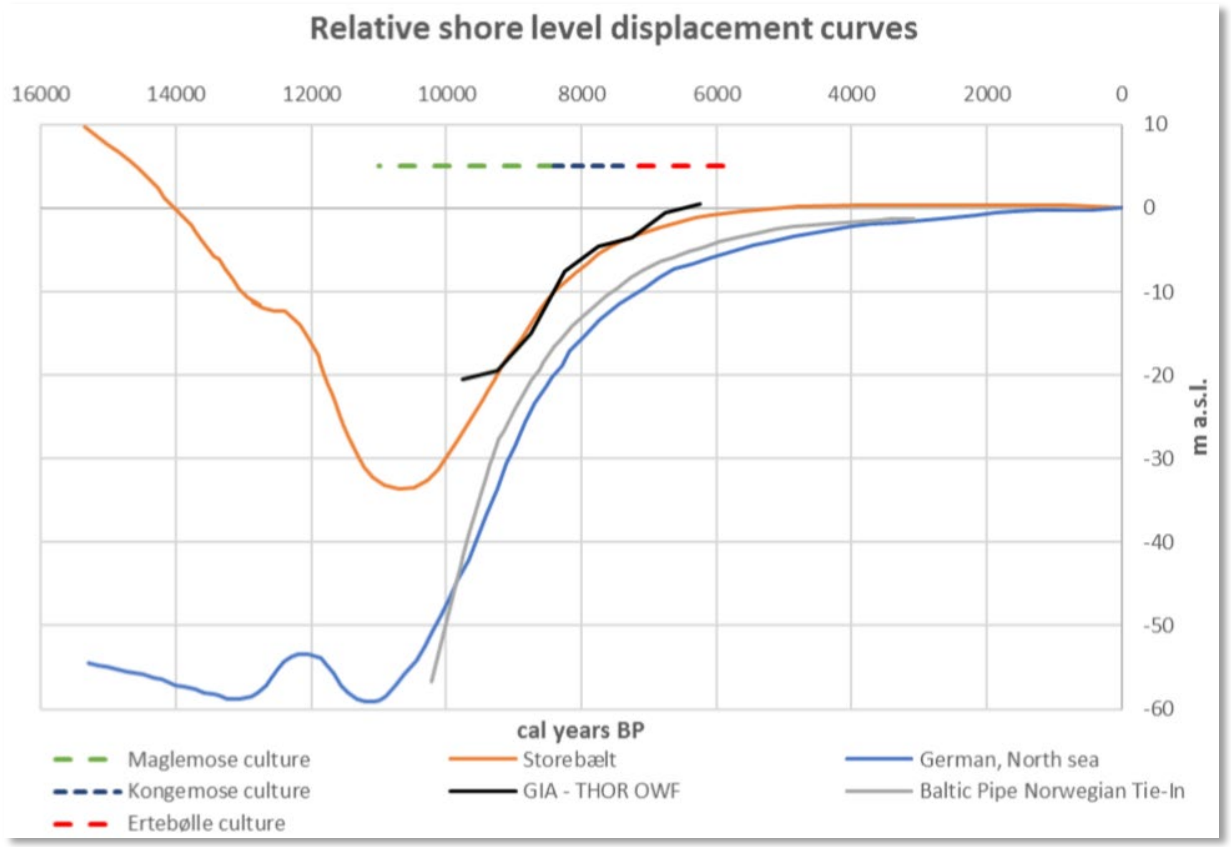

Figure 8. Relative coastal displacement curves representing the situation around the Thor field. The orange curve is based on data from the Great Belt, the blue curve represents data from the northern part of Germany, while the gray one is compiled in compiled in the connection with the Baltic Pipe investigation, and based on C14 dated samples. The dotted lines represent the different Mesolithic periods. (Marstal & Petersen 2019 p. 8)

Coastal Displacement curves shown in Figure 8 and Figure 9 indicate that the lowest water level in the area happened during the Maglemose period's older part (about10500 BP). At that time there was dry land in almost the entire study area. Depth conditions in most of the area where the wind turbines are to be erected vary from -34 to -24 m below the water surface. This means, given the coastal displacement curves and coastlines in Figures 8 and 9, we can exclude younger settlements from the Kongemose (8350-7350 BP) and Ertebølle periods (7350-5950 BP) in most of the area, since the majority of the study area was transgressed already during the Maglemose period (see Figure 9).

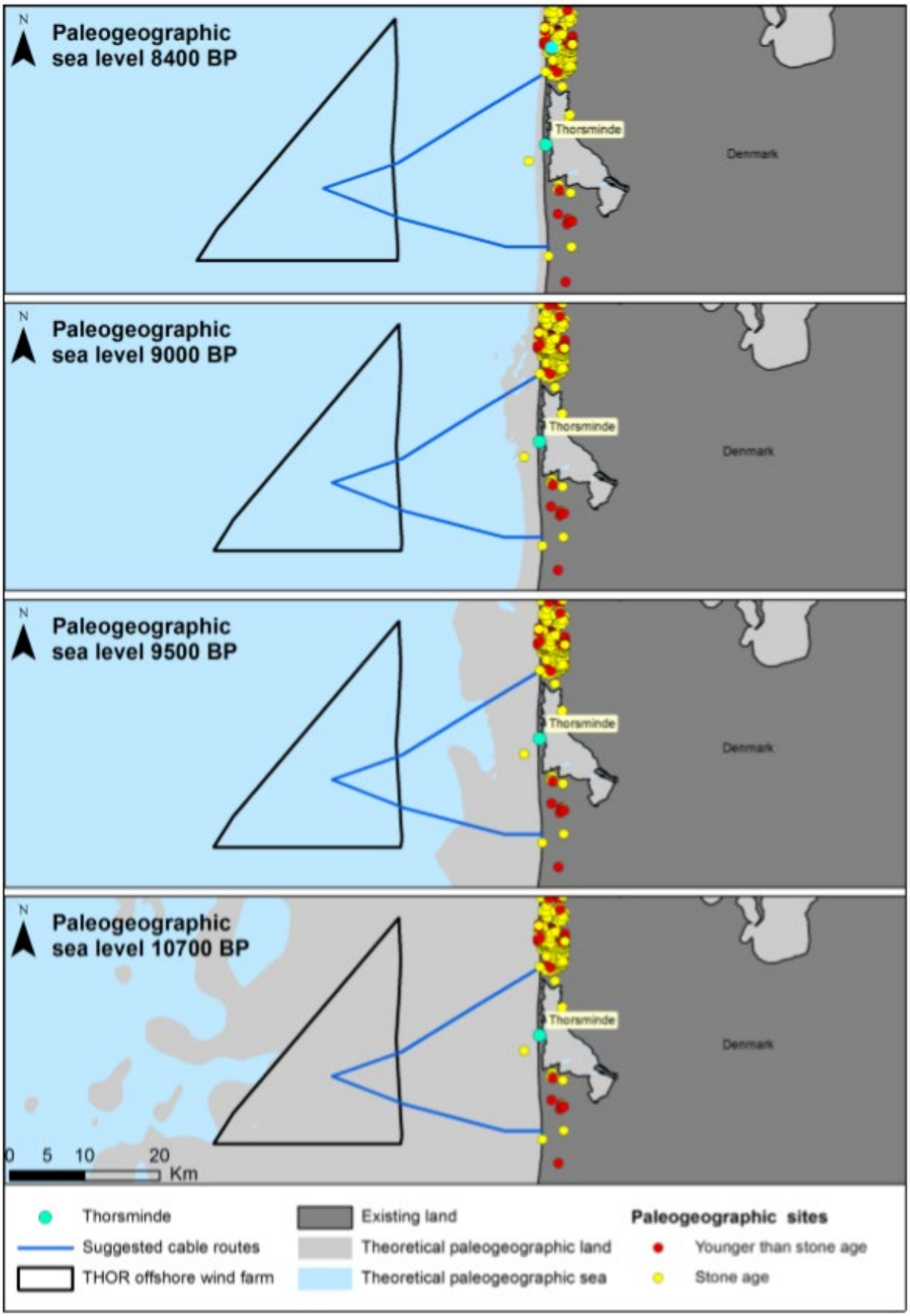

Figure 9. Theoretical reconstruction of the affected area on the basis of selected sea levels between 10,700 and 8400 BP. After (Marstal & Petersen 2019. p. 14).

Rambøll's mapping of the coastline at 4 time intervals (10,700BP, 9500BP, 9000BP and 8500 BP) in Figure 9 is designed on the basis of the depths indicated in the coastal displacement curve from the Great Belt and modern bathymetry in the project area. As is also pointed out in Rambøll's report, the modern depth ratios do not constitute a perfect analogy to the topographical conditions of the time. This means that the model is most representative in areas where there has been neither erosion nor accumulation. The area affected by the construction work is relatively flat and has an altitude difference of approx. 10 m (-34 to -24 m). It must be assumed that the level differences were greater in the Stone Age, since sediments from the highest points will have been deposited in lowlands over time.

The lowest / deepest areas on the bathymetric maps are thus interesting because they are likely to represent ancient lake basins. The material deposited over the lake basins / peat layers of the time is distinguished by both protecting the deposits and making them difficult to explore. Higher altitude areas on the slopes, on the other hand, are more exposed to erosion, but are typically also more suitable for diving operations. Therefore, a seismic survey and interpretation of the glacial surface may help to reconstruct topographic elements such as lakes and creeks, which we know from inland settlements were crucial to the location of settlements during the Maglemose period.

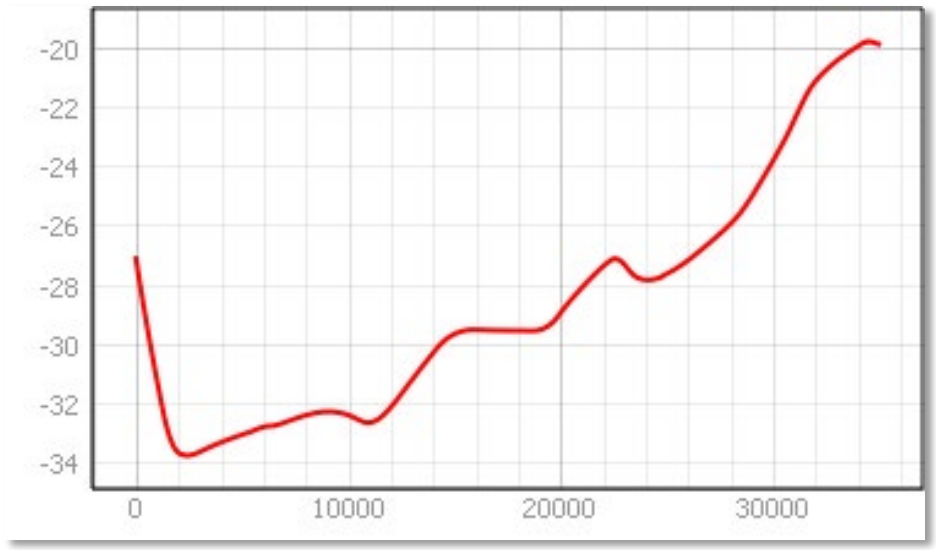

Figure 10. Profile of depth conditions in the southernmost part of the area in the line between the proposed boreholes 1 and 8. See Figure 11 for the location of the eight boreholes within the 30 km long east-west- stretch.

Core samples

In the absence of specific knowledge of coastal transgressions and topographical conditions (locations of ancient lakes, rivers, etc.) in the area, the museums are asking Energinet to collect a number of core samples from the area as well as getting dates of relevant samples prior to the

geo-archaeological assessment. On August 23, 2019, there was an agreement between Energinet and MAJ that eight extra boreholes will be made in the wind farm area, in addition to the ones Energinet already planned in the cable corridors. Analysis of relevant samples will help to resolve a number of issues such as:

- Develop an accurate coast-displacement curve that is based on local data.
- Determine which environments characterized the different parts of the area throughout the Stone Age.
- Determine where potential settlements have been preserved or eroded.
- In addition, core data will be used to verify the seismic data and the geophysical models.

Figure 11. Map showing the two routes (yellow) where the borehole locations will be placed. Scale 1: 300 000

The exact positions of the boreholes will be determined in the future, but basically they will be placed in two rows along the two different cable corridors, one in the north and one in the south (Figure 10). In doing so, the samples will provide new data from different depths, which is required for the preparation of the coastal displacement curve. In connection with the *Baltic Pipe* investigation (a gas pipeline planned to run from Poland to Norway), 26 "vibrocores" were made in a continuous 105 km stretch of up until c. 3 km from the coast in the North sea (Astrup, Verner Karlsen, & Skriver, 2018). This made it possible to create a coherent profile which, through study of the samples, resulted in the establishment of a new coastal displacement curve. It is desirable to place the bores on a line from deep to shallow water to determine the sea level rise and its horizontal displacement over a long period of time. In this way, samples of, for example, marine shells, which do not normally provide a precise fixed point for water levels, can be used to verify the coastline models that will be produced for the geoarchaeological analysis.

In the subsequent selection of samples, emphasis will be placed on analyzing samples which are most suitable for determining the sea level (see attached document with guidelines made for Energinet in connection with the *Baltic Pipe* study). In addition, emphasis will be placed on analysis of samples that contribute information on the environment, vegetation, salinity etc. of the time.

Seismic studies

As previously mentioned, the seabed within the proposed area is a result of erosion and sediment transport that has occurred since the area was transgressed. The original streams, fjords, lake basins and coastal slopes have been smoothed to a certain degree so that they can no longer be identified on the basis of present depth / bathymetry. Therefore, there is a need to make use of sub-bottom seismology to identify the buried landscapes. This is necessary to reconstruct the landscape of the Mesolithic and to determine where settlements were eroded away and/or buried under younger sediments. Therefore, for the geo-archaeological analysis, seismic data from the area is needed and will be used to identify the buried valleys, islands and lakes.

To carry out this work, we ask Energinet to provide the following data:

1. Raster Model I: The top levels of the glacial deposits.
2. Raster Model II: The thickness of the Holocene sediments.
3. Side scan sonar - will preferably be used to identify, for example, potential aircraft and shipwrecks, but will also be examined in relation to finding tree trunks and stumps from the Stone Age.

The two raster models will be used in the geoarchaeological analysis to trace the coastline in prehistoric times as well as to identify areas with the greatest archaeological potential. By using

Raster Model I, the coastline of prehistory will be recreated from the glacial surface rather than from today's seabed, which is the result of millennia of sediment transport. Raster Model II will be used to identify sediment thicknesses in different areas. Areas with greater sediment thicknesses often reflect terrain (for example, former streams or lakes) that have been filled with sediments during the subsequent transgressions. From the inland settlements, we know that it is these areas, bordering lakes and streams, that were among the most favorable for Maglemose activities. Therefore, it is estimated that the probability of finding archaeological remains is greater on the edge of these areas than in higher-lying areas far from these wetlands.

Raster Model II will thus be used to derive relevant information such as:

1. In which areas potential archaeological material have been spared erosion
2. Where it may be difficult to reach the strata in follow-up studies
3. Where the strata are located too deep to be affected by the construction work (here, in particular, the cable routing, which only touches the top few meters of the sea floor as opposed to the windmill foundations that go deeper).

In other words, it will be crucial for the geo-archaeological analysis to use the two models to target the archaeological surveys in the areas where the construction work is potentially damaging and exclude areas where it is not practical to do an archaeological survey.

Sediment analyses

The seismic data will, for the first time, show a detailed picture of the landscape in an area from which we have no prior knowledge. Therefore, if the seismic data are available before the boreholes are made there will be the possibility to check whether the locations are optimal and possibly adjust these according to the conditions detected by the seismic studies. Geophysical data can help map the coast, lakes and creeks, all of which are important to our interpretation of the activities that took place in the area during the Mesolithic . The drill samples will contain information about the environment during the Mesolithic and can therefore serve as a supplement to the seismic studies. It is therefore desirable that some of the most interesting core samples undergo scientific analyzes of e.g. pollen, foraminifera, diatoms, macrofossils and 14C dating. This will help to reconstruct the contemporaneous environments and salinities.

Conclusion

The above forms the basis for the museums' recommendations for Energinet to act upon before the construction work is started. The museums have reason to believe that there may be cultural heritage in the form of Stone Age settlements in the proposed area, but at present it is not

possible to point out certain areas as particularly vulnerable. This is due to a lack of data for the area in question.

As can be seen in Figure 9, according to Rambøll's analyses, there was dry land throughout the area approximately 10,700 BP. Circa 7500 BP these areas were flooded and any Stone Age settlements in the area should therefore be at depth ranges corresponding to the early part of Maglemose culture (the Preboreal period c. 11,450-9950 BP and potentially also early Boreal c. 9950-9450 BP). Very few settlements from the Preboreal period are known from the rest of Denmark and it is therefore considered unlikely they will be found in the North Sea by random sampling. From the Boreal period, far more settlements from lakes and wetlands are known, and it is therefore considered more likely that any Stone Age settlements are located in areas with freshwater or coastal deposits.

For the purpose of preparing the geoarchaeological analysis, it has therefore been agreed with Energinet that core samples will be collected and that funds will be allocated for scientific analyses of relevant samples. The actual designation of archaeological areas of interest will be based on the geoarchaeological analysis.

Summary

The archaeological analysis shows that there are a number of shipwreck reports without precise positions in the *Fund og Fortidsminder* database in and around the affected area. There are also some known positions in the area, but where the sinking date is unknown. With this uncertainty in the data, it is difficult to say where the objects are and whether they are old enough to be protected by the Museum Act. Against this background, MAJ Energinet recommends that an archaeological survey of the geophysical material be completed, which according to the construction company will be obtained as part of the planned seabed surveys.

The museums also assume the presence of cultural remains in the form of Stone Age settlements in the proposed area and that it is impossible, based on the current data, to assess and rank whether some areas have greater archaeological potential than others. The actual designation of archaeological areas of interest will therefore be presented based on the geo-archaeological analysis.

For the preparation of the geo-archaeological analysis, MAJ therefore requests that Energinet, in addition to other studies, collect a number of core samples at strategic positions and that funds are allocated for scientific analyses of relevant samples.

References

Amkreutz, L., & Spithoven, M. (2019). Hunting beneath the waves. Bone and antler points from North Sea Doggerland off the Dutch coast. I (. Groß, D., Lübke, H., Meadows, J. and Jantzen, D. , *Working at the sharp end: from bone and antler to Early Mesolithic life in Northern Europe.Untersuchen und Materialen zur Steinzeit in Schleswig-Holstein und im Ostseeraum* (s. 1-21). Kiel/Hamburg.

Astrup, P. M. (2018). *Sea-level change in Mesolithic southern Scandinavia. Long- and short-term effects on society and the environment.* Jutland Archaeological Society Publications Vol 106.

Astrup, P. M., Verner Karlsen, T., & Skriver, C. (2018). *Baltic Pipe - Nordic Tie-in, Nordsøen. Arkæologisk og geoarkæologisk analyse.* Thorsminde: Strandingsmuseet St George.

Hohlenberg, J. (1883). *Strandinger for maaneder og dage [på Danmarks kyster i tidsrummet] Oktober 1860 - 4 August 1882.* Hentet fra Det Kongelige Bibliotek: http://www.kb.dk/maps/kortsa/2012/jul/kortatlas/object67925/da/

Hohlenberg, J. (1885). *Chart showing the strandings on the coasts of Denmark and on the Swedish coast between Marstrand and Carlskrona during the period from 1st January 1858 to 31st December 1885.* Obtained from *Det Kongelige Bibliotek*: http://www.kb.dk/maps/kortsa/2012/jul/kortatlas/object67921/da/

Laursen, A. (1973). *Danske dampskibe.* København: Høst og Søns Forlag.

Lisby Kjær, A., Olsen, S., & Villadsen, J. (2012). *Historien om Fjaltring og Trans.* Norderstedt, Tyskland: Fjaltring Trans Lokalarkiv/Books on demand.

Marstal, S. B., & Petersen, A. R. (2019). *800MW Thor OWF. Geological desk study – Geoarchaeology.* Rambøll.

Mertz, E. (1924). *Oversigt over De sen- og postglaciale Niveauforandringer i Danmark, Danmarks Geologiske Undersøgelse Nr. 41.* København.

Normann, G. (2000). *Skibsvrag ved Vestkysten.* Ringkøbing: Bollerup Boghandels Forlag.

Sørensen, S. (1996). *Kongemosekulturen i Sydskandinavien. Egnsmuseet Færgegården.* Engsmuseet Færgegården.

Tarbensen Christensen, C. (1995). *De nærer sig af vrag - : blandt strandfogeder, bjergere og redningsmænd imellem Nymindegab og Thorsminde.* Skjern: Gullanders Bogtrykkeri a-s.

Verner Karlsen, T., Moe Astrup, P., & Skriver, C. (2019). *Vesterhav Sys, Nordsøen. Beretning for forundersøgelse af havmøllepark og to ilandføringskorridorer.* Thorsminde: Strandingsmuseet St George.

Other sources

Fund og fortidsminder: www.kulturarv.dk/fundogfortidsminder/

Vragguiden: www.vragguiden.dk

Danish Maritime Authority's wreck database

Appendix

Appendix 1. Table showing objects in *Fund og Fortidsminder* within 500 m of the wind farm area and cable routes

Appendix 2. Table showing objects in Danish Maritime Authority's and *Vragguidens* wreck databases, within 500 m from the wind farm area and cable routes

Appendix 3. Guidelines for data acquisition of Sea-Level Index Points