Netherlands Enterprise Agency

Site Studies Wind Farm Zone Hollandse Kust (zuid)

Unexploded Ordnance (UXO) desk study part II Revised naval mine field information and UXO survey properties

>> *Sustainable. Agricultural. Innovative. International.*

Author: REASeuro

REASeuro

Offshore wind energy Netherlands

Site Data Hollandse Kust (Zuid) wind farm zone

Unexploded Ordnance (UXO) – Revised naval mine field information and UXO survey properties

HKZ_20170322_REASeuro_UXO-desk study_EvdBerg_V2_F
Riel, March 29, 2017

Riel Explosive Advice & Services Europe B.V. • Alphenseweg 4a 5133 NE Riel The Netherlands • PO Box 21
5133 ZG Riel The Netherlands • T +31 (0)13 518 60 76 • F +31 (0)13 518 60 77 • www.reaseuro.com
info@reaseuro.com • KvK 180.501.31 • IBAN NL09ABNA0475239288 • BIC ABNANL2A • BTW NL81.50.08.387.B01

Site data Hollandse Kust (Zuid) wind farm zone
Unexploded Ordnance (UXO) – Revised naval mine field information and UXO survey properties

Client	:	The Netherlands Enterprise Agency
Label	:	HKZ_20170322_REASeuro_UXO-desk study_EvdBerg_V2_F
Place and date	:	Riel, March 29, 2017
Authors	:	Mr. L.J.J. Arlar MA, Historian Mr. E. van den Berg BSc, Senior Consultant
Checked by	:	Mr. J. Kapel, Senior UXO-Expert
Approved by	:	Mrs. N. van Domburg, MA, Head of Advice department

REASeuro

Mrs. N. van Domburg
Head of Advice department

The Netherlands Enterprise Agency

Mr. F. van Erp, MSc
Project manager

Table of contents Page

ACRONYMS AND ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
BaMa	Bundesarchiv-Militärarchiv in Freiburg, Germany
D	Diameter
DGPS	Differential Global Positioning Systems
DTS	Desk Top Study
EEZ	Dutch Exclusive Economic Zone
EM	Electro Magnetic
EMC	Einheitsmine C (German moored contact mine)
EO	Explosive Ordnance
EOD	Explosive Ordnance Disposal
ETRS89	European Terrestrial Reference System 1989
FLAK	Flugabwehrkanone (anti-aircraft guns)
GIS	Geographical Information System
GP	General Purpose
HE	High Explosive
kg	Kilogram
km	Kilometre
kts	Knots (1 kts = 1.852 km/h)
KMA	Küstenmine-A (German anti-invasion mine)
L	Length
lb	Pound (weight)
LMB	Luftmine B (German non-ferrous ground mine)
m	Metre
MAG	Magnetometer
MBD	Maximum burial depth
MBES	Multi Beam Echo Sounder
MCM	Mine Countermeasures
mm	Millimetre
MSL	Mean sea level
MW	Mega Watt
NAP	Normaal Amsterdams Peil (normal Amsterdam level)
NEQ	Net Explosive Quantity
NM	Nautical Mile
NMZ	Nautical Mile Zone
ROV	Remotely Operated Vehicle
SAP	Semi Armour Piercing
SBP	Sub bottom Profiler
SSS	Side Scan Sonar
TNA	The National Archives in London, Great-Britain.
TNT	Trinitrotoluene
UKHO	United Kingdom Hydrographic Office in Taunton, Great-Britain.
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
WSCS-OCE	Werkveld Specifiek Certificatie Schema – Opsporen Conventionele Explosieven
WWI	World War One
WWII	World War Two

1 INTRODUCTION

The Ministry of Economic Affairs has requested The Netherlands Enterprise Agency (RVO.nl) to prepare and collect all site data required for the development of offshore wind farms in Hollandse Kust (Zuid) offshore wind farm zone. In this context The Netherlands Enterprise Agency has commissioned an unexploded ordnance (UXO) desk study. REASeuro has conducted this desk top study in 2016.[1]

After issuing of the report new historical information has become available after a recent visit to the Bundesarchiv-Militärarchiv (BaMa) in Freiburg, Germany, enabling further refinement of the previously conducted historical research. Besides documentation from the BaMa, historical naval charts were obtained from the United Kingdom Hydrographic Office (UKHO) in Taunton, Great-Britain, and from the Marinemuseum in Den Helder, the Netherlands. In addition to this, REASeuro recently conducted research in The National Archives (TNA) in London, Great-Britain. Besides this information obtained from primary sources, several secondary sources have been consulted to complement the primary historical sources.

The newly acquired documents offer more information about the locations of World War II naval minefields and the types of mines that have been laid. In this additional research, the relevant naval minefields are thoroughly specified. The potential presence of non-ferrous UXO (German LMB mines) is determined. Especially the possible presence of non-ferrous ground mines (LMB) might necessitate a combination of geophysical survey methodologies to mitigate UXO related risks to a level that is considered ALARP. In order to achieve this, a dedicated UXO geophysical survey must be carried out to identify objects on the seabed that could potentially be UXO. This report briefly considers the types of technology that may be used in such a survey. In order to set the scope of work for the UXO survey, appropriate threshold level(s) for modelling of anomalies detected by a UXO survey in Hollandse Kust (Zuid) wind farm zone are determined.

1.1 HOLLANDSE KUST (ZUID) WIND FARM ZONE AREA OF INVESTIGATION

The Hollandse Kust (Zuid) Wind Farm Zone, shown in Figure 1, is a designated wind farm zone located off the province of Zuid-Holland (South Holland). It is enclosed by the main shipping routes of IJmuiden and Rotterdam and the coastline. In Figure 1 the designated wind farm zone is shown.

1 REASeuro, Site data Hollandse Kust (Zuid) wind farm zone, Unexploded Ordnance (UXO) – Desk Study (February 12, 2016).

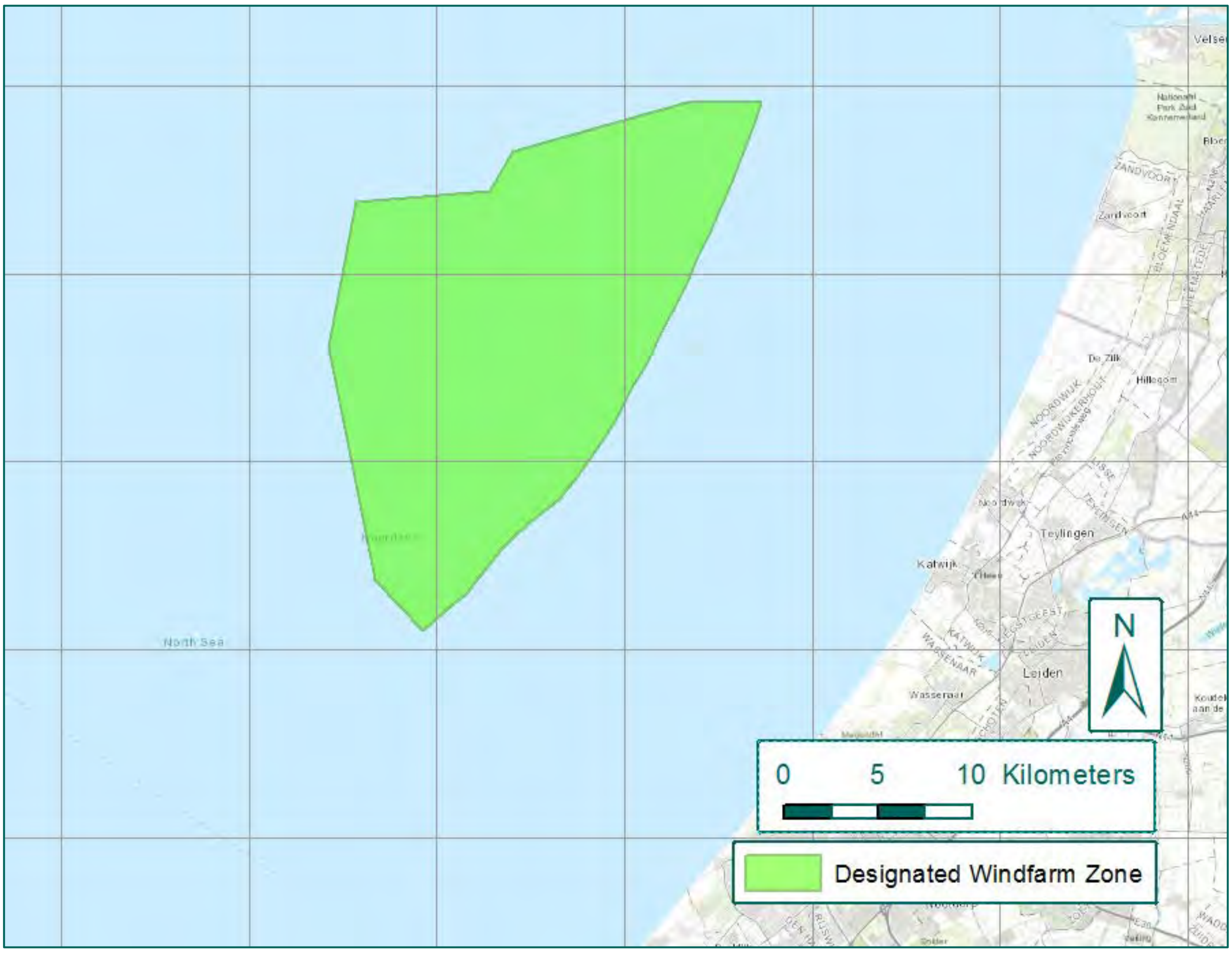


Figure 1: The Hollandse Kust (Zuid) wind farm zone.

The wind farm zone of approximately 356 km^2 will be sub-divided into four wind farm sites. In total, 1,400 MW offshore wind is planned in the zone, roughly 350 MW per site. The investigation area for this study also includes an additional area of ten kilometres around specified Hollandse Kust (Zuid) wind farm zone.

1.2 RESEARCH OBJECTIVES

The objectives of this additional historical research is to advise on:

1. Types of naval mines that might be present in the Hollandse Kust (Zuid) wind farm zone, according to the newly acquired historical sources.
2. Geophysical survey methodologies most suitable for detecting the suspected types of UXO[2].
3. Threshold levels to be applied for interpretation of the geophysical survey data from the dedicated UXO geophysical survey.

[2] This objective regards the geophysical survey methodologies for the dedicated UXO survey campaign to be performed prior to wind farm installation operations, not the geophysical survey commissioned by RVO.nl (in the framework of the site package).

1.3 STRUCTURE OF THE REPORT AND TOPICS ADDRESSED IN EACH CHAPTER

The structure and content of this report is as follows:

- Chapter 2 holds the additional historical research on naval mines to be expected in the Hollandse Kust (Zuid) wind farm zone.
- Chapter 3 contains a brief description of suitable UXO geophysical survey techniques that could be applied in the Hollandse Kust (Zuid) wind farm zone.
- In chapter 4 the recommended provisional thresholds needed to mitigate the risk to a level that is considered ALARP, are set.
- Chapter 5 describes our conclusion and advice.
- In chapter 6 the relevant consulted sources are analysed.

2 ANALYSIS OF ADDITIONAL HISTORICAL SOURCES

The objective of this additional research is to determine what types of mines may be present in the area of investigation. In particular the possible presence of non-ferrous (LMB) mines is of importance because LMB mines will be normative for the geophysical UXO survey required. In order to reach this objective, a plethora of additional historical sources has been consulted. The relevant additional sources are shown in Chapter 6. The historical sources yielded no information on minelaying in the area of investigation in World War I. It did yield information on several mining operations during World War II by both belligerents. In this chapter, the mining operations are analysed. World War I is analysed first, followed by analysis of allied and German minelaying in World War II. Minesweeping in the post-war period is covered in paragraph 2.3. The conclusion completes this chapter.

2.1 WORLD WAR I: GERMAN LAID MINEFIELDS OF THE DUTCH COAST

During World War I, the German fleet used naval mines to hinder Allied shipping close to the Dutch coast. In the area of investigation two German minefields were present[3]). Research in the Bundesarchiv department Militärarchiv in Freiburg yielded fragmented information regarding German World War I minefields. However information regarding the minefields in the investigation area was not found.

The World War I minefields only contained moored mines. This type of mine has been encountered several times by fisherman since 2005 (see Annex, paragraph 6.5). Since the mine types are not specified in the reports of these contemporary encounters, it is possible that these encounters concerned World War I mines. This, however, cannot be confirmed with historical sources. The presence of World War I minefields, however, is an indication that World War I mines may still be present in the area of investigation.

2.2 WORLD WAR II: BRITISH AND GERMAN MINELAYING

Development of naval mines continued during the interbellum, leading to the development of the ground mine, with new mechanisms to detonate mines (acoustic, magnetic) and to lay them (aircraft, submarines). The North Sea was a heavily mined area, with British as well as German mining activities in the area. The British and German minefields are investigated in the following chapters.

2.2.1 British minelaying

British forces laid mines near the Hollandse Kust (Zuid) wind farm zone with surface vessels (motor torpedo boats, motor gun boats and destroyers) and aircraft.

In 1940 the British air forces Bomber Command and Coastal Command started several minelaying campaigns (source: Air 15/772). The mines were laid in so called ‘Gardening’ operations. The naval minefields were called ‘gardens’, with codenames of vegetables, flowers, trees or fish. The aircraft mining area closest to the investigation area laid off IJmuiden and was codenamed “Whelks”.

[3] Source: Offshore wind energy Netherlands, Site Data Hollandse Kust (Zuid) wind farm zone, Unexploded Ordnance (UXO) - Desk Study, reference HKZ_20160212_REASeuro_UXO-desk study_EvdBerg_V2_F, date February 12, 2016, See paragraph 2.2.1 and Figure 5.

The closest British minefield laid by surface vessels was a large offensive minefield situated at the eastern edge of the area of investigation, as shown on maps from the National Archives.[4]

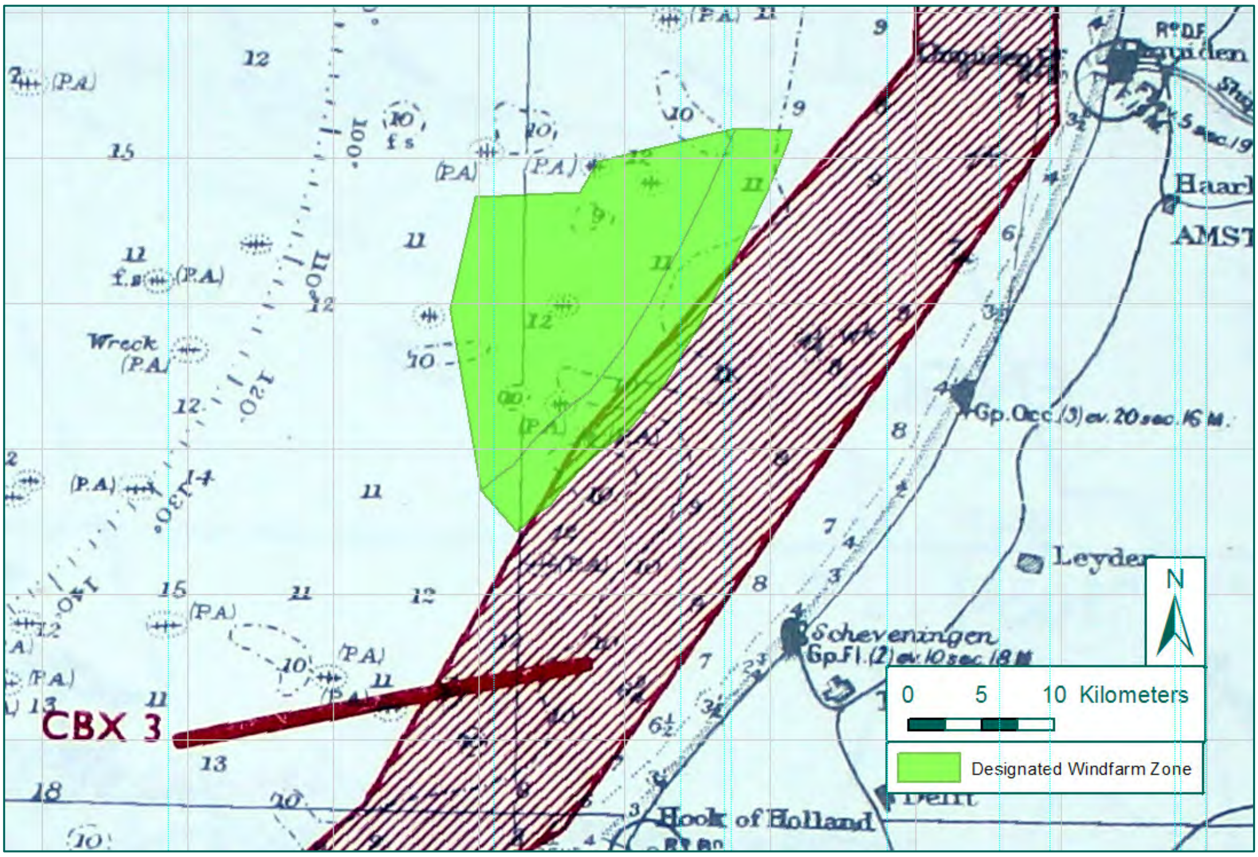


Figure 2: Minelaying by surface craft off the French, Belgian and Dutch coast between Cap Griz Nez and the Texel May 1940 to May 1944 (Source: TNA, ADM 243/560).

The mining operations in the investigation area were code named "QU" and were carried out by the 51st ML Flottila and the 21st MTB Flotilla. The German shipping lanes between Texel and Hoek van Holland were mined in dozens of Coastal Forces craft mining operations. The first lay in the QU series was conducted November 5, 1942. A total of 18 Mk I-IV mines were laid off IJmuiden. The last mining operation by surface vessels was QU27, conducted on April 23, 1943. In this operation 52 mines of various types (A Mk I-IV, A Mk VI, Mk XIX, Mk XII, Mk XVII, M Mk I, M Mk III) were laid off IJmuiden. A total of approximately 1,000 mines were laid during the QU operations.

In the spring of 1944 nights became too short for Coastal Forces operations. The British air forces Bomber Command and Coastal Command resumed the minelaying campaigns in "Whelks". Aircraft laid 136 magnetic ground mines off IJmuiden.[5] On 26th May 1944 the IJmuiden area (Whelks) was passed to Bomber Command for aerial mining. Documents from the National Archives (see annex, paragraph 6.3) show no indications of gardening fields overlapping Hollandse Kust (Zuid) wind farm zone. The closest gardening field was Whelks, at a distance of approximately 10 kilometres from the Hollandse Kust (Zuid) wind farm zone.

[4] The National Archives (Londen), record ADM 243/560.
[5] These figures are according to documents from the German Bundesarchiv (see annex, paragraph 6.1).

Figure 3: Gardening fields near the Hollandse Kust (Zuid) wind farm zone (source: TNA, ADM 234/561).

2.2.2 German minelaying

German minelaying near the Hollandse Kust (Zuid) wind farm zone started in May 1940. The German air force deployed magnetic mines (LMA mines) in front of the harbour of IJmuiden. British minesweepers tried to clear the shipping lanes, but soon afterwards new mines were laid (source: *Oorlogsstorm over zee en havens, IJmuiden 1939-1946*, Burg, G. van den, March 1995).

From September to November 1944 minefields E38, C45, C46 and C47 (allied designation) were laid in deeper waters. The minefield C45 intersects with the eastern part of the windfarm zone. Minefield C46 borders the wind farm zone. In field C45 a total of 72 LMB ground mines were laid in two separate lines with a spacing of 150 meters. In field C46 a total of 124 LMB ground mines were laid in two separate lines with a spacing of 150 meters.

In minefield C47 a total of 160 moored EMC mines and 40 static cutter sweeping obstructers were laid in three separate lines with a spacing of 200 m. With a chain four mines were attached to one obstructer. The sweeping obstructers were equipped with cutters to disable minesweeping gear. In minefield E38 a total of 90 LMB and 90 EMC were laid in two separate lines with a spacing of 150 meters.

A minefield chart from the Bundesarchiv[6] is shown in Figure 4. The minefields mentioned above are shown in this chart.

[6] Bundesarchiv-Militärarchiv (Freiburg), record ZA5/50.

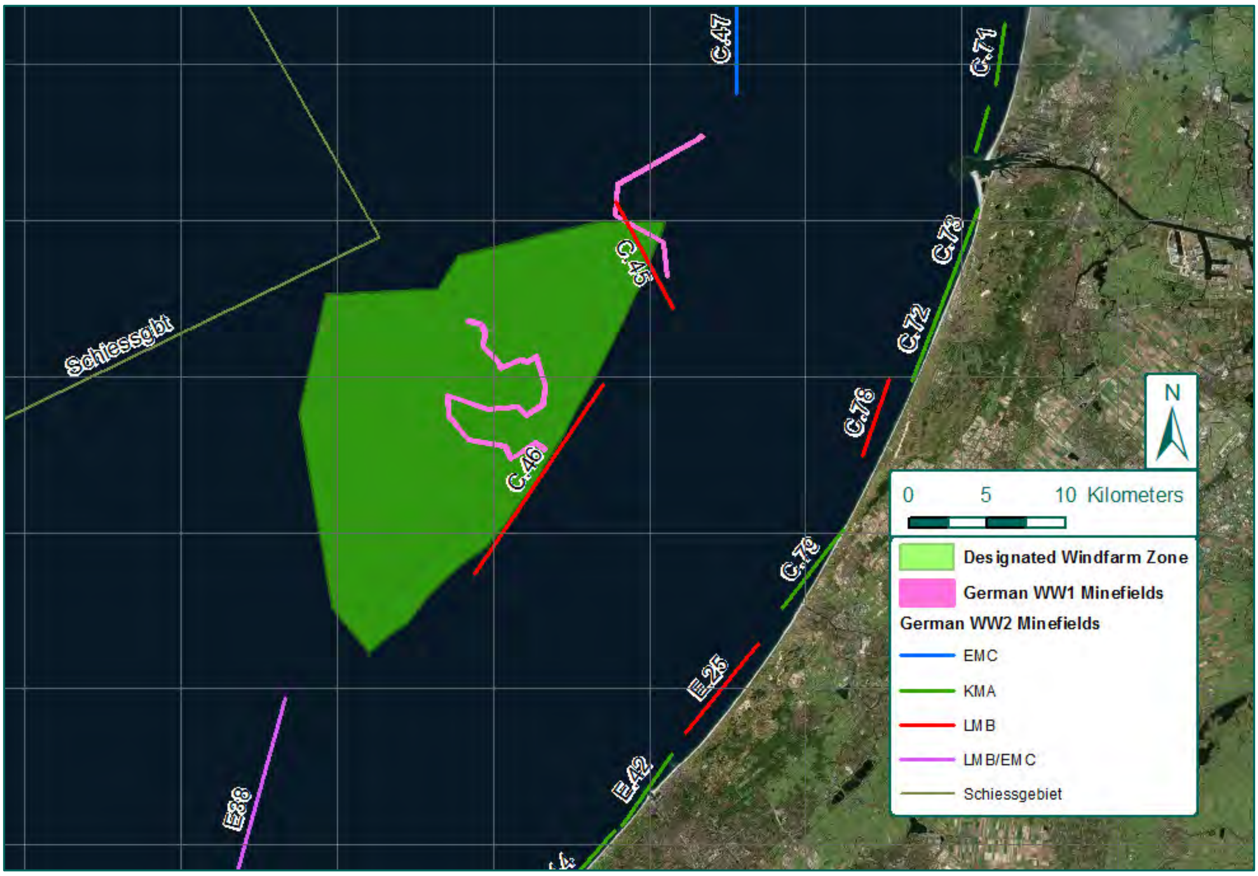


Figure 4: German minefields in and around the Hollandse Kust (Zuid) wind farm zone (Source: Bundesarchiv-Militärarchiv, ZA5/50)

The chart in Figure 8 does not show minefields laid by German aircraft, since these operations remain obscure until today. The chart also shows a “Schiessgebiet”. This is an area designated for military exercises.

Primary documents from the German Bundesarchiv and the British National Archives indicate the presence of one German minefield in the area of investigation, one bordering the area of investigation and another two in the vicinity of the area of investigation. Records on UXO-encounters by the Royal Netherlands Navy from 2005 onwards, show that fishermen encountered several naval mines in the area of investigation. A German LMB mine was encountered near the area of investigation, just south of minefield C 46. This confirms the suspicion that German moored and ground mines, including the then-advanced LMB mines, may still be present in the area of investigation. Besides, non-explosive sweeping obstructers may be present.

2.3 POST-WAR MINE CLEARANCE

Mines continued to pose a danger to shipping after World War II. In order to combat this threat, a large scale minesweeping campaign was set up. The Hollandse Kust (Zuid) wind farm zone was situated in the Dutch minesweeping zone. Charts of the Marinemuseum show that a large portion of the Hollandse Kust (Zuid) wind farm zone was a designated danger area.

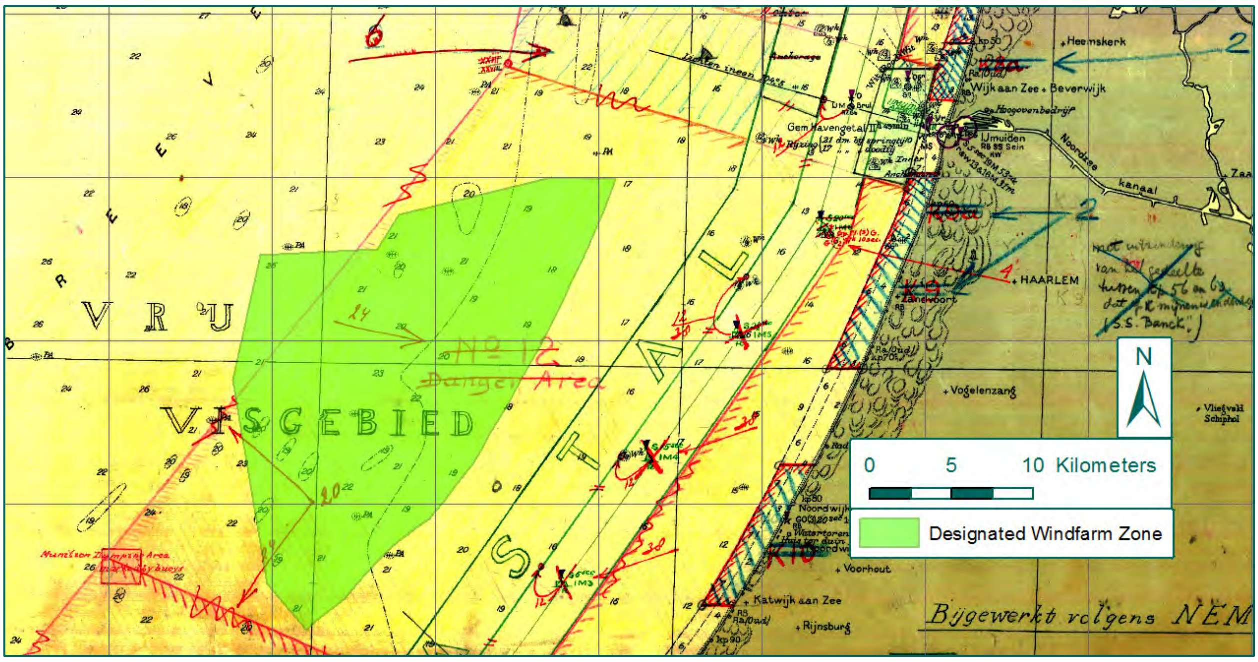


Figure 5: Extract of minesweeping map NEMEDRI 227 (source: Marinemuseum; see annex, paragraph 6.4).

Minesweeping was conducted with a variety of methods. Moored mines were usually swept with Oropesa sweeping gear[7].

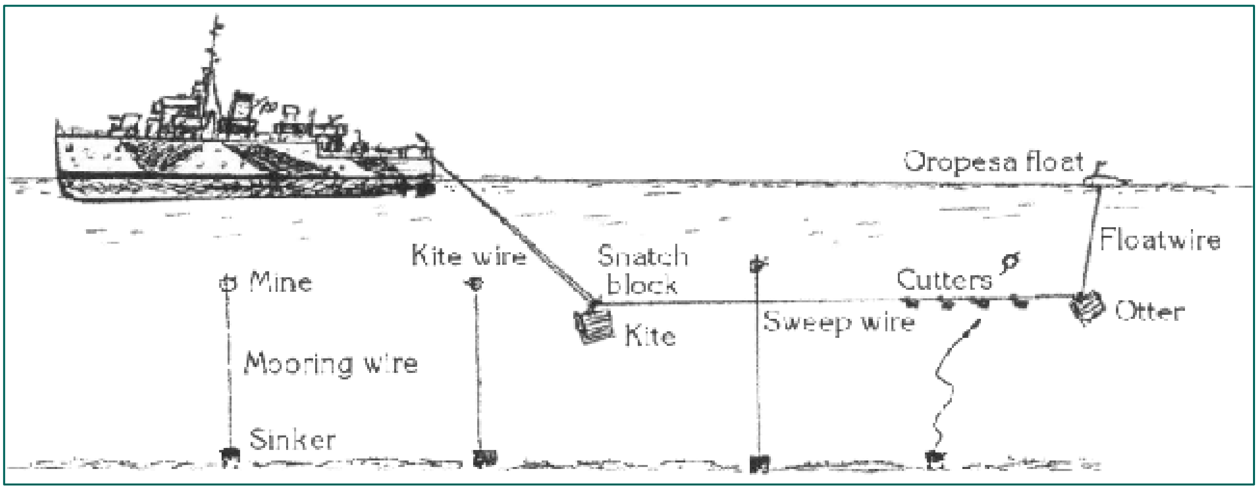


Figure 6: Oropesa sweeping (source: 'The 'Art' of Minesweeping' (27 May 2013) http://www.minesweepers.org.uk/sweeping.htm (consulted 6 December 2016).

The moorings of the mines were cut with cutters dragged on a wire behind a ship. Cutting the mooring caused the mines to float to the surface, where the mines could easily be shot with cannon or rifle fire. Shooting the mines caused them to sink or to detonate. Ground mines were swept with acoustic hammer boxes, triggering the acoustic mines, or by magnetic sweeping gear to trigger magnetic mines.

The efficiency of minesweeping was poor. The sinking of a Dutch lugger in October 1945 and the damage the Norwegian freighter "Betty" suffered on March 12, 1946 in a swept channel illustrates this observation.

7 So named after the World War I trawler in which the technique was first developed. Till then all sweeping was done using two ships joined by a single wire.

The fact the fishermen nowadays often find naval mines from both world wars entangled in their nets is yet another indication of the presence of naval mines in the area of investigation.

2.4 CONCLUSION: EXPECTED TYPES OF MINES IN THE HOLLANDSE KUST (ZUID) WIND FARM ZONE

The Unexploded Ordnance (UXO) – Desk Study[8] already showed that mining operations took place in and near the Hollandse Kust (Zuid) wind farm zone in World War I and in World War II. The additional research confirmed this conclusion and yielded detailed information regarding the exact locations, specific types and numbers of mines deployed. An overview of all known minefields in the area of investigation are shown in Figure 7.

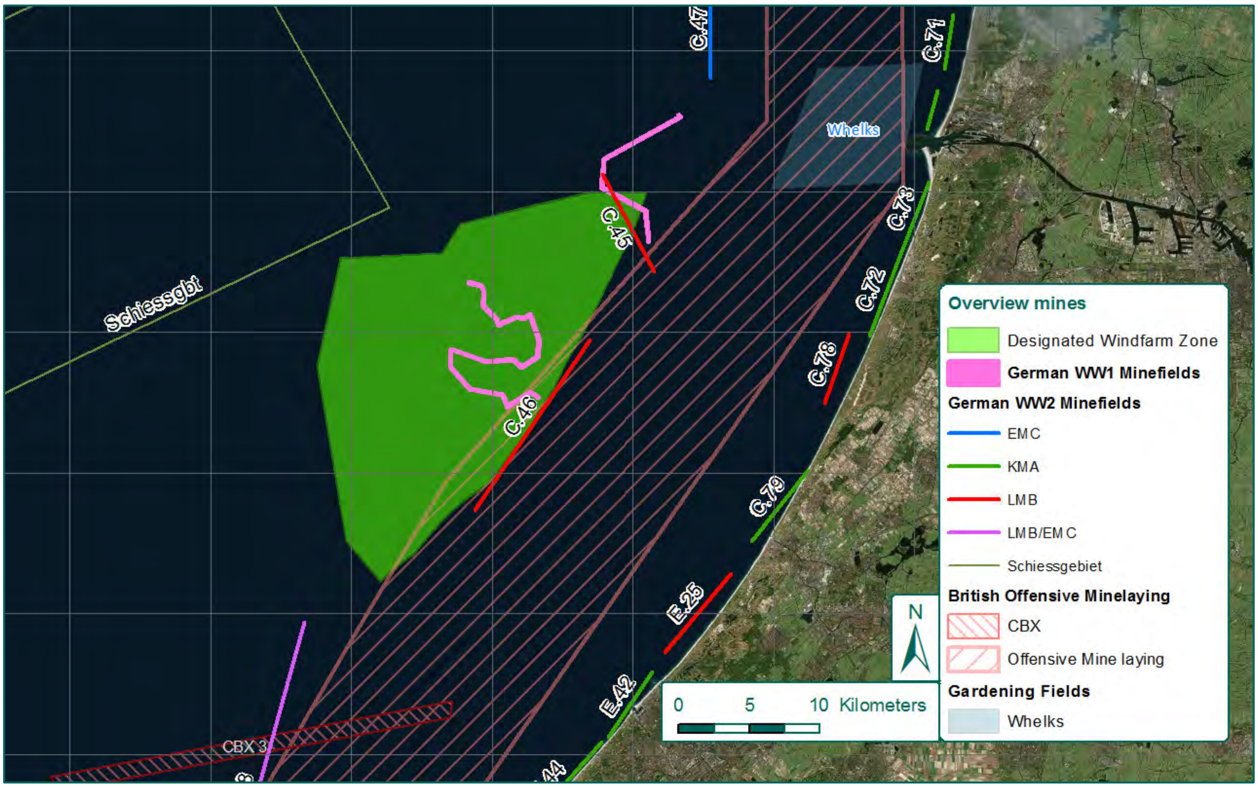


Figure 7: Overall view of World War I and World War II minefields.

The following table shows the types of mines that may be present in the Hollandse Kust (Zuid) wind farm zone, according to the consulted historical sources.

Naval mines and sweeping obstructers in the Hollandse Kust (Zuid) wind farm zone
World War I
German moored mines. • Within the Hollandse Kust (Zuid) wind farm zone two German minefields were present (source: ncp windfarm south.jpg, The Netherlands Enterprise Agency). The conducted additional research did not yield additional information on the exact types of mines deployed. The most likely type of mine deployed is the standard German contact mine (E-mine).

[8] Site data Hollandse Kust (Zuid) wind farm zone, Unexploded Ordnance (UXO) – Desk Study

Naval mines and sweeping obstructers in the Hollandse Kust (Zuid) wind farm zone
World War II
German EMC moored mines German static cutter sweeping obstructers. • In 1944, minefields C47 and E38 were laid in the vicinity of the Hollandse Kust (Zuid) wind farm zone. In minefield C47 a total of 160 EMC moored contact mines were laid, along with 40 static cutter sweeping obstructers. In minefield (E38) 90 EMC mines were laid (sources: BaMa ZA 5/44, ZA 5/50).
German LMB ground mines. • In 1944, minefield C45 was laid in what is now the Hollandse Kust (Zuid) wind farm zone. This minefields contained a total of 72 LMB mines. Minefield C46 was laid at the border of the Hollandse Kust (Zuid) wind farm zone. This minefields contained a total of 124 LMB mines. In the vicinity of the Hollandse Kust (Zuid) wind farm zone one other minefield (E38) containing a total of 90 LMB mines was present (sources: BaMa ZA 5/44, ZA 5/50).
British Mark A I-IV, A VI, M Mk I and M Mk III ground mines. • Extensive mining operations code named "QU" were carried out by the 51st ML Flottila and the 21st MTB Flotilla. A total of approximately 1,000 mines were laid during the QU operations, mainly consisting of ground mines (ADM 234/560, ADM 234/561). Additionally a total of 136 magnetic ground mines were deployed in gardening zone "Whelks" (Air 14/1557, Air 14/1952, Air 14/2064, Air 15/267, Air 15, 772, BaMa ZA 5/27) [9].
British Mark XIX contact mines. • During operation QU8 on April 11, 1943 a total of 24 Mark XIX contact mines were laid off Scheveningen (ADM 234/560, ADM 234/561)[8].
British Mark XVII moored mines. • Extensive mining operations code named "QU" were carried out by the 51st ML Flottila and the 21st MTB Flotilla. A total of approximately 1,000 mines were laid during the QU operations, partly consisting of moored mines (ADM 234/560, ADM 234/561)[8].

Table 1: Expected types of naval mines (for specifications of the mines, see paragraph 4.1, Table 3).

It must be taken into account that this table is based on the minefields actually present in the area of investigation. Because of migration of UXO by fishing activities, dredging or other means it may be possible that mines or other UXO have migrated into the Hollandse Kust (Zuid) wind farm zone. However, based on historical sources, the types of mines mentioned in Table 1 are considered the most plausible types of mines to be present based on this additional historical research.

[9] The relevant documents acquired from TNA do not provide exact coordinates of the mining operations. All mines were laid in the designated mining area QU. This area intersects with the Hollandse Kust (Zuid) wind farm zone. Therefore it is not possible to distinguish whether the mines were laid "inside" the Hollandse Kust (Zuid) wind farm zone or "nearby.

3 GEOPHYSICAL SURVEY METHODOLOGIES

The conducted historical research and this additional historical research has shown that several types of naval mines could be present within the entire Hollandse Kust (Zuid) wind farm zone, including non-ferrous mines. Due to the types and sizes of UXO likely to be present there is no "silver bullet solution" for the UXO geophysical survey. Especially the possible presence of non-ferrous ground mines (LMB) might necessitate a combination of geophysical survey methodologies to mitigate UXO related risks to a level that is considered ALARP.

In order to reduce the risk to ALARP, a dedicated UXO geophysical survey must be carried out to identify objects on the seabed that could potentially be UXO. This chapter briefly considers the types of technology that may be used in such a survey and the key issues that should be considered during the planning phase. Following the survey, data interpretation, contact avoidance and contact investigation/disposal (where avoidance is not feasible) should be the sequential phases of UXO mitigation prior to wind farm development.

Geophysical techniques that might be considered for the Hollandse Kust (Zuid) wind farm zone are as follows:

- Magnetometry (MAG);
- Electro Magnetic (EM);
- Side scan sonar (SSS);
- Multibeam echo sounding (MBES);
- Seismic sub bottom profiling (SBP).

There are a number of other technologies available to profile the seabed but are yet considered to be either unproven in the commercial sector or employed by the military and cost-prohibitive.

RVO.nl has already performed a geophysical investigation, in which some of the techniques mentioned were applied. This investigation however was not intended as a dedicated UXO survey. A dedicated UXO survey is recommended to be executed. The available geophysical data can be used to design the dedicated UXO survey campaign.

In general, due to the possibility of UXO migration, the time periods lapsed from completion of the geophysical survey, UXO-anomaly investigation, UXO disposal phase and wind farm development operations, must be kept to a practical minimum. This is to ensure that UXO migration cannot nullify the validation period of the final ALARP clearance certification.

The maximum permissible safe time interval between the conclusion of a geophysical UXO survey, UXO clearance operations and the commencement of construction works is assessed to be approximately one year.

3.1 MAGNETOMETRY

Magnetometry is generally considered the most reliable and common method of UXO geophysical survey. The method relies upon the UXO causing a spatial variation in the Earth's magnetic field. Since the majority of WWI and WWII munitions were constructed from iron or steel and were relatively large, this technology is seen as a prime methodology for offshore UXO detection. Either gradiometers or total field sensors can be used. The aim is to detect and interpret objects that meet the determined threshold criteria to the required depth below the seabed (burial depth or depth of the intrusive activities). Large ferrous objects (e.g. large calibres air dropped bombs or a ferrous ground mine) can be detected up to 5-8 m distance to the MAG sensors (dependent on the type of sensors).

3.1.1 Gradiometers

Vertical gradiometers (such as fluxgate magnetometers) require careful vertical alignment. To have good gradiometer data, the system must be stable, with all the sensors keeping their position on the respective axis. This is why gradiometers are usually deployed from a stable platform such as a Remotely Operated Vehicle (ROV). The gradiometer determines the gradient of the "Z component" of the Earth's magnetic field. Motion must be compensated for on all axes in order to be able to re-estimate the proper gradient axis, particularly roll and pitch effects. The Z axis still has to be compensated (altimeter pressure sensor for marine applications) to keep a same reference level.
Gradiometers have shown that they can offer a high degree of immunity from diurnal and external influences in the ambient magnetic field; they can enhance near-surface, small or weakly magnetic anomalies; and they can provide obvious improvements in spatial resolution over the total field measurement alone.

3.1.2 Total Field Magnetometers

A total field magnetometer is a single sensor magnetometer that measures the actual magnetic field strength at any given position. The majority of towed marine magnetometers are total field systems, using either proton or caesium vapour detectors. The latter have a higher resolution and sampling rate than proton magnetometers. There are a range of types, configurations and deployment methods of magnetometer systems currently used in the market, which will incorporate different sensitivities, towing characteristics and array mountings. A determination of which configuration is "best for UXO detection" is not easily achieved from a desk based exercise. The choice of the appropriate instruments depends on the individual site conditions and the UXO hazard in question.

3.2 ELECTRO MAGNETIC

Electromagnetic (EM) systems have the ability to detect all types of conductive metallic materials by observing the induced secondary electromagnetic field produced when the target is stimulated by a primary electromagnetic field. On land these systems are used for the detection of non-ferrous ordnance. However in seawater the presence of a highly conductive media surrounding the transmitter and receiver coils can substantially reduce the effectiveness of the system. The limiting factors imposed by saline conditions however can be solved by some technological modifications to the system. With these modifications large UXO items can be detected up to approximately 2-4 m distance from the coils.

3.3 SIDE SCAN SONAR

Side scan sonar, when used for UXO detection, is a proven and capable remote sensing tool. The low grazing angle of the side scan sonar beam over the target and sea floor results in distinctive shadows being cast behind objects proud of the seabed. For relatively flat and featureless terrain, high resolution side scan sonar will allow the discrimination and identification of large UXO items proud of the seabed. However the more irregular the seabed morphology as present in the Hollandse Kust (Zuid) wind farm zone, the more difficult it becomes to identify man-made debris. Partial burial of objects, short wavelength bedform fields (ripples/mega ripples) and heavy concretion on UXO may also make identification difficult. For detection of relatively small UXO, such as bombs and projectiles, where conditions are suitable a high frequency side scan sonar should be employed; typically a dual frequency tow fish with a minimum frequency of 500 KHz (nominal value) for UXO identification. The swath width should be set to ensure always 200% data coverage, with the side scan sonar profiles being run in two mutually perpendicular directions to ensure that any targets are illuminated by the sonar from two directions. This technology will ensure that LMB ground mines (if present) are detected if the seabed conditions are suitable and the objects are on the seabed or partly buried. SSS on its own is not considered to be a reliable system to mitigate the risks of the presence of LMB mines. This system should always be combined with other survey techniques, for example MAG and EM survey.

3.4 MULTIBEAM ECHO SOUNDER (MBES)

MBES, unlike side scan sonars, have their transducers rigidly mounted to the hull of the survey vessel, eliminating almost all chances of casting shadows. Using MBES for object detection requires a focus on the resultant bathymetry rather than shadows. The resolution of a multibeam echo sounding system in shallow coastal waters is such that gridding of data at the 0.2m bin is required for the detection of potential UXO on the seabed.

The results of a high resolution multibeam bathymetric survey can provide very useful information to assist with the interpretation of side scan sonar imagery, in particular providing improved accuracy for coordinates of targets. However, as an acoustic system, the efficacy of MBES for discriminating targets is also degraded in uneven seabed environments.
MBES on its own is not considered to be a reliable system to mitigate the risks of the presence of LMB mines. This system should always be combined with other survey techniques, for example MAG and EM survey.

3.5 SEISMIC (SUB BOTTOM PROFILING)

Seismic sub bottom profiling systems are commonly used for geological profiling but can locate and determine the burial depths of pipelines. Pipeline detection systems rely on wide beam width systems, usually pingers, to produce diagnostic hyperbolic reflections from pipeline structures. High resolution, narrow beam systems such as parametric sources produce very small search footprints on the seabed, which therefore requires greater line density to detect small targets such as UXO. Reflections from features are created by sharp changes in acoustic impedance (product of acoustic velocity and density); metallic objects provide a very strong contrast in acoustic impedance when buried in sediments. Despite this theory, in reality, discrimination between geological and manmade features is difficult when interpreting seismic information. Recent advances in 3D chirp technology have made SBP a much more effective tool in UXO detection. With SBP it is possible to detect LMB mines that are on the seabed or partly buried but SBP on its own is not considered to be a reliable system to mitigate the risks of the presence of LMB mines. This system should always be combined with other survey techniques, for example MAG and EM survey.

3.6 COMPARISON OF SURVEY TECHNIQUES

In Table 2 a comparison of the survey techniques explained in the previous paragraphs is provided. The strengths and limitations of the different techniques are given. In general magnetometry is the most suitable technique for detecting ferrous UXO. In order to make the risk of encountering a non-ferrous LMB mine ALARP it is recommended to preform additional survey operations with a spectrum of survey techniques, for example Electro Magnetic (EM), side scan sonar (SSS) and magnetometer. To enhance the evaluation process it is recommended to correlate the SSS, EM and magnetometer data.

Method	Strengths	Limitations
Magnetometry	• Will detect ferrous UXO either buried or below the seabed (within bounds). • Not as susceptible to weather as other methodologies. • Ability to model the source target using the anomaly response. • Can detect larger ferrous objects at deeper depths than EM methods. • Multiple systems can be linked together in an array to enhance production rates and increase efficiency. • Data can be analysed to estimate target size and depth.	• Influenced by some geological features and manmade features. • Small survey footprint per magnetometer. • Will not detect non-ferrous UXO. • Instrument response may be affected by nearby power lines and cultural features.
Electro Magnetic	• Advanced systems have multiple frequency and time gates. • Ability to detect all types of metallic munitions (ferrous and non-ferrous). • Additional data can provide information on target shape, orientation, and material properties. • Multiple sensors can be linked together in an array to enhance production rates and increase efficiency. • EM systems are less susceptible to cultural noise sources, such as utilities, than magnetic methods.	• Smaller detection range than a magnetometer. • Only specialist organisations operating with the equipment. • Could be affected by saline conditions.
Side Scan Sonar	• Large swath of data can be captured per run line. • Side scan sonar is the most suitable tool when searching for debris lying on the seabed. • A wide range of equipment and different frequency tow fish are commercially available. • Likely to identify large NEQ items of UXO. • 200% coverage allows contact position to be improved.	• Data quality influenced by marginal weather and water turbidity. • If USBL positioning is compromised then the positioning accuracy of seabed contacts may be limited. • Length dimensions may be exaggerated by a number of reasons including tugging. • Will not identify buried UXO. • Difficult to distinguish between UXO and other seabed feature such as boulders.
Multi Beam Echo Sounder	• Ability to identify UXO size targets on the seabed, with better accuracy than the side scan sonar. • Positional accuracy is very good, especially as the equipment is hull mounted. • Option of exceptionally high sounding accuracy, and a dense pattern of soundings to cover the seafloor in order to reveal small seabed features. • In addition to the soundings, the multibeam echo sounders produce seabed image data similar to a side scan sonar image (backscatter).	• Will not detect buried UXO. • A multibeam system can produce excellent results in this application only when positioned very close to the seabed. • The option to use echo sounder backscatter data analysis to characterise the seabed is complex and not commonly used for UXO identification. • Discrimination performance is degraded in rocky, uneven seabed conditions.

Method	Strengths	Limitations
Seismic Sub Bottom Profiling	• Potential to detect buried UXO. • Option for LMB threat.	• Small survey footprint. • Difficult to discriminate between manmade and geological features.

Table 2: Comparison of survey techniques

For a dedicated advice regarding survey techniques to be applied for Hollandse Kust (Zuid) wind farm zone see paragraph 5.2.

4 THRESHOLD LEVELS TO BE APPLIED

The possible effects of a UXO detonation on vessels, equipment, personnel, foundations and cables form an intolerable risk. The likelihood of a UXO detonation on impact is low to medium, but the consequence/harm is high to severe. This means mitigation measures are required to reduce the risks to as low as reasonably practicable (ALARP). The mitigation measures consist of UXO survey, avoidance of significant objects[10], Identification of potential UXO objects that cannot be avoided and disposal of actual UXO objects that cannot be avoided.

In order to set the scope of work for the UXO survey, appropriate threshold level(s) for modelling of anomalies detected by a UXO survey in Hollandse Kust (Zuid) wind farm zone need to be determined. In determining the thresholds, the possible presence of non-ferrous UXO and the expected installation methodologies[11] with respect to blast impact mitigation need to be taken into account. This chapter provides the provisional thresholds needed to mitigate the risk to a level that is considered ALARP. The threshold levels need to be reassessed based on the preliminary design and proposed installation methodologies.

4.1 SPECIFICATIONS OF NAVAL MINES TO BE EXPECTED

Table 3 provides the known specifications of the types of naval mines to be expected). The specifications are derived from the Mine Disposal Handbook, 1945, created by the U.S. Navy Bomb Disposal School near the end of WWII.

Type of mine		
German moored mines (WWI, exact types unknown)	Shape	Cylindrical and spherical dependent on type
	Size	0.80 – 0.86 m (dependent on type)
	Material	Steel
	Charge	81 – 150 kg dependent on type (wet gun cotton, cast TNT)
	Weight in air	254 – 322 (dependent on type)
German EMC moored mines	Shape	Two hemispheres joined by a 2" cylindrical mid-section
	Size	1,2 m
	Material	Steel
	Charge	300 kg Hexanite
	Weight in air	630 kg
German static cutter sweeping obstructers	Shape	Conical
	Size	0,48 m (D) x 1,12 m (L)
	Material	Steel
	Charge	Non-explosive anti sweep device
	Weight in air	Unknown
German LMB ground mines	Shape	Cylindrical, with hemispherical nose and tapered tail
	Size	0,66 m (D) x 3,0 m (L, depending on configuration)
	Material	Aluminium
	Charge	700 kg Hexanite
	Weight in air	990 kg
	Shape	Cylindrical

[10] Objects that meet the set survey thresholds.

[11] For the assumed installation methods see Site data Hollandse Kust (Zuid) wind farm zone, Unexploded Ordnance (UXO) – Desk Study (February 12, 2016).

Type of mine		
British A Mk I-IV ground mines	Size	0,45 m (D) x 2,87 m
	Material	Steel
	Charge	340-352 kg
	Weight in air	680 kg
British A Mk VI ground mines	Shape	Cylindrical
	Size	0.49 m (D) x 2.57 m (L)
	Material	Steel
	Charge	454 kg amatol or 499 kg Minol
	Weight in air	907 kg
British Mk XIX contact mines	Shape	Cylindrical
	Size	0,79 (D)
	Material	Steel
	Charge	45 kg TNT or Amatol
	Weight in air	131
British Mk XVII moored mines	Shape	Two hemispheres joined by a 8" cylindrical mid-section
	Size	0,79 (D)
	Material	Steel
	Charge	145 kg or 227 kg
	Weight in air	255 kg
British M Mk I ground mines	Shape	Two hemispheres joined by a 8" cylindrical mid-section
	Size	0.98 m (D) 1.28 m (L)
	Material	Steel
	Charge	227 kg TNT
	Weight in air	545 kg
British M Mk III ground mines	Shape	Cylindrical with 4 wheels on the bottom and a buoyancy chamber on one side
	Size	0.69 m (D) 1,8 m (L)
	Material	Steel
	Charge	680 / 794 kg Minol or 726 kg Amatol
	Weight in air	1,135 kg

Table 3: Specifications of naval mines to be expected.

4.2 THRESHOLD LEVELS FERROUS UXO

The exact types of German naval mines deployed in WWI are not known. The mines most commonly used (E-mine) are all fabricated of steel and have a ferrous mass well over 100kg. The U-mine is an exception. This anti-submarine mine was small, only carrying 20 kg charge. If present these mines do not pose a threat to wind farm development operations due to the limited explosive charge.

With the exception of the LMB mine all WWII naval mines were constructed out of steel. All ferrous mines have a ferrous mass well over 75 kg. The German static cutter sweeping obstructers do not pose a threat to wind farm development operations since they are non-explosive.

Taking the likelihood of encounter and the consequences of a detonation into account, it is assessed that the 250 lb (114 kg) British General Purpose (GP) High Explosive (HE) bomb is deemed the smallest ferrous threat item for an ALARP sign-off. These items are cylindrical/tear-drop in shape, made of steel and, depending on the variant, contain around 54 kg of HE. The body diameter is 26 cm and the length (without tail) is 0.7m. The ferrous weight is approximately 60 kg. Assuming these items can be successfully detected and identified within the geophysical datasets, larger objects will also be detectable. The provisional MAG threshold is set on 50 kg ferrous mass.

This threshold is also sufficient to detect the ferrous naval mines to be expected in the area. Most of these mines have a ferrous mass over 150 kg (with exception of the Mark XIX).

4.3 THRESHOLD LEVELS NON-FERROUS MINES

With the possible presence of LMB mines, the LMB mines will be normative for the ferromagnetic weight level for the modelling of anomalies detected by a magnetometer survey in the wind farm zone. These mines necessitate a ferromagnetic weight threshold under 10 kg for the magnetometer survey. Also the distance between the sensors and the LMB mine needs to be within 2 m to be able to detect these types of naval mines at all.

In order to make the risk of encountering a LMB mine ALARP it is recommended to perform additional Electro Magnetic (EM) and side scan sonar (SSS) survey operations. To enhance the evaluation process it is recommended to correlate the EM and SSS data with the magnetometer data.

<u>EM survey threshold</u>
EM detectors are capable of detecting ferrous as well as non-ferrous metals. The principle is based on the effect that the target metal responds on the magnetic field created by the detector, creating a secondary magnetic field. The magnetic field lines, caused by eddy currents, travel only in the top 0.4 mm of the metal skin. Therefore the surface area is more important for setting the survey threshold than the metal mass. Based on the different dimensions of LMB mines the threshold for the surface area is set to objects with a minimum of 4 m^2.

<u>SSS thresholds</u>
For the SSS the following thresholds are advised:

- Size
  There were different types of LMB-mines in armament. All LMB-mines had a diameter of 0.66 m. The length varied from approximately 1.8 m to over 3.0 m. Based on these dimensions the size threshold is set to 1.5 x 0.5 m.
- Shape
  All LMB-mines are cylindrical. Therefor the shape threshold needs to be cylindrical.
- Structure
  LMB-mines were fitted with several small external features. These features may be noticed during evaluation of the SSS data.

4.4 DETECTION RANGE

Deltares has performed a morphology study for Hollandse Kust (Zuid) Wind Farm Zone [12] Average sand wave migration speeds of 0.7 m/year to 3.0 m/year are observed. In general sand waves in the northern part migrate faster than in the southern part. Locally migration speeds as high as 5.2 m/year are observed. Wavelengths between 200 m and 1,000 m and wave heights between 1.1 and 4.0 m are observed. Sand waves are higher and shorter in the western part of the wind farm which is characterised by deeper water depth. Sand waves may be superimposed with megarippels, which have wavelengths up to 20 meters and crest heights up to 0.3 m and through depths up to 0.2 m.

[12] Morphodynamics of Hollandse Kust (Zuid) Wind Farm Zone, Report No.: CR-SC-DNVGL-SE-0190-02453-2_Morphodynamics, date 2016-12-24 (Deltares).

Based on the currently available data the Maximum Burial Depth (MDB) of UXO is assessed to be in order of 5 m below seabed. In the MBD the presence of superimposed megarippels and burial of UXO due to scour up to 60% of the diameter of the UXO is taken into account. However migrating sand waves are the predominant factor for UXO burial in the investigation area.

4.5 AREAS TO BE SURVEYED

The size of the exclusion zones and the areas to be surveyed is dependent on the actual design, installation methodologies and geophysical parameters. The size of the areas to be surveyed needs to be assessed in an additional risk assessment based on the (provisional) design of the wind farm and the relevant site data. The exact scope for the survey, identification, removal and disposal operations needs to be determined in a detailed UXO mitigation strategy.

4.6 VALIDATION OF GEOPHYSICAL UXO SURVEY EQUIPMENT

It is not recommended to prescribe a certain technique in the specifications for the UXO geophysical survey. The selection of the appropriate detection techniques and devices is the full responsibility of the contractor. It is mandated by the WSCS-OCE that all detection devices used during the geophysical UXO survey are to be subjected to a thorough UXO validation. The purpose of the validation is to establish the maximum detection range limits for the specified thresholds of objects. This detection range threshold may then be used to check for achieved detection depths below seabed and/or 'coverage achieved' on completion of the data acquisition. The variables which influence the degree of coverage are primarily sensor altitude, horizontal separation between adjacent lines, distance between the sensors and clearance requirements as specified by the wind farm zone developer.

The relevant survey parameters such as sensor altitude and line spacing can only be determined on the validation results of the actual survey equipment (combination between survey array and vessel/ROV). The survey contractor needs to assess the line spacing required based on the applicable thresholds, the required detection depth, the proposed MAG/EM system and the validation results of these systems.

5 CONCLUSION AND RECOMMENDATIONS

This chapter summarizes the conclusions of the additional historical research, the recommended survey techniques and provisional threshold levels for the Hollandse Kust (Zuid) wind farm zone.

5.1 TYPES OF NAVAL MINES POSSIBLY TO BE PRESENT

Additional historical research has shown that intense mining operations took place in and near the Hollandse Kust (Zuid) wind farm zone in World War I and in World War II. The following types of mines that may be present in the Hollandse Kust (Zuid) wind farm zone, according to the consulted historical sources:

- German moored mines (WWI);
- German EMC moored mines (WWII);
- German static cutter sweeping obstructers (WWII);
- German LMB ground mines (WWII);
- British A Mark I-IV and Mark VI ground mines (WWII);
- British Mark XIX contact mines (WWII);
- British Mark XVII moored mines (WWII);
- British M Mark I and III ground mines (WWII).

The German LMB ground mines are mainly constructed of aluminium. All other mines are constructed of steel.

It must be taken into account that this overview is based on the minefields actually present in (the vicinity of) the area of investigation. Because of migration of UXO by fishing activities, dredging or other means it may be possible that mines or other UXO have migrated into the Hollandse Kust (Zuid) wind farm zone. However the types of mines mentioned are considered the most plausible types of mines to be present based on this additional historical research.

5.2 GEOPHYSICAL SURVEY METHODOLOGIES[13]

The conducted historical research and this additional historical research has shown that several types of naval mines could be present within the Hollandse Kust (Zuid) wind farm zone, including non-ferrous mines. Due to the types and sizes of UXO likely to be present there is no “silver bullet solution” for the UXO geophysical survey. Especially the possible presence of non-ferrous ground mines (LMB) might necessitate a combination of geophysical survey methodologies to mitigate UXO related risks to a level that is considered ALARP.

Geophysical techniques that might be considered for the Hollandse Kust (Zuid) wind farm zone are as follows:

- Magnetometry (MAG)
- Electro Magnetic (EM)
- Side scan sonar (SSS)
- Multibeam echo sounding (MBES)
- Seismic sub bottom profiling (SBP)

There are a number of other technologies available to profile the seabed but are yet considered to be either unproven in the commercial sector or employed by the military and cost-prohibitive.

---

[13] The recommendations apply to the dedicated UXO geophysical survey campaign to be performed prior to wind farm installation operations. They are not applicable to the geophysical survey commissioned by RVO.nl (in the framework of the site package).

For all ferrous UXO magnetometry is the recommended survey technique. For the non-ferrous UXO a combination between Magnetometry (MAG), Electro Magnetic (EM) and Side scan sonar (SSS) is recommended. To enhance the evaluation process it is recommended to correlate the EM and SSS data with the magnetometer data.

5.3 THRESHOLD LEVELS TO BE APPLIED

The provisional thresholds needed to mitigate the risk to a level that is considered ALARP are set. The threshold levels need to be reassessed based on the preliminary design and proposed installation methodologies.

For ferrous UXO an overall ferrous weight threshold of 50 kg sufficiently reduces the risk to ALARP. For these UXO no additional survey techniques are required. In order to make the risk of encountering LMB mines ALARP it is recommended to preform additional survey operations with an Electro Magnetic (EM) survey and side scan sonar (SSS). To enhance the evaluation process it is recommended to correlate the EM and SSS data with the magnetometer data.

Survey technique	Ferrous UXO	Non-ferrous UXO
Magnetometry	50 kg	n.a. MAG data need to be correlated with the EM and SSS data
Electro Magnetic	n.a.	4 m^2
Side Scan Sonar	n.a.	Size: 1.5 m x 0.5 m. Shape: Cylindrical. Structure: external features might be noticed during evaluation of the SSS data.

Table 4: Summary of provisional threshold levels.

5.4 DETECTION RANGE, AREAS TO BE SURVEYED AND VALIDATION OF GEOPHYSICAL UXO SURVEY EQUIPMENT

The provisional maximal detection range is equal to the MBD and is estimated to be in the order of 5 m below seabed.

The size of the areas to be surveyed needs to be assessed in an additional risk assessment based on the (provisional) design of the wind farm and the relevant site data.

It is not recommended to prescribe a certain technique in the specifications for the UXO geophysical survey. The selection of the appropriate detection techniques and devices is the full responsibility of the contractor. It is mandated by the WSCS-OCE that all detection devices used during the geophysical UXO survey are to be subjected to a thorough UXO validation. The relevant survey parameters such as sensor altitude and line spacing can only be determined on the validation results of the actual survey equipment (combination between survey array and vessel/ROV).

6 ANNEX: CONSULTED SOURCES

In this annex, on overview of the additionally consulted relevant historical sources is given. The additional historical sources have been consulted in the following institutions:

- Bundesarchiv-Militärarchiv (BaMa) in Freiburg, Germany.
- United Kingdom Hydrographic Office (UKHO) in Taunton, Great-Britain.
- The National Archives (TNA) in London, Great-Britain.
- Marinemuseum in Den Helder, The Netherlands.
- UXO-encounters reported to the Royal Netherlands Navy.

6.1 BUNDESARCHIV-MILITÄRARCHIV

Archival research was conducted in the Bundesarchiv-Militärarchiv (BaMa) in Freiburg, Germany. Objective of this research was primarily to gain more insight in German naval and coastal warfare during the First and Second World War. German Air Force documents were also consulted. Heavy bombing of Germany during World War II led to the destruction of large parts of the archives and subsequent gaps in the documentation.

Documents from the following record groups were consulted:

- RM 2: Kaiserliches Marinekabinett.
- RM 5: Admiralstab der Marine / Seekriegsleitung der Kaiserlichen Marine.
- RM 7: Seekriegsleitung der Kriegsmarine.
- RM 8: Kriegswissenschaftliche Abteilung der Marine (Marinearchiv).
- RM 35-I: Marinegruppenkommando Ost / Nord der Kriegsmarine.
- RM 35-II: Marinegruppenkommando West der Kriegsmarine.
- RM 43: Dienststellen und Kommandostellen der Kaiserlichen Marine im Heimatbereich.
- RM 45-II: Dienststellen und Kommandostellen der Kriegsmarine im Bereich Deutsche Bucht und Niederlande.
- RM 48: Flottenkommando der Reichsmarine und Kriegsmarine.
- RM 51: Geschwader und Gruppen der Kaiserlichen Marine.
- RM 52: Führer von Torpedobootstreitkräften der Kaiserlichen Marine.
- RM 65: Handelsschutzverbände der Kaiserlichen Marine.
- RM 86: Befehlshaber der Unterseeboote der Kaiserlichen Marine.
- RL 2-II Generalstab der Luftwaffe / Luftwaffenführungsstab.
- ZA 5: Deutscher Minenräumdienst (German Minesweeping Administration).

The following relevant documents were acquired during this research:

RM 35-I Marinegruppenkommando Ost / Nord der Kriegsmarine	
RM 35-I/267	Minen, Allgemein Minensperren Nordsee 10. Aug. 1940 - 1. Okt. 1943
Relevant information on German minelaying per minefield. Forms the basis for ZA 5 maps (see further in this annex).	

ZA 5 Deutscher Minenräumdienst (German Minesweeping Administration)	
ZA 5/27	(Im Kriege geworfene Minensperren in der Ost- und Nordsee etc.)
Relevant information on British minelaying ('Gardening'): • For the investigation area the gardening fields Whelks (IJmuiden) and Oysters (Rotterdam and Hoek van Holland) are relevant. According to the summary a total of 136 mines were laid in the gardening fields with code name Whelks 1&2 and 62 mines in the gardening field with code name Oysters.	
ZA 5/28	Minenkarten, Deutsches Hydrographisches Institut (Großformat) 1960 Deutsche Minensperren des Zweiten Weltkrieges 1939 - 1945.- Erläuterungen zu den Minenkarten
Relevant, information on the progress of post war mine clearance, per minefield.	
ZA 5/44	Summary of Enemy Minelaying, The Admiralty, United Kingdom (Großformat)
Relevant, detailed information on all German naval minefields, including those near the area of investigation.	
ZA 5/50	German Minelaying 1939 - 1945, Hydrographic Department of the Admiralty (Minenkarten, Großformat) 1945 Chart C: The North Sea.- Southern Sheet
Relevant. Map indicating the locations of German naval minefields. Minefield numbers refer to ZA 5/44. Several minefields were situated near the area of investigation. The chart excludes mines laid by aircraft and ground mines laid before 1942. The minefields are geographically positioned on the contemporary map in GIS, based on the information from this chart and the coordinates mentioned in record ZA5/44. The relevant German minefields are registered in Table 5.	
ZA 5/66	Stand der Verminung
Relevant, information on the progress of demining in April 1947. Infographics indicate the danger the mines still posed after the war.	

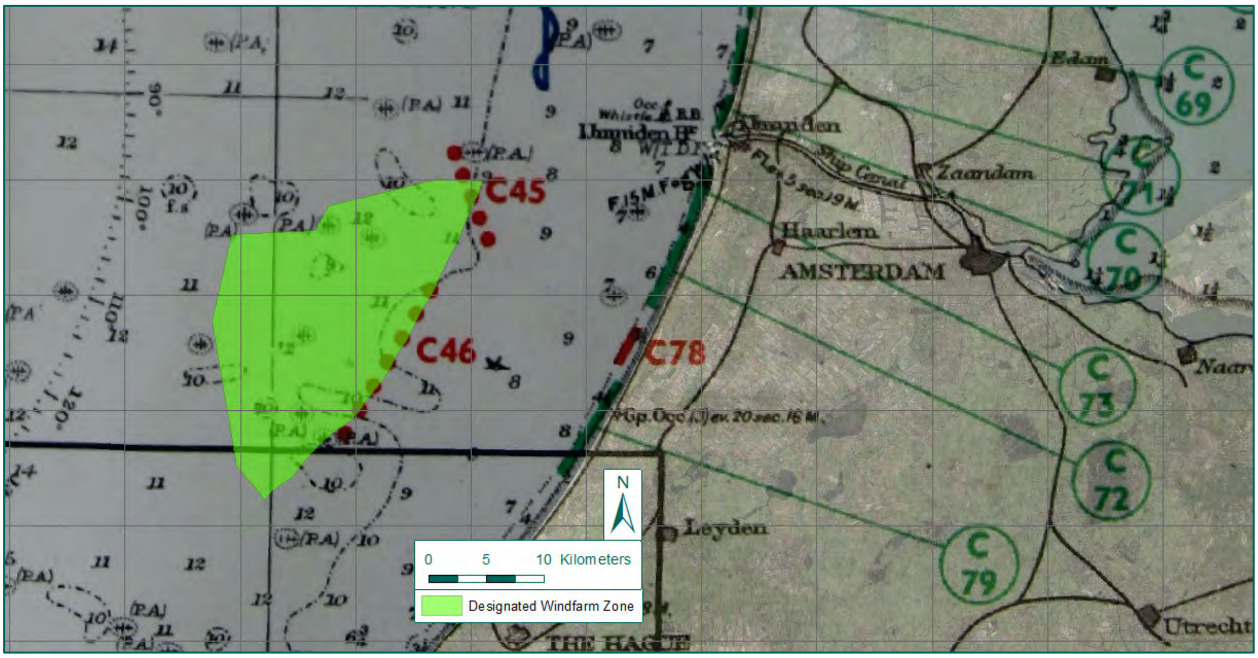


Figure 8: German mine fields in proximity including the Hollandse Kust (Zuid) wind farm zone (based on chart ZA 5/50).

Table 5 presents the specifications of the German minefields in the vicinity of the investigation area. The information about these minefields as mentioned in the Summary of Enemy Minelaying (ZA 5/44) is shown in Table 5.

Ref. no.	Date laid [m/Y]	Position [UTM 31N] X	Position [UTM 31N] Y	Degree of accuracy [miles]	Contents	Depth [feet]	Spacing [yards]	Lines No.	Lines Spacing [yards]
C.45	9/44	583265	5810869	.5	72 LMB[14]	-	240	2	165
		586898	5804071						
C.46	9/44	582327	5799172	.5	124 LMB[15]	-	260	2	165
		574563	5786811						
C.47	11/44	593903	5817551	1	160 EMC[16] 40 stCtr[17]	10	270	3	220
		590200	5834171						
E. 38	9/44	562714	5778489	.5	90 LMB 90 EMC	- 10	180	1 1	165
		559127	5763613						

Table 5: Information on German minefields in proximity of the Hollandse Kust (Zuid) wind farm zone, derived from ZA 5/44: Summary of Enemy Minelaying.

[14] Type DM-1, with a pressure and magnetic fuze.
[15] Type DM-1, with a pressure and magnetic fuze.
[16] EMC is a moored mine. Depth in feet under the waterline.
[17] Mine sweeping obstructer (static cutter), with chain 4 mines to one obstructer.

6.2 UNITED KINGDOM HYDROGRAPHIC OFFICE

The UKHO has a large collection of historical maps and charts, including charts of minefields off the Dutch coast. REASeuro ordered the following maps from UKHO catalogue:

Mine Charts: Netherlands, Belgium, France, etc.	
MOF 6229	Hook of Holland to IJmuiden, August 11, 1944
Relevant, covers the area of investigation. Minefield 1091X is intersecting the area of investigation.	
MOF 6550	Dunkerque to Hook of Holland, July 6, 1945
Not relevant, does not show the area of investigation.	
MOF 01	Dunkerque to Hook of Holland, October 15, 1943
Not relevant, does not show the area of investigation.	

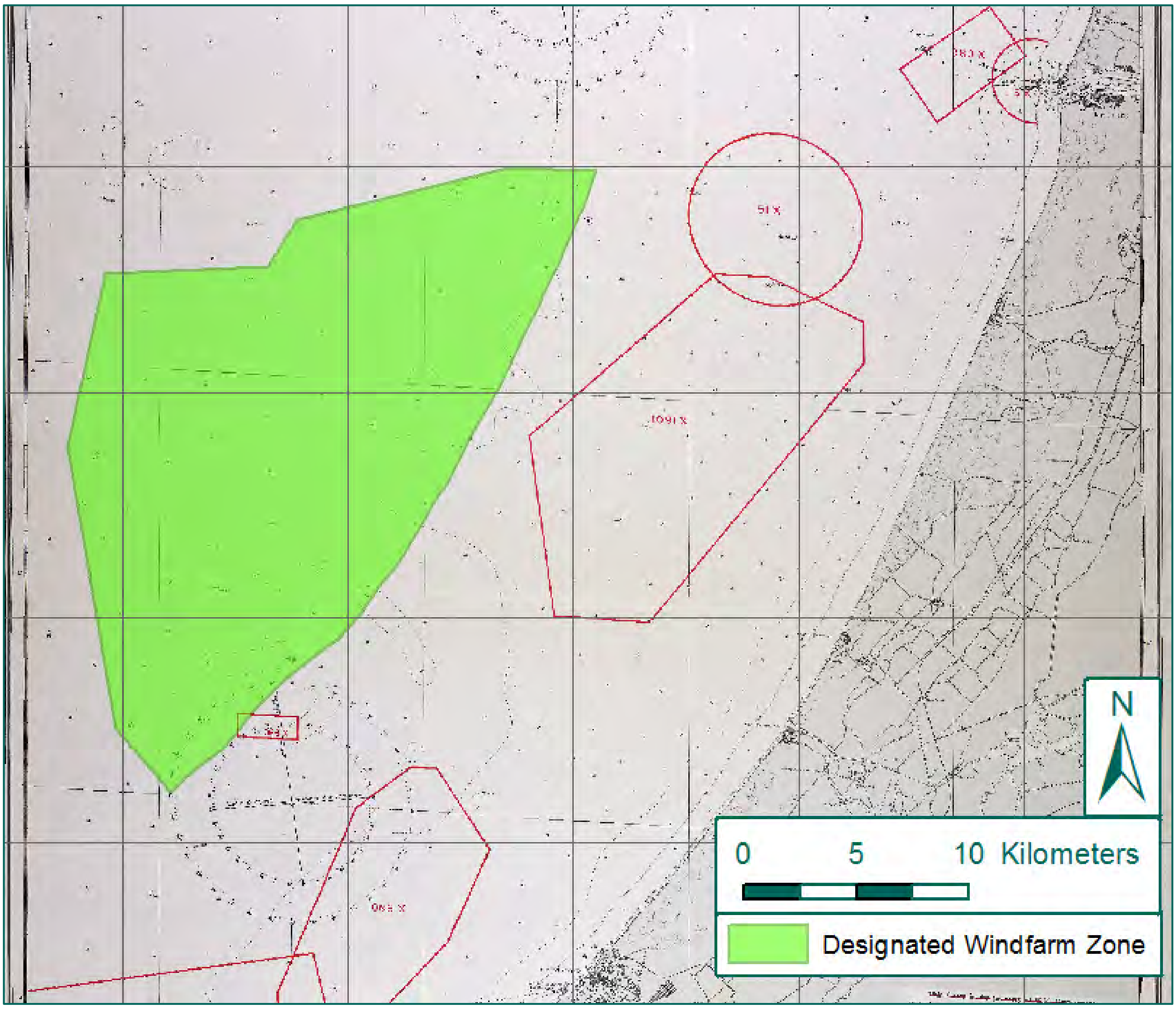


Figure 9: Extract of chart MOF 6229, showing the Hollandse Kust (Zuid) wind farm zone.

6.3 THE NATIONAL ARCHIVES

The National Archives (TNA) in Kew (London) keep the records of the United Kingdom from the Middle Ages to the present. Additional research in TNA was conducted to gather more information on British minelaying in and near the area of investigation. The following tables show the relevant documents acquired from TNA.

ADM 1: Admiralty, and Ministry of Defence, Navy Department: Correspondence and Papers.	
ADM 1-19745	Post-war mine clearance in European waters: first interim report of International Central Board. With charts, 1946-1947.

Chart indicating the dangerous areas in the European waters due to mining, dated August 1945.

The report also includes a list of ships sunk by mines in the post-war period. On the list is a Dutch lugger, name unknown, which was sunk by a mine in October 1945 of the Dutch coast. Off IJmuiden the Norwegian freighter Betty was damaged by a mine on 12 March 1946.

ADM 1/18760	STRATEGY AND TACTICS (82): Minesweeping reports on clearance of areas in QZY 593.

Concerns minefields off Texel, not the minefield situated in the area of investigation.

ADM 234: Admiralty, and Ministry of Defence, Navy Department: Reference Books (BR Series).	
ADM 234/560	British mining operations 1939-1945: Vol 1.

Operations	Date	mines	Remarks
QU1	5-11-42	18 A Mk I-IV	Off IJmuiden
QU2	21-2-43	18 A Mk I-IV	S off IJmuiden
QU7	28-2-43	18 A Mk I-IV	N off Scheveningen
QU7(A)	16-3-43	18 A Mk I-IV	N off Scheveningen
QU2(A)	18-3-43	18 A Mk I-IV	S off IJmuiden
QU8	11-4-43	24 Mk XIX	Off Scheveningen
QU8(A)	13-4-43	18 A Mk I-IV	N off Scheveningen
QU7(B)	15-4-43	18 A Mk I-IV	S off IJmuiden
QU2(B)	17-4-43	12 A Mk I-IV	Off IJmuiden

QU8(B)	20-4-43	18 A Mk I-IV	N off Scheveningen
QU10	29-5-43	12 A Mk I-IV	Off Scheveningen
QU11	29-5-43	16 A Mk I-IV	N off IJmuiden
QU14	5-8-43	18 A Mk I-IV	Off Egmond
QU11(A)	1-9-43	8 A Mk I-IV	Off Egmond
QU11(B)	1-9-43	22 A Mk I-IV	Off Scheveningen
QU11(C)	1-9-43	16 A Mk I-IV	Off Scheveningen
QU11(D)	3-9-43	8 A Mk I-IV	Off IJmuiden
QU11(E)	3-9-43	16 A Mk I-IV	Off IJmuiden
QU11(F)	3-9-43	22 A Mk I-IV	Off Scheveningen
QU11(G)	9-9-43	28 A Mk I-IV	Off Scheveningen
QU26	24-10-43	36 A Mk I-IV	Off Scheveningen
QU23	27-10-43	32 A Mk I-IV	Off Scheveningen
QU18	4-11-43	24 A Mk I-IV	Off IJmuiden
QU26(A)	23-2-44	48 A Mk I-IV	Off Scheveningen
QU25	19-3-44	26 A Mk I-IV	Off Scheveningen
QU29	17-4-44	32 A Mk I-IV	Off IJmuiden
QU28	19-4-44	18 Mk XVII 36 A Mk I-IV	Off IJmuiden
QU27	23-4-44	16 Mk XVII 36 A Mk I-IV	Off IJmuiden

"Whelks" New aircraft mining area off IJmuiden to be used when nights became too short for Coastal Forces operations in Phase III and during Phase IV.

"Four large lays were completed by the Nore flotillas, three of them off IJmuiden, and a total of 49 Mk XVII (49/50), 44 A Mk VI (K1011 and D411) and 104 A Mk I-IV mines with standard assemblies were laid."

17-4-1944

The 17th April was a busy day for the minelayers in all areas and the first operation – "QU 29" – took place in the Nore Command. Commencing at 0130, MTBs 234, 245, 83, 80, 223, 225, 233 and 244 of the 21st and 22nd Flotillas operating from Felixstowe, laid 32 A Mk I-IV mines off Ymuiden within an area enclosed by lines joining positions:

a. 52°29'N, 04°31'E

b. 52°29'N, 04°32'E

c. 52°26'N, 04°32'E

d. 52°26'N, 04°31'E

Assemblies: 4 D 413)
16 D 407) standard
12 B 231)

Sterilizers for the D assemblies were set to operate on 3rd May. Those for the B assemblies were set, in error, to operate on the same day as they armed, 8th May.

... and 2320 on 18th.

Operation "QU 28". 19th April 1944

MLs 100, 105, 110 and MTBs 234, 223, 244, 233, 225, 245, 83, 88 and 93 left Felixstowe at about 1630 on 18th April to carry out Operation "QU 28" off Ymuiden. Commencing at 0215 on 19th a total of 54 mines were laid within an area enclosed by lines joining positions:

a. 52°25.0'N, 04°21.5'E
b. 52°25.0'N, 04°26.0'E
c. 52°22.0'N, 04°27.5'E
d. 52°22.0'N, 04°23.0'E

The total was made up of:

18 Mk XVII (49/50)/XVIII at a depth of 23 feet

20 A Mk I-IV - B 231)
8 A Mk I-IV - D 413) standard assemblies
8 A Mk I-IV - D 407)

Arming clocks in the B 231 assemblies were set to operate four days after laying. Sinkers were set to release in three groups of six on 26th, 28th and 30th May. Flooders and sterilizers were set for 16th June 1944. The lay was without incident.

Operation "QU 27". 23rd April 1944

Coastal forces from Felixstowe visited Ymuiden for the last time on the night of 22nd/23rd April. The minelaying force, consisting of MLs 100, 105, 110 and MTBs 223, 224, 225, 233, 234, 244, 83, 93 and 245, left Felixstowe at about 1600 on 22nd April. "QH" and a radar bearing and range of Ymuiden lighthouse were used for fixing, and commencing at 0145 on 23rd a mixed bag of moored and ground mines was laid within an area enclosed by lines joining positions:

a. 52°30'N, 04°26'E
b. 52°30'N, 04°28'E
c. 52°26'N, 04°29'E
d. 52°26'N, 04°26'E

The total of 52 mines was made up of:

9 Mk XVII (49/50)/XVII - at a depth of 23 feet
7 Mk XVII (49/50)/XVIII - at a depth of 22 feet

12 A Mk VI - K 1011)
6 A Mk VI - D 411) Special assemblies

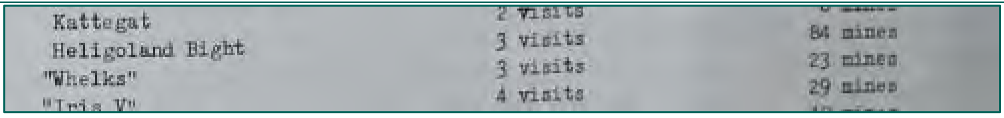
18 A Mk I-IV - D 413 Standard assemblies

Flooders and sterilizers were set to operate on 17th June 1944 and Mk XVIII sinkers to release on 31st May 1944. The lay was without incident.

"On 26th May the IJmuiden area (Whelks) was passed to Bomber Command, the nights having become too short for Coastal Forces craft to operate."

"Whelks" 3 visits, 35 mines

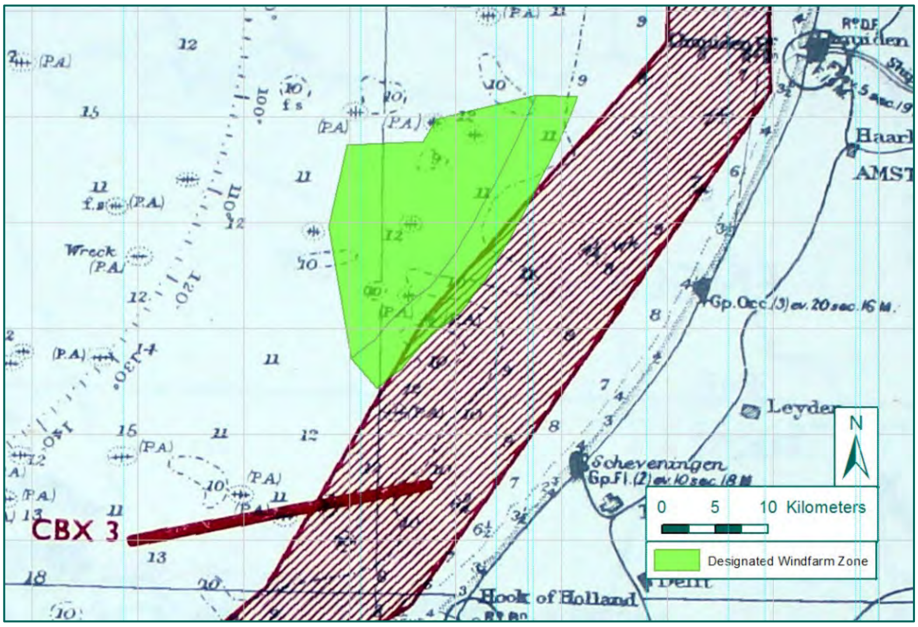
Operation Maple phase VI:



Kattegat	2 visits	
Heligoland Bight	3 visits	84 mines
"Whelks"	3 visits	23 mines
"Iris V"	4 visits	29 mines

ADM 234/561	British mining operations 1939-1945: Vol 2.

Annex to volume 1, containing, maps, plans, tables and charts. The following images are relevant to the area of investigation.



AIR 14: Air Ministry: Bomber Command: Registered Files.	
AIR 14/1557	Sea mining operation results, 1941 Jan. - 1944 July.

Relevant summary of shipping losses caused by mines laid by aircraft of Bomber and Coastal Command, up to 31 December 1941. No known losses of ships near the area of investigation are enclosed in the summary.

The overview of mines laid shows 20 mines laid by Coastal command aircraft off IJmuiden.

DIEPPE		6	6			
IJMUIDEN		20	20			
MAAS RIVER	1	79	79	4	4	12,600

AIR 14/1952	Bomber offensive: minelaying. 1944 Feb.-May.

Bomber Command mine laying offensive 1st January 1944 to 30th April 1944

Chart showing 277 mines were laid off IJmuiden and Den Helder.

Bomber Command tactical mine laying requirements of the “pre-Overlord” and “Overlord periods”.

TACTICAL MINELAYING

1. Phase 3 (D-24 to D-3)

   Laying of special mines off:-

   Le Havre
   Cherbourg
   Ijmuiden
   Hook
   West of Scheldt
   Western Frisian Islands
   St. Malo
   Brest
   Chenal de Four.

2. Phase 4 (D-2 to D-1)

   Laying of special mines off:-

   Ijmuiden
   Hook
   West Scheldt
   Brest
   Chenal de Four.

3. With the exception of the Western Frisian Islands, it is hoped that approximately 500 mines will be laid in these areas, requiring an effort of approximately 125 bombers over 20 days.

Mine laying plan operation "Neptune"

Phase IV (D-2 to D-1)

Laying of special type mines only by available coastal force minelayers, the main concentration being off LE HAVRE, CHERBOURG, CALAIS and BOULOGNE; and by aircraft minelayers off IJMUIDEN, HOOK, WEST SCHELDT, CHENAL DU FOUR and BREST.

III	Y-22 onwards	6. (a) COASTAL FORCES as in Phase II, plus laying of A.Mk. IV(M.X.C.15) where practicable in the areas specified, and A.Mk. IV(Standard assemblies) in the TONGUE area. (b) APOLLO as in Phase II plus laying off CASQUETS if required. (c) PLOVER as in Phase II. (d) AIRCRAFT (i) As in Phase II plus laying of A.Mk. VI (D.410 & G.706) and A.Mk.IV(D414) off LE HAVRE and CHERBOURG. (ii) Take over laying off IJMUIDEN, HOOK and W. SCHELDT areas when nights become too short for operation of Coastal Forces. (Mines as in 6(d)(i).
	Y-8	7. On or as soon as possible after Y-8 AIRCRAFT laying of A.Mk. VI(K.1002, G.706, D.410) on maximum practicable scale in standard areas outside Channel plus FRISIAN Is.(North) and of A.Mk. VI(K.1006, K.1010) off IJMUIDEN, HOOK, W. SCHELDT, CHERBOURG, BREST and CHENAL DU FOUR.
	Y-6	8. Mk. XVII(49/50) mines begin to release in all areas except SANDETTIE.

/Y-1 ....

IV	D - 2/D - 1	11. (a) COASTAL FORCES. Laying of A.Mk. IV (M.X.C.15 & D.415), A.Mk. VI(K.1011) and Mk. XVII (49/50) off CALAIS, BOULOGNE, LE HAVRE and CHERBOURG. (b) AIRCRAFT. Laying of A.Mk. IV(M.X.C.16) and A.Mk. VI(D.412) off IJMUIDEN, THE HOOK, W. SCHELDT, CHENAL DU FOUR and BREST. (c) APOLLO loaded at MILFORD HAVEN (M. XVII (49/50) and M.Mk. I). (d) PLOVER. As ordered.

Coordinates Whelks:

IJMUIDEN - WHELKS (Aircraft)
An area bounded by lines joining:-

(a) 52°31'00" N. 04°26'30" E.,
(b) 52°30'00" N. 04°34'30" E.,
(c) 52°25'30" N. 04°32'30" E.,
(d) 52°26'30" N. 04°24'30" E.

The summary also provides an extensive overview of the type of mines, moorings, chutes, sensors settings, etc. This information is analysed to determine the type of mines likely to be present in the area of investigation.

AIR 14/2064	Air Ministry: Bomber Command: Registered Files. Operation "Gardening". 1 March 1940 - 31 December 1943

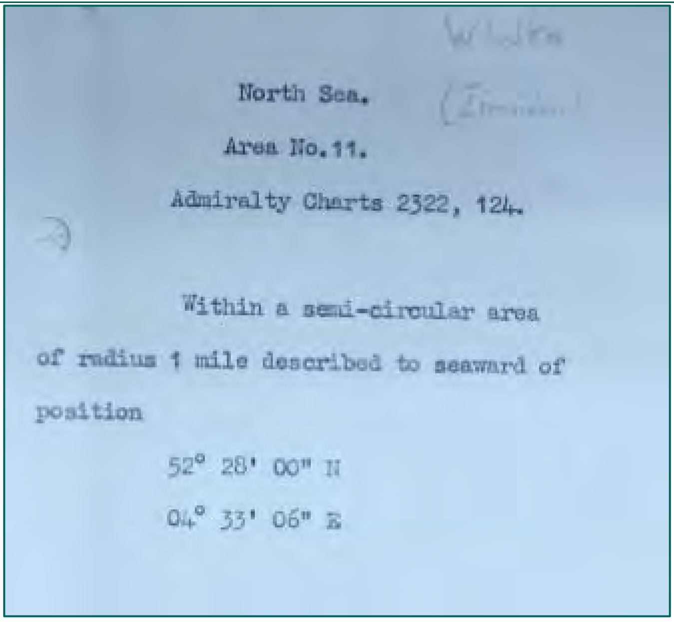
Policy information on Gardening. The following information is relevant:

- Wellington, Halifax and Lancaster II bombers conducted Gardening operations in the gardens near the investigation area. Inexperienced Lancaster crews were also eligible for conducting these operations.

AIR 15: Air Ministry and Admiralty: Coastal Command: Registered Files.	
AIR 15/267	Minelaying areas, 1942 Oct. 1944 Dec.

Coordinates of the relevant Gardening Fields in early stages of the war:

Whelks (IJmuiden).



North Sea.

Area No. 11.

Admiralty Charts 2322, 124.

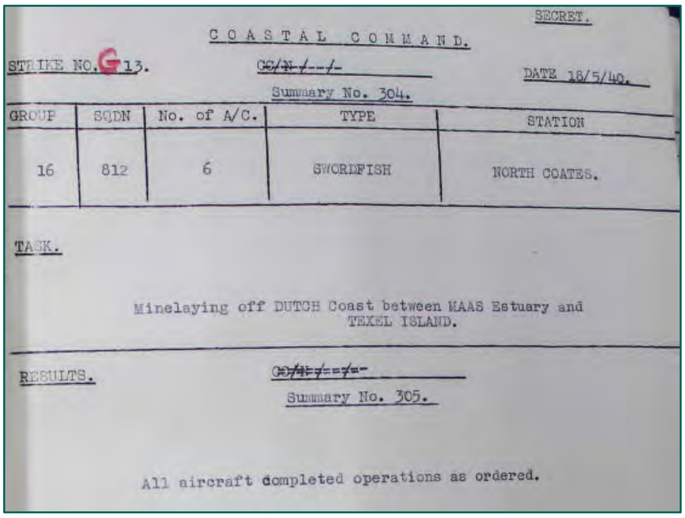
Within a semi-circular area of radius 1 mile described to seaward of position

52° 28' 00" N

04° 33' 06" E

AIR 15/772	Relevant, Coastal Command minelaying reports with summary of minelaying per area and a chart of the gardening zones.

Minelaying reports, drafted per aircraft. In 1940, most minelaying sorties were flown by Coastal Command aircraft of 16 Group. Several minelaying operations were carried out in the vicinity of the investigation area.



SECRET.

COASTAL COMMAND.

STRIKE NO. G13. CC/~~N/--/-~~ DATE 18/5/40.

Summary No. 304.

GROUP	SQDN	No. of A/C.	TYPE	STATION
16	812	6	SWORDFISH	NORTH COATES.

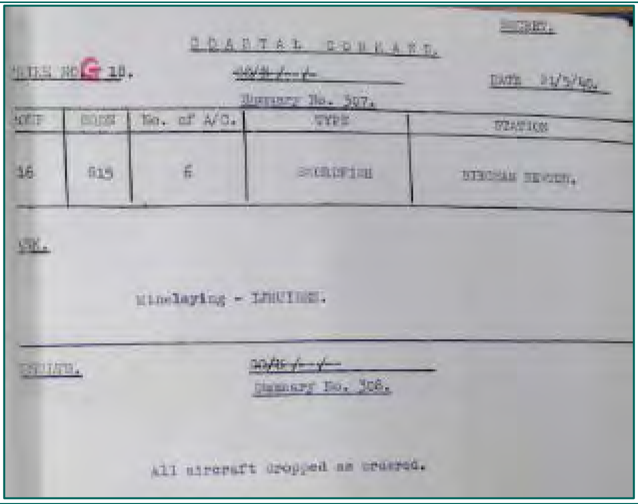
TASK.

Minelaying off DUTCH Coast between MAAS Estuary and TEXEL ISLAND.

RESULTS. CC/~~4t/--/-~~

Summary No. 305.

All aircraft completed operations as ordered.



SECRET.

COASTAL COMMAND.

DATE 21/5/40.

Summary No. 307.

[illegible]	[illegible]	No. of A/C.	TYPE	STATION
16	815	6	[illegible]	[illegible]

Minelaying - IJMUIDEN.

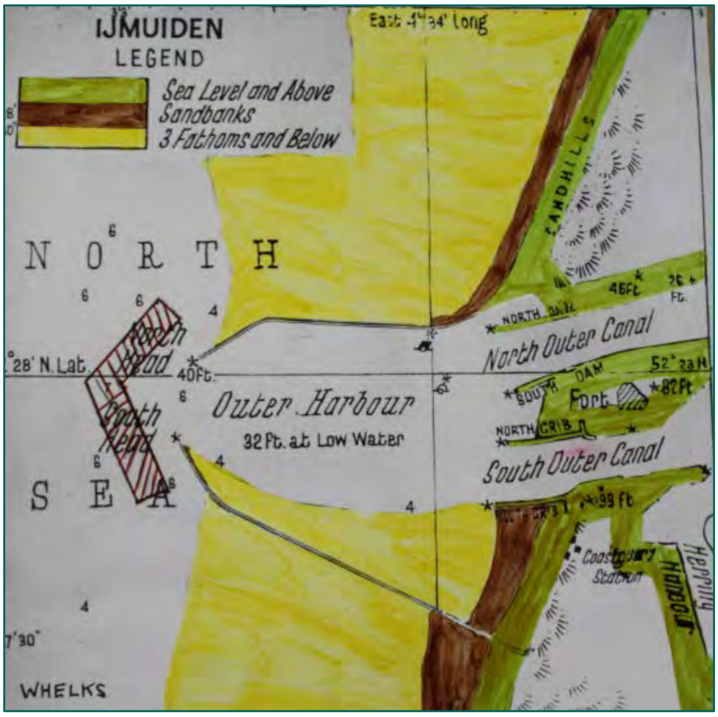
Summary No. 306.

All aircraft dropped as ordered.

AIR 40: Air Ministry, Directorate of Intelligence and related bodies: Intelligence Reports and Papers.

AIR 40/1961	Air Ministry, Directorate of Intelligence and related bodies: Intelligence Reports and Papers. AIR INTELLIGENCE 9. France, Holland and Belgium target identification maps and photographs: emergency port book including "Gardening" charts. 1940 June-1941 July

Folder containing charts with “Gardening” fields near the area of investigation.



Extract from AIR 40/1961. Dashed lines indicate the ‘Whelks’ Gardening fields at the entrance of IJmuiden port. The Whelks area would be expanded several times over the course of the war.

CAB 101: War Cabinet and Cabinet Office: Historical Section: War Histories (Second World War), Military.	
CAB 101/324	Air Offensive Against Enemy Shipping and Bomber Command Minelaying Operations, 1 September 1944 - 5 May 1945
Reports on air offensive operations against enemy shipping and minelaying operations holding several sections on aerial attacks off the Dutch coast and aerial attacks on the E-boat shelters in IJmuiden.	

6.4 MARINEMUSEUM

The Navy Museum ('Marinemuseum') keeps a collection of Royal Netherlands Navy maps and charts. The collection includes maps of post-war minesweeping operations. REASeuro ordered several relevant maps for this additional research. It concerns the following maps:

Zeekaart Nederlandse kust van West Hinder tot Texel; NEMEDRI 227; mijnenveegoperaties 1949-1954.

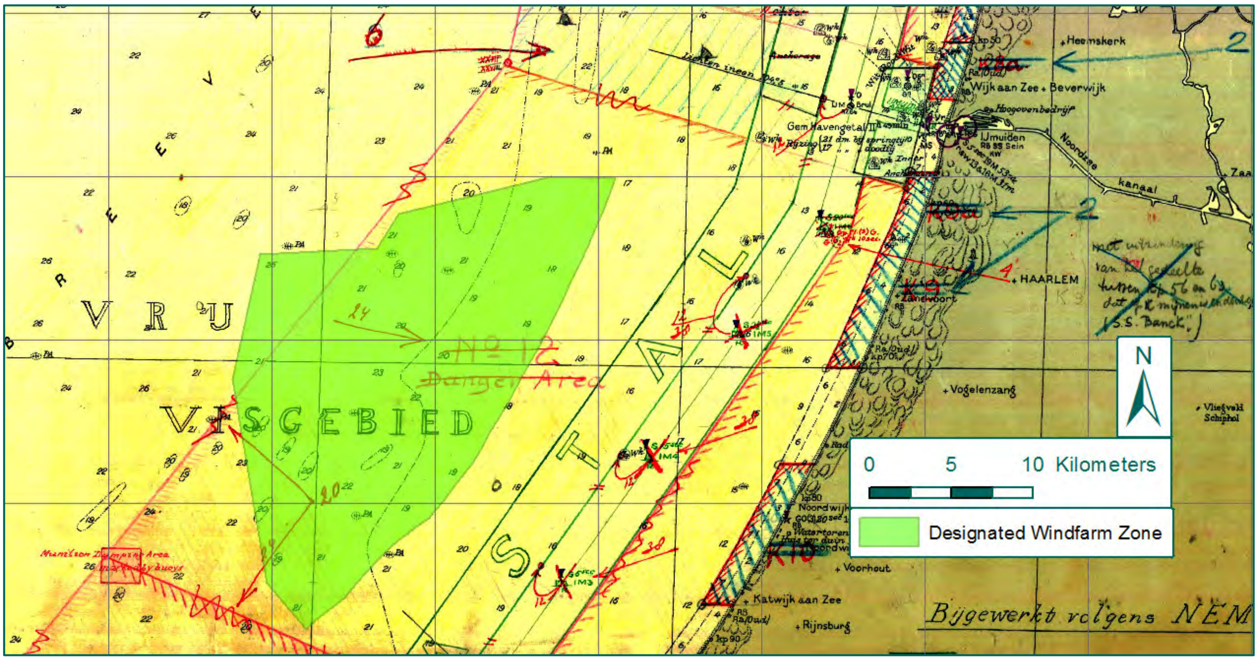


Figure 10: Extract of NEMEDRI 227 mine map. The Hollandse Kust (Zuid) wind farm zone is partly situated in a marked danger area. The danger area was in the process of clearance, marking it as 'reduced to several small areas'.

Zeekaart The North Sea southern sheet; NEMEDRI 2182a; mijnenveegoperaties 1950-1951.

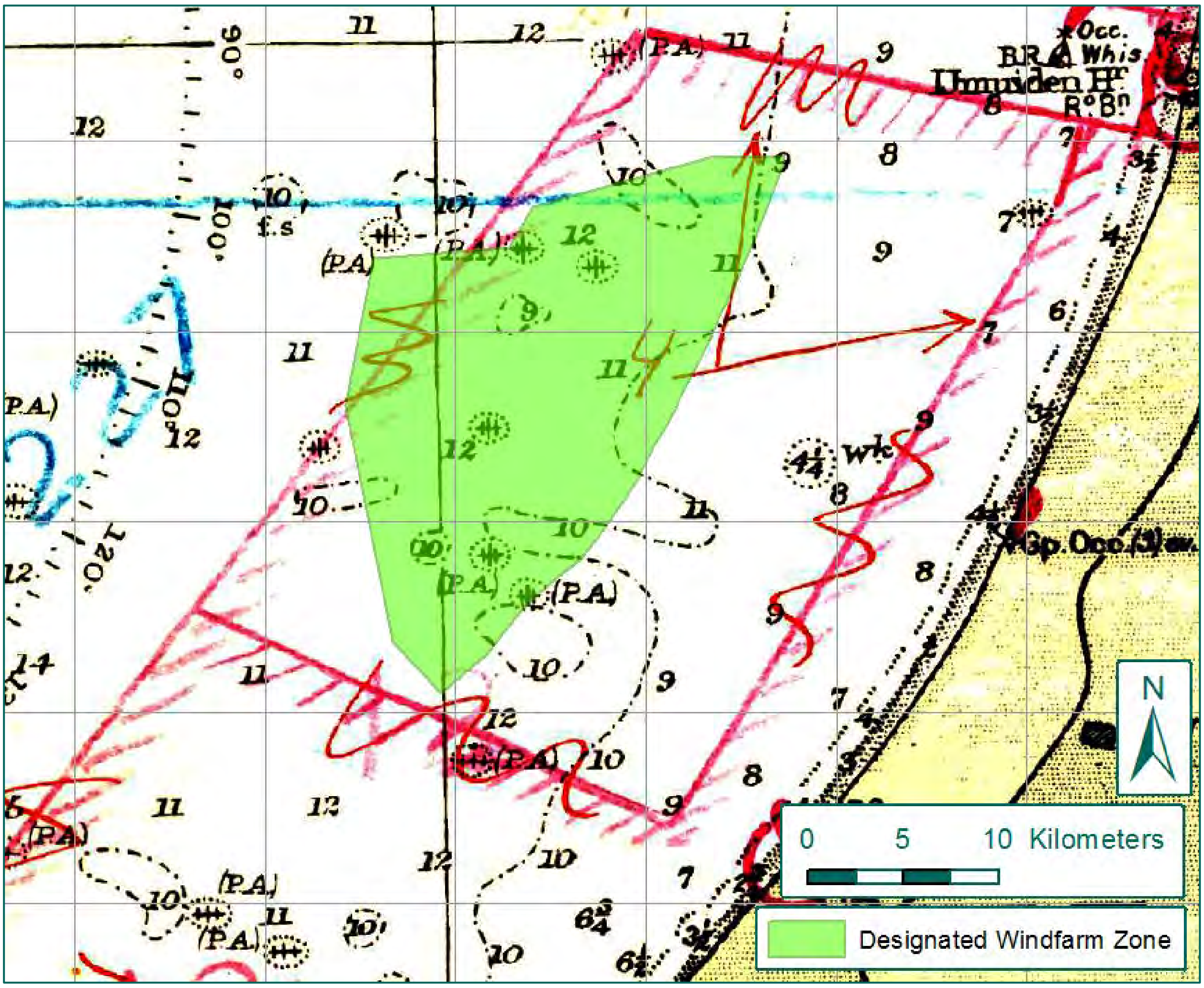


Figure 11: NEMEDRI 2182a, dated after NEMEDRI 227, indicates the Hollandse Kust (Zuid) wind farm zone as cleared for shipping.

6.5 POST-WAR UXO CLEARANCE: ROYAL NETHERLANDS NAVY AND OSPAR COMMISSION

The area of investigation is situated in the North Sea. Therefore the UXO-related interventions of the Royal Netherlands Navy[18] are consulted. The Royal Netherlands Navy keeps a detailed administration regarding encountered UXO in the North Sea. Since 2005 around 1.800 UXO-items were reported to the coast guard, Royal Netherlands Navy and other authorities. From this database, the locations where mines were reported to the Royal Netherlands Navy were selected and geographically positioned. The following figure shows the positions where mines were encountered in the area of investigation. In the majority of the encounters, the type of mine is not reported. However, in one case, it is mentioned that the mine encountered was a German LMB mine. The location of the encountered LMB mine is featured in red. Several other reports mention moored mines. The figure also shows the UXO encounters during the construction of Luchterduinen wind farm.

[18] The Royal Dutch Navy keeps a detailed registration on UXO encounters in the Dutch and Belgian part of the North Sea. The registration provides information on UXO encounters since 2005.

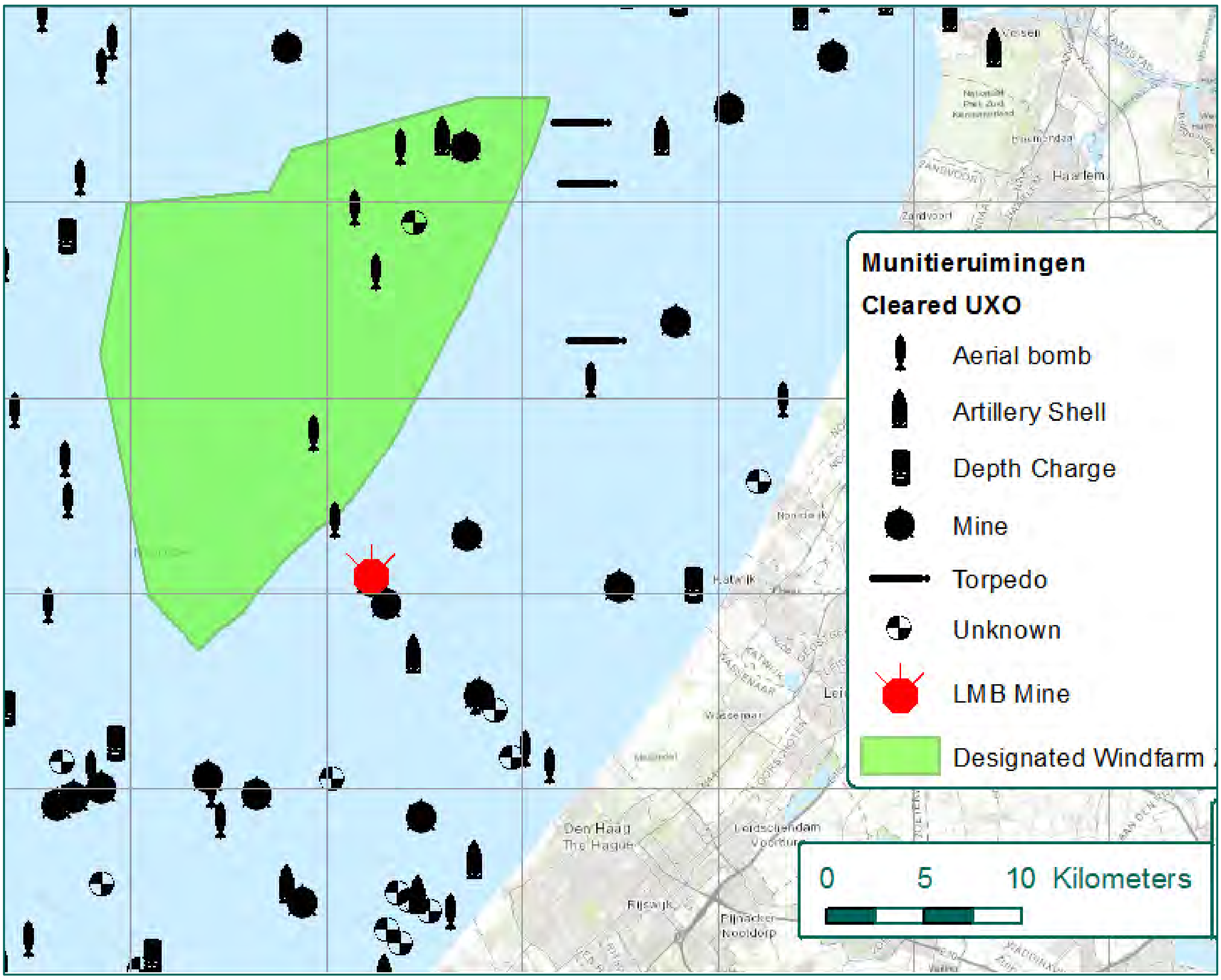


Figure 12: Locations of encountered mines in proximity of the Hollandse Kust (Zuid) wind farm zone.

Most of the encounters of mines were reported by fishermen, entangling these mines in their nets. The exact location where the nets picked the mines up from the sea floor cannot be determined. Besides, in most cases it is not known which type of mine was encountered. Despite these remarks, the UXO-encounters offer a good indication of the amount of mines still present in the wider area.

Contacts
Netherlands Enterprise Agency (RVO.nl)
Croeselaan 15 | 3521 BJ | Utrecht
P.O. Box 8242 | 3503 RE | Utrecht
www.rvo.nl / http://english.rvo.nl

Netherlands Enterprise Agency (RVO.nl) | March 2017