Netherlands Enterprise Agency

UXO Desk Study -Unexploded Ordnance-

Hollandse Kust (west) Wind Farm Zone

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UXO Desk Study

Unexploded Ordnance

Site Data Hollandse Kust (west) Wind Farm Zone (HKWWFZ)

73065 / RO-180140 version 3.0
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UXO Desk Study

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Site Data Hollandse Kust (west) Wind Farm Zone (HKWWFZ)

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SUMMARY

This unexploded ordnance (UXO) desk study is part of the site data on Hollandse Kust (west) Wind Farm Zone. This UXO desk study consists of a historical research and a UXO risk assessment.

Historical research

The Hollandse Kust (west) Wind Farm Zone and its surrounding areas were the scene of many war related activities in World War I and World War II. Due to these events the entire Hollandse Kust (west) Wind Farm Zone is to be considered a UXO risk area. The UXO items considered most likely to be present within the investigation area are shown in the overview below. Note that the overview shows the expected likelihood of presence of generic UXO types within the site based on the evidence gathered about potential UXO sources. See Table 5 for the used definitions of terminology for the likelihood of presence.

Type of UXO	Calibres	Likelihood of presence	Confidence level	Remarks
Aerial bombs	All possible calibres, including but not limited to 4, 25, 30, 40, 100, 250, 500, 1,000 lbs	Highly likely	High	Information on attacks on shipping and jettisons in the vicinity available. Encountered UXO from aerial bombs reinforce this conclusion.
Rockets	3 inch air-to-ground with 60 lbs SAP warhead	Possible	High	Evidence of attacks on shipping.
Naval mines (contact)	E-Mine EMC mine	Likely	Very high	Minefields from WWI and WWII containing significant amounts of moored mines were present in and near the area of investigation.
Naval mines (ground, ferrous)	Mark XIV Mark XVII	Highly unlikely	Very high	No ground minefields situated in the vicinity of the area of investigation.
Naval mines (ground, non-ferrous)	LMA LMB	Highly unlikely	Very high	No LMA or LMB minefields situated in the vicinity of the area of investigation.
Artillery shells (Flak)	Possible calibres include 2 cm, 3.7 cm, 5 cm, 7.5 cm, 8.8 cm, 10.5 cm (German)	Unlikely	Very high	The area of investigation lies outside the range of coastal Flak positions. Only shells from Flak on board of ships could be left behind. This renders the presence of UXO from AAA remote.
Artillery shells (coastal artillery)	15 up to 28 cm (Dutch/German)	Highly unlikely	Very high	The area of investigation is out of range of coastal artillery. One artillery shell was encountered in the direct vicinity of the AOI, but the relation between the coastal guns and this encounter cannot be proven.
Aircraft cannon shells	20 mm (including incendiary, HE, AP)	Possible	High	Evidence of attacks on shipping in the direct vicinity of the area of investigation.
Torpedoes	Unknown	Unlikely	Moderate	Evidence of aerial attacks with torpedoes on shipping in the wider vicinity. No torpedoes have been encountered in the direct vicinity of the area of investigation.
Depth charges	Unknown	Possible	Moderate	Evidence of aerial attacks with depth charges on shipping in the wider vicinity.

Type of UXO	Calibres	Likelihood of presence	Confidence level	Remarks
				UXO from depth charges have been encountered in the area of investigation.

UXO Risk Assessment
In dynamic sediment conditions, UXO items are likely to become buried. UXO burial is predominantly due to one or a combination of three mechanisms: burial on impact, scour and bedform migration. Due to the water depths in the area of investigation burial on impact will not have occurred.

Detailed information on seabed mobility in the area of investigation is not yet available. A detailed morphology study will be undertaken by RVO.nl at a later stage, in which UXO burial will also be considered. The preliminary Maximum Burial Depth (MBD) is assessed to be 5.7 m, rounded off to 6 m. This assessment was based upon the morphological information available in the Noordzeeloket. It is recommended to reassess the UXO burial depths after the seabed mobility study has become available. Seabed mobility studies are very important to assess the possible depth of the UXO below the seabed.

Human activity may have a significant impact on UXO migration. Especially dredging and fishing activities have the capacity to move items of UXO. It is not possible to quantify the UXO migration due to human interaction. Therefore it is recommended to exclude human interaction in the ALARP (as low as reasonably practicable) certificates because of the risk of a UXO unintentionally being dragged into the cleared areas by fisherman. This migration factor is part of the baseline residual risk. 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 two years.

The conducted historical research has shown that several calibres of aerial bombs, naval mines and torpedoes and depth charges could be present within the investigation area. The possible effects of a detonation on vessels, equipment, personnel, and surroundings may form an intolerable risk. The Working Conditions Legislation requires mitigation measures to reduce the risks and ensure a safe working environment for all personnel involved. It is recommended to reduce the risks to a level that is considered as low as reasonably practicable (ALARP). It is recommended to investigate the possible presence of UXO by performing a UXO geophysical survey prior to any intrusive works. The mitigation measures consist of UXO survey, identification of potential UXO objects and disposal of actual UXO objects.

Magnetometry is generally considered the most reliable and common method of UXO geophysical survey. The provisional magnetometer (MAG) threshold is set on 50 kg ferrous mass. This threshold is sufficient to detect all UXO items that pose a threat for installation operations. The risks will be mitigated sufficiently by using the recommended threshold.

The required detection range for UXO is to the intended intrusion depth +0.5m (inter-array cables) or the assessed preliminary MDB (turbine foundations). Therefore the maximum required detection range is assessed to be approximately 5 m below seabed. The maximum detection range will be relative to the top of the crests of the sand waves.

It is mandated by the Dutch legislation (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. On completion of the data acquisition the detection range threshold determined during validation,

together with the sensor altitudes achieved is used to QC the survey data and to check for achieved detection depths below seabed and ‘coverage achieved’.
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 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.

It Is recommended to adopt a avoidance strategy where possible. In this case standoff distances are implemented around all geophysical survey anomalies above the applicable detection threshold (so called targets) that not yet have been confirmed as non-UXO or UXO through investigation by diver or ROV. Thus, the risk of a detonation caused by intrusive activities will be prevented, if the object proves to be UXO.

Where magnetic or acoustic anomalies above the threshold level are encountered during the UXO survey rerouting of inter-array cables within the cable installation corridors or repositioning of the turbine locations is typically the first mitigation measure considered[1]. For avoidance purposes chapter 14 provides the formulas for calculating standoff distances to encountered anomalies. If avoidance proves impossible identification, removal of confirmed non-UXO and disposal of identified UXO is required.

1 Avoidance may be a cost effective mitigation measure as it will limit the amount of anomalies that meet the threshold criteria (targets) that need to be identified during a UXO identification campaign.

SAMENVATTING

Deze studie is onderdeel van de site data voor het windgebied Hollandse Kust (west). De bureaustudie bestaat uit een historisch vooronderzoek en een risicoanalyse.

Historisch vooronderzoek
In het windgebied Hollandse Kust (west) en de omgeving daarvan hebben zich in de Tweede Wereldoorlog diverse oorlogshandelingen voltrokken. Ten gevolge van deze oorlogshandelingen moet het gehele gebied als verdacht gebied worden beschouwd. De soorten Niet Gesprongen Explosieven (NGE) die mogelijk zijn achtergebleven zijn weergegeven in onderstaande tabel. Opgemerkt wordt dat in de tabel de waarschijnlijkheid van aanwezigheid van de verschillende soorten NGE is weergegeven. Deze waarschijnlijkheid is gebaseerd op het verzamelde historische feitenmateriaal. Zie onderstaande tabel voor de definities van de gebruikte categorieën "Waarschijnlijkheid van aanwezigheid".

Soort NGE	Kalibers	Waarschijnlijkheid van aanwezigheid	Zekerheid	Opmerkingen
Geallieerde vliegtuigbommen	Alle mogelijke kalibers zoals 4, 25, 30, 40, 100, 250, 500, 1,000 lbs	Zeer waarschijnlijk	Hoog	Overtuigend bewijs voor luchtaanvallen op schepen en noodafworpen. Dit wordt bevestigd door het aantal in de omgeving aangetroffen vliegtuigbommen.
Raketten	3 inch lucht grond raket met 60 lbs SAP gevechtskop	Aannemelijk	Hoog	Bewijs voor luchtaanvallen op schepen en konvooien.
Zeemijnen (contact)	E-Mijn EMC mijn	Waarschijnlijk	Zeer hoog	Zowel in de Eerste als Tweede Wereldoorlog bevonden zich mijnenvelden met aanzienlijke aantallen mijnen in en nabij het onderzoeksgebied.
Zeemijnen (grondmijnen, ferro)	Mark XIV Mark XVII	Onwaarschijnlijk	Zeer hoog	In de nabijheid van het onderzoeksgebied waren geen mijnenvelden met ferro grondmijnen aanwezig.
Zeemijnen (grondmijnen, non-ferro)	LMA LMB	Onwaarschijnlijk	Zeer hoog	In de nabijheid van het onderzoeksgebied waren geen mijnenvelden met non-ferro grondmijnen aanwezig.
Artilleriegranaten (Flak)	Kalibers 2 cm, 3.7 cm, 5 cm, 7.5 cm, 8.8 cm, 10.5 cm (Duits)	Niet aannemelijk	Zeer hoog	Het onderzoeksgebied bevindt zich buiten bereik van het luchtdoelgeschut op de kust. Alleen granaten van Flak op schepen kunnen zijn achtergebleven.
Artilleriegranaten (kust geschut)	15 up to 28 cm (Dutch/German)	Onwaarschijnlijk	Zeer hoog	Het onderzoeksgebied bevindt zich buiten bereik van het kust geschut. In de nabijheid van het onderzoeksgebied is één artilleriegranaat aangetroffen. De relatie met het kustgeschut kan echter niet worden aangetoond.
Granaten van boordgeschut	20 mm (brand, HE, AP)	Aannemelijk	Hoog	Bewijs voor luchtaanvallen op schepen en konvooien.
Torpedo's	Onbekend	Niet aannemelijk	Matig	Er is bewijs voor luchtaanvallen op schepen en konvooien met

Soort NGE	Kalibers	Waarschijnlijkheid van aanwezigheid	Zekerheid	Opmerkingen
				torpedo's in de omgeving van het onderzoeksgebied. Er zijn geen torpedo's aangetroffen in het onderzoeksgebied.
Dieptebommen	Onbekend	Aannemelijk	Matig	Er is bewijs voor luchtaanvallen op schepen en konvooien met dieptebommen in de omgeving van het onderzoeksgebied. Er zijn dieptebommen aangetroffen in het onderzoeksgebied.

NGE Risico Analyse

In dynamische morfologische omstandigheden, zoals aanwezig in de Noordzee, is het waarschijnlijk dat NGE begraven raken. Het begraven raken van NGE kan worden veroorzaakt door één of een combinatie van drie mechanismen: penetratie bij inslag, begraving door erosie en migratie van zandgolven. Vanwege de waterdiepte zal in het onderzoeksgebied van penetratie bij inslag geen sprake zijn. Voor het vaststellen van de verticale afbakening is geen studie naar de mobiliteit van de zeebodem beschikbaar. Op basis van de beschikbare gegevens is de verticale afbakening voorlopig vastgesteld op 5,7 m, afgerond 6 m. Na het beschikbaar komen van de resultaten van de studie naar de mobiliteit van de zeebodem dient de verticale afbakening te worden geverifieerd.

Menselijke activiteiten kunnen een significant effect hebben op de migratie van NGE. Vooral baggerwerkzaamheden en visserij hebben een grote invloed. Het risico op migratie van NGE ten gevolge van menselijk handelen kan niet worden gekwantificeerd. Het resterende risico wordt gezien als restrisico. De houdbaarheid van de detectiedata wordt op basis van de beschikbare gegevens ingeschat op circa 2 jaar.

Het mogelijke effect van een detonatie op schepen, personeel en omgeving vormt een ontoelaatbaar risico. Om dit risico tot aanvaarbare proporties terug te brengen zijn mitigerende maatregelen nodig. Aanbevolen wordt om de bron van het risico aan te pakken door het uitvoeren van een NGE-bodemonderzoek voorafgaand aan de uitvoering van grondroerende werkzaamheden.

De voorlopige drempelwaarde voor de magnetometer (MAG) detectie is vastgesteld op 50 kg ferrohoudende massa. Deze drempelwaarde is toereikend om de mogelijk achtergebleven NGE te detecteren.

Het vereiste detectiebereik is gelijk aan de diepte van de grondroerende werkzaamheden vermeerderd met 0,5 m veiligheidsmarge of de vastgestelde verticale afbakening.

In gevolge het Werkveldspecifiek certificatieschema voor het Systeemcertificaat Opsporen Conventionele Explosieven (WSCS-OCE) dient alle in te zetten detectieapparatuur te worden gevalideerd. Het doel van de validatie is het vaststellen van het maximale detectiebereik waarop objecten met een ferrohoudende massa overeenkomstig de vastgestelde drempelwaarde kunnen worden gedetecteerd. Het vastgestelde meetbereik kan vervolgens worden gebruikt om na het verzamelen van de data de detectiediepte onder de zeebodem en de dekkingsgraad te controleren.

De grootte van de te detecteren gebieden is afhankelijk van het ontwerp, de gekozen installatiemethoden en de geotechnische parameters. De grootte van de te detecteren gebieden dient daarom te worden vastgesteld in een additionele risicoanalyse gebaseerd op het (voorlopige) ontwerp van het windgebied en de relevante gebiedspecifieke informatie.

Aanbevolen wordt om waar mogelijk een vermijdingsstrategie te hanteren. Hierbij worden veiligheidsafstanden gehanteerd rondom anomalieën die aan de vastgestelde drempelwaarden voldoen en die nog niet zijn geïdentificeerd. Op deze manier wordt het risico op een detonatie weggenomen indien de betreffende anomalie een NGE blijkt te zijn.

1 GENERAL INFORMATION

The Netherlands Ministry of Economic Affairs has requested "The Netherlands Enterprise Agency" to prepare and collect all site data required for the development of offshore wind farms in Hollandse Kust (west) Wind Farm Zone. In this context The Netherlands Enterprise Agency (RVO.nl) has commissioned this UXO desk study. In this chapter a general introduction on offshore wind energy is given. Subsequently the area of research for this UXO desk study, the purpose, and main objectives are detailed.

1.1 MOTIVE

The Dutch Government has developed a systematic framework under which offshore wind farm zones are designated. Any location outside these wind farm zones is not eligible to receive a permit. Within the designated wind farm zones the government designates the specific sites where wind farms can be constructed using a so-called Wind Farm Site Decision ('Kavelbesluit'). This contains conditions for building and operating a wind farm on a specific site. The Dutch Government provides relevant site data and Dutch transmission system operator TenneT is responsible for grid connection. Winners of the site development tenders will be granted a permit to build a wind farm according to the Offshore Wind Energy Act (Wet Windenergie op zee) and will be offered a grid connection to the main land. The Ministry of Economic Affairs and Climate Policy provides site data, which can be used for the preparation of bids for these tenders.

In light of the success of the road map towards 4,500 MW (2015-2019), the Ministry has published a new roadmap to 2030. This calls for the deployment of an additional 7,000 MW of offshore wind by 2030. In total, the additional MW's planned would bring the Netherlands' total offshore wind capacity to 11,500 MW. RVO.nl and TenneT have already started preparations for the first Wind Farm Zone to be developed under the 2030 roadmap, Hollandse Kust (west). The Government foresees 1.4 GW in this Wind Farm Zone.

The Netherlands Enterprise Agency has been requested to prepare and collect site data required for commercial developers to prepare a competitive bid. As part of the future Permit Call for Tender document(s), the participants will receive information packages in which detailed information on the offshore site is included. Detailed information on the risks for UXO's at the site will be part of this information package.

1.2 AREA OF INVESTIGATION

The HKW Wind Farm Zone is located off the west coast of the Netherlands. The area of investigation of this desk study is shown in Figure 1.

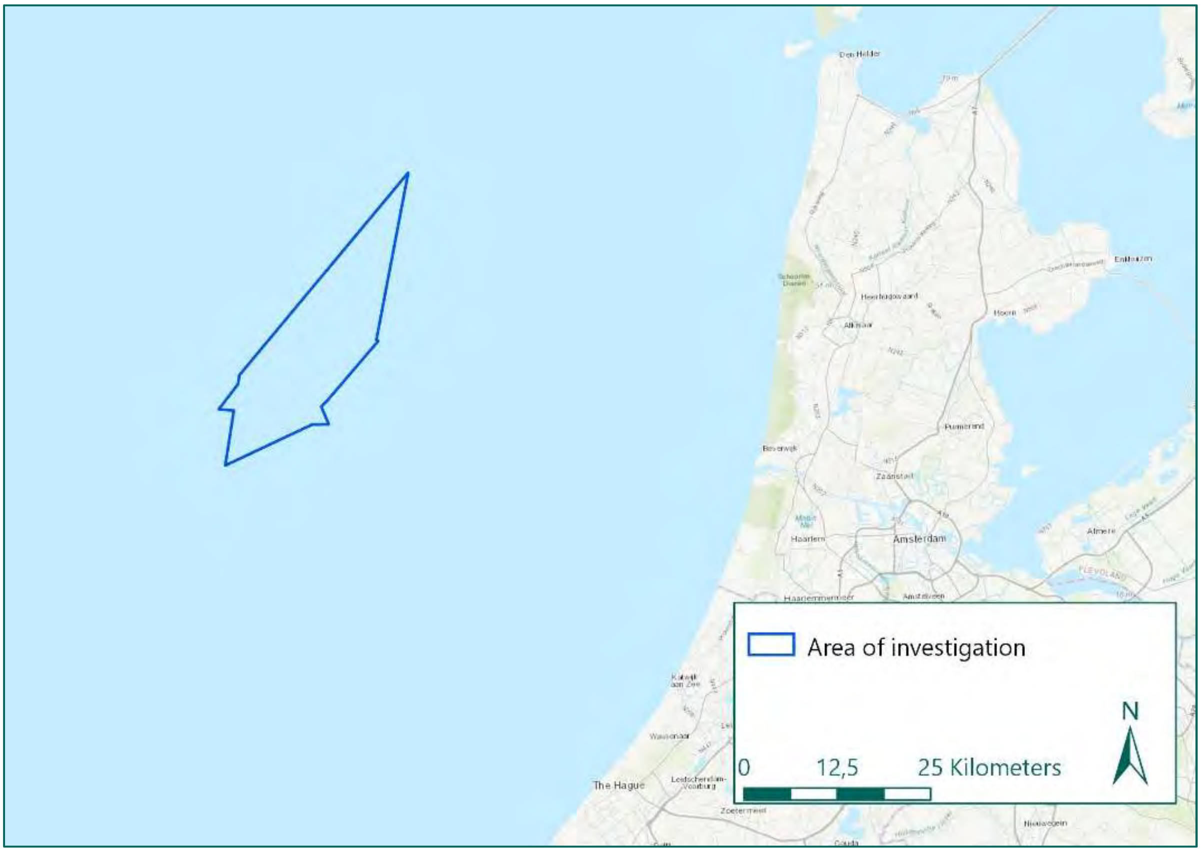

Figure 1: Area of investigation HKW Wind Farm Zone (source: RVO.nl).

1.3 PURPOSE AND MAIN OBJECTIVES

The purpose of the UXO desk study is to detail the areas within the HKW Wind Farm Zone which present an increased risk of encountering unexploded ordnance (UXO).

The main objectives of this study are:

1. Identification of possible constraints for offshore wind farm related activities in the HKW Wind Farm Zone as a result of the possible presence of items of UXO.
2. Identification of areas within the HKW Wind Farm Zone that could preferably not be selected for the installation of offshore wind farms and/or cables.
3. Identifying the requirements from a UXO perspective that should be taken into account for:
    a. Determining the different concession zones in the wind farm zone.
    b. Carrying out safe geophysical & geotechnical investigations.
    c. Installation of wind turbine foundations.
    d. Installation of cables.

1.4 STRUCTURE OF THE REPORT

This report describes phase 1 (historical research) and phase 2 (UXO risk assessment) of the UXO risk management process. These phases are rendered within the red highlighted area within Figure 2. The full UXO risk management process is also described in Figure 2 (see Annex 1 for a larger image). The execution of the following phases of the UXO risk management process is the responsibility of the future developer.

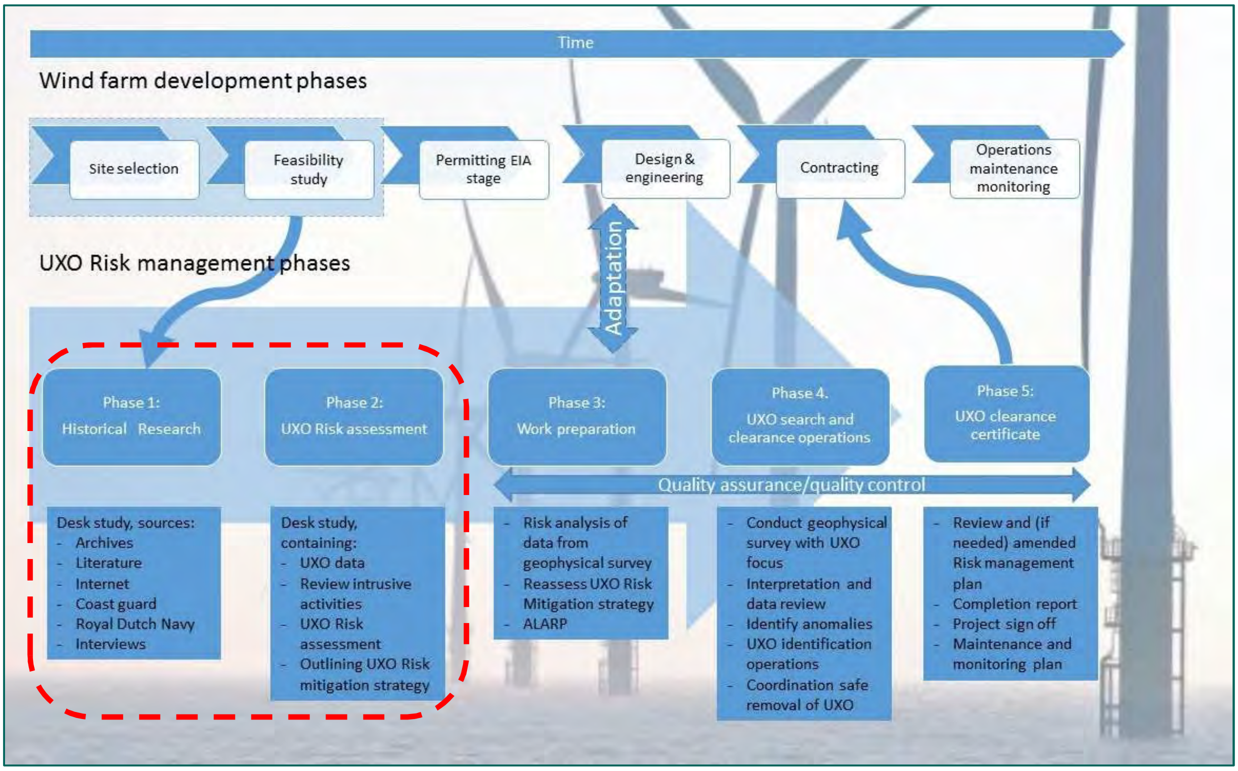

Figure 2: UXO risk management phases.

This historical research consists of two main components: 1.) identification and appraising the relevancy of the available historical sources and 2.) identifying the relevant war related events and their consequences for the area of investigation. An overview of the chapters in each part is given in Table 1. A glossary of terms, additional figures and the elaboration of consulted sources are included within the Annexes.

Phases of the UXO risk management process	Chapters
Phase 1: Historical Research	- Chapter 2: Assessment of historical sources - Chapter 3: War related events - Chapter 4: Gaps in knowledge and UXO risk area
Phase 2: UXO Risk Assessment	- Chapter 5: UXO burial assessment - Chapter 6: UXO migration assessment - Chapter 7: Hazards of UXO likely to be encountered - Chapter 8: Effects of detonations - Chapter 9: Installation methods - Chapter 10: UXO risk assessment - Chapter 11: Outlining the UXO mitigation strategy - Chapter 12: UXO survey methodologies - Chapter 13: Threshold levels to be applied - Chapter 14: Standoff distances - Chapter 15: UXO survey recommendation for the geotechnical survey - Chapter 16: Input for project plan - Chapter 17: Conclusions - Chapter 18: Annexes

Table 1: The included phases of the UXO risk management and related chapters in this report.

1.5 GLOSSARY OF TERMS

This report contains a number of terms and abbreviations. Table 2 provides an alphabetical list of terms/abbreviations with the definitions for those terms.

Term	Definition	Term	Definition
AAA	Anti-Aircraft Artillery	m	metre
AC	Alternating Current	M	Margin based on the dimensions of the UXO to be expected
ALARP	As Low As Reasonably Practicable	MAG	MAgnetic Gradiometer
AP	Armour Piercing	MBD	Maximum Burial Depth
ASA	Accuracy of the Sample Apparatus (ASA).	MBES	Multi Beam Echo Sounder
BAMA	Bundesarchiv – Abteilung Militärarchiv (in Freiburg)	MCM	Mine Counter Measure
BD	Backhoe Dredger	MIPI	Military Intelligence Photographic Interpretation
BI	Burial on Impact	mm	millimetre
BS	Burial due to Scour	MTL	Master Target List
Cm	Centimeter	mV	milliVolt
CPT	Cone Penetration Test	MW	Mega Watt
CSD	Cutter Suction Dredger	n.a.	not applicable
D	Depth of dredging	NAP	Nieuw Amsterdams Peil
DL	Depth of Lowering	NARA	The National Archives Records Administration
DP	Dynamic Positioning	NEN	NEderlandse Norm
DS	Desk Study	NEW	Net Explosive Weight
DT	Dynamic Tracking	NM	Nautical Mile
DV	Depth Variation at landfall	NMRL	Non Mobile Reference Level
EEZ	Dutch Exclusive Economic Zone	NMZ	Nautical Mile Zone
EIA	Environmental Impact Assessment	OSPAR	Oslo and Paris Convention
EM	Electromagnetic	PDH	Positional accuracy Drag Head
EMC	Einheitsmine C (German moored contact mine)	PLGR	Pre Lay Grapnel Run
EO	Explosive Ordnance	PMTL	Preliminary Master Target List
EOD	Explosive Ordnance Disposal	PT	Positional accuracy Target
FLAK	Flugabwehrkanone (anti-aircraft gun)	QA/QC	Quality Assurance/Quality Control
GIS	Geographical Information System	R	Radius
HB	Height of Bedform	RHIB	Rigid-Hulled Inflatable Boat
HDD	Horizontal Directional Drilling	RN	Royal Navy
HE	High Explosive	ROV	Remotely Operated Vehicle
HKNWFZ	Hollandse Kust (noord) Wind Farm Zone	RPL	Route Positions List
HKN	Hollandse Kust (noord)	S	Gradient of the side slopes of the dredged profiles that will form
HKW	Hollandse Kust (west)	SAP	Semi Armour Piercing
HMS	His Majesty's Ship	SBP	Sub-Bottom Profiler
HS	Height of Sediment placement	SIT	Surrogate Item Trial
HSF	Hull Shock Factor	SQRA	Semi Quantitative Risk Assessment
HW	mean High Water	SS	Steam Ship

Term	Definition	Term	Definition
H&S	Health and Safety	SSS	Side Scan Sonar
IIZ	Intrusion Influence Zone (the zone influenced by the energy of the cable burial tool)	TNA	The National Archives (in London)
IMCA	International Marine Contractors Association	TNT	TriNitroToluene
IMW	Imperial War Museum	TSHD	Trailer Suction Hopper Dredger
JS	Jetting Sledge	TW	Trench Width (planned)
kg	Kilogram	UKHO	United Kingdom Hydrographic Office
km	Kilometre	UMB	U-bootmine B (German moored contact mine against submarines)
KMA	Küstenmine-A (coastal mine A)	USA	United States of America
KP	Kilometre Point	UTM	Universal Transverse Mercator
KSF	Keel Shock Factor	UXO	Unexploded Ordnance
kts	Knots	VC	VirbroCore
kV	kilo Volt	VI	Vertical Injector
LAC	Laying Accuracy Cable (relative to the planned RPL)	VKA	Voorkeursalternatief (preferred option)
LAT	Lowest Astronomical Tide	WSCS-OCE	
lbs	Pound (weight)	WT	Width of the Trencher
LMA	Luftmine A (German ground mine)	WWI	World War One
LMB	Luftmine B (German non-ferrous ground mine)	WWII	World War Two
LW	mean Low Water		

Table 2: Glossary of terms.

Phase 1: Historical research

2 APPRAISAL OF HISTORICAL SOURCES

This chapter describes the consulted sources. Detailed information extracted from each source is included within the Annexes. Information extracted from the sources, results in an overview of relevant war events. These events are the starting point for the review and analyses of sources in chapter 3 of this historical research.

2.1 SOURCES

Detailed historical research is conducted for this UXO desk study. Source material from the following sources has been consulted:

Literature

An overview of used literature can be found in Annex 3. A variety of local, national and international books were consulted. These books have been studied for descriptions and events which might be relevant to the area of investigation. The resulting events are shown in chronological order in the tables in Annex 3. The references (book and page) for each event are included in the tables.

Crashed aircraft

The Dutch Air War Study Group 1939-1945 (Studiegroep Luchtoorlog 1939-1945) maintains an online database of all military airplane losses in the Netherlands during WWII. This record is checked and the results are presented in Annex 3.

Ship wrecks

Information regarding the presence of ship wrecks is retrieved from the naval charts and the wreck register from the Hydrographic Service.

Marinemuseum, Den Helder

The Navy Museum ('Marinemuseum') holds a collection of Royal Netherlands Navy maps and charts. The collection includes maps of post-war minesweeping operations. The relevant information is added in Annex 4.

Noordzeeloket

The North Sea Desk ('Noordzeeloket') is a cooperation between all Ministries with tasks and responsibilities on the North Sea. The website of this cooperation provides different kinds of information, including the map 'Military Use', see Annex 4.

Hydrographical Service, Royal Netherlands Navy

The Sea Map of the Hydrographical Service of the Royal Netherlands Navy were consulted. This map also indicates known wreck sites, wreck remains and foul areas, see Annex 4.

Bundesarchiv- Abteilung Militärarchiv (BAMA) in Freiburg, Germany

A variety of records form the Bundesarchiv- Abteilung Militärarchiv in Freiburg were consulted. This section of the German national archive preserves records of the German army from 1495 till 1990. Copies of war diaries, maps, correspondence and aerial photographs are part of the records that were used for this historical research. The results can be found in Annex 5.

The National Archives (TNA), London

A variety of data from The National Archives in London were consulted, comprising of Operations Record Books of the British Royal Air Force units such as Second Tactical Air Force, Fighter Command, Coastal Command and Bomber Command.

These information sources were checked for bombardments or other aerial war events that took place within or near the area of investigation. The results are presented in Annex 6.

United Kingdom Hydrographic Office (UKHO), Taunton

The UKHO has a large collection of historical maps and charts, including charts of minefields off the Dutch coast. These maps were consulted, but no relevant results have been obtained.

The National Archives Records Administration (NARA), Washington D.C.

The collection of records from the U.S. National Archives and Records Administration was consulted. Sources obtained include mission reports of the American 8th Air Force, aerial photographs, strike photos, and military intelligence reports. The consultation of NARA has provided relevant data for the area of investigation, which can be found in Annex 7.

Post-war UXO Clearance

The area of investigation is situated in the North Sea, 12 Nautical Miles off the Dutch coast. Therefore, the UXO-related interventions of the Royal Netherlands Navy[2] and the database of the OSPAR Commission[3] were consulted. The results of these consultations can be found in Annex 8.

Previous UXO Research

Earlier preformed research has been conducted nearby the area of interest. These studies were checked for relevant information. Results are described in Annex 9.

2.2 WAR RELATED EVENTS RELEVANT FOR THE AREA OF INVESTIGATION

Based upon the consultation of the above mentioned historical sources the following war-related events possibly relevant for the area of investigation are identified:

- German and allied minelaying operations,
- Aerial warfare,
- Naval warfare,
- Wrecks of surface vessels and airplanes,
- Post-war disposal of UXO.

The events mentioned above, happened during WWI and WWII, or in the aftermath of these conflicts. These possible relevant war events are analysed in Chapter 3 in order to determine the likelihood of presence of UXO in the area of investigation due to these events.

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2 The Royal Netherlands 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.

3 The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR-convention) provides a framework for reporting encounters with conventional and chemical munitions in the OSPAR maritime area.

3 WAR RELATED EVENTS

This chapter discusses the different war related events that possible led to the presence of UXO in or near the area of investigation. As stated in paragraph 2.2, the war related events are mostly related to World War I and II, or the aftermath of these conflicts. The war related activities are analysed per event for both wars, followed by the analyses of post-war UXO-dumping and artillery exercises.

3.1 NAVAL MINES

Naval mines were used during both World Wars and could have been used as an offensive or defensive weapon. During WWI, the North Sea was a major theatre of the war. The British Grand Fleet took position against the German High Seas Fleet. Britain's larger fleet could maintain a blockade of Germany, cutting it off from overseas trade and resources. The German fleet remained mostly in the harbours behind a screen of mines, occasionally attempting to lure the British fleet into battle.

During WWII, German and allied forces laid various defensive minefields along their shores. The German offshore minefields were part of the coastal defence. The belligerent parties also laid mines along each other's convoy routes and harbours. Initially, contact mines were employed, usually tethered at the end of a cable just below the surface of the water. By the beginning of WWII, most nations had developed mines that could be dropped from aircraft, making it possible to lay them in enemy harbours. The following paragraphs describe the German and allied minelaying activities, and the post-war clearance.

3.1.1 World War I: German minefields

Although the Netherlands remained neutral during World War I, this conflict also bears consequences for the area of investigation. The German Navy laid minefields near the Dutch coast during the First World War to protect their shipping routes. A large minefield was situated directly southwest of the area of investigation, see Figure 3. Research in the Bundesarchiv (Freiburg) yielded fragmented information about German World War I minefields. However, information regarding this minefield was not obtained. World War I minefields only contained moored mines. The German E-Mine, see Annex 2, was most common during WWI.

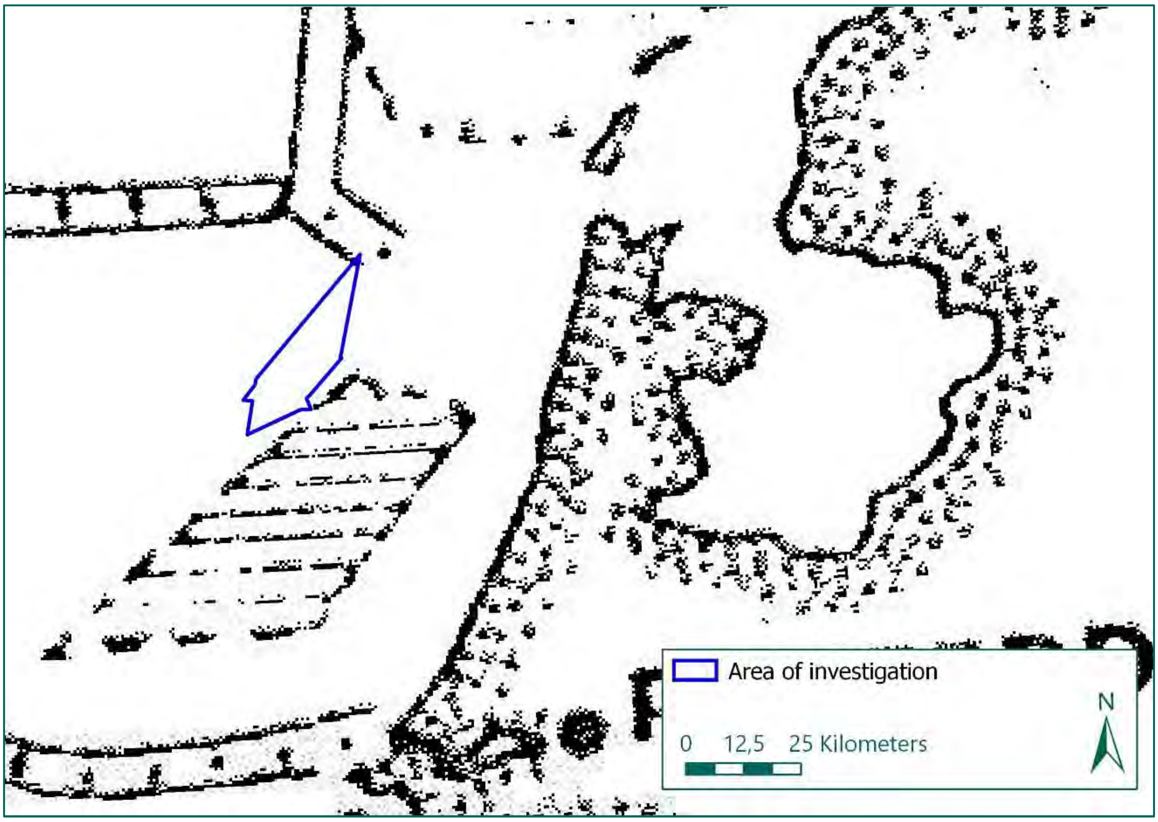


Figure 3: German WWI minefields near the area of investigation (source: CRO, see Annex 3).

During WWI approximately 430 German mines washed ashore the Dutch coast (see Annex 3). Since 2005, one moored contact mine was encountered in the vicinity of the area of investigation (see Annex 8). The specific type of the encountered mine is not reported, but this type of mine was used during World War I. While unsupported by historical sources, this mine might have been laid during World War I.

3.1.2 World War II: German minelaying

German minelaying in the North Sea commenced on 10 May 1940. German aircraft deployed magnetic mines (LMA and LMB mines, *Luftmine A & B*) in the IJmuiden harbour entrance. Four days later, German planes laid LMA and LMB mines just off the Dutch coast. Approximately 24 mines of each type were dropped in the zones near Texel, Den Helder and IJmuiden (see Annex 3). The exact position of the plants is not known.

A selection of naval minefield charts was consulted in the Bundesarchiv – Militärarchiv (see Annex 5). These charts provide a complete overview of all German laid minefields. The German minefields are indicated on a map, see Figure 4. Each minefield has its own number, which refers to an index that provides information about the quantity, type of mines, the date on which the field was laid, and the positional coordinates. An example is given in Figure 5.

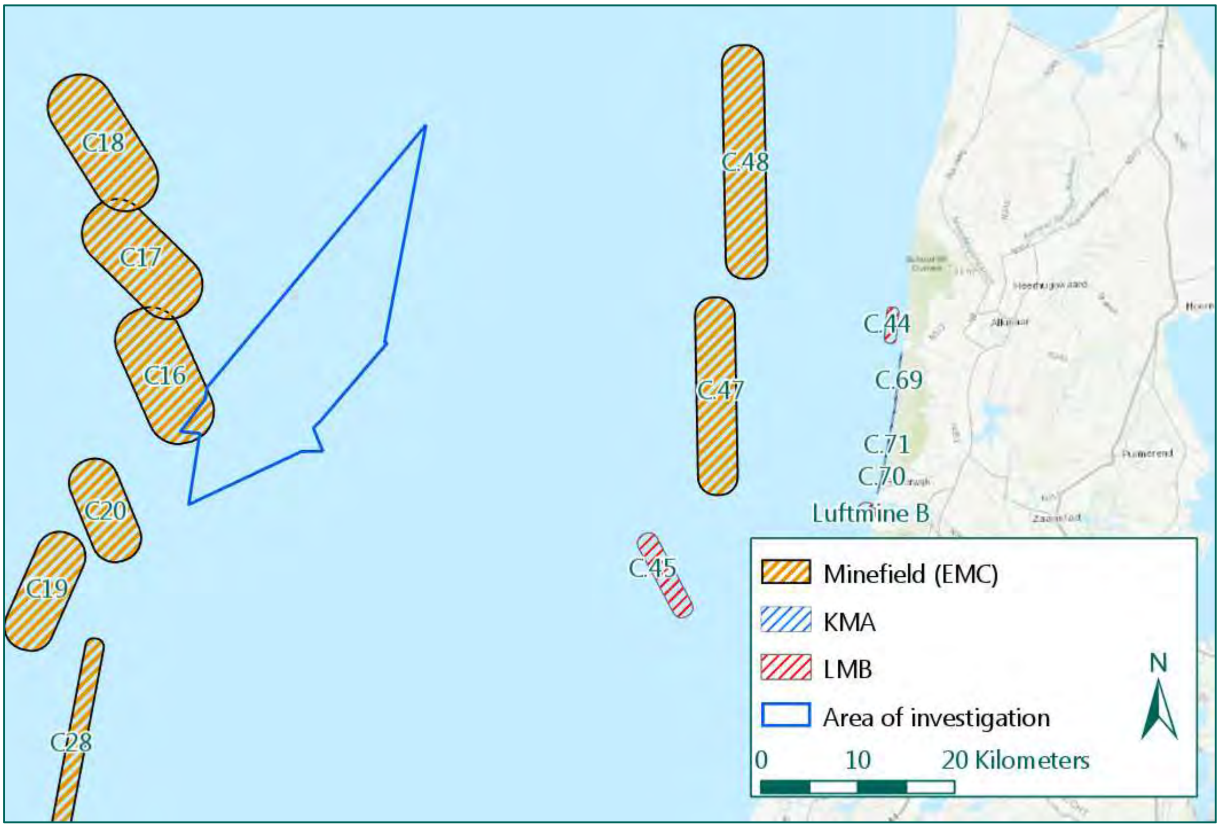


Figure 4: German Minelaying since 1 January 1942, excluding aircraft minelaying (Source: Annex 6, BAMA, ZA 5/50).

C16	SW-o	1/42	52 38.4 N 03 28.6 E 52 34.0 N 03 31.2 E	2	112 EMC		M	10	4	165	110 Fathoms mooring wire. With tombac sheathing.

Figure 5: Summary of German Minelaying (Source: Annex 6, BAMA, ZA 5/44).

Based on this map and charts, it appears that one German minefield was partly located in the area of investigation. This minefield consisted of 112 German EMC moored mines, laid in four parallel lines with 165 meters spacing. The accuracy of the plant was estimated to be 2 miles. This minefield may have caused the recent encounter of a moored mine near the area of investigation.

Since 2005 moored mines were not encountered in the area of investigation. This however does not entirely rule out the presence of moored naval mines. The buoyancy of moored mines enables these mines to migrate over significant distances when loose from their anchors, being moved by adverse weather, fishing activities or unintentionally being dragged during mine clearance operations[4] (also see paragraph 3.1.4). The proliferation of moored mines in the wider vicinity of the area of investigation is illustrated in Figure 6.

[4] The aim of the sweeping gear is to cut the mooring wires/cables, causing the mines to float to the surface, where the mines could easily be shot with cannon or rifle fire. If the wires/cables were not cut, but got snagged, mines could have been dragged into adjacent areas.

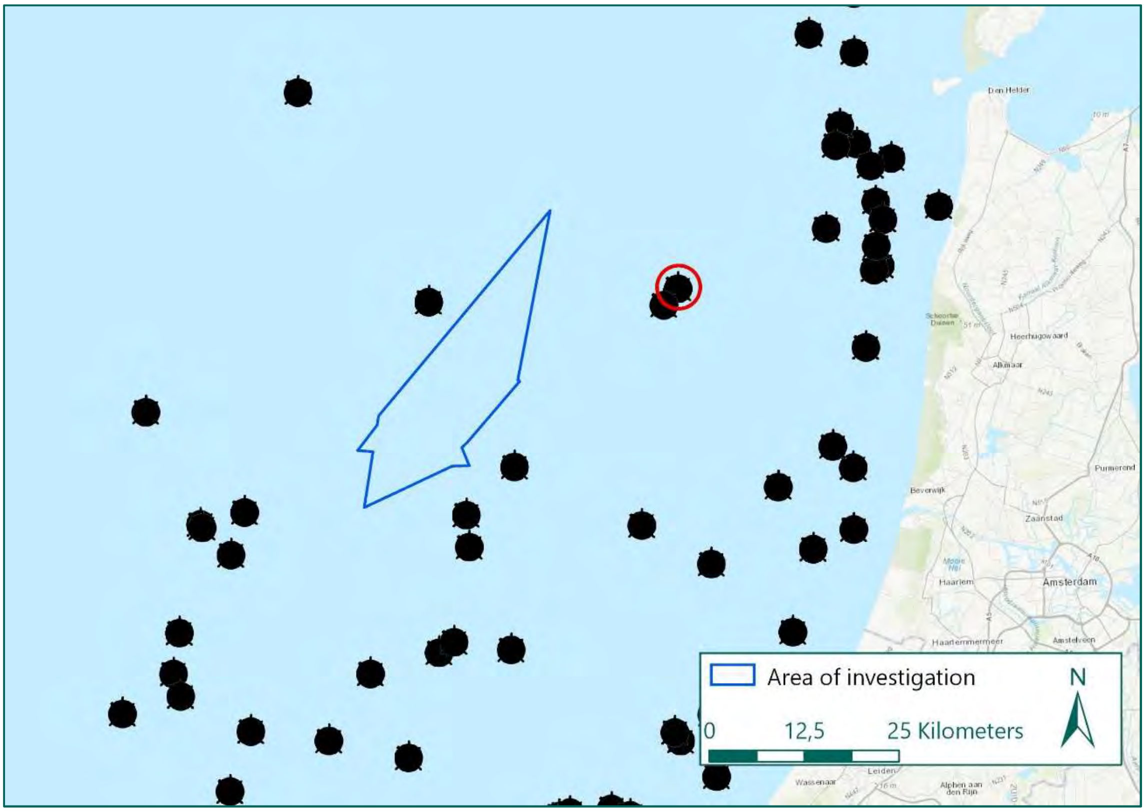


Figure 6: Naval mines near the area of investigation. The LMB mine is highlighted within the red circle (Source: RN Coast Guard).

Based on the historical sources, German contact mines from World War I and World War II may be left behind in the area of investigation.

3.1.3 World War II: British minelaying

The British navy and air force undertook several operations to lay minefields off the Dutch coast. Documentation on these operations has been consulted in The National Archives in Kew, London (see Annex 6). The majority of these operations took place near the shore, at a significant distance from the area of investigation. One British minefield however was planted approximately 15 kilometres east of the area of investigation. This minefield was planted by the destroyers HMS Intreprid and the HMS Impulsive to cover allied operations in the France during the German invasion in May 1940. A total of 60 Mk. XIV/XVII mines were laid in a zig-zag line extending for 3.5 miles from 52°42.2’N to 04°0.3’E at eight feet deep. This is specifically mentioned in documentation found in the National Archives (See Annex 6: ADM 234/560).

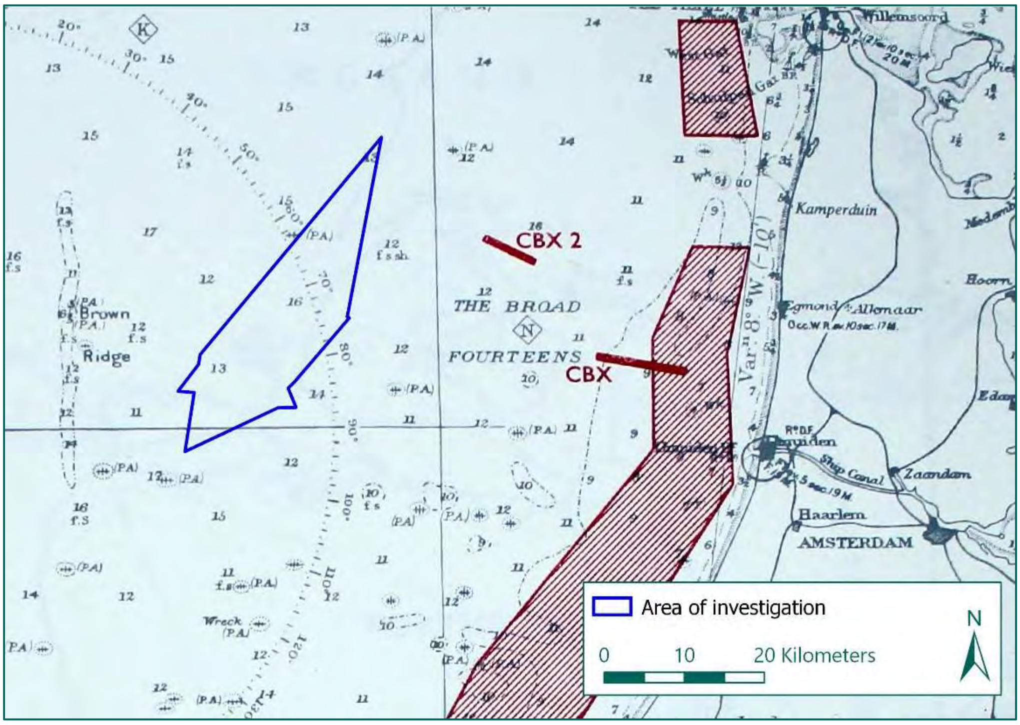


Figure 7: CBX 2 position (Source: TNA, ADM 243/561).

Recently, a moored contact mine was encountered and reported to the Coast Guard and the OSPAR commission (see Annex 8). The CBX minefield may be another cause of the presence of this mine. Since the exact types of mines encountered remains unknown, the relation between the UXO encounters and this minefield cannot be verified. The CBX 2 minefield is the only known British minefield near the area of investigation.

3.1.4 Post-war mine clearance

After World War I, a large effort was made to clear shipping lanes of naval mines (moored mines). It took several months and a fleet of minesweepers to clear the minefields. This 'clearing' was carried out by sweeping a cable with anchors below the water surface. The cable was dragged by two ships.

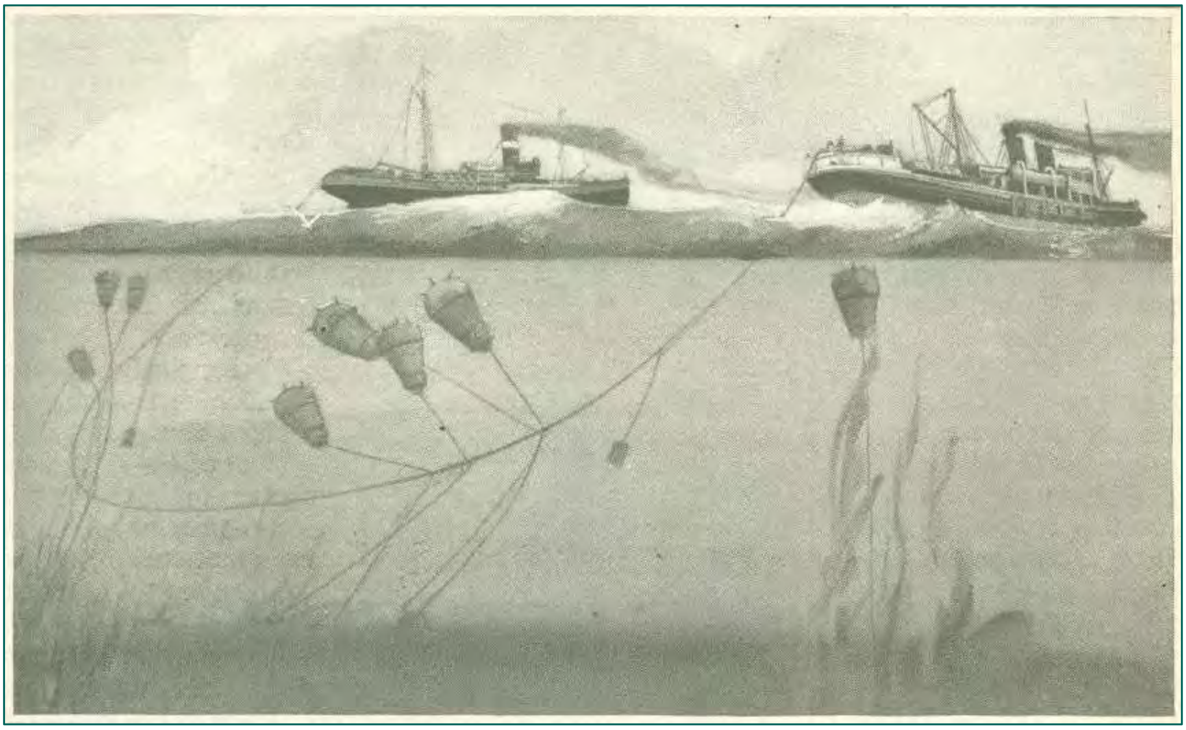


Figure 8: Post-WWI mine sweeping (Source: http://www.digitalhistoryproject.com/2012/06/submarine-mines-in-world-war-i-byleland.html).

Mines also 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 area of investigation is situated in the Dutch sweeping zone. Charts of the Marinemuseum (see Annex 4) show that a large part of the area of investigation was a designated danger area. Minesweeping was conducted with a variety of methods. Moored mines were usually swept with Oropesa sweeping gear.[5]

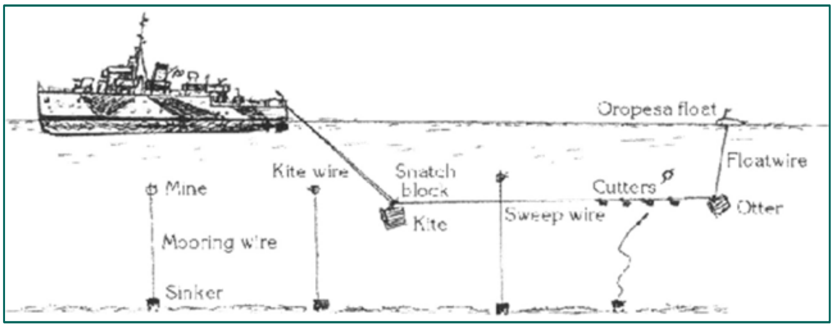


Figure 9: Oropesa sweeping (source: 'The 'Art' of Minesweeping', 27 May 2013, http://www.minesweepers.org.uk/sweeping.htm, consulted 6 December 2016).

The moorings of the mines were cut with cutters dragged on a wire behind a ship. Cutting the mooring wires/cables 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. The mines were not taken out of the sea. Ground mines were swept with acoustic hammer boxes, triggering the acoustic mines, or by magnetic sweeping gear to trigger magnetic mines.

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

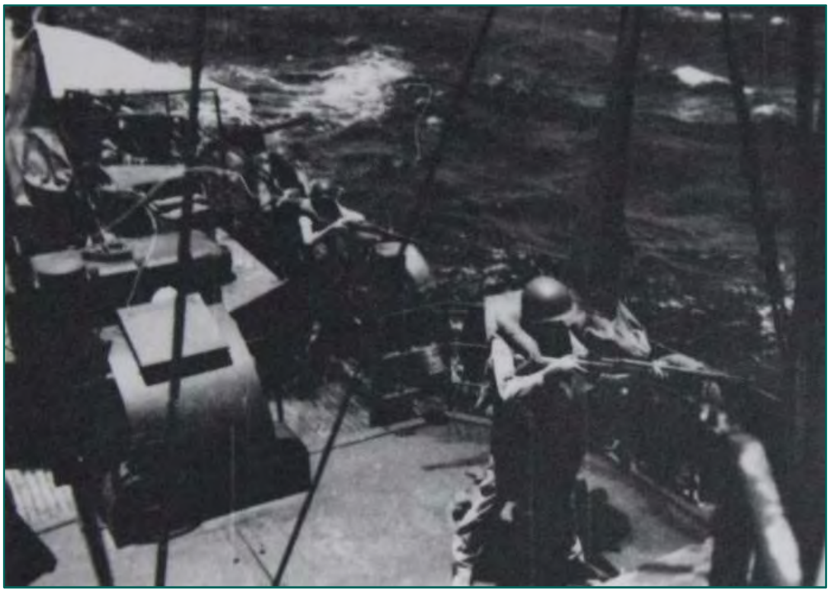


Figure 10: Mine disposal team preparing to fire their M1 Garand rifles on swept mines (Source: TNA, ADM 199/154).

The efficiency of minesweeping was poor. Despite intensive post-war clearance operations, the seabed is still littered with unexploded mines. Nowadays, fishermen and dredging vessels still encounter naval mines on a regular basis (see Annex 8). As a cause of clearance operations, tidal and other weather conditions, moored mines could break loose from their anchor and migrate. Furthermore, due to extensive trawling (bottom fishing) there is often no clear relation between the positions of encountered mines and the locations of historical minefields.

3.1.5 Conclusion on naval mines

Consultation of historical sources results in the conclusion that the area of investigation is situated outside known naval minefields from World War I and II. The only relevant minefield was laid directly adjacent to the area of investigation during World War I. Coast Guard and OSPAR documentation, shows the proliferation of moored naval mines in the wide vicinity of the area of investigation. Ground mines yield a lower risk of migrating owing to negative buoyancy, and the significant distance between the area of investigation and the known ground minefields (approximately 34 kilometres).

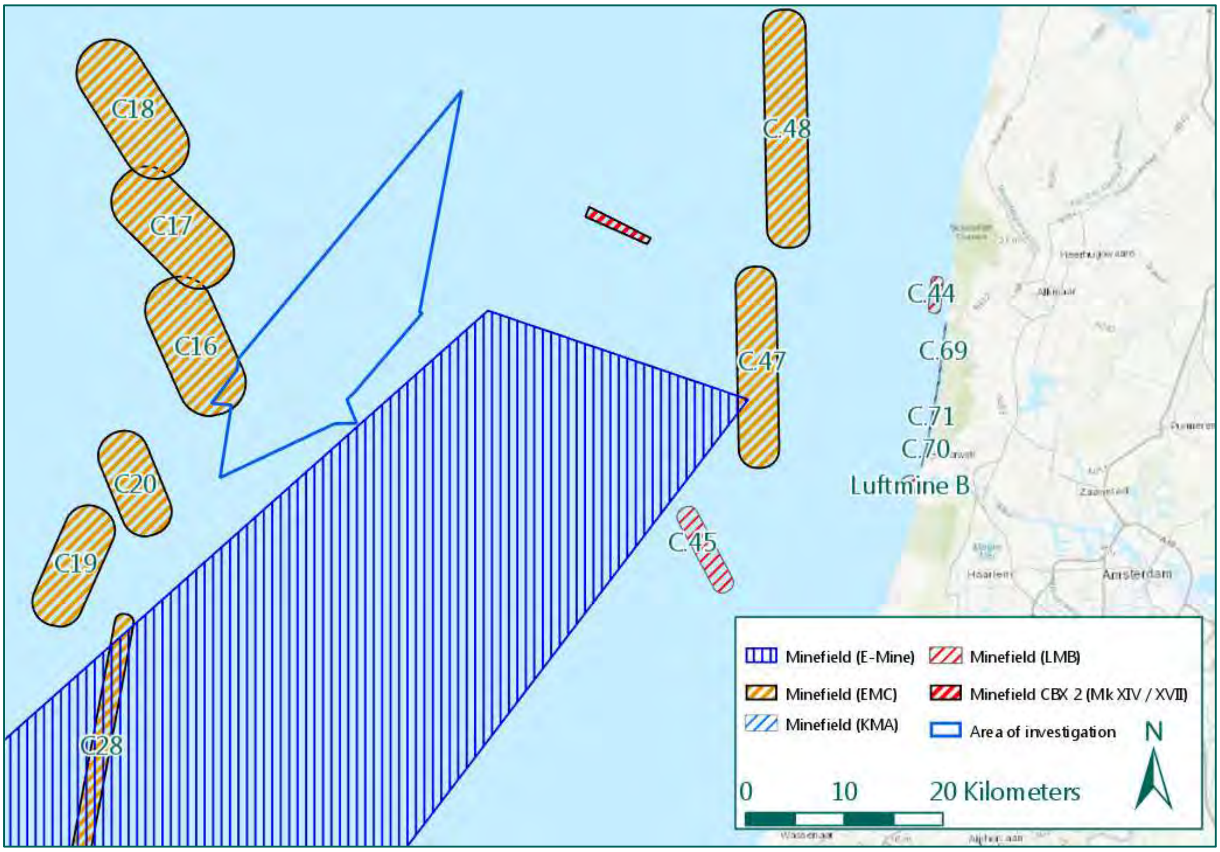


Figure 11: Minefields relevant for the area of investigation.

According to the historical sources, no minefields were situated inside the area of investigation. However, the distribution of naval mine encounters since 2005 (see figure 6) clearly shows that there no longer is a relation between the locations of former mine fields and the locations of naval mine encounters. The vicinity of a major World War I minefield and post war usage of the seabed (e.g. bottom fishing) may have been the root cause of this proliferation. The likelihood of presence of naval mines is defined in paragraph 4.2. It must be highlighted that this table is based on the minefields actually present in the area of investigation. According to the consulted historical sources, the types of mines mentioned in Table 4 are considered the most plausible types of mines to be present in the area of investigation. Moored mines are most likely to have lost their buoyancy and sunk on the seabed. Displacement of mines through trawling or other means is not included in these tables.

3.2 AERIAL WARFARE

Aerial Warfare was introduced during WWI and was further developed during WWII. Germany depended on an air force that was closely integrated with land and naval forces. Germany underestimated the advantage of fleets of strategic bombers and was late in appreciating the need to defend against allied strategic bombing. By contrast, Britain and the United States initially took an approach that greatly emphasized strategic bombing and to a lesser degree, tactical control of the battlefield by air, and adequate air defences. They both built a strategic force of large, long-range bombers that could carry the air war to the enemy’s homeland.

3.2.1 Flight paths of allied bomb raids

An around-the-clock campaign attacked German occupied territory, with British bombers at night and U.S. aircraft during the day. From 1942 onward, the intensity of the British bombing campaign against Germany and German occupied territory became less restrictive, increasingly targeting industrial sites and eventually civilian areas. By 1943, the United States had significantly reinforced these efforts.

The controversial fire bombings of Hamburg (1943), Dresden (1945), and other German cities followed. Depending on the target, allied bombers flew various routes over the North Sea and the Continent. An example of a flight path is given in Figure 12.

Navigation was not as developed as nowadays and formed a great challenge for the bomber crews. It occurred that pilots could not locate their primary or alternative targets. To avoid the risk of crash landing with bombs on board, bombers often jettisoned their bomb load in the North Sea on the way back to England. Besides that, bombers also jettisoned their bombs in case of an emergency, e.g. due to mechanical problems or damage by enemy anti-aircraft-artillery. In that case the bombs were jettisoned in order to reduce weight and increase the chance of reaching friendly territory. Bomb loads could be jettisoned in a safe or armed condition. Safe condition means the initiation device fitted within the bombs were not in their armed state. Specific information about the positions of these jettisons are often lacking, most logbooks simply state 'jettisoned in the North Sea'.

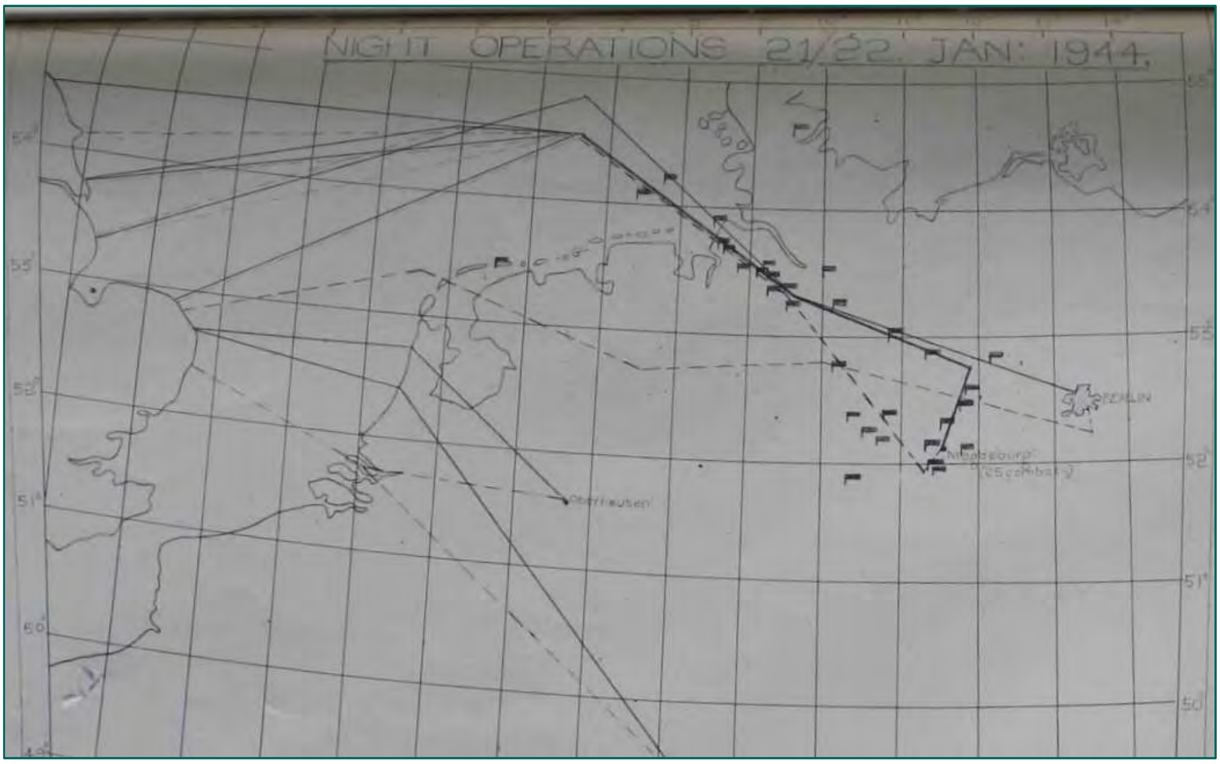


Figure 12: Example of allied flight paths used for bombing raids in the night of 21/22 January 1944 (Source; The National Archives, AIR 24/264).

Since allied bombers frequently traversed the North Sea, also crossing over the area of investigation, it is highly likely that aerial bombs were jettisoned and still remain in the North Sea. Approximately half of the UXO encounters in the North Sea consist of air dropped bombs.

3.2.2 Aerial attacks on ships and convoys

Besides allied bombing raids in German occupied territory and on the coast, allied planes also attacked enemy ships and convoys. Most attacks on ships and convoys were conducted by planes of Coastal and Bomber Command and occasionally by Fighter Command. A brief selection of attacks on ships and convoys, based on literature (see Annex 3) is given in Table 3.

Date	Event
28 May, 1940	Coastal Command. Swordfishes attacked three motor torpedo boats 60 km west-north-west of IJmuiden. Results from these patrols were not reported.
11 September, 1940	Bomber Command. Nine Blenheim bombers on sea sweep and ports reconnaissance. One aircraft bombed a convoy off Dutch coast.
18 March, 1941	Coastal Command. A Blenheim bomber attack a Dutch fishing trawler 70 km north west off IJmuiden with two small bombs. Near misses.
2 August, 1941	Bomber Command. One Blenheim attacked two small trawlers 5 km west off IJmuiden. However, the bombs fell wide from target.
6 January, 1942	Coastal Command. Four Hudson bomber patrolling the Dutch coast. One Hudson attacked a 1,000 ton ship 20 km north-north-west off IJmuiden. Results were not observed.

Table 3: Examples of aerial attacks on ships and convoys. See also Annex 3 for additional attacks.

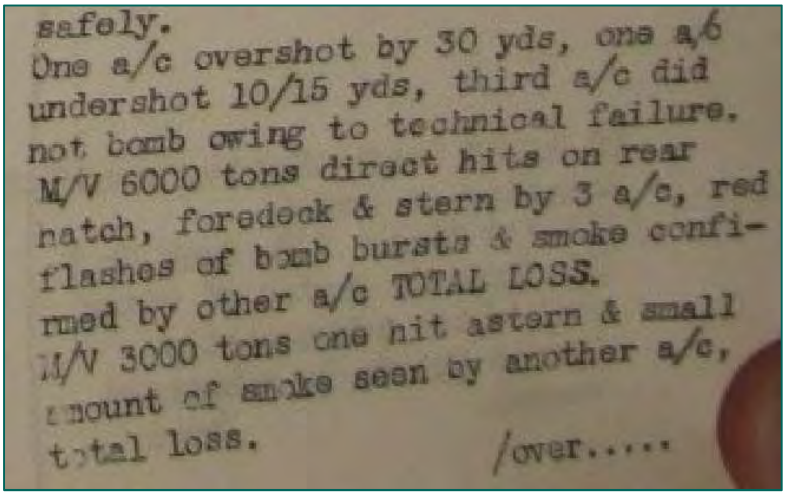
A ship is a relatively small moving target, making it difficult to hit with aerial bombs. For allied pilots the only certainty to strike a ship, was by flying at low altitude and dropping the payload just above the ship. This means that planes had to fly a few meters above sea level and had to pull up sharply in front of the target. The bombs would hit the ship almost immediately after pulling up. To ensure the pilots would have enough time to get to a safe distance prior to detonation, the bombs were equipped with a time delayed fuse. This tactic made airplanes vulnerable for the ships anti-aircraft guns (Flak or *Flugabwehrkanone*). Aircraft cannons and machine guns were fired during these attacks to supress enemy flak.

Notwithstanding the pilot's courage, sinking ships was a difficult task. Furthermore, the planes could only carry bombs of smaller calibres, such as 100 lbs, 250 lbs and 500 lbs. More effective were attacks with torpedoes. Torpedoes were dropped from planes flying less than 30 meters above the sea, about 600 meters distance from the target. Figure 13 and Figure 14 give an impression of aerial attacks on convoys in front of the Dutch coast near IJmuiden. The aerial photographs below are available obtained from the Imperial War Museum, London.

Figure 13: Oblique aerial photograph taken during an anti-shipping strike by Bristol Beaufighter on a heavily-armed northbound convoy off IJmuiden, Holland. The arrowed vessel is a 'Sperrbrecher' (magnetic-mine detonating vessel) (Source: http://www.iwm.org.uk/collections/item/object/205023235).

Figure 14: Low-level oblique aerial photograph showing a Lockheed Hudson of No. 59 Squadron dropping its torpedo during an attack by six aircraft on an enemy convoy off IJmuiden, Holland (Source: http://www.iwm.org.uk/collections/item/object/205023107).

Allied attacks on ships and convoys are documented in the Operations Record Books of Bomber Command and Coastal Command, see Annex 7. The records refer to coordinates and the locations where attacks took place. An extract of an Operations Record Book from a Bomber Command attack on 14 July, 1941 is shown in Figure 15. The terms 'overshot' and 'undershot' indicate that bombs fell too far off or too short from the target. Attacks were carried out with bombs, (25 lbs incendiary, 250 lbs Semi Armour Piercing (SAP), 500 lbs SAP) and 3 inch air-to-ground rockets, equipped with 60 lbs SAP warheads. An outstanding example of a strike with rockets took place on 19 October 1943, when two Beaufighter maritime strike aircraft Squadrons attacked shipping off IJmuiden with a total of 48 rockets and cannon fire. The strike left the ships heavily damaged, at the loss of only one Beaufighter (see Annex 7).



safely.
One a/c overshot by 30 yds, one a/c
undershot 10/15 yds, third a/c did
not bomb owing to technical failure.
M/V 6000 tons direct hits on rear
hatch, foredeck & stern by 3 a/c, red
flashes of bomb bursts & smoke confi-
rmed by other a/c TOTAL LOSS.
M/V 3000 tons one hit astern & small
amount of smoke seen by another a/c,
total loss.
/over.....

Figure 15: Extract from an Operations Record Book (Source: Annex 7, TNA, AIR 24/233).

Besides surface ships, allied aircraft also targeted U-boats. This was especially the case near the area of investigation, where Coastal Command aircraft hunted down German midget submarines from 1944 to 1945 (see Annex 6). An effective weapon against U-boats was the depth charge. According to the post-war munition encounters, a depth charge was encountered within the area of investigation (see Annex 10).

By August 1944, the German Command had been forced to cease sending convoys by day along the Dutch coast. The toll taken by the allied air attacks had become too heavy. The only possible tactic was to sail the convoy by night in short hops from port to port, sheltering in strongly defended harbours during daylight hours. In response, the allied air forces tried to attack convoys at night using new tactics. Because of the minelaying activities, German convoys were stuck to certain sea routes. Figure 16 shows that a major German sea route was situated east of the area of investigation. Convoys along these routes are likely to have been attacked by allied planes.

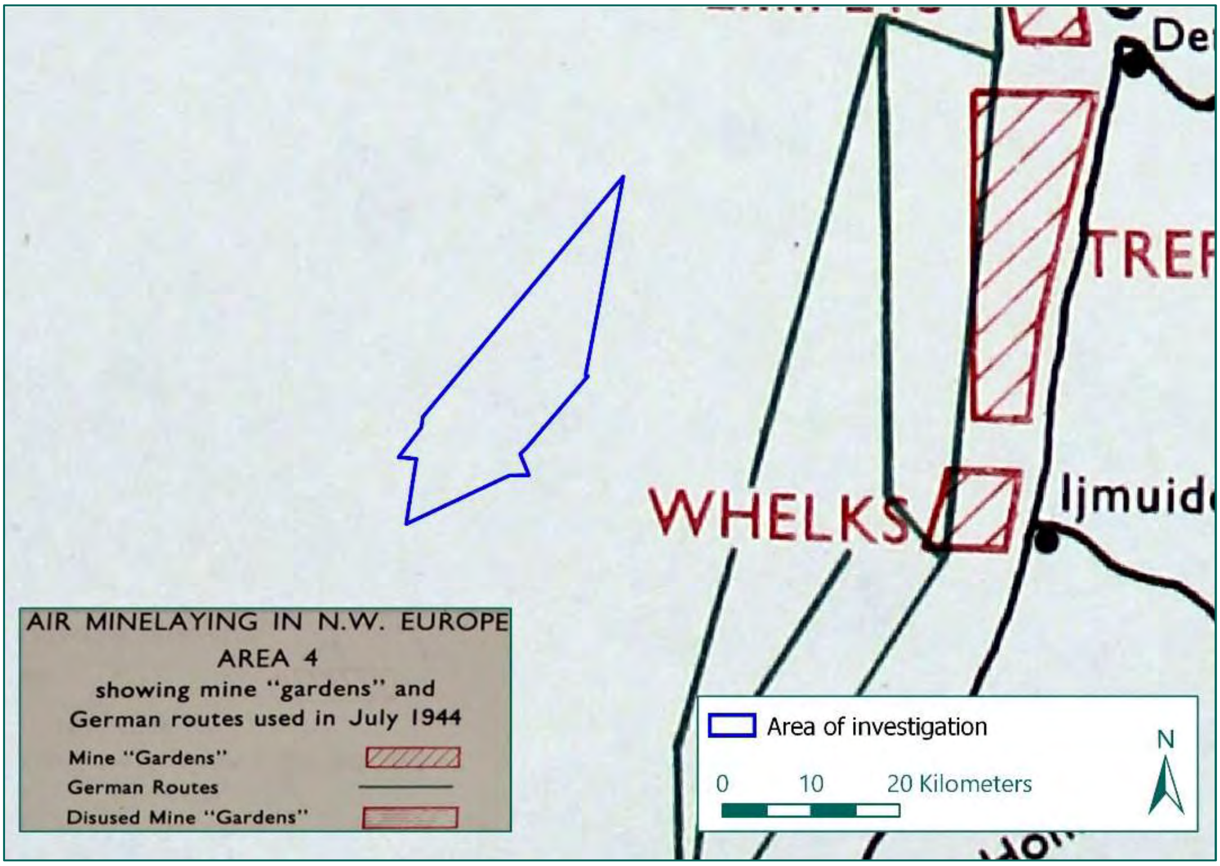


Figure 16: German sea routes (Source: Annex 6, TNA, ADM 234/561).

3.2.3 Conclusion on Aerial Warfare

Due to jettisons by returning and/or damaged allied bombers, aerial bombs could have remained in and near the area of investigation. Most common calibres during WWII are 250, 500 and 1,000 lbs.

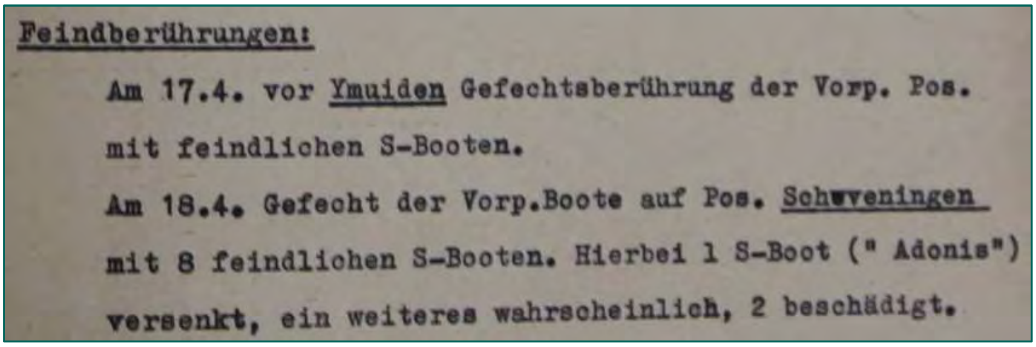
Various aerial attacks on ships took place in the vicinity of the area of investigation. Aerial attacks on ships, convoys, and U-boats could have led to the presence of aerial bombs and depth charges. According to the OSPAR munition encounters and the reports of the Dutch Coastguard (see Annex 10), various aerial bombs and depth charges have been encountered in the North Sea off the Dutch coast. A list of possible calibres is shown in Table 4.

Category	Calibres	Remarks
Aerial bombs	4, 25 and/or 30 lbs incendiary, 40 lbs, 100 lbs, 250 lbs, 500, 1,000 lbs	May be present due to jettisons or aerial attacks.
Rockets	3 inch air-to-ground with 60 lbs Semi-Armour-Piercing (SAP) warhead	May be present due to attacks on ships.
Cannon shells	20 mm of different types (AP, incendiary etc.)	May be present due to attacks on ships.
Torpedoes	Unknown	May be present due to attacks on ships. No direct indications.
Depth charges	Unknown	May be present due to attacks on submarines. No direct indications.

Table 4: UXO possibly to be present due to aerial attacks.

3.3 NAVAL WARFARE

Research for naval warfare, e.g. engagements between vessels or submarines, has also been conducted for this desk study. Except for some German reports (see Annex 6) about attacks using torpedoes or engagement between small vessels (Motor Gun Boats or Motor Torpedo Boats), no strong evidence was found for naval warfare in the area of investigation. Furthermore, the German records do not mention exact positions, see Figure 17 for example.



Feindberührungen:

Am 17.4. vor Ymuiden Gefechtsberührung der Vorp. Pos. mit feindlichen S-Booten.

Am 18.4. Gefecht der Vorp.Boote auf Pos. Schweveningen mit 8 feindlichen S-Booten. Hierbei 1 S-Boot (" Adonis") versenkt, ein weiteres wahrscheinlich, 2 beschädigt.

Figure 17: Extract from Heft II: Lageübersicht Westraum/Nordsee. Kriegstagebuch Teil BII. 15. Oct. 1941 – 31. Dec. 1943 (Source: Annex 6, BAMA, RM 7/86).

Since there is no factual evidence for naval warfare related to the area of investigation, the presence of UXO due to these events is not expected.

3.4 GERMAN SHOOTING AREA

A German naval chart acquired from the Bundesarchiv (see Annex 5, ZA 5/62) indicates the presence of a German shooting range overlapping the area of investigation. The map was compiled by the Central Mine Clearance Board, responsible for the postwar mine clearance. The shooting range (*'schießgebiet'*) is shown on a contemporary map in Figure 18.

Figure 18: Location of the German shooting range as indicated on map ZA 5/62.

The Bundesarchiv yielded no further information on this shooting range. It is therefore unknown if shooting took place from ships, aircraft or otherwise. Other sources do not offer additional information on the shooting range. Since no further information is available on the shooting range, a UXO risk area cannot be specified.

3.5 WRECKS OF AIRCRAFT AND VESSELS

During World War II a large number of aerial missions (e.g. bombing runs, reconnaissance flights, and attacks on ships and convoys) were carried out by the allied air forces. Allied planes had to deal with German flak ships, coastal flak batteries and German (night) fighters. As a consequence, a large number of airplanes crashed into the North Sea. The Dutch Air War Study Group maintains an online Crash database (see Annex 3) with military airplane losses in the Netherlands. According to the database about 758 aircraft crashed into the North Sea. Several aircraft crashed off the coast near IJmuiden, Egmond, Noordwijk, Alkmaar and Castricum. The crash database only provides estimated distances, e.g. 25 West off IJmuiden. Therefore, it is not possible to retrieve the exact location of crashed airplanes.

Wrecks of military vessels are not expected in the area of investigation. The Wreck Register ('Wrakkenregister') has been consulted to obtain information on war-related wreckages present in the area of investigation. This yielded no significant results.

Conclusion

Although exact information about aircraft crash locations is lacking, it cannot be excluded that the remnants of plane wrecks and their associated payload could be present in the area of investigation.

4 GAPS IN KNOWLEDGE AND UXO RISK AREA

4.1 GAPS IN KNOWLEDGE

During the analysis and review of historical sources some gaps in knowledge occurred that could not be filled in with the consulted sources:

- Knowledge of previous UXO clearance operations is often absent. Therefore, it is not fully known if during the period 1914-2016 UXO were encountered in and/or removed out of the investigation area, e.g. it is not known if UXO were encountered during installation of Amalia and Egmond windfarms.
- Compared to land, the North Sea offers few reference points. Therefore, specific information about locations is often lacking. Furthermore, it must be noticed that specific information can be inaccurate.
- There is no specific information about crashed airplanes in the vicinity of the site.
- There is no exact information about the total amount of dropped bombs during aerial attacks or jettisons above the North Sea.
- There is no specific information on the nature of the shooting range indicates on a German naval chart.

4.2 MAPPING THE WAR RELATED EVENTS

Based on analysis of the consulted historical sources, the significant war related events have been identified. By using Geographic Information System software, several of these significant war related events have been placed on the map. The map is provided in an attachment to this report (Annex 10), and visualizes the conclusions drawn in paragraph 4.3.

4.3 UXO RISK AREA

Based upon the analysis of historical sources it is evident that different war related events took place within and nearby the area of investigation. Because of these events it is expected that UXO remained in the area of investigation. This expectation is supported by the UXO encounters in the (vicinity of) the area of investigation (see annex 8).

The following UXO may be present within the area of investigation:

- Artillery shells;
- Aircraft cannon shells;
- Aerial bombs;
- Rockets;
- Naval contact mines;
- Depth charges;
- Torpedoes.

In Annex 10 an overview of all identified war related events near the area of investigation is presented.

4.3.1 Defining the UXO Risk Area

The information gathered and assessed provides a reliable indication of the types of UXO that may be left behind and the qualitative likelihood. However, it is not possible to demarcate the exact areas where different types of UXO are to be expected. Based on the consulted sources the entire area of investigation is considered a UXO Risk Area. The UXO items most likely to be present within the area of interest are shown in Table 7. Note that the table shows the probable presence of generic UXO types within the work site. It is important to recognise that the presence of a UXO type does not necessarily mean that it will be encountered.

The likelihood of encounter (i.e. an interaction with the UXO during a specific project activity), will generally be less than the probability of items of that particular UXO type being present across the whole area of interest; given that the actual footprint of planned operations will be less than the total investigation area volume. In Table 5 the definitions of the terminology are provided.

"Presence" Term	Meaning
Highly unlikely	No evidence pointing to the presence of this type of UXO within an area but it cannot be discounted completely.
Unlikely	Some evidence of this type of UXO in the wider region but it would be unusual for it to be present within the area of study.
Possible	Evidence suggests that this type of UXO could be present within the area.
Likely	Strong evidence[6] that this type of UXO is likely to be present within the area.
Highly likely	Indisputable evidence[6] that this type of UXO is present within the area.

Table 5: Definitions of terminology used for the likely presence of UXO.

Table 7 also provides an indication of the confidence level in regards to the 'Likelihood of Presence' based on the amount of factual historical data on war related events. In Table 6 the definitions of the terminology are provided.

"Confidence" Term	Meaning
Very high	A strong amount of very reliable information from primary sources with a high level of detail.
High	A strong amount of reliable information from primary sources with a moderate level of detail.
Moderate	A moderate amount of reliable information from secondary sources with a moderate level of detail.
Low	A poor amount of reasonably reliable information from secondary sources with a moderate level of detail.
Very Low	A poor amount of reasonably reliable information from secondary sources with a poor level of detail.

Table 6: Definitions of terminology used for indicating the confidence level of the outcome of the analysis.

Table 7 shows the details of the UXO Risk Area at the HKW Wind Farm Zone.

Type of UXO	Calibres	Likelihood of presence	Confidence level	Remarks
Aerial bombs	All possible calibres, including but not limited to 4, 25, 30, 40, 100, 250, 500, 1,000 lbs	Highly likely	High	Information on attacks on shipping and jettisons in the vicinity available. Encountered UXO from aerial bombs reinforce this conclusion.
Rockets	3 inch air-to-ground with 60 lbs SAP warhead	Possible	High	Evidence of attacks on shipping.
Naval mines (contact)	E-Mine EMC mine	Likely	Very high	Minefields from WWI and WWII containing significant amounts of moored mines were present in and near the area of investigation.
Naval mines (ground, ferrous)	Mark XIV Mark XVII	Highly unlikely	Very high	No ground minefields situated in the vicinity of the area of investigation.

[6] Strong evidence means there are several reliable and verifiable indications from primary sources indicating the likely presence of UXO in the area of investigation. In case of indisputable evidence these UXO are actually encountered in the area of investigation in the past.

Type of UXO	Calibres	Likelihood of presence	Confidence level	Remarks
Naval mines (ground, non-ferrous)	LMA LMB	Highly unlikely	Very high	No LMA or LMB minefields situated in the vicinity of the area of investigation.
Artillery shells (Flak)	Possible calibres include 2 cm, 3.7 cm, 5 cm, 7.5 cm, 8.8 cm, 10.5 cm (German)	Unlikely	Very high	The area of investigation lies outside the range of coastal Flak positions. Only shells from Flak on board of ships could be left behind. This renders the presence of UXO from AAA remote.
Artillery shells (coastal artillery)	15 up to 28 cm (Dutch/German)	Highly unlikely	Very high	The area of investigation is out of range of coastal artillery. One artillery shell was encountered in the direct vicinity of the AOI, but the relation between the coastal guns and this encounter cannot be proven.
Aircraft cannon shells	20 mm (including incendiary, HE, AP)	Possible	High	Evidence of attacks on shipping in the direct vicinity of the area of investigation.
Torpedoes	Unknown	Unlikely	Moderate	Evidence of aerial attacks with torpedoes on shipping in the wider vicinity. No torpedoes have been encountered in the direct vicinity of the area of investigation.
Depth charges	Unknown	Possible	Moderate	Evidence of aerial attacks with depth charges on shipping in the wider vicinity. UXO from depth charges have been encountered in the area of investigation.

Table 7: Summary of types and calibres of UXO likely to be present within the area of investigation.

4.3.2 Condition of expected UXO

The majority of the expected UXO are likely to be in an armed condition. This means that the safety devices preventing the UXO from premature detonation, e.g. during handling, are removed. Therefore, the explosive train, is in line. The explosive train is a sequence of events that culminates in the detonation of explosives.

- In the case of aerial bombs which were dropped by aircraft in distress situations, the bombs could have been dropped with safety features still in place, however they still present an explosive risk, e.g. as a result of corrosion of vital safety features.
- Some of the expected UXO, e.g. naval munitions, contain a large quantity of explosives and may be encountered in very poor condition as the thin metal casings may have been severely eroded. In many cases, the explosive capability could remain more or less undiminished. Some explosive charges neither absorb nor dissolve in water, and some charges do. However, stability of the munition possibly may have deteriorated with age.
- Naval contact mines from the period of interest typically contained a dry cell battery with an electrical detonating circuit which was connected to external conventional switch horns. These batteries will have now deteriorated and no longer have the ability to supply sufficient power to function the mine. However, the condition of the explosives can be highly sensitive, as mechanical anti-handling devices in the ordnance do not need battery power to function.
- Contact mines with Hertz Horns were also common from WWI onwards. Each horn contains a container of acid. Heavy contact with the horn can breach the acid container within, which subsequently energises a battery and functions the main charge. Therefore, this type of mine must be handled with extreme caution.

- Torpedoes were initiated by means of a pistol/exploder which sometimes had a tendency to be unreliable. As these can contain a mechanical detonator striker, they must be handled with extreme caution.
- Depth charges are initiated by a hydrostatic switch, which is sensitive for fluctuating pressure levels. Stability of this mechanical detonating mechanism may have deteriorated over time. Given the large number of high explosives the depth charges, caution should be exercised.
- The SAP warhead of a 3 inch air to ground rocket projectile highly likely got separated from the tail/rocket motor. The shape of the warhead (60lbs) is similar to a small aerial bomb. The fuze is placed on the tail/bottom of the warhead.

The exact state of encountered UXO can only be determined after positive identification by an EOD-expert.

Phase 2: UXO Risk Assessment

5 UXO BURIAL ASSESSMENT

In dynamic sediment conditions, UXO items are likely to become buried; the depth of burial in the investigation area is depending on two variables that will be explored below. In the area of investigation UXO burial is predominantly due to one or a combination of the following two mechanisms:

- Scour;
- Bed form migration.

Due to the water depths in the investigation area of approximately LAT 20 – 30 m UXO burial on impact will not have occurred.[7]

In this chapter a preliminary assessment of the UXO burial depth is provided. Since specific data on seabed mobility is not yet available the assessment is based on public data obtained from the North Sea Atlas (www.noordzeeloket.nl). The UXO burial depths need to be reassessed after the seabed mobility study has become available.

5.1 SCOUR[8]

Scour is the change in bed configuration due to the change in flow pattern around an object such as a UXO placed on or near the surface of a movable bed. The presence of the object modifies the flow pattern around the object, generating vortices that locally increase and decrease the bottom flow stresses. The vortices cause depressions and mounds to form on the bed surface. Objects placed on beds where the flow was causing no apparent motion can locally increase the bed stress behind the object and induce bed motion and scour.

Studies of mines placed on sandy bottoms show that subsequent burial occurs through a series of scour events followed by rolling or sliding of the mine into the scour depression. It has been shown that the amount and rates of scour and burial of objects on the sea floor under the influence of waves and currents is a function of their size, weight, and shape. Shape is an essential variable because scour is related to the intensity of the vortex system that forms around the object as the current flows past it. Thus, streamlined bodies scour less rapidly than bluff (blunt) bodies. Once scour depressions develop around a UXO, then UXO bury incrementally by moving into the depressions formed by the scour process, either by rolling or sliding (see figure 19).

In general, small UXO items scour and bury deeper relative to their diameters than large UXO, while absolute burial as measured from sediment surface to UXO keel is greater for large UXO. Furthermore, three-dimensional UXO (ovoid's and hemispheres) bury more slowly than two-dimensional (cylindrical) UXO.

The scour process stops when the UXO is at a depth where it is protected against the scour. Experiments and modelling have shown this depth to be approximately 0.6 x diameter for large objects in sandy sediments. UXO burial due to scour to the maximum scour depth is to be expected in the investigation area. The largest UXO possibly to be present is a German EMC moored mine. This mine has a diameter of 1.2 m and can be buried due to scour up to approximately 0.7 m below seabed.

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[7] Conclusion based on Chu P.C. et al, Semi Empirical Formulas of Drag/Lift Coefficients for High Speed Rigid Body Manoeuvring in Water Column, May 2008.

[8] Source: Douglas L. Inman et al., Scour and burial of bottom mines, A Mine Burial Primer, September 2002.

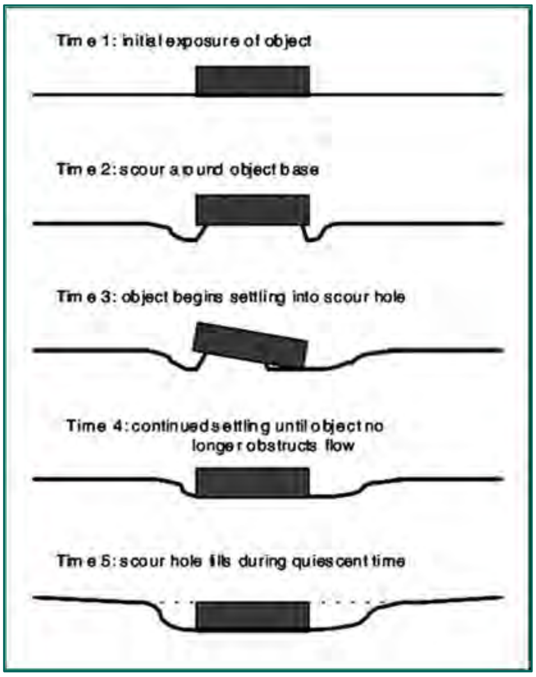

Figure 19: Scour mechanism.[9]

5.2 BED FORM MIGRATION

Assessment of possible UXO burial requires insights in the behaviour of the mobile morphological features within the investigation area. UXO burial (and exposure) may be caused by the formation and migration of bed forms. The spatial scale of the bed forms range from several meters to several kilometres and migration speeds range from < 1 m/year to > 100 m/year. Table 8 summarizes the six different types of bed forms can be distinguished at the Dutch continental shelf.

Bed form	Length (m)	Height (m)	Migration speed (m/year)	Evolution time scale
Ripples	0.1 – 1	0.01 – 0.1	100 – 1,000	Hours
Mega ripples	1 – 10	0.1 – 1	100 – 1,000	Hours – days
Sand waves	100 – 1,000	1 – 5[10]	1 – 10	Decades
Long bed waves	1,500	5	Unknown	Centuries
Shore face connected ridges	5,000 – 8,000	1 – 5	1 – 10	Centuries
Tidal sand banks	5,000 – 10,000	1 – 5	< 1	Centuries

Table 8: Overview of bed forms located at the Dutch continental shelf[11].

The ripples and mega ripples are too low to be of major importance for the UXO burial assessment. Long bed waves, shore face connected ridges and tidal sand banks migrate to slow to be of importance for the UXO burial assessment. Due to their height and migration rates sand waves are the predominant bed forms in regards to the burial depth of UXO.

The Geological Desk Study Hollandse Kust (west) Wind Farm Zone[12] shows water depths in the area of investigation vary between 21 and 33 m (LAT).

[9] Source: www.researchgate.net.
[10] Average values. The maximum height/depth ratio observed to be about 1/3.
[11] Menninga J., 2012. Analysis of variations in characteristics of sand waves observed in the Dutch coastal zone: a field and model study. MSc dissertation thesis. Utrecht University, 2012.
[12] Thal, J., Socko, L., Feldmann, S, Brock, J. P. (2018). Geological Desk Study for the Hollandse Kust (west) Wind Farm Zone. Arcadis Nederland B.V. and Geo-Engineering.org GmbH, 180017. Netherlands Enterprise Agency. (RVO.nl).

The sand banks in the area are north-south orientated with an elevation change of up to 10 m from top to bottom. These banks are approximately 10-30 km long, 1-3 km wide and around 4-8 km apart from each other. On top of these sand banks are the smaller scale sand waves that create a relief with up to 5 m in height difference from crest to surrounding lows. They are between several hundreds to ~3 km long and oriented in a NW-SE direction, more or less perpendicular to the sand banks. Based on the maximum sand wave height, the burial depth of UXO due to bed form migration is expected to be approximately 5m. This burial depth may be present at the crests of the sand waves in the sand wave fields. Between the sand waves and outside of the sand wave area burial is assessed to be limited.

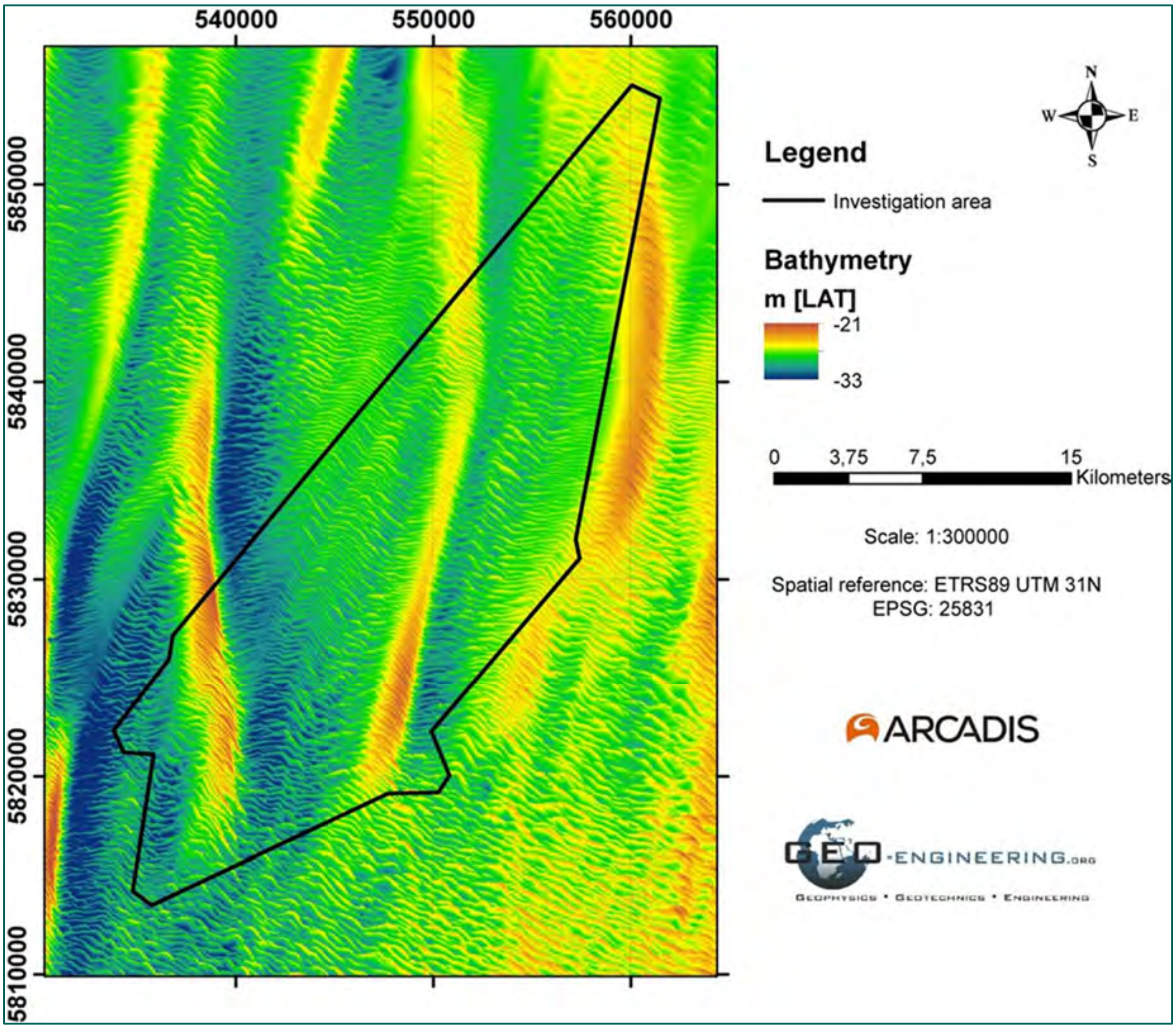

Figure 20: Most recent bathymetry of the investigation area (source: Geological Desk Study Hollandse Kust (west) Wind Farm Zone).

Sand waves of the coast of IJmuiden are assessed to migrate with an average speed of approximately 10m/year[13]. In the 'Seabed mobility study route comparison Windpark Hollandse Kust (noord)'[14] maximum migration rates are assessed to range from 4 and 15 m/yr. (dependent on the route option).

[13] Marine Sampling Holland B.V., Wandelende onderzeese duinen, reference MN-1705, July 7, 2017.

[14] Svasek, Seabed mobility study route comparison Windpark Hollandse Kust (noord), reference 1901/U17229/C/LdW, November 17, 2017.

Recent study[15] has shown that the tops of sand waves are not contaminated with UXO deployed in the area during WWI and WWII. The reason behind this is that over the years any high- density objects will have migrated down to the non-mobile layer i.e. the layer which is not been affected by the mobility of the sand waves. UXO will come to rest on this layer. This layer is shown in figure 21 as “Base of sand wave”.

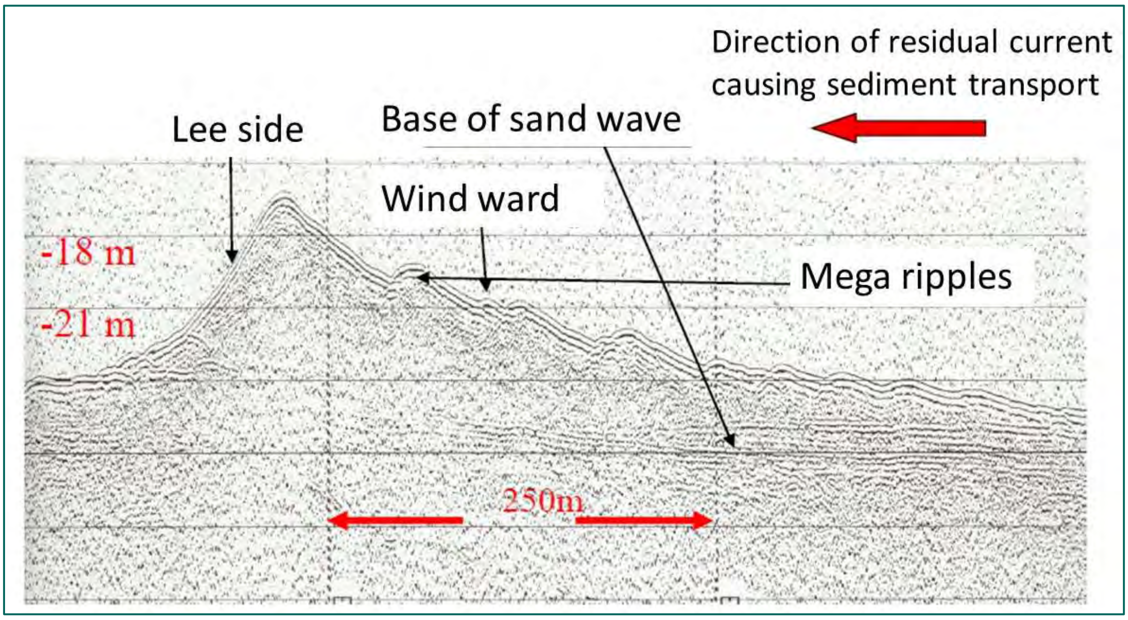

Figure 21: Presence of tidal sand banks and sand waves on the Dutch continental shelf (source: Noordzeeloket).

5.3 CONCLUSIONS

Based on the mechanisms outlined in the previous paragraphs, the likely maximum burial depth (MBD) for an item of UXO in the investigation area can be calculated using the basic formula:

MBD = BS + HB

Where:

MBD	=	Maximum Burial Depth
BS	=	Burial due to Scour
HB	=	Height of Bedform

Equation 1: Formula for calculating the maximum burial depth of UXO.

The BS is 0.7 (see paragraph 5.1 for substantiation). The HB is assessed to be 5.0 m (see paragraph 5.2 for substantiation). The total sum (MBD) is 0.7 + 5.0 = 5.7 m, rounded off to 6 m. The HB is relative to the top of the crest of the sand waves.

It is recommended to reassess the UXO burial depths after the seabed mobility study has become available. Seabed mobility studies are very important to assess the possible depth of the UXO below the seabed.

15 Marine Sampling Holland B.V., Wandelende onderzeese duinen, reference MN-1705, July 7, 2017.

6 UXO MIGRATION ASSESSMENT

In preparation for the geophysical UXO survey, the potential migration of UXO needs to be assessed. UXO migration may be relevant in determining the maximum permissible safe time interval between the conclusion of a geophysical UXO survey, UXO clearance operations and the commencement of construction works.

Migration can occur due to environmental and natural causes and also human activity. In this chapter the possible migration of UXO is assessed.

6.1 MIGRATION BY NATURAL CAUSES

Migration by natural causes may occur due to hydrodynamics and/or morphodynamical behaviour. In this paragraph these aspects will be assessed.

6.1.1 Hydrodynamics

The hydrodynamics within the investigation area is characterized by tide and wind generated currents and waves. The tide is predominantly semi-diurnal tide. Table 9 presents the mean tidal water levels at IJmuiden to illustrate the tidal characteristics. The mean tidal range is 1.69 m, with a mean high water of LAT 2.04 m and a mean low water of LAT 0.35 m.

Tide	HW [m LAT)	LW (m LAT)	Tidal range (m)
Mean tide	2.04	0.35	1.69
Spring tide	2.19	0.31	1.88
Neap tide	1.79	0.42	1.37

Table 9: Tidal water levels IJmuiden[16].

The average tidal streams during average weather conditions (wind south-west force 3 to 4) reaches speeds up to 1.5 kts (2.3 kts at spring tides)[17]. The given speeds of tidal streams are average calculated speeds. The actuals speeds depend upon a large number of variables. Therefore, the actual speeds may be higher than the calculated speed.

The shapes, dimensions and weights of the UXO that can be expected in the investigation area are such that they are not likely to be transported over long distances by normal wave and tidal conditions. The forces on the objects are relatively low and the objects are not likely to migrate a great distance from their original resting position. In contrast, scour will develop around the object and this may result in burial[18].

6.1.2 Morphodynamic behaviour

The migration of objects is more likely to be influenced by morphological changes in the area. Horizontal channel migration or erosion on the slopes of sand waves may cause horizontal UXO migration. An object may for example be buried in a channel side slope or other steep slope. If the channel or sand wave migrates and erosion occurs on the slope in which the object is buried, it may become unburied and released from the slope. The object is then likely to roll down the side of the slope towards the deepest section of the channel, where it will remain or become buried by vortex scouring.

16 Source: Rijkswaterstaat, Kenmerkende waarden getijgebied 2011.0, July 22, 2013. LAT = NAP-103 cm.
17 Source: HP33, Waterstanden en stromen 2018, 2018. Mentioned speeds are current speeds at the surface.
18 Source: ARCADIS, Memo UXO mobility TenneT cable, reference 078983999 0.2, June 21, 2016.

Assessed migration rates of sand waves are in the order of 10 m/year[19]. This means sand waves in the investigation area have migrated approximately 700 m since the war. The width of the crests of the sand waves is in the same order as the post war migration of the sand waves. Due to the migration rate and width of the sand waves it is assessed that present-day sand waves crests are mainly sediments from the post war period. Therefore, it is not likely that UXO are present well above the non-mobile reference level of the seabed[20] (also see figure 21). The risk of UXO getting unburied in the slopes of sand waves is assessed to be negligible. Therefore, UXO migration due to morphodynamical behaviour is not a factor to consider in the determination of the maximum permissible safe time interval between the conclusion of a geophysical UXO survey, UXO clearance operations and the commencement of construction works.

6.2 MIGRATION DUE TO HUMAN ACTIVITY

Human activity may have a more significant impact on UXO migration than natural causes. Especially dredging and bottom fishing activities have the capacity to move items of UXO.

Particularly in areas where beam and pair trawling are prevalent. Currently the investigation area is fished several times a year[21]. It is expected that some trawlers may have unintentionally moved UXO. These UXO items may have been transported with the movements of the vessel's nets for considerable distances before they are returned to the seabed. In such circumstances, fishing nets have been known to move UXO up to 30 miles (48km) from their original location[22].

Wind farm zones are not navigationally controlled. After completion the wind farm zone may be crossed by vessels smaller than 24 m. Therefore, the risk of UXO being moved unintentionally by fisherman after conduction of the UXO survey and completion of the wind farm remains.

It is not possible to quantify the UXO migration due to human interaction. Therefore, human interaction is not a factor in the ALARP sign off certification process. This migration factor is part of the baseline residual risk. If is unintentionally dragged into the area of investigation by fisherman, it will lie on the seafloor. Therefore, a large calibre UXO will most likely be visible in for example SSS data.

6.3 MAXIMUM PERMISABLE SAFE TIME INTERVAL

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 installation operations, must be kept to a practicable minimum. This is to ensure that UXO migration cannot nullify the validation period of the final ALARP clearance certification. It is therefore imperative to manage and plan the phases of the project, in an educated and calculated manner. This can be achieved by ensuring that vessel planning, vessel availability, weather windows, vessel/contractor capability, project phase execution and management are carefully planned and implemented to guarantee that the operations are carried out within the specified time scale reflective of the UXO migration assessment information.

For the investigation area horizontal migration of UXO is most likely to occur due to human interference. However, it proved not to be possible to quantify the horizontal migration rate.

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19 Marine Sampling Holland B.V., Wandelende onderzeese duinen, referentie MN-1705, d.d. 10-7-2017.

20 The non-mobile reference level (NMRL) of the seabed is the level which lies below the mobile upper cover of mega ripples and sand waves. It is used a reference level for cable burial below fast moving seabed features.

21 Source: http://www.clo.nl/indicatoren/nl2093-ecologische-duurzaamheid-bodemvisserij, Visserij Intensiteit op het Nederlands Continentaal Plat, 2007-2011 and https://odims.ospar.org/maps/530, OSPAR Bottom Fishing Intensity.

22 Unexploded Ordnance Munitions Migration Assessment, Report Number: P3872-E3MMA, August 2014

The maximum permissible safe time interval between ALARP sign off and the commencement of construction works is assessed to be approximately two years.

In the event of expiration of the validity period of the ALARP sign-off certificate, an assessment need to be made by a UXO expert with knowledge of the local conditions whether the validity of the certificate can be extended without additional survey efforts or whether a Side Scan Sonar (SSS) survey or high resolution multi beam echo sounder (high res MBES) is to be conducted to assess the potential presence of UXO which might have migrated into the cleared areas as a result of human interference (e.g. pair and beam trawling[23]). UXO migrated into the area are assessed to be located on top of the seabed hence detectable by SSS or by high res MBES.

[23] The bottom fishing intensity on the North Sea is monitored. Data on bottom fishing intensity can be obtained from the OSPAR database (https://odims.ospar.org/maps/530) and the Noordzeeloket (https://www.noordzeeloket.nl/atlas/).

7 HAZARDS OF UXO LIKELY TO BE ENCOUNTERD

In this chapter the types of UXO likely to be encountered are described. The given information, together with the effect of a detonation (see chapter 8), the planned installation methods (see chapter 9) and the specific characteristics at the wind farm zone provide the input for outlining the UXO mitigation strategy (see chapter 11).

7.1 AERIAL BOMBS

An aerial bomb is a type of explosive weapon intended to travel through the air with predictable trajectories, designed to be dropped from an aircraft. As with other types of explosive weapons, aerial bombs are designed to kill and injure people and destroy enemy materiel through the projection of blast and fragmentation outwards from the point of detonation. Therefore, most bombs were accommodated with a high explosive charge, although incendiary bombs were also put to use.

The deployed fuzes are highly important for the likelihood of a bomb to detonate as a consequence of seabed activities. Fuzes have two purposes, one is to prevent the bomb from detonating before it has left the aircraft and at close range of the aircraft, and the other to cause the bomb to detonate.

The pistols/fuzes are armed during and after the bombs are dropped. Upon impact, the pistol/fuze has a striking pin or electrical circuit that detonates the bomb. If the fuze has a striking pin, that pin is driven into a small firing cap that sets off the explosive train, and thus the main charge. An electrical fuze uses an electrical detonator to set off the detonation charge.

Fuzes can have various timer devices to make the timing of the blast more effective. Some function at a given time after arming, e.g. chemical long delay pistol such as tail pistol no. 37 Mk I or the mechanical clockwork fuze LZtZ 17 (see Figure 22). More common are short delay or instantaneous pistol/fuzes to delay the detonation for a few fractions of a second.

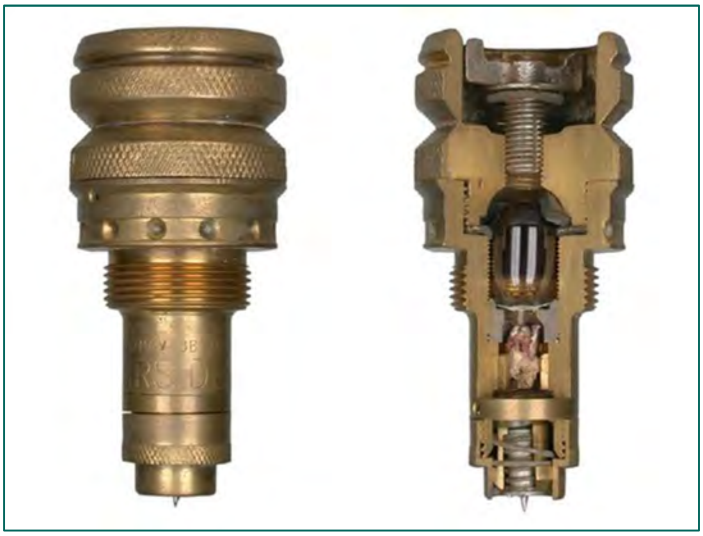

Figure 22: Tail fuze no. 37 Mk I.

Long delay fuze LZtZ 17

Once a fuze is armed, shock, movement or manipulation can cause the bomb to detonate. Fuzes, and long delay fuzes in particular, are sensitive to movement and accelerations with an amplitude > 1 m/s^2 in the surrounding soil. This kind of accelerations can occur as a consequence of vibrations caused by piling operations.

7.2 DEPTH CHARGES

A depth charge is an anti-submarine warfare weapon intended to destroy or cripple a target submarine by subjecting it to a powerful hydraulic shock. Most depth charges are fitted with conventional high explosives and a fuze set to cause detonation at a preselected underwater depth. Depth charges can be dropped by ships and patrol aircraft.

Depth charges were detonated by a spring-loaded firing pin released by a water pressure driven bellows system. The mechanism could be set to various depths based on the attacking vessel's estimate of the depth of the submarine. A late war variant included a magnetic detonator which automatically detonated the depth charge when it reached the proximity of a submarine. The chance of encountering the latter type of fuzing is estimated to be low.

7.3 TORPEDOES

A torpedo is a self-propelled weapon with an explosive warhead, launched above or below the water surface, propelled underwater towards a target, and designed to detonate either on contact with its target or in proximity to it.

A proximity fuze is a fuze that detonates an explosive device automatically when the distance to the target becomes smaller than a predetermined value, which can also take place when the fuze and the target pass by each other. Proximity fuzes were developed later in World War II. The chance of encountering this type of fuze is estimated to be low.

7.4 NAVAL MINES

Naval mines can be classified into three major groups: contact, remote and influence mines. Naval mines can be subdivided by appearance or the way they are positioned in the water column, such as:

- Moored mines;
- Ground mines;
- Drifting mines;
- Oscillating mines;
- Crawling mines;
- Limpet mines.

Moored mines and ground mines are the most commonly used. Exercise mines exist as variants of all types of war type naval mines with only absence of the warhead and extra equipment such as floats for marking the position and initiation of the exercise mine. The presence of explosives components with a small explosive payload in exercise mines cannot be ruled out.

7.4.1 Contact mines

The earliest mines were usually of this type. They are still in use today, as they are extremely low cost compared to any other anti-shipping weapon and are effective in sinking enemy ships. Contact mines need to be touched by the target before they detonate, limiting the damage to the direct effects of the explosion and usually affecting only the single vessel that triggers them.

Based on the different firing systems, one can summarize the following types of contact mines:

- Mechanical: upon contact a firing pin will function the detonator initiating the explosive train;
- Electrical: contact mines with an electrical firing system are often equipped with Hertz Horns (or chemical horns), switch horns or galvanic horns.
    - Hertz Horn: these fuzes work reliably even after the mine has been in the sea for several years. The mine's upper and/or lower half is studded with hollow lead protuberances, each containing a glass vial filled with chromium acid. When a ship's hull crushes the metal horn, it cracks the vial inside it, allowing the acid to run down a tube and into a lead–acid battery which until then contains no acid electrolyte. This energizes the battery, which detonates the explosive.
    - Switch Horn: this horn acts as the switch in the electrical circuit. Closing this circuit will set off the electrical detonator initiating the explosive chain. An internal battery is needed for the supply of the electrical power.
    - Antenna or Galvanic Horn: this type of horns works on the principle of creating battery power based on the salt water environment. A copper antenna or horn fitted to the mine casing acts as positive electrode. When another metallic object (i.e.: ship's hull) makes contact with the antenna or horn.

During the initial period of World War I, the British Navy used contact mines in the English Channel and later in large areas of the North Sea to hinder patrols by German submarines. Later, the American antenna mine was widely used because submarines could be at any depth between the surface and the seabed.

This type of mine had a copper wire attached to a buoy that floated above the explosive charge which was weighted to the seabed with a steel cable. If a submarine's steel hull touched the copper wire, the slight voltage change caused by contact between two dissimilar metals was amplified and ignited the explosives.

7.4.2 Influence mines

These mines are triggered by the influence of a ship or submarine, rather than direct contact. Such mines incorporate electronic sensors designed to detect the presence of a vessel and detonate when it comes within the blast range of the warhead. There was also a small amount of other specialised devices but these were few in number and are unlikely to be encountered.

Even as far back as the Second World War it was possible to incorporate a "ship counter" facility into mine fuzes e.g. set the mine to ignore the first two ships to pass over it (which could be mine-sweepers deliberately trying to trigger mines) but detonate when the third ship passes overhead, which could be a high-value target such as an aircraft carrier or oil tanker.

7.5 ARTILLERY SHELLS

Artillery shells were deployed by aircraft (20 mm), FLAK, submarines and warships. It is possible that Artillery shells could be encountered, initially used on land and dumped at sea as a matter of clearance. Artillery ammunition can be deployed with different kinds of artillery fuzes.

The types of fuzes most commonly used would cause the shell to detonate or release its contents when its activation conditions were met. This action typically occurred on time after firing (time fuze), on physical contact with a target (contact fuze) or a detected proximity to the ground, a structure or other target (proximity fuze).

7.6 ANTI-HANDLING DEVICES

Some fuzes, e.g. those used in air-dropped bombs and naval mines may contain anti-handling or anti withdrawal devices specifically designed to kill bomb disposal personnel. Generally, the more sophisticated the mine design, the more likely it is to have some form of anti-handling device fitted in order to hinder clearance. The technology to incorporate booby-trap mechanisms in fuzes has existed since at least 1940 e.g. the German ZUS40 anti-removal bomb fuze or the earlier mentioned Pistol No. 37.

7.7 SELF-DESTRUCTION DEVICES

The Hague Conventions of 1907[24] states that is forbidden (article 1):

- To lay unanchored automatic contact mines, except when they are so constructed as to become harmless one hour at most after the person who laid them ceases to control them.
- To lay anchored automatic contact mines which do not become harmless as soon as they have broken loose from their moorings.
- To use torpedoes which do not become harmless when they have missed their mark.

As a consequence of The Hague convention naval mines were presumed to be equipped with a deactivating or self-destruction device. These devices often did not work properly. In case a self-destructing device malfunctioned, the UXO holding the device is to be considered highly sensitive to handling (movement). Because washed up mines were falsely considered safe they claimed many casualties during and after the wars. Despite the prohibitions of The Hague conventions, naval mines and torpedoes must be considered dangerous at all times.

[24] Laws of War: Laying of Automatic Submarine Contact Mines (Hague VIII); October 18, 1907.

8 EFFECTS OF DETONATIONS

In this chapter the effects of underwater detonations are given. These effects on vessels, equipment, constructions, crew members and surroundings will determine the level of risk during the preparation phase (site investigations), execution phase (construction works) and operational phase (maintenance) of the wind turbines and inter-array cables.

8.1 EFFECTS OF UNDER WATER DETONATIONS

The damage that may be caused by an underwater detonation depends on the "shock factor value", a combination of the initial strength of the explosion and of the distance between the target and the detonation. When taken in reference to ship/vessel hull plating, the term "Hull Shock Factor" (HSF) is used, while keel damage is termed "Keel Shock Factor" (KSF). If the explosion is directly underneath the keel, then HSF is equal to KSF, but explosions that are not directly underneath the ship/vessel will have a lower value of KSF[25]. The effect of a detonation mainly depends on the amount of explosive content (Net Explosive Weight) of the UXO and the type of explosive content (e.g. TNT, Torpex, etc.).

8.1.1 Direct damage

Direct damage can occur to vessels and platforms that come into contact with e.g. a contact mine. Direct damage is a hole blown in the ship or platform. Among the crew, fragmentation wounds are the most common form of damage. Flooding typically occurs in one or two main watertight compartments which can sink smaller ships or disable larger ones. Contact mine damage often occurs at or close to the waterline near the bow but depending on circumstances a ship could be hit anywhere on its outer hull surface.

It is unlikely that direct damage to ships/vessels will occur due to seabed activities, unless operating in very shallow water. For the area of investigation, UXO will only be present in or on the seabed, unless otherwise brought to the surface.

8.1.2 Bubble jet effect

An underwater explosion also results in a gas bubble, which contains about half of the explosive energy and, therefore, can also result in damage to ships and vessels. The gas bubble exhibits a low frequency oscillation and migration. Because of its large size, gas bubble oscillation goes together with large motions in the surrounding water, which in turn solicits ship hull vibrations. This hull response is known as whipping. For heavy scenarios, thus for high HSF values, whipping may be damaging. Whipping may be even worse, when the lowest hull bending natural frequency is close to the bubble frequency[26].

When a detonation happens close to a ship's hull, there may be additional gas bubble effects influencing the ship. The detonation gases are enclosed in a bubble that alternately grows and shrinks during an upward movement to the water surface. The bubble may migrate toward the hull, which considerably worsens whipping and may result in overall hull failure. Furthermore, at the first bubble minimum a devastating water jet directed toward the ship may result in even more global damage to the ship. If the bubble collapses at close proximity to the ship's hull the ship can be severely damaged, resulting in fatal loss of buoyancy and/or hydrostatic stability and fatalities to the crew within the affected areas.

[25] The Response of Surface Ships to Underwater Explosions. DSTO-GD-0109, September 1996.

[26] Van Aanholt et al., Effects of an explosion on a trailing suction head dredger, reference TNO 2017 R11126, December 4, 2017 (confidential, non-releasable).

8.1.3 Shock effect

If a UXO detonates at a distance from a ship, the change in water pressure causes the ship to resonate. The whole ship is dangerously shaken and everything on board is tossed around. Engines and equipment can be dislodged from their positions etc. A ship which experiences a large shock effect usually sinks quickly, with hundreds, or even thousands of small leaks all over the ship and no way to power the bilge pumps. The crew fare no better, as the violent shaking tosses them around[27]. This shaking is powerful enough to cause disabling injury to knees and other joints in the body, particularly if the affected person stands on surfaces connected directly to the hull (such as steel decks).
In Table 10 the distances on with a certain amount of shock damage is expected are shown for the common types of allied bombs. The distances are calculated by TNO. Leakage is to be expected in case of a Hull Shock Factor (HSF) > 0.3 $kg^{0.5/m}$. Damage to equipment is to be expected in case of a HSF > 0.02 $kg^{0.5/m}$[28]. The table provides the distances relative to the point of detonation where the above-mentioned criteria are met.

NEW [kg]	Leakage of working vessels [m]	Damage to equipment [m]
51 (e.g. bomb 250 lbs	29	430
105 (e.g. bomb 500 lbs)	41	617
270 (e.g. bomb 1,000 lbs)	66	989

Table 10: Distances for shock damage due to detonation[18].

Table 10 shows that in case a UXO detonates, it is highly likely severe damage to the equipment and injury of personnel will occur. Furthermore, damage to foundations (mono piles) cannot be ruled out, depending on the distance between the detonation and the foundation.

8.1.4 Shredding effect or spalling

A shock wave with a peak pressure of 37.2 bar and higher reflecting against the water surface, will generate a cracking effect on this water surface. The water particles in the surface layer will be thrown out into the air with great force. This phenomenon, where a shock wave travels from a dense medium (water) into a less dense medium (air) and thus creating a distortion of the surface layer between water and air, is called the “shredding effect” or “spalling”.

The mechanism of wounding a human body can be explained by this shredding effect. A shockwave travelling through a human body will cause severe damage to tissue around air filled cavities such as ears, lungs and intestines.

8.1.5 Lethality of fragments

Fragments from explosives charges in water quickly lose energy. A scientific study on the effects of fragments travelling under water after detonation, is used by the Dutch EOD for calculating the safe distances[29].

The water depth needed to detain fragmentation of explosives with up to 1,000 kg Net Explosive Weight is illustrated in figure 23. Based on this chart and the water depths within the area of investigation it is concluded that it is unlikely lethal fragments will be ejected above the surface of the water.

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[27] TNO-rapport Beveiligd ‘baggeren Maas, stuwpand Sambeek’, May 11, 2012 (confidential, non-releasable).
[28] TNO-rapport Beveiligd ‘baggeren Maas, stuwpand Sambeek’, May 11, 2012 (confidential, non-releasable).
[29] VS 9-861, Voorschrift Opruimen en Ruimen van Explosieven, September 29, 2010.

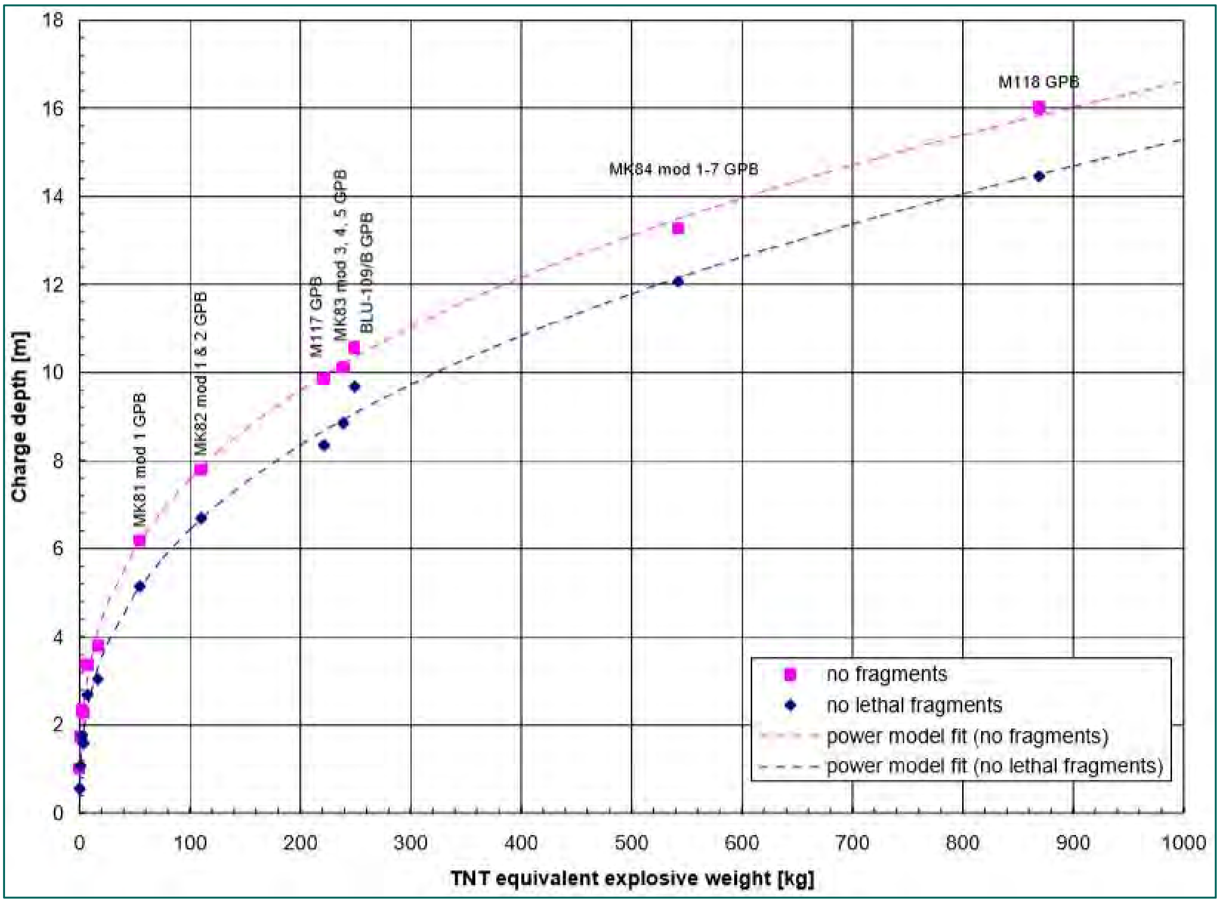

Figure 23: Minimal water depth to detain fragmentation of explosives with a Net Explosive Weight (NEW) of 0-1,000 kg TNT equivalent[24].

8.2 SAFE DISTANCES

The Dutch EOD regulation provides formulas for calculating the safe distances in case of a controlled demolition of UXO in water. In case of a controlled demolition of UXO in water in the stated area[30]:

a)	$R = 270\ 3\sqrt{W}$	diving is not allowed;
b)	$R = 24\sqrt{W}$	civilian shipping is not allowed;
c)	$R = 36\sqrt{W}$	tankers are not allowed;
d)	$R = 12\sqrt{W}$	warships are not allowed.

Where:

R	=	Radius in meters
W	=	Net Explosive Weight (NEW) in kg. TNT-equivalents

Equation 2: Formulas for calculating the safe distances in case of a controlled demolition of UXO in water.

[30] VS 9-861, Voorschrift Opruimen en Ruimen van Explosieven, 29th september 2010.

In Table 11 the safe distances for UXO with a net explosive weight of 100, 200, 300 and 1,000 kg TNT are given. The safe distances are calculated with the formulas stated above. The explosive weights are representative for the types and calibres of UXO likely to be present in the wind farm area (e.g. naval mines, aerial bombs, depth charges and torpedoes).

W [NEW]	Diving [m]	Civilian shipping [m]	Tankers [m]	Warships [m]
100 kg	1,253	240	360	120
200 kg	1,579	339	509	170
300 kg	1,807	416	624	208
1,000 kg	2,700	759	1,138	380

Table 11: Safe distances for controlled demolition.

9 INSTALLATION METHODS

The installation methods described within this chapter are provided for information and guidance purposes only. The following investigation and (pre) installation methods may be used for site investigations, installing wind turbines and the inter-array cables:

- preliminary geotechnical site investigations;
- route clearance;
- dredging;
- cable installation and trenching;
- excavation;
- scour protection;
- rock placements;
- piling.

In this chapter the (pre) installation methods will be clarified in due course in order assess the potential UXO risks for typical installation methods. After award of the permit construct and operate the wind farm and completion of the preliminary design of the windfarm, the installation methods will require reassessing and amending where applicable.

9.1 GEOTECHNICAL SITE INVESTIGATIONS

RVO.nl and future developers will conduct geotechnical site investigations. The following soil survey methods are likely to be considered:

- Cone Penetration Tests (CPT's);
- Rotary drilling or pulse drilling;
- Vibrocore sampling (VC's);
- Grab samples;
- Drop core sampling.

9.1.1 Cone Penetration Tests

The cone penetration test (CPT) is a common in situ testing method used to determine the geotechnical engineering properties of soils and assessing subsurface stratigraphy. The testing apparatus consists of an instrumented still cone having a tip facing down, with a usual apex angle of 60° and cross-section area of 1,000 mm^2. The cone is attached to an internal still rode than can run inside an outer hollow rod, which itself is attached to a sleeve.

The test is carried out by first pushing the cone into the ground at a standard velocity of 1 to 2 cm/s while keeping the sleeve stationary. It is possible to conduct CPT's up to depths of approximately 25 m below the seabed.

<u>Potential UXO risks</u>

Potential UXO risks are:

- Direct contact[31] between a UXO and jacks, anchors and/or suction anchors of the vessels conducting the site investigations.
- Direct contact between a UXO and the cone during the geotechnical investigations.

9.1.2 Rotary drilling or pulse drilling

Rotary drilling or pulse drilling is often used for deep seabed sampling for pilling associated with piling for wind turbines.

[31] Direct contact may initiate the fuze on a UXO or crush a UXO causing a detonation.

Rotary drilling is used for obtaining representative samples of sediments which could not be recovered using traditional cable percussion or window sampling. The drilling method involves a powered rotary cutting head on the end of a shaft, which is driven into the ground as it rotates. The sample is recovered using an inner barrel or a removable tube or liner to be recovered and brought to the surface.

A pulse drilling is a cased drilling system in which the sample is recovered from the bore hole with a pulse attached to a winch. The support tube can be rotated with the aid of a turntable and can be moved up and down.

<u>Potential UXO risks</u>

Potential UXO risks are:

- Direct contact between a UXO and jacks, anchors and/or suction anchors of the vessels conducting the site investigations.
- Direct contact between a UXO and the cutting head/pulse during the geotechnical investigations.

9.1.3 Vibrocore sampling

Vibrocoring is a technique used for collecting samples of unconsolidated saturated sediments. A core tube is attached to a source of mechanical vibration (the power head) and lowered into the sediment. The vibrations provide energy for rearranging the particles within the sediment in such a way that the core tube penetrates under the static weight of the vibrocoring apparatus. The core length depends on the system used and varies from 3 up to 12 m.

<u>Potential UXO risks</u>

Potential UXO risks are:

- Direct contact between a UXO and jacks, anchors and/or suction anchors of the vessels conducting the site investigations.
- Direct contact between a UXO and the vibrocore during the geotechnical investigations.
- Accelerations/vibrations with an amplitude > 1 m/s^2 in the surrounding soil during the sampling.

9.1.4 Grab sampling

A grab sampler is a simple form of seabed soil sampler. The grab units tend to be either hydraulically or manually operated. The unit is typically deployed from a vessel's crane or A-frame to recover the samples back to deck. Grab samples can be additionally ballasted to assist in the sampling of compacted sediments and allowing the grab to be deployed in strong currents. This can be achieved through the use of lead ballast weights mounted on the rear of both buckets and also on to both arms.

Grabs commonly cover an area of $0.05m^2$ to $0.2m^2$, usually penetrating to a maximum depth of 15 cm into the sea floor.

The grab is lowered vertically towards the sea floor, at an even rate of speed. The survey vessel is kept in position and the wire maintained vertically during the winch operation. Between approximately 5 and 10 m above the sea floor, the lowering speed is reduced to a complete stop, followed by slow lowering (< 0.5 ms-1) for the last few meters allowing the grab to set down on the sea bed as gently as possible. Because of this the impact on UXO that might be present on the seabed is limited. The impact of the grab sampler on the seabed is assessed to be too small to initiate the fuze on UXO.

Potential UXO risks

Potential UXO risks are:
- Direct contact between a UXO and jacks, anchors and/or suction anchors of the vessels conducting the site investigations.

9.1.5 Drop core sampling

Drop core samplers are capable of obtaining continuous core samples in any water depth, subject to the availability of a suitable vessel and installed deployment system. The gravity corer, which drops in free-fall from a limited height, penetrates the seabed merely under gravity.

The stationary piston corer is a gravity corer which also drops in freefall from a limited height but has the lower end enclosed by a piston, until penetration into the soil commences. The piston, connected to the main lift cable by wire which becomes taut when the coring tube comes into contact with the seabed, remains approximately stationary as the tube penetrates. The presence of the piston creates a negative pressure in the coring tube, enabling the frictional forces of the core on the walls of the tube to be overcome. This generally results in recovery rates which are better than those obtained with a standard gravity corer. A piston is particularly suited to soft cohesive soils.

Gravity and piston corers can be operated from a large variety of nonspecialised survey vessels, having adequate handling capabilities (crane, derrick, boom, or portal or A-frame). Depending on the system used it is possible to collect samples of up to 6 metres in length.

Potential UXO risks

Potential UXO risks are:
- Direct contact between a UXO and jacks, anchors and/or suction anchors of the vessels conducting the site investigations.
- Direct contact between a UXO and the drop core sampler during the geotechnical investigations.

9.2 ROUTE CLEARANCE

Prior to the start of marine operations, it is essential to ensure the inter-array cable routes are clear of obstructions that may hinder the operation. First out of service cables in the area (if present) will be pulled up with a grapnel. The vessel will cut out the abandoned cables and recover a section of the cable to open a gap through which the burial machine can pass. The two cut ends of the cable at either side of the gap will be fitted with weights to secure them against movement before they are returned to the seabed. The grapnel will be designed to penetrate the seabed up to 2 m.

Seabed debris such as scrap trawler warps or ships’ crane wires that may have been jettisoned by vessels onto the seabed, abandoned communications cables and other debris can be detrimental to the burial machine. Therefore a “visual” seabed route clearance operation and a Pre-Lay Grapnel Run (PLGR) are carried out, preferably shortly prior to inter-array cable installation.

A “visual” seabed route clearance operation usually involves the use of side scan sonar techniques to check the route for large debris such as shipwrecks etc. The targets will be inspected by either Remotely Operated Vehicle (ROV) or divers to investigate the preferred method of removal. Large debris items will be salvaged either using large grabs or installing hoisting cables.

The PLGR involves a vessel towing a grapnel train arrangement over the seabed. The grapnel wire pulling the grapnel train will have a length of at least 4-5 times the water depth.

The vessel follows the cable route to hook in and recover all small debris like lost fishing nets, ropes and wires from the seabed, following the centre line of the planned inter-array cable routes with a certain tolerance either side of the planned cable routes. This work is done in order to clear the route prior to the installation of the cables. The grapnel train configuration will only 'scratch' the surface of the seabed. Penetration of the seabed is dependent on the type of grapnel train and the speed of the towing vessel.

There also is a possibility the developer will deploy the Vertical Injector (VI) to clear the path of the cables to the required depth and remove debris. In this case the vessel will be located above the VI in water depths over 10 m.

Debris hooked or grabbed will be recovered to deck of the vessel for appropriate licensed disposal ashore.

<u>Potential UXO risks</u>

Potential UXO risks are:

- Direct contact between a UXO and grabs.
- Direct contact with a UXO during installation of hoisting cables.
- Direct contact between a UXO and the grapnel train arrangement during the Pre-Lay Grapnel Run and Route Clearance.

9.3 DREDGING

Pre-sweeping by dredging may be used to reduce the height of the sand waves along the inter-array cables routes and produce a flatter path for the installation equipment to move along. This also allows for greater control of the burial depth of the cables. It also makes the protection afforded by burial more resistant to sand wave mobility and therefore more durable over time.

This pre-sweeping operation may be undertaken just prior to laying operations to ensure the dredged path remains open for the installation to take place. The pre-sweeping is likely to be carried out by Trailing Suction Hopper Dredgers (TSHD) dredging sand in layers by shaving off the crest lines of sand waves.

It is assumed that the dredged material will be re-deposited onto the seabed in the immediate vicinity of the pre-sweeping activity. Consequently, there is no spoil extraction from the marine environment.

A TSHD has large, powerful centrifugal pumps that enable it to suck up sand and clay from the seabed. One or two suction pipes run from the vessel to the bed. A drag head is attached to the end of the pipe and lowered to just above the seabed, making it possible to regulate the mixture of sand and water that it takes in. A TSHD stores the dredged material in its own hopper and discharges the left-over water (and silt) overboard. The TSHD is a self-propelled vessel which runs slowly forward over the dredging area using Dynamic Tracking (DT) and thus enabling the drag heads to "catch" the sand within the cable corridors.

<u>Potential UXO risks</u>

Potential UXO risks are:

- Direct contact between a UXO and the drag head during the dredging operations, or in the barge and at the disposal site. In these situations, the detonation effects are more severe.
- A detonation of a UXO in the pipes or pump of a TSHD.

9.4 CABLE INSTALLATION AND TRENCHING

The inter-array cables will be buried at a minimum of 1.0 m below the non-mobile reference level. Cable installation (burial) can take place either in-situ during installation or post-lay. In the in-situ method the cable will be simultaneously laid and buried. Post lay cable installation involves an ROV with a cable jetting tool, fluidising the soil to lower the cable op to the required burial depth.

The cables will be buried into the seabed by use of the following trenchers, depending on the selected installation method:

a) 'Vertical Injector' cable jet lance, penetrating the seabed to the required burial depth.
b) Jetting sledge or a jet trencher remotely operated vehicle with jet swords penetrating up to the required burial depth.
c) Self-propelled cable trenching systems (cable trencher) in areas with clay and other soils which are too difficult to penetrate with a jet trencher with a chain cutter penetrating the seabed up to the required burial depth.

9.4.1 Vertical injector

A vertical injector (VI) may be used to install the inter-array cables. The VI utilises water jets to fluidise the sediment along the cable routes to the target burial depth. During this installation phase the cable will be fed into the VI while it is towed along the route by the cable laying barge. As the soil is fluidised and displaced the foot penetrates the seabed to the required depth and the cable is laid at the rear. The soil refills the cable trench covering the laid cable as the VI passes. This methodology uses water jetting which has a relatively low energy in comparison to e.g. chain cutter trenching.

During operations, the VI is secured amidships by steel wires from which two runs beneath the bottom of the vessel. The jetting unit consists of high performance pumps injecting water through the water pipes of the sword shaft to the nozzles at the sword foot. The cables are fed directly from the vessel into the VI by tensioners pulling cables out of shipboard cable tanks.

<u>Potential UXO risks</u>

Potential UXO risks are:

- Direct contact between a UXO and the jet swords during cable installation operations.
- Direct contact between a UXO and divers/ROV's during inspections and as-built checks.
- UXO landing in the cable trench.

9.4.2 Jetting sledge or a jet trencher Remotely Operated Vehicle (ROV)

The jetting sledge (JS) is a sledge or skid system which is towed over the seafloor. The burial depths are in most cases limited to approximately 3 m - 7.5 m. Burial is achieved by using jet water on a plough/finger construction to fluidise the seafloor at the moment of laying the cable. The cable runs through the plough/finger construction. Alternatives are diver operated sledges or ROV operated sledges. The principles of burying the cable are the same as above described.

<u>Potential UXO risks</u>

Potential UXO risks are:

- Direct contact between a UXO and the sledge, skid, tracks, plough/finger construction during cable installation operations.
- Direct contact between a UXO and divers/ROV's during inspections and as-built checks.
- UXO landing in the cable trench.

9.4.3 Self-propelled cable trenching systems (cable trencher)

These types of cable trenching techniques are self-propelled and thus highly manoeuvrable. The machines are equipped with tracks running itself over the seafloor. The cable is buried using digger chains or V-cut trenching. It is very useful to deploy in areas where stiffer material is expected such as clay. A combination of jetting and digging is also possible.

Potential UXO risks

Potential UXO risks are:

- Direct contact between a UXO and the tracks, chain cutter/jet swords/cable jet lance during cable installation operations.
- Direct contact between a UXO and divers/ROV's during inspections and as-built checks.
- UXO landing in the cable trench.

9.5 SCOUR PROTECTION

Sandy soils, such as present in the HKW Wind Farm Zone, can be more or less susceptible to a type of erosion called scour. Due to tidal currents, a significant section of the soil around the piles can be removed, due to the effect of the foundation on the local flow pattern and velocities. Therefore, depending on the local conditions, scour protection may be needed. A common way of scour protection is rock dumping around the piles. Typically, the scour protection will be realized using layers of natural, crushed rock, increasing in size when going up from the seabed. The lowest layer of rock, which is small enough to restrain the soil, may be replaced by a geotextile. Prior to applying the scour protection seabed preparation may be needed.

Potential UXO risks

Potential UXO risks are:

- Direct contact between a UXO and dredging equipment and/or gravel or rock during the removal of obstructions, the preparation of the seabed and dumping of gravel/rock.
- Direct contact between a UXO and divers/ROV's during inspections and as-built checks.

As a consequence of scour buried UXO in the vicinity of the piles can change position or even get moved by tides. This risk can occur in the operational phase of the platform.

9.6 ROCK PLACEMENT

Rock placements may be carried out at the crossing locations with in-service cables and pipelines. Rock placements can be carried out by side stone dumping vessels. These vessels are self-propelled and outfitted with a strengthened flat deck to load the rock. Stones are pushed overboard with lateral hydraulic slides. The vessels are either outfitted with a series of anchors and winches for accurate positioning or with a Dynamic Positioning (DP) system.

In deeper water a rigid fall pipe mounted to the side of the ship can be used. The rock will be loaded into a funnel mounted on the fall pipe. The use of a fall pipe improves the positioning of rock placements and reduces the impact of falling rocks on the seabed. The positioning can be achieved by either using anchors or DP.

Potential UXO risks

Potential UXO risks are:

- Direct contact between a UXO and dredging equipment and/or gravel or rock during the removal of obstructions, the preparation of the seabed and dumping of gravel/rock.
- Direct contact between a UXO and divers/ROV's during inspections and as-built checks.

9.7 PILING

A wind turbine consists of a nacelle with rotor blades, a support structure and a foundation. For the UXO risk assessment only intrusive activities (all activities that influence the soil) are relevant. There are several suitable foundation options. The decision for a foundation type will be based on a range of factors, including water depth; tidal, wind and wave conditions; logistical practicalities; commercial factors; ease of construction and installation; and the type and size of turbine chosen. Figure 24 shows three possible foundation types.

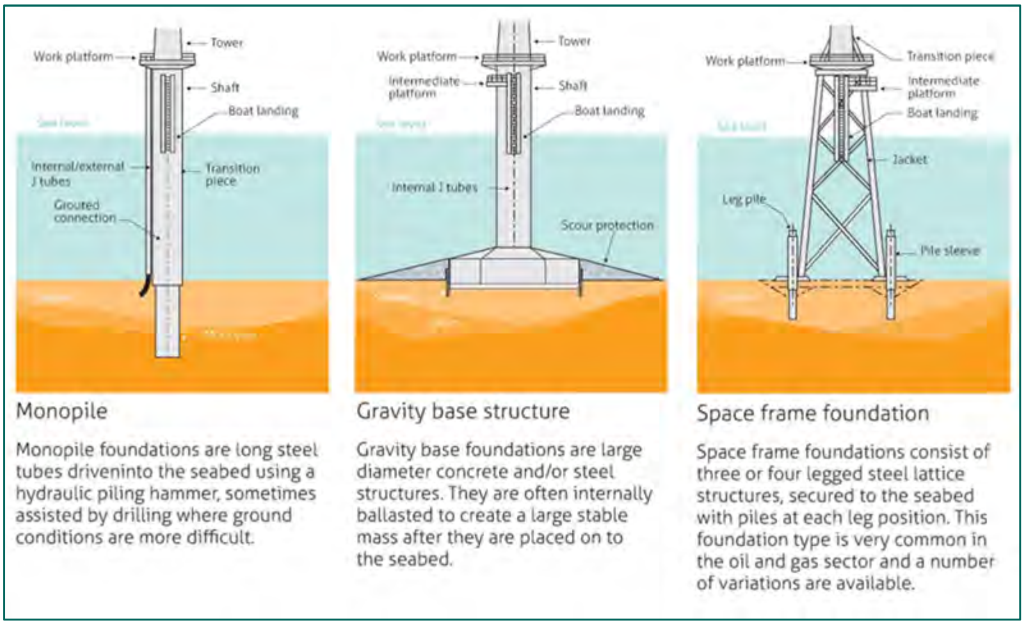

Figure 24: Example of suitable foundation types[32].

Monopiles or a jacket structure with driven piles as foundation are the most likely foundation types to be utilized. The dimensions of the piles are not yet known. The piles will be driven into the seabed using a hydraulic piling hammer. The type of pilling hammer to be used is yet unknown. The vessels/platforms for installing the foundation may be anchored to the seabed with jacks.

<u>Potential UXO risks</u>

Potential UXO risks are:

- Direct contact between a UXO and jacks of the vessels installing the foundation.
- Direct contact between a UXO and dredging equipment and/or gravel or rock during the removal of obstructions, the preparation of the seabed and/or gravel/rock dumping.
- Direct contact between a UXO and the foundation during the placement of the foundation.
- Accelerations with an amplitude > 1 m/s^2 in the soil surrounding a UXO during the placement or removal of the foundation (depending on the type of foundation, there are techniques that are vibration-free). These accelerations can occur up to well over 100 m around the piles.

[32] Source: www.navitusbaywindpark.co.uk

10 UXO RISK ASSESSMENT

In assessing the overall UXO risks for the project a Semi Quantitative Risk Assessment (SQRA) process was applied. SQRA is widely considered best practice in the offshore industry. The assessment is based on the conclusions of the conducted historical research (see chapter 4), the planned installation methods (see chapter 9), the hazards of the UXO likely to be encountered (see chapter 7) and the effects of detonations (see chapter 8).

10.1 RISK ASSESSMENT MATRIX

The following matrix (Table 12) is used to quantify the risk. Each generic UXO hazard is assessed for 'Severity / Consequence Class' and 'Likelihood of Risk Event'. The 'Likelihood of Risk Event' is related to the 'Likelihood of Presence', the 'Confidence Level' and the likelihood of initiation of an item of UXO[33].

			Likelihood of Risk Event (%)				
			A	**B**	**C**	**D**	**E**
			Rare (< 1%)	Unlikely (1% - 10%)	Possible (10% - 25%)	Likely (25% - 50%)	Almost Certain (> 50%)
Severity / Consequence Class[34]	**1**	Trivial	LOW 1	LOW 2	LOW 3	LOW 4	MEDIUM 5
	2	Minor	LOW 2	LOW 4	LOW 6	MEDIUM 8	MEDIUM 10
	3	Moderate	LOW 3	MEDIUM 6	MEDIUM 9	MEDIUM 12	MEDIUM 15
	4	Major	MEDIUM 4	MEDIUM 8	HIGH 12	HIGH 16	HIGH 20
	5	Severe	HIGH 5	HIGH 10	HIGH 15	HIGH 20	HIGH 25

Table 12: UXO Risk Assessment Matrix.

[33] The risk factor values assigned in the SQRA are determined by UXO-experts and are consequently subjective and open to different interpretation. Data for a statistical analysis is not available. Therefore risk calculation results must be treated with caution and an understanding of their origin.

[34] A measure of the effect of the risk occurring.

10.2 CRITERIA FOR DETERMINING RISK TOLERABILITY

The applied risk management matrix divides risk into three bands, LOW, MEDIUM and HIGH. In regards to assessing UXO related risks the 'As Low As Reasonably Practicable' (ALARP) principle is applied. This means mitigation measures are required to reduce the risks to 'As Low As Reasonably Practicable' (ALARP). The concept of "reasonably practicable" implies assessing risks against the effort, time and money required to (further) reduce those risks. Thus, ALARP sets the level to which workplace related risks are to be reduced by specific means which are considered to be reasonable and not excessive. Please note there will always be a residual risk that cannot be further controlled.

The ALARP principle relates to risk management matrix as follows.

LOW : Adequate mitigating measures in place. Acceptable risks, no further action required.

MEDIUM : Further assessment for additional controls may be required to reduce the risk.

HIGH : Further assessment is required to identify additional controls and reduce the risk (ALARP)

10.3 RISK ASSESSMENT RESULTS HOLLANDSE KUST (WEST) WIND FARM ZONE

Table 13 shows the UXO risks within the HKW Wind Farm Zone prior to the conduction of mitigation measures. The resulting risk for each source item is a function of the 'Likelihood of Risk Event' and the 'Severity / Consequence Class'.

The 'Likelihood of Risk Event' is the product of the 'Likelihood of Presence' and the likelihood of initiation of an item of UXO by the planned installation operations. The values assigned to each factor in the risk calculation are subjective and based on many variables, which themselves are difficult or impossible to quantify. Data for a statistical analysis is not available. Therefore, risk calculation results must be treated with caution and an understanding of their origin.

UXO risk is generally considered a low probability but very high consequence event, therefore it is the latter factor that usually dictates the overarching risk score. The potential consequence of a UXO detonation is by far the dominant factor in the calculation.

The 'Severity / Consequence Class', for example, will depend on the precise circumstances of the receptor (construction, equipment/personnel, vulnerability, depth of water, lay-back etc.). Likelihood of encounter will be governed by, inter alia, whether the UXO is likely to be completely buried, and to what depth, measured against the depth of intrusion into the sediment of a particular activity. The values assigned cannot be absolute or based upon statistical data (for example, of previous occurrences) because the data is not generally available and there are a great many permutations of the factors involved. The UXO specialist provides a professionally informed judgement based upon empirical, qualitative and anecdotal evidence employed in a consistent approach.

The purpose of the risk calculation at this stage is only to produce a relative order of merit to provide input for the Risk Mitigation Strategy. Nevertheless, despite its limitations, the risk assessment matrix as currently used is suitable for adequately assessing and grading Health and Safety (H&S) risk, which is generally mandated by legislation as well as individual company policy. It is also a robust tool for assessing project risk tolerability.

Type of UXO	Likelihood of presence	Likelihood of Risk Event	Severity / Consequence Class	Risk Result
Aerial bombs	Highly Likely	C	5	15
Naval mines (contact)	Likely	B	5	10
Depth charges	Possible	B	5	10
Torpedoes	Unlikely	A	5	5
Rockets	Possible	B	2	4
Aircraft cannon shells	Possible	B	1	2
Artillery shells (Flak)	Unlikely	A	1	1

Table 13: Risk Assessment results.

There is evidence that aerial bombs are highly likely to be present within the investigation area. There is also strong evidence indicating the likely presence of naval contact mines in the area. Since 2005 several air dropped bombs have been encountered in the area of investigation. Also several naval mines have been encountered in the vicinity of the area of investigation (see annex 8). The planned installation operations may cause an aerial bomb or naval mine to detonate. A detonation is assessed to be 'possible' and may be initiated by e.g. crushing with a cable trencher during cable lay operations, a kinetic energy created during pile foundation operations, etc.

In case of a detonation under water, the water column provides protection against fragmentation. The bubble jet and shock effect however, may cause serious damage to the vessel, compromising the integrity of the ship. Also, personnel may be injured or killed due to the shock or sinking of the vessel.

11 OUTLINING THE UXO MITIGATION STRATEGY

In strategic terms, the UXO risk on the project can either be:

- Accepted by all parties and no further proactive action is taken.
- Mitigated with measures to contain, and/or eliminate the UXO risks (by reducing the probability or consequences).
- Carried with the balance of any residual risk remaining after conduction of the mitigation measures transparently exposed to those parties involved with site works.

Although mitigation is generally the most cost effective and efficient option for dealing with UXO risks, a balanced blend of the options is usually required to comply with best practice. This desk-based study and risk assessment has shown that the risk from UXO to the proposed operations are either 'Low', or 'High'. Mitigation is required to reduce the 'High' risks to ALARP. All combinations with a 'Low' risk level do not require mitigation measures. It is recommended to accept the residual risk and conduct the operations as planned.

11.1 AIM OF THE RECOMMENDED UXO RISK MANAGEMENT STRATEGY

Research for this study has established that there is a UXO hazard as the following three components are present:

- Source – a UXO hazard that exists,
- Pathway – a mechanism that may cause UXO to detonate,
- Receptors – these would be at risk of experiencing an adverse response following the detonation of a UXO.

The purpose of hazard mitigation is to take action to address one or more of these components to reduce the probability of the problem occurring or to limit the impact of the problem if it does occur. Thereby eliminating the hazard or reducing the hazards to an acceptable level. When considering the hazards associated with UXO the most logical approach is to employ measures to reduce the probability of an event occurring. For the HKW Wind Farm Zone this is best achieved by addressing the source of the hazard.

The primary aim of the recommended UXO risk management strategy is to reduce the health and safety risk to personnel to ALARP. The objectives of the mitigation strategy, are:

- Reduce the H&S risks to ALARP,
- Ensure it is technically robust within the bounds of available technology,
- Take account of the potential for buried UXO,
- Provide a solution that is pragmatic and at best value to developer.

11.2 METHODOLOGY

The conducted historical research has shown that several types and calibres of aerial bombs, rockets, naval contact mines, torpedoes and depth charges could be present within the investigation area. The potential effects of a possible detonation of a UXO on people, equipment, vessels and surroundings are to be considered unacceptable. The risk associated with UXO's shall therefore be mitigated by reducing the probability on encountering UXO's during the site investigation, site preparation and installation activities. This means mitigation measures are required to reduce the risks to as low as reasonably practicable (ALARP). It is recommended to investigate the possible presence of UXO by performing a UXO geophysical survey, re-routing of inter-array cables and re-positioning of turbine locations to avoid identified targets that meet the threshold criteria, identification of targets that cannot be avoided and disposal of actual UXO objects prior to any intrusive works.

12 UXO SURVEY METHODOLOGIES

The conducted historical research and this additional historical research has shown that several types of UXO could be present within the entire HKW Wind Farm Zone. Due to the types and sizes of UXO likely to be present there is no “silver bullet solution” for the UXO geophysical survey.

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.

UXO survey techniques that are most likely to be considered for the HKW Wind Farm Zone 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 these are yet considered to be either unproven in the commercial sector or employed by the military and cost-prohibitive. Acoustic survey and electrical resistance survey techniques are being tested in pilot projects to improve possibilities for classification of anomalies.

12.1 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).

12.1.1 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 weak magnetic anomalies; and they can provide obvious improvements in spatial resolution over the total field measurement alone.

12.1.2 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.

12.2 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.

12.3 SIDE SCAN SONAR (SSS)

Side scan sonar, when used for UXO detection, is a proven and capable remote sensing tool. Objects can be distinguished in SSS data based on e.g. size, shape, structure and shadow. The shadows cast behind an object, proud of the sea floor, are the tell-tale sign that an object has just been ensonified. 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 HKW 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 UXO covered in concretion[35] or natural accretion (e.g. barnacles, clamshells, etc.) 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 large UXO items (if present) are detected if the seabed conditions are suitable and the objects are on the seabed or partly buried. Buried UXO will not be detected. SSS on its own is not considered to be a reliable system to mitigate the risks of the presence of large UXO items. This system should always be combined with other survey techniques, for example MAG survey.

12.4 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. Buried UXO will not be detected.

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[35] Concretion is a compact mass of mineral matter.

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 large UXO items. This system should always be combined with other survey techniques, for example MAG survey.

12.5 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 large UXO items 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 large UXO items. This system should always be combined with other survey techniques, for example MAG survey.

12.6 COMPARISON OF SURVEY TECHNIQUES

In table 15 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 enhance the data evaluation, it is recommended to preform survey operations with a spectrum of survey techniques, for example MAG, SSS and MBES. To enhance the evaluation process, it is recommended to correlate the data obtained with the different survey techniques.

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.

Method	Strengths	Limitations
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.
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 14: Comparison of survey techniques.

For a dedicated advice regarding survey techniques to be applied for HKW Wind Farm Zone see chapter 13.

13 THRESHOLD LEVELS TO BE APPLIED

The SQRA has shown that certain types of UXO necessitate mitigation measures to reduce the risks to as low as reasonably practicable (ALARP). The mitigation measures consist of UXO survey, avoidance of significant objects[36], 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 for modelling of anomalies detected by a UXO survey in the HKW Wind Farm Zone needs to be determined. This chapter provides the provisional thresholds needed to mitigate the risk to a level that is considered ALARP. <u>The threshold levels need to be reassessed based on the preliminary design and proposed installation methodologies.</u>

13.1 SPECIFICATIONS OF UXO THAT REQUIRE MITIGATION MEASURES

Table 15 provides the known specifications of the UXO likely to be present that require mitigation measures.

Category	Type	Calibre	Origin	Diameter (cm)	Length (cm) (without / with tail section)	Weight in air (kg)	NEQ (kg) (dependent on type of charge)	Ferrous mass (dependent on main charge)
Aerial bomb	GP MK I-III	250 lbs	UK	26	70 / 140	112	28.6 / 30.8	83.5 / 81
Aerial bomb	GP MK IV - VII	250 lbs	UK	26	70 / 142	104	30.7	73.3
Aerial bomb	GP	250 lbs	US	27.7	91.4 / 115.3	117	56.1 / 58.5	60.9 / 58.8
Aerial bomb	Demolition	300 lbs	US	27.7	100 / 123.4	124	62	62
Aerial bomb	GP	500 lbs	UK	32.6	94.5 / 179.3 or 141.2	213.4	64.8	148.6
Aerial bomb	GP	500 lbs	US	36	118.4 / 150	227	120	107
Aerial bomb	GP	1.000 lbs	UK	41	133.4 / 180 or 220	486	151 / 171.5	335 / 314.5
Aerial bomb	GP	1.000 lbs	US	47.8	135 / 170	443	240 / 253	203 / 190
Aerial bomb	MC	250 lbs	UK	26	70 / 133.4	102	37	65
Aerial bomb	MC	500 lbs	UK	32.8	94.5 or 104 / 145 or 179	226	92 / 101	124 / 125
Aerial bomb	MC MK I	1.000 lbs	UK	45	133.4 / 183	549	215 / 238	334 / 311
Aerial bomb	MC MK III	1.000 lbs	UK	41	140 / 180	550	166 / 195	384 / 355
Aerial bomb	HC	4.000 lbs	UK	76	189 / 279	1707	1006 / 1102	701 / 605
Aerial bomb	LC	4.000 lbs	US	86	241 / 298	1860	1472 / 1525	388 / 335
Aerial bomb	SAP	250 lbs	UK	23	802 / 125	111	19	92
Aerial bomb	SAP	500 lbs	UK	33.5	106 / 156	222	41	181
Aerial bomb	SAP	500 lbs	US	30	120 / 147	227	73.5	153.5
Aerial bomb	AS	250 lbs	UK	29	89.5 / 147	112	60 / 62	52 / 50
Aerial bomb	Fragmentation	260 lbs	US	21.5	82 / 111	118	15	103
Underwater ordnance	Depth charge	n.a.	UK	28	98	134	73	61

[36] Objects that meet the set survey thresholds.

Category	Type	Calibre	Origin	Diameter (cm)	Length (cm) (without / with tail section)	Weight in air (kg)	NEQ (kg) (dependent on type of charge)	Ferrous mass (dependent on main charge)
	(Mk. VIII & MK XI)							
Underwater ordnance	Torpedo	18 inch	UK	45,7	495	789	202	Unknown
Underwater ordnance	Moored contact mine Mk XIV	n.a.	UK	79	n.a.	255	145 / 204 / 227	110 / 51 / 28
Underwater ordnance	Moored acoustic mine Mk XVII	n.a.	UK	79	n.a.	255	145 / 227	110 / 28
Underwater ordnance	Moored mine EMC	n.a.	GER	120	n.a.	630	300	330

Table 15: Specifications of UXO possibly to be present.

13.2 THRESHOLD LEVEL FOR MODELLING OF ANOMALIES

For the installation of the wind farm several installation methods are considered. For a short explanation of the installation methods see chapter 9. The effects on personnel and equipment will depend on the distance between the detonation point and the vessels/platforms and personnel and the water depth at the point of detonation. In deep water fragmentation is not considered to be a critical factor.

Taking the results of the SQRA into account, it is assessed that the 250 lb 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 between 30 and 60 kg of HE. The ferrous weight can range from 50 to 83 kg dependent on the make, modification and type of munition. Assuming these items can be successfully detected and identified within the geophysical datasets, larger objects will also be detectable. Magnetometry is generally considered the most reliable and common method of UXO geophysical survey. The provisional magnetometer (MAG) threshold is set on 50 kg ferrous mass. This threshold is also sufficient to detect ferrous naval mines which are likely to be present in the area. The risk also posed by the possible presence of depth charges, torpedoes and large calibre artillery shells will be mitigated sufficiently by applying the recommended threshold value.

13.3 REQUIRED DETECTION RANGE

The required detection range for UXO is to the intended installation depth +0.5m (inter-array cables) or the assessed MDB (turbine and platform foundations). Therefore, the maximum required detection range is assessed to be 5 m below seabed. The maximum required detection range is only applicable to the crests of the sand waves and needs to be reassessed after the seabed mobility study has become available.

13.4 AREAS TO BE SURVEYED

The size of the exclusion zones and the areas to be surveyed is dependent on the actual design, installation methodologies, geophysical parameters and the recommended standoff distances. 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.

13.5 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. On completion of the data acquisition the detection range threshold determined during validation, together with the sensor altitudes achieved is used to QC the survey data and to check for achieved detection depths below seabed and 'coverage achieved'. 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 survey system and the validation results of these systems.

13.6 REGULATION AND STANDARDS

The applicable regulation on EOD-operations in the Netherlands is the "Werkveldspecifiek Certificatie Schema – Opsporen Conventionele Explosieven (WSCS-OCE)". According to the WSCS-OCE all UXO clearance companies must be certified for 'scope A' and/or 'scope B'. A 'scope A' certified UXO clearance company is responsible for all UXO search and clearance operations. A 'scope B' company can be responsible for supporting the operations on the level of civil engineering.

The International Marine Contractors Association (IMCA) is the international trade association representing offshore, marine and underwater engineering companies. IMCA guidelines and standards are applicable to the offshore industry. Though not mandatory, use of the IMCA guidelines and standards is recommended.

13.7 ADDITIONAL SAFETY PRECAUTIONS

In addition to the UXO risk mitigation strategy outlined in chapter 11 some additional safety precautions are recommended.

13.7.1 Geotechnical sampling

There are a small chance 20 mm shells will be encountered and recovered to deck during geotechnical sampling. It is not possible to mitigate this risk by use of geophysical survey techniques. The risk can be reduced satisfactorily to below the ALARP threshold through procedural mitigation measures alone (e.g. safety instructions, safe working protocols, etc.).

13.7.2 Dredging and pre-sweeping

There is a possibility of UXO below the applicable threshold level being sucked up by a TSHD during pre-sweeping operations. A TSHD can be protected by utilisation of a grid in front of the suction head. This will prevent UXO with a diameter larger than the grid size to enter the system. A grid size of 100 mm will prevent UXO with a NEW > 1 kg to enter the system. Smaller UXO can enter the system and may detonate. The overall UXO risk for these items (NEW < 1 kg) can be reduced satisfactorily to below the ALARP threshold through existing procedural mitigation measures alone (e.g. safety instructions, safe working protocols, etc.).

13.7.3 Safe distance

With regards to the shredding effect that will occur in case of a detonation it is mandatory that no divers are present within the safe distance to simultaneous piling or trenching operations. The Dutch EOD regulation provides formulas for calculating the safe distances in case of a controlled demolition of UXO under water. In case of a controlled underwater UXO demolition the following formula is applicable for diving operations[37]:

$$R = 270 \sqrt[3]{W}$$

Where:

R	=	Radius safe distance in meters
W	=	NEW in kg. TNT-equivalents

Equation 3: Formula for calculating safe distances for diving operations in case of a controlled underwater UXO demolition.

The safe distance is calculated to be ≈ 730 m. This distance is calculated for a NEW of 20 kg, because of the possibility of a detonation of a 100 lbs air dropped bomb. This is the largest item of UXO that may be left behind after completion of the UXO clearance operations, since it's ferrous mass is below the determined threshold.

[37] Source: VS 9-861, Voorschrift Opruimen en Ruimen van Explosieven, September 29, 2010, note number 2010013496 (Dutch).

14 STANDOFF DISTANCES

Where magnetic or acoustic anomalies above the threshold level are encountered during the UXO survey, rerouting of inter-array cables or re-positioning of wind turbines may be the first mitigation measure. In such a case for example the cable will be rerouted around the magnetic anomaly, taking into account the other cable routes and the separation between the cables as well. In case re-routing/re-positioning around an anomaly appears not to be possible, the anomaly in the seabed will be investigated and identified. If the anomaly appears to be UXO which poses a risk to installation operations, the UXO would have to be removed or destroyed by the Dutch Navy if a reconsideration of the re-routing/re-positioning options does not resolve the matter.

Standoff distances are implemented around all geophysical survey anomalies above the applicable detection threshold (so called targets) that have not yet been confirmed as UXO through investigation by diver or ROV. Thus, the risk of a detonation caused by intrusive activities will be prevented if the object proves to be UXO. In this paragraph formulas for determining the standoff distances for inter-array cable installation by dredging and trenching and piling operations are provided. The standoff distance is the distance between the target and the RPL's of the inter-array cables or the centre of the pile. Maintaining the recommended standoff distances will ensure UXO related risks are sufficiently mitigated to a level that is considered ALARP.

14.1 STANDOFF DISTANCES FOR DREDGING AND PRE-SWEEPING

In this paragraph the recommended standoff distances for dredging with a TSHD are provided. A CSD cannot be protected due to the specific design of the cutter head. It is not foreseen that CSD will be used for the installation of the HKW inter-array cables. If, however CSD would be considered, then a separate assessment on the applicable standoff distances is to be made. The standoff distances in the case of the application of a CSD will be relative to any location at or in the seabed where the cutter head (crown) of the CSD would or could come.

In determining the standoff distances, the following factors need to be taken into account:

- Positional accuracy target (PT);
- An additional safety margin (M) based on the dimensions of the UXO to be expected;
- Positional accuracy TSHD drag head (PDH);
- Dredging depth (D) and slope (S);
- Trench width (TW).

14.1.1 Positional accuracy target and margin

The positional accuracy of the targets on the PMTL is largely dependent on the positional accuracy of the survey vessel and survey equipment deployed. In general, the use of estimated or measured layback is not accurate enough and is not recommended. The use of an over side portable (shallow water) or through-hull (deep water) USBL system for underwater positioning is preferred. The performance of the system needs to be in accordance with the IMCA standard for underwater acoustic positioning (IMCA S 017, April 2011).

In determining the positional accuracy, a correct interpretation of the survey data is a prerequisite. The coordinates of the target need to be determined based on the magnetic centroid of the anomaly. Positioning bases on magnetic peak values will lead to considerable deviations (several metres) in positioning.

In Figure 25 the positional differences between positioning based on magnetic centroid and magnetic peak is illustrated.

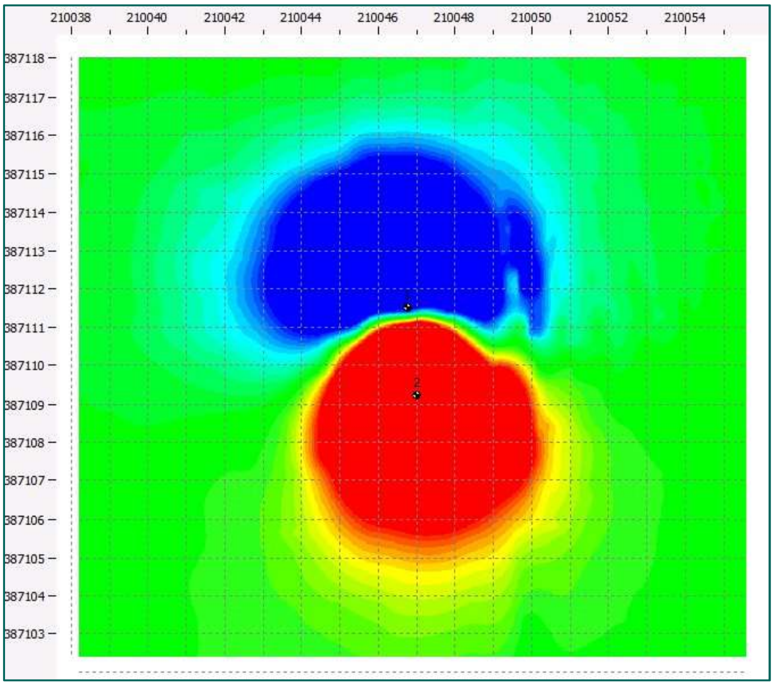


Figure 25: Illustration on the positional differences between magnetic centroid (1) and magnetic peak (2).

Taken into account all factors influencing the positional accuracy and a correct interpretation of the survey data the maximum positional error of targets (PT) on the (P)MTL is assessed to be approximately 2.5 m. Performed OA/QC operations on several projects show this is a realistic value.

The coordinates of targets on the PMTL represent the magnetic centroid of the objects. Therefore, an additional margin (M) needs to be taken into account to prevent the cable installation tool interacting with the target (possible UXO). This margin needs to be based upon the actual dimensions of the UXO expected. The largest UXO to be expected in the area of investigation are ground mines (length up to 4.10 m) and torpedoes (length 4.95 m). Based on these dimensions a margin (M) of 2 m is recommended.

14.1.2 Positional accuracy drag head

The drag head and the bottom part of the suction tube are cardanically connected to the top part of the suction tube and the vessel. This cardanical connection enables radial movement between the drag head and the vessel. Also, the vessel can turn over or away from the drag head. On a flat seabed a vacuum is established and maintained over the drag head during dredging. The vacuum will prevent large radial movements of the drag head. This might not be the case on a slope (e.g. sand wave). Several sensors on the drag head and the suction tube provide positional information to the bridge of the vessel. These sensors have a certain accuracy dependent on the type, length of the suction tube, etc..

14.1.3 Dredging depth and slope

The dredging depth is dependent on the applicable Depth of Lowering (DL) and the height of the seabed or mobile seabed features. The maximum dredging depth is dependent on the trencher to be deployed by the contractor. The gradient of the side slopes of the dredged profiles that will form is expected to be approximately 1:2.5 up to 1:4 in the sediments present in the investigation area.

14.1.4 Trench width

The trench width of the pre-swept or dredged trench is dependent on the size of the trencher to be deployed in the trench.

14.1.5 Standoff distance dredging

Based on the substantiation provided in this paragraph the standoff distance for dredging can be calculated by the following formula:

Standoff distance = PT + M + (D x S) + PDH + (0.5 x TW)

Where:

PT	=	Estimated positional accuracy of the target
M	=	An additional safety margin based on the dimensions of the UXO to be expected
D	=	Depth of dredging
S	=	Gradient of the side slopes of the dredged profiles that will form
PDH	=	Positional accuracy drag head
TW	=	Trench width (planned)

Equation 4: Formula for calculating the standoff distance for dredging.

The standoff distance and all parameters in the formula above are depicted in Figure 26.

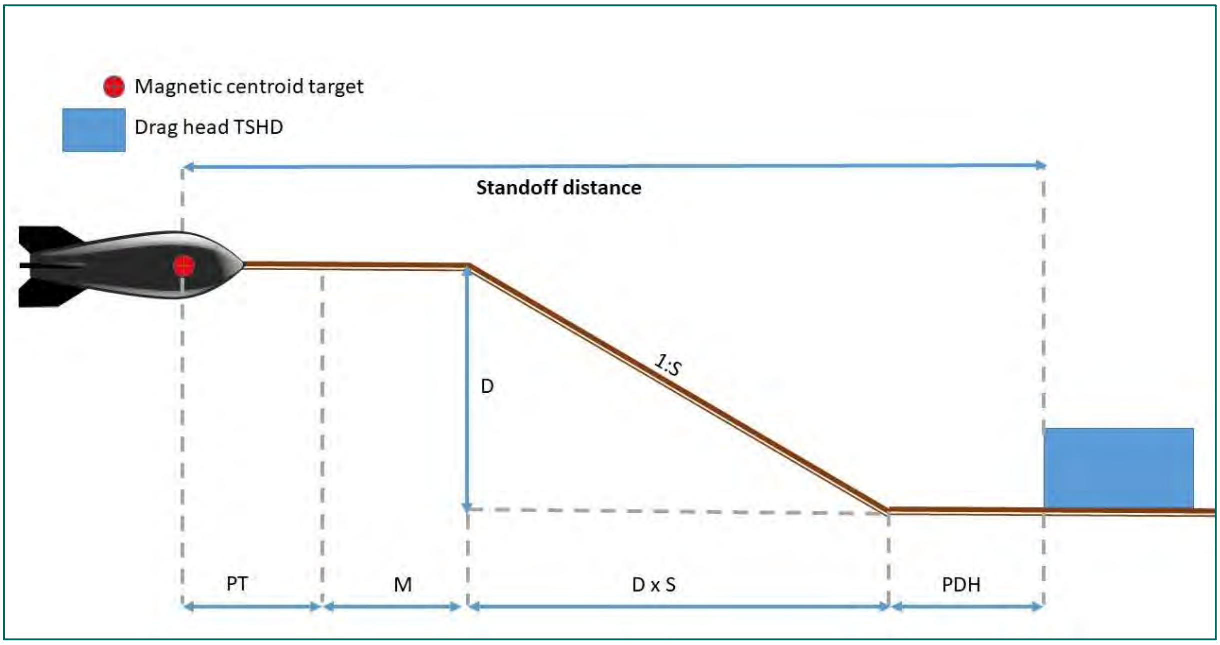


Figure 26: Illustration on the different zones and errors relevant for determining standoff distances for dredging/pre-sweeping.

The standoff distance for dredging is applicable to all dredging except for the pre-sweeping of sand waves.

14.1.6 Standoff distance pre-sweeping

Prior to cable installation sand waves might be pre-swept. In the sand waves UXO are to be expected at the bases of the sand waves, on the NMRL. As pre-sweeping does not go deeper than the NMRL, the standoff distance for pre-sweeping of sand waves can be calculated by the following formula:

Standoff distance = PT + M + PDH

Where:

PT	=	Estimated positional accuracy of the target
M	=	An additional safety margin based on the dimensions of the UXO to be expected
PDH	=	Positional accuracy drag head

Equation 5: Formula for calculating the standoff distance for pre-sweeping.

The standoff distance and all parameters in the formula above are depicted in Figure 26.
The standoff distance for pre-sweeping is applicable to the sand waves only.

14.2 STANDOFF DISTANCES FOR CABLE TRENCHING

In this paragraph the recommended standoff distances for cable trenching operations are provided. For cable trenching two situations need to be assessed:

- Trenching at locations with a post war sedimentary layer;
- Trenching at locations without a post war sedimentary layer.

14.2.1 Trenching at locations with a post war sedimentary layer

At locations where a post war sedimentary layer over 2 m thick is present, such as the dredge spoil area and the crests of the sand waves the trencher moves over the post war sediment. The tracks or skids of the trencher deployed will not pose a threat in these areas. UXO originating from both World Wars will lie underneath the post war sediments. Therefore the risk of the tracks or skids interacting with UXO is absent. Only the jet swords, plough blade, stinger, cutter chains, etc. will penetrate the seabed to a depth where UXO are to be expected.

In determining the standoff distances, the following factors need to be taken into account:

- Positional accuracy target (PT);
- A margin between the target and the jet swords, plough/finger construction, digger chains, etc. (M);
- The width of the intrusion influence zone (IIZ);
- Laying accuracy of the cable (LAC).

For substantiation on the positional accuracy of the target and the recommended margin see paragraph 14.1.1. The intrusion influence zone is estimated to be approximately 1 m width and is centred on the axis of the jet sword, chain cutter, etc.

The positional accuracy of the trencher is heavily dependent on the specific type and size of the trencher.

Based on the substantiation provided in this paragraph the standoff distance for cable trenching can be calculated by the following formula:

Standoff distance = PT + M + (0.5 x IIZ) + LAC

Where:

PT	=	Estimated positional accuracy of the target
M	=	An additional safety margin based on the dimensions of the UXO to be expected
IIZ	=	Intrusion influence zone, the zone influenced by the energy of the cable burial tool
LAC	=	Laying accuracy of the cable relative to the planned RPL

Equation 6: Formula for calculating the standoff distance for trenching at locations with a post war sedimentary layer.

The standoff distance needs to be measured from the middle of the jet swords, plough blade, stinger or cutter chain. The standoff distance and all parameters in the formula above are depicted in Figure 27.

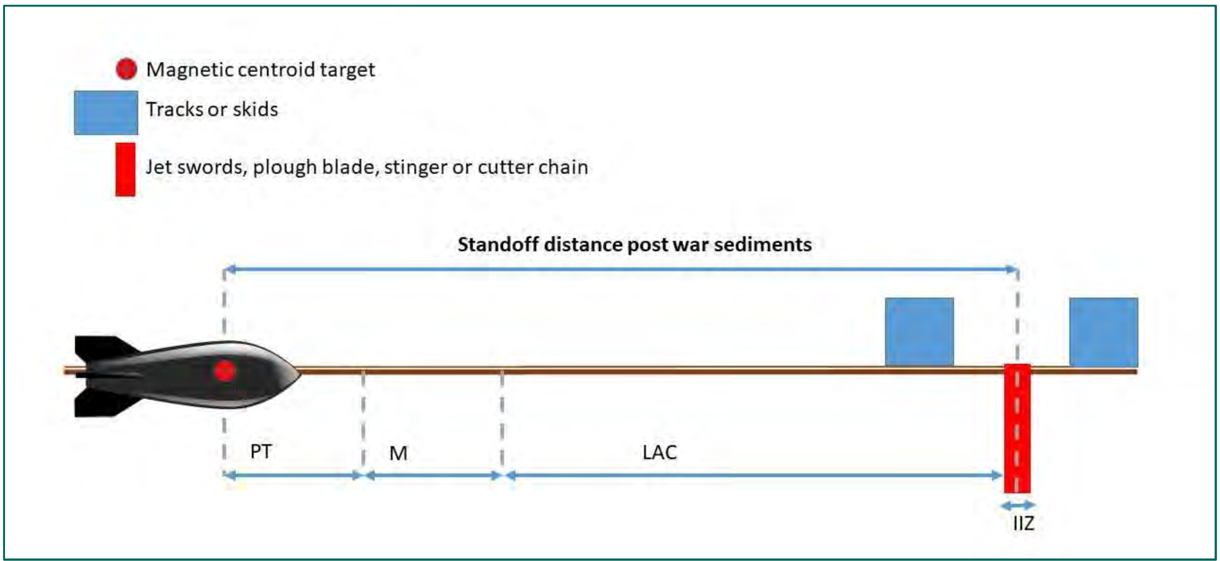


Figure 27: Illustration on the different zones and errors relevant for determining standoff distances for cable trenching at locations with a post war sedimentary layer.

14.2.2 Trenching at locations without a post war sedimentary layer

At locations where there is no post war sedimentary layer UXO are expected to be present proud on the seabed or partly buried. At these locations the possibility of direct contact between a UXO and the tracks or skids needs to be mitigated. This can be achieved by adding half of the width of the trencher (WT) to the standoff distance to the provisional standoff distances outlined in the previous paragraph.

The standoff distance for locations without a post war sedimentary layer is illustrated in Figure 28.

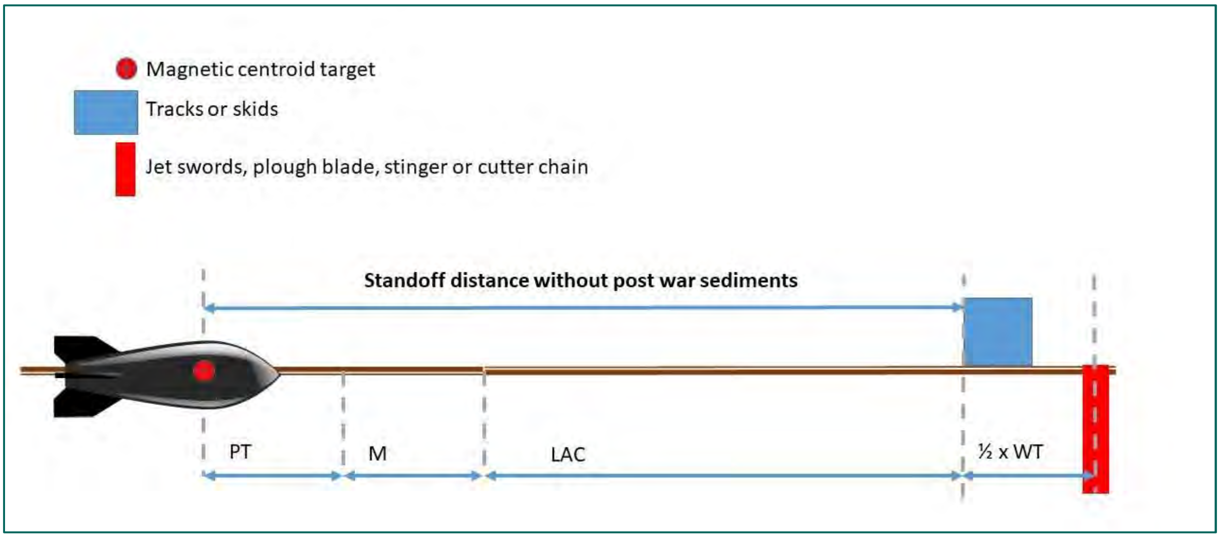


Figure 28: Illustration on the different zones and errors relevant for determining standoff distances for cable trenching at locations without a post war sedimentary layer.

Based on the substantiation provided in this paragraph the standoff distance for cable trenching can be calculated by the following formula:

Standoff distance = PT + M + (0.5 x WT) + LAC

Where:

PT	=	Estimated positional accuracy of the target
M	=	An additional safety margin based on the dimensions of the UXO to be expected
WT	=	Width of the trencher
LAC	=	Laying accuracy of the cable relative to the planned RPL

Equation 7: Formula for calculating the standoff distance for trenching at locations without a post war sedimentary layer.

14.3 STANDOFF DISTANCE FOR PILLING OPERATIONS

With regards to wind turbine installation only the construction of the foundation is relevant. The foundation of the turbines is likely to consist of monopiles. These piles will be driven into the seabed using a hydraulic piling hammer. The dimensions of the piles and the specific type of piling hammer are not known at this point in time.

The fuzes on air dropped bombs, and long delay fuzes in particular, are sensitive to movement and accelerations with an amplitude > 1 m/s^2 in the surrounding soil. This kind of accelerations will occur as a consequence of vibrations caused by piling operations. The radius of the area where these kinds of accelerations occur (AIZ) can be calculated. The dimensions of the piles, the type of piling hammer and the geotechnical data of the location are input for these calculations.

Based on the substantiation provided in this paragraph the standoff distance for piling can be calculated by the following formula:

Standoff distance = PT + M + AIZ + PAP + (0.5 x PD)

Where:

PT	=	Estimated positional accuracy of the target
M	=	An additional safety margin based on the dimensions of the UXO to be expected
AIZ	=	Acceleration influence zone
PAP	=	Positional accuracy pile
PD	=	Pile diameter

Equation 8: Formula for calculating the standoff distance for piling operations.

The standoff distance for piling operations is illustrated in Figure 29.

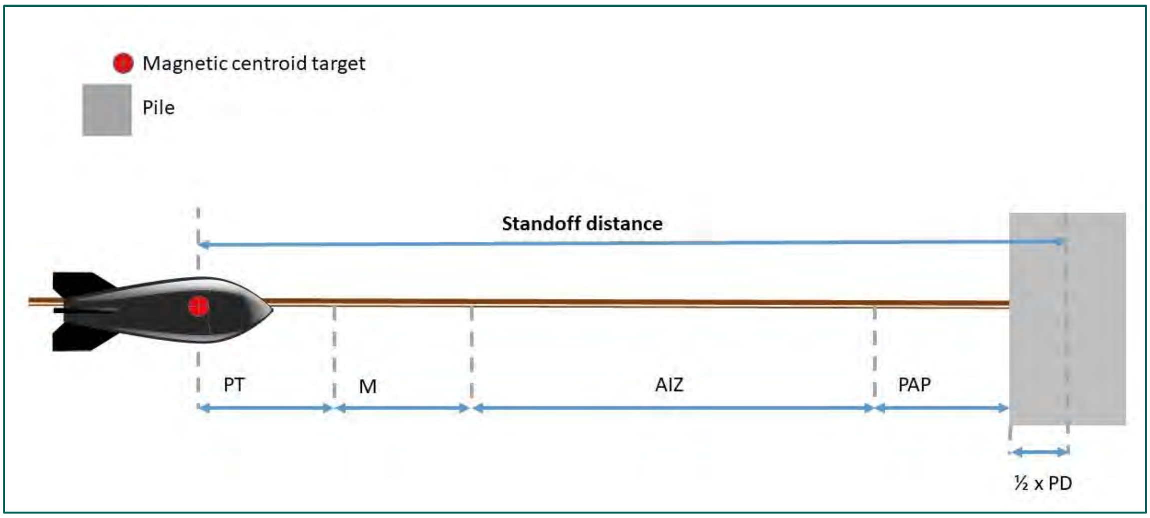


Figure 29: Illustration on the different zones and errors relevant for determining standoff distances for piling operations.

The provided formula for determining the standoff distance does not take into account the anchoring areas around the turbine locations, where a specific anchoring pattern might be required to install the turbines. After the design of the anchoring patterns around the turbines, the need for additional identification of targets within the anchoring patterns, but outside the determined standoff distance, needs to be assessed.

15 UXO SURVEY RECOMMENDATION FOR THE GEOTECHNICAL SURVEY

Because the investigation area was located just north of the main flight paths of Allied bombers, the frequent aerial attacks on shipping in the area and the fact that several minefields were present and several UXO were encountered, the entire investigation area must be considered a UXO risk area. For safe conduction of the geotechnical survey a UXO risk mitigation strategy is needed. In this chapter the UXO risk mitigation strategy for conducting the geotechnical survey is outlined.

15.1 IS A UXO SURVEY REQUIRED PRIOR TO GEOTECHNICAL SURVEY OPERATIONS?

The possible presence of UXO in the area, is not a constraint for geotechnical survey activities. With proper UXO Risk Management the risks can be reduced to a level that is as low as is reasonably practicable (ALARP). This risk management will require some form of UXO survey prior to the geotechnical survey operations.

15.2 RECOMMENDED SURVEY METHOD(S)

The survey methods to be applied depend on the survey thresholds and the maximal burial depth of UXO. This paragraph provides recommendations on the survey methods for the different geotechnical survey operations. For the recommended thresholds see chapter 13.

For all geotechnical survey operations, it is recommended to use DP vessels where possible. This will ensure the vessels position is maintained without jacks and/or anchors. This will limit the quantity/area of UXO survey operations significantly. In the event of positioning vessels with jacks and/or anchors attention should be paid to perform a UXO survey of these areas first. If objects that meet the threshold criteria are present, these locations should be avoided.

The applicable regulation on all UXO survey operations is the "Werkveld Specifiek Certificatie Schema – Opsporen Conventionele Explosieven (WSCS-OCE)". According to the WSCS-OCE the UXO survey contractor must be certified for 'scope A'.

According to the applicable regulation, the minimum requirement is to have all personnel, directly involved in UXO-search and removal projects, to hold a certificate "Basic OCE" as a minimum. This certificate assures that all personnel are properly trained and aware of the safety regulations involved with UXO-clearance. Therefore, it's recommended to train and certify the personnel involved with the geotechnical investigations to the level "Basic OCE". All personal involved in actual UXO survey and/or identification operations need to hold the applicable certificate required for their tasks.

15.2.1 CPT

For conducting the CPT's it is recommended to deploy a CPT with magnetometer cone where possible. This will enable real time detection of anomalies. In case an anomaly is detected it is recommend to move the location of the CPT to a location that is free of anomalies. In this case clearance operations in the preparation phase can be avoided. It is also possible to perform a non-intrusive magnetometer-based survey. The CPT's can be performed at locations that are free of anomalies that meet the threshold criteria.

At locations with larger water depths where the CPT system will be deployed on the seabed it is recommended to perform a magnetometer survey. In case an anomaly is detected it is recommend to move the CPT location to a location that is free of anomalies. In this case clearance operations in the preparation phase can be avoided.

15.2.2 Vibrocore and drop core sampling

Prior to the VC, grab and drop core sampling it is recommended to conduct a non-intrusive survey at each sample location. Due to the possible burial depth the most suitable technique is a magnetometer-based survey.

In case the locations of the VC samples in the sand wave area are located in the troughs, UXO burial will not be significant. For these locations, survey by Pulse Induction Metal Detectors (non-intrusive) is possible.

If sampling is limited to the tops of the sand waves (above the NMRL) in which UXO are not expected a UXO survey prior to the sampling is not mandatory.

The UXO survey may be conducted using survey vessels, UXO divers[38] or ROV's fitted with detection equipment. In the case of a diver conducted survey, although not mandatory, use off the IMCA guidelines and standards[39] is recommended. All divers also have to comply with the Dutch certificate B[40].

In case an anomaly is detected it is recommend to move the sample location to a location that is free of anomalies. In this case clearance operations in the preparation phase can be avoided.

15.2.3 Grab sampling

The impact of a grab sampler on the seabed is assessed to be too small to initiate a fuze on a UXO. Therefore, no UXO mitigation measures are necessary for grab sampling operations.

The only risk to mitigate is the risk of initiating a UXO by direct contact with jacks, anchors and/or suction anchors. This risk is mitigated by using DP vessels or by avoiding objects resulting from a magnetometer survey.

15.3 SIZE OF THE AREA TO BE SURVEYED

In case of CPT's with a magnetometer cone fitted, only the point of impact of the cone will be surveyed. If an anomaly is detected the test will be aborted and the CPT will be performed on a location in the vicinity of the planned location that is free of anomalies.

The size of the areas to be surveyed utilising 'standard' CPT's, VC and drop core samples is limited to the direct surroundings of the sample locations. The size of the area mainly depends on the positional errors to be reckoned with. In case anomalies are interpreted in the detection data and a new location free of anomalies has to be found, it is recommended to survey a slightly larger area. It is estimated that an area of 20 x 20 m centred on each sample location will be sufficient to locate a sample location free of anomalies outside the recommended standoff distances.

It might also be considered to perform a UXO survey in the preparatory stage of the project. In this case the survey results can be used to locate sample locations free of anomalies.

15.4 STANDOFF DISTANCES GEOTECHNICAL SURVEY OPERATIONS

The effects of most sample methods are limited to the point of impact of the sampling apparatus used. Only vibrocore sampling may have an effect on its surroundings.

[38] WSCS-OCE level "assistent OCE-deskundige" for survey operations and level "OCE-deskundige" for identification operations.

[39] IMCA International Code of Practice for Offshore Diving, February 2014.

[40] Arbeidsomstandighedenregeling, artikel 6.3, 01-01-2007.

The vibrations caused by the vibrocore sampler however, are assessed to have an acceleration under 1 m/s^2. This is the critical acceleration for initiation of a fuze mounted on an air dropped bomb[41]. Vibrations/accelerations may occur if the vibrocore hits a rock or other hard object and the surrounding soil starts resonating.

In determining the standoff distances, the following factors need to be taken into account:

- Positional accuracy target (PT);
- A margin between the target and the sample apparatus (M);
- The position accuracy of the sample apparatus (ASA);
- The radius of the intrusion influence zone (IIZ; only applicable to vibrocoring).

For substantiation on the positional accuracy of the target and the recommended margin see paragraph 14.1.1. The intrusion influence zone is the zone where accelerations > 1 m/s^2 are to be expected as a result of the vibrocore operations.

Based on the substantiation provided in this paragraph the standoff distance for geotechnical survey operations can be calculated by the following formula:

Standoff distance = PT + M + (0.5 x IIZ) + ASA

Where:

PT	=	Estimated positional accuracy of the target
M	=	An additional safety margin based on the dimensions of the UXO to be expected
IIZ	=	Intrusion influence zone, the zone influenced by the energy of the vibrocore
ASA	=	Position accuracy of the sample apparatus

Equation 9: Formula for calculating the standoff distance for geotechnical survey operations.

The standoff distance needs to be measured from the centre of the sample apparatus. The standoff distance and all parameters in the formula above are depicted in Figure 30.

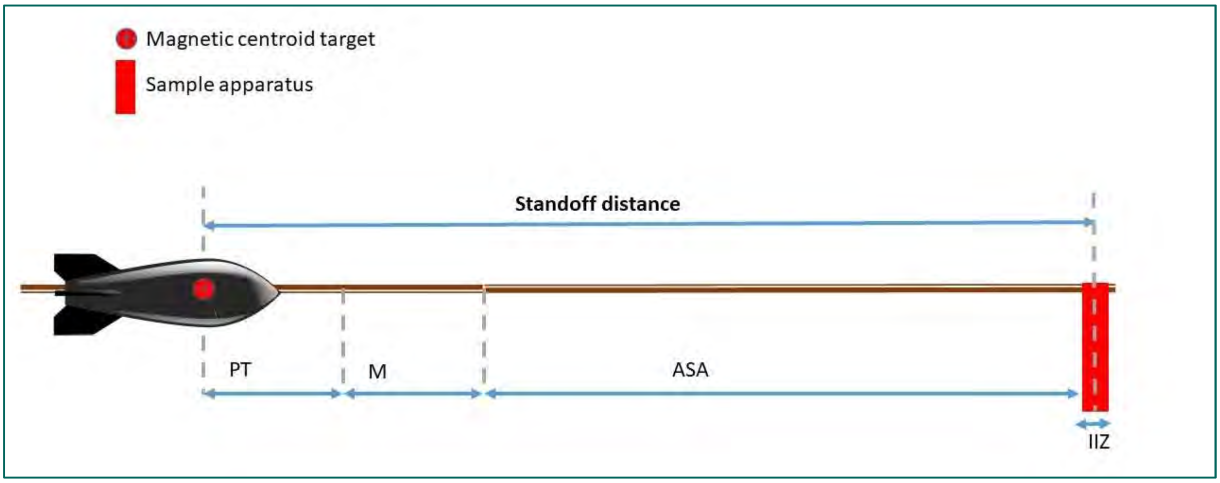


Figure 30: Illustration on the different zones and errors relevant for determining standoff distances for geotechnical survey operations.

[41] Mogelijke ondergrondse bomexplosies als gevolg van trillingen veroorzaakt door heien, 1989, onderzoek, Instituut voor Funderingscontrole (IFCO)" and "Risico van een ondergrondse bomexplosie als gevolg van trillingen veroorzaakt door heien, EOCKL, nr. 4267, 2005.

16 INPUT FOR PROJECT PLAN

At a later stage future developer will prepare a project plan for the installation of the HKW Wind Farm Zone, covering the areas dealing with potential UXO. As input for the project plan in this chapter advice is given with regards to:

1. Survey methods:
   a) For the specific UXO types which are to be expected with";
   b) For the specific installation depths along the route.
2. Compliance with WSCS-OCE in particular with regards to:
   a) Description of the method of detection and of the survey instruments to be used;
   b) Description of the method of localisation, unearthing and identification including equipment needed;
   c) Description of the method for temporary storage and security of UXO.

16.1 REGULATION AND STANDARDS

The applicable regulation on EOD-operations in the Netherlands is the "Werkveldspecifiek Certificatie Schema – Opsporen Conventionele Explosieven (WSCS-OCE)". According to the WSCS-OCE all UXO clearance companies must be certified for 'scope A' and/or 'scope B'. A 'scope A' certified UXO clearance company is responsible for all UXO search and clearance operations. A 'scope B' company can be responsible for supporting the operations on the level of civil engineering.

The International Marine Contractors Association (IMCA) is the international trade association representing offshore, marine and underwater engineering companies. IMCA guidelines and standards are applicable to the offshore industry. Though not mandatory, use of the IMCA guidelines and standards is recommended.

16.2 GEOPHYSICAL UXO SURVEY EQUIPMENT

To meet the requirements of the detection thresholds and depths as outlined in chapter 13 and 5 a variety of different sensors and techniques are recommended. The additional survey equipment proposed to complete the survey work and meet the ALARP principle for the cable installation is listed below.

Sensor	Data Type	Detection range into seabed[42]
Multibeam Echo Sounder (MBES)	Acoustic bathymetry with the possibility to detect ferrous and non-ferrous and non-metal objects on the seabed surface	Nil
Side Scan Sonar (SSS)	Acoustic imagery of seafloor detecting ferrous and non-ferrous and non-metal objects on the seabed surface	Nil
Sub-bottom Profiler (SBP)	Acoustic detection of sub-seabed strata and objects	Limited
Electromagnetic system (EM)	Active electromagnetic detection of ferrous and non-ferrous objects on the seabed surface and below seabed surface	Up to 3 meters

[42] Distance sensor to object. Variables are object size and/or ferrous mass. On site validation of the sensors needs to show actual performance of the system.

Sensor	Data Type	Detection range into seabed[43]
Magnetic Gradiometer (MAG)	Passive magnetic detection of ferrous objects on the seabed surface and below seabed surface	Up to 5 meters[44]
Acoustic survey techniques	Acoustic imagery of seafloor detecting objects on the seabed surface and below seabed surface	Up to 3 - 5 meters[45]
Electrical resistance survey	Electrical resistance imagery of seafloor detecting objects on the seabed surface and below seabed surface	Up to 3 - 5 meters[46]

Table 16: Survey equipment proposed to complete the survey work and meet the ALARP principle for the cable installation.

With the current available offshore non-intrusive detection equipment it is not possible to detect ferrous anomalies down to the assessed MBD at the crests of the sand waves. With regards to required detection depths, the UXO mitigation strategy and the definition of the ALARP level in the sand wave area it is recommended first to perform a detailed assessment of the variations between the current bed level and the lowest bed level since WWII. If this assessment proves the layer where UXO are to be expected is within detection range ALARP can be reached in one survey operation. If not, a layered detection method may have to be adopted. If this proves impossible or is deemed disproportional an increase of the survey thresholds might be considered in order to reach ALARP.

16.3 SURROGATE ITEM TRIAL(SIT)

It is recommended not to prescribe certain techniques 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 industy standard practice that all detection devices used during the geophysical UXO survey are to be subjected to a thorough UXO validation. The purpose of a SIT is to establish the maximum equipment detection range limits (see chapter 5 for assessed MBD) for the specified thresholds of objects (see chapter 13). On completion of the data acquisition the detection range threshold determined during validation/SIT, together with the sensor altitudes achieved is used to QC the survey data and to check for achieved detection depths below seabed and 'coverage achieved'. 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.

It is highly recommended to perform a SIT and this should be the responsibility of the contractor. The site selected for the SIT will need to be relatively flat and in water depths exceeding 25 m. Given the anticipated layback of the MagWing from the vessel, this is to allow more stable USBL positioning when attempting to fly at the highest elevations during the trial. Prior to the deployment of the UXO surrogate items the chosen location will be surveyed with SSS and MBES. The area required will be approximately 1 km long and 200 m wide. Once confirmed clear of obstructions the central portion of the area will be surveyed with a magnotometer. Sufficient data needs to be collected to demonstrate that the proposed area for surrogate item deployment is magnetically clean. If objects are discovered in advance of the emplacement of the surrogate UXO items, they need to be accurately recorded in terms of their position and responses. It is recommended to use inert UXO models for the SIT trial.

[43] Distance sensor to object. Variables are object size and/or ferrous mass. On site validation of the sensors needs to show actual performance of the system.
[44] Depending on sensor altitude and ferrous weight threshold applicable.
[45] Depending of the size of the object. Currently systems are being developed with a larger detection range.
[46] Depending of the size of the object.

Once the SIT has been completed and the data processed the contractor will be required to produce a SIT report detailing the findings and the conclusions in preperation for the impending geophysical survey.

16.4 CORRIDOR SURVEY/WIDTH

The actual corridor widths and area dimensions to be investigated and cleared will be stipulated and confirmed by developer, based on project-specific installation techniques and vessels, taking into account:

- The width of vessel facing along track;
- Wether or not anchor corridors will be utilized;
- Installation route curvature radii;
- Installation positioning tolerance;
- Re-routing avoidance distance;
- The radius of the area around each foundation where accelerations exceeding 1 m/s^2 are to be expected;
- Safety factor.

A phased approach is needed for the UXO clearance operations. The interpretation of the survey data will provide a Provisional Master Target List (PMTL). Subsequently re-routing/re-positioning might be conducted around the targets on the Provisional MTL to avoid as many of these targets as possible, resulting in a final MTL and wind farm design. The re-routing/re-positioning will possibly necessitate additional survey operations.

Due to the time laps between conclusion of the UXO clearance campaign and the start of the installation operations, there is a possibility UXO may have migrated in to the cleared areas as a result of human interference (e.g. pair and beam trawling). UXO's which have migrated into the area are assessed to be located on seabed surface. It is recommended that when possible, the geophysical survey, UXO identification/removal and cable lay operations should commence consecutively on completion of each phase. Practically this will not always be possible, therefore to mitigate this risk it is recommended to conduct an SSS survey prior to the start of installation operations.

16.5 IDENTIFICATION EQUIPMENT

With the current expertise and techniques available in the offshore UXO clearance industry the following equipment for the identification (and disposal) work is listed below.

Item	Application
ROV	To locate targets, excavate, assist the air-lift when used and to re-locate/recover items where possible
High Resolution Acoustic Camera	For localizing and classification of targets with the air-lift and/or ROV in low-visibility conditions
Video Cameras	For identification and classification of targets and for providing a visual record of the investigation and disposal operations
EM-system	Fitted on ROV to localize ferrous and non-ferrous targets and perform as-left surveys
Dredge pump and/or Jet pump	Fitted on ROV to excavate those targets that are buried
Air-lift	To assist ROV and/or Divers to excavate those targets that are buried

Table 17: Equipment needed for identification (and disposal).

16.6 UXO DISPOSAL AND DETONATION EQUIPMENT

The equipment required to execute UXO disposal operations will depend on the nature and the agreed disposal method of any UXO items that are located. The Netherlands EOD Authorities will handle all disposal and depending on the location and circumstances, will make use of:

- A platform of the contractor responsible for the UXO scope of work;
- A Dive Support Vessel of Netherlands Defence;
- A MCM vessel of Netherlands Defence.

The EOD will be responsible for disposal of all UXO items discovered within the working area of the wind farm zone. Prior to operations it is recommended that a planning meeting is conducted between the EOD and the UXO consultant.

As such it is not possible to specify exactly what is required at this time but it is likely that some of the items listed in the table below may be deployed by the WSCS-OCE certificate holder to assist in the UXO disposal operations.

Item	Application
ROV	To re-locate targets, excavate, assist (monitoring) with detonation charge placement if required.
Dredge Pump and/or Jet pump	Fitted on ROV to re-excavate buried targets
Air-lift	To assist ROV or divers to excavate those targets that are buried
Bubble Curtain	To create a sound/shockwave suppression barrier around UXO that have to be detonated
Mammal Scarers	Will be sounded at regular intervals up to moment of detonation
Marker Buoys	For marking UXO locations
Lifting Bags	For raising UXO to surface if required
Air-diving Spread	Diving operations with UXO dive team as required
UXO Storage container	A WSCS-OCE certified temporary safe storage unit
RHIB	Diving assistance, relocation of UXO and transport of personnel

Table 18: Items that may be deployed by UXO Clearance Contractor to assist in the UXO disposal operations.

16.7 HANDLING AND STORAGE OF UXO

The Netherlands EOD Authority is the primary responsible authority in deciding if UXO can be removed from its location. The actual handling and removal of the UXO may only take place after approval from the Netherlands EOD Authority. Temporary securing of UXO is allowed to be executed by the WSCS-OCE certificate holder.

Awaiting the handover to and after consulation with the Netherlands EOD Authority, the handling and storage of UXO by the WSCS-OCE certificate holder is permitted to a certain extent. Although procedures for the handling and temporary securing of UXO are extreamly strict, the occurrence of an uncontrolled explosion can never be ruled out entirely.

Strict operational procedures and methods are followed during all UXO handling and securing activities ensuring the risk is managed correctly. This handling and securing procedure must be managed by the WSCS-OCE certified company to ensure that UXO will not explode in an uncontrolled manner or at least minimize the effects for the immediate surroundings and environment in case of an uncontrolled explosion.

The handling and securing of UXO includes all activities after the identification procedures which may be deemed necessary to minimize the risks of explosions related to the surroundings/environment up to and including the moment of UXO hand over to the Netherlands EOD authorities.

16.7.1 Main Activities related to the securing of UXO

It is assessed that there will be no handling of UXO other than the removal from its original position and transfer to the securing facility. The process of handling and securing will take place upon completion of the identification process and approval from the Netherlands EOD Authority, and may consist of the following activities:

- Safety measures;
- Protective measures;
- Risk assessment on the situation;
- Safe removal of the UXO from its original position;
- Transfer/transport of the UXO to the securing facility;
- (Temporary) securing.

Methods for safe handling of the UXO are determined by the WSCS-OCE certificate holder and may include:

- Leave the UXO in situ, do not touch and mark the location.
- Leave the UXO in situ, implement mitigation, do not touch, and mark the location.
- Move the UXO to another location at a safe distance away from the working area, mark the new location.
- Remove the UXO from its location and transfer to a temporary securing facility.

16.7.2 Requirements of the temporary UXO securing facility

As required a temporary UXO securing facility may be provided to assist in the securing of UXO on the deck of a vessel or on land. This temporary securing facility needs to adhere to WSCS-OCE certification standards and can be summarized as follows:

- The maximum allowed NEW is 10kg.
- The requirements on the construction of this securing facility are amongst others:
    - Walls, floor and roof construction/materials to be fire resistant for at least 60 minutes (NEN 3884/6069).
    - Walls must be fragmentation resistant by using steel plating of minimal 7 mm with 40mm multiplex/plywood attached on the steel.
    - The floor of the unit must be non-conductive.
    - The door of the unit must be self-closing at all circumstances and needs to able to be opened from the inside.
    - Electrical installations, including lighting, needs to be gas- and explosion safe.
    - Etc., (see WSCS-OCE for further details).

All UXO is to be stored in such a way that direct contact with the floor is avoided (i.e.: use of pallets). UXO expected to contain white phosphorous are to be stored separately and submerged fully in water. UXO with a blast and fragmentation effect are to be stored in such ways preventing sympathetic detonation at all times (minimum distance between UXO > 3 x Radius). All UXO is to be stored in an orderly way and stable condition. The unit may only be used for the purpose of storage of UXO. The WSCS-OCE certificate holder has responsibility on the safe securing, monitoring and administration of UXO. The registration on the UXO needs to include (but not limited to):

- Category, subcategory and nationality of the UXO.
- Arming condition of the fuzes (if any).
- Number of UXO's and estimate of the total NEW.

16.7.3 Temporary Underwater UXO securing facility

For reasons of explosives safety it may be necessary to set up a temporary offshore UXO securing on the seabed. In mutual consent with The Netherlands EOD Authority and the UXO consultant a suitable location may be selected prior to the actual UXO clearance phase. In such a case the following principles must apply:

- Explosive safety distances to divers and assets must be applied and monitored.
- Small items of UXO are to be contained in a wire pallet to prevent movement.
- The store area is to be clearly marked with a buoy, which is NOT anchored to the container and accurate coordinates taken of the site. In addition, the area is to have a maritime exclusion zone consummate in with the NEW of explosives held.
- Ideally, wire pallets containing UXO for destruction is to be fitted with a pinger, which is to be checked for serviceability on a regular basis. This will ensure items are not lost during tidal movement.

16.8 UXO DISPOSAL

Within the Dutch EEZ the Netherlands EOD Authority is responsible for all maritime UXO disposal operations. Where the Netherlands EOD Authority concludes that identified UXO's are unsafe to transport, these shall be detonated on site under appropriate conditions. Appropriate conditions include (but are not limited to):

- Safe distances;
- Safety zones to be maintained by guard vessel;
- Safe distances applied will be according to the Netherlands EOD safety procedures;
- Suitable weather conditions (sea state, swell and visibility);
- Local environmental and/or natural habitat.

Safe distance from detonation center	Meters	Nautical Miles
Vessel (e.g.: RHIB) assisting UXO disposal team, during detonation of UXO's	250	0.14
Operational vessel and/or guard vessel	925 – 1,850	0.5 – 1.0
Other vessels, subsea cables, oil wells, wrecks	3,700	2.0
Coastline (UXO <500 lbs/250 kg)	5,550	3.0
Pipelines and pump stations	7,400	4.0
Offshore installations (Platforms)	9,250	5.0
Coastline (UXO >500 lbs/250 kg)	9,250 –14,800	5.0 – 8.0

Table 19: Safe distances from detonation centre.

17 CONCLUSIONS

Based on the results of the historical research and UXO risk assessment the research questions are answered as follows:

- *Identification of possible constraints for offshore wind farm related activities in the HKW Wind Farm Zone as a result of the possible presence of items of UXO.*

  Based upon the analysis of historical sources, it is evident that different war related events took place within and nearby the area of investigation. Due to these events the entire area of investigation is to be considered a UXO risk area. A variety of UXO are likely to be present which include aerial bombs, naval mines, depth charges and torpedoes. The likely presence of UXO in the area, however, is not a constraint for offshore wind farm development. With applying professional UXO Risk Management these risks can be reduced to a level that is considered As Low As Reasonably Practicable (ALARP).

- *Identification of areas within the HKW Wind Farm Zone that could preferably not be selected for the installation of offshore wind farms and/or cables.*

  Within the proposed area there are no UXO risk free areas identified, however since the entire HKW Wind Farm Zone is to be considered a UXO risk area and the risks posed by the presence of UXO can be sufficiently mitigated to ALARP, the entire HKW Wind Farm Zone can be selected for the installation of offshore wind farms and/or cables. In regards to the required detection range it is recommended to avoid the crests of sand waves exceeding 3 m as much as possible.

- *Identifying the requirements from a UXO perspective that should be taken into account for:*
  a. Determining the different concession zones in the wind farm zone.
  b. Carrying out safe geophysical & geotechnical investigations.
  c. Installation of wind turbine foundations.
  d. Installation of cables.

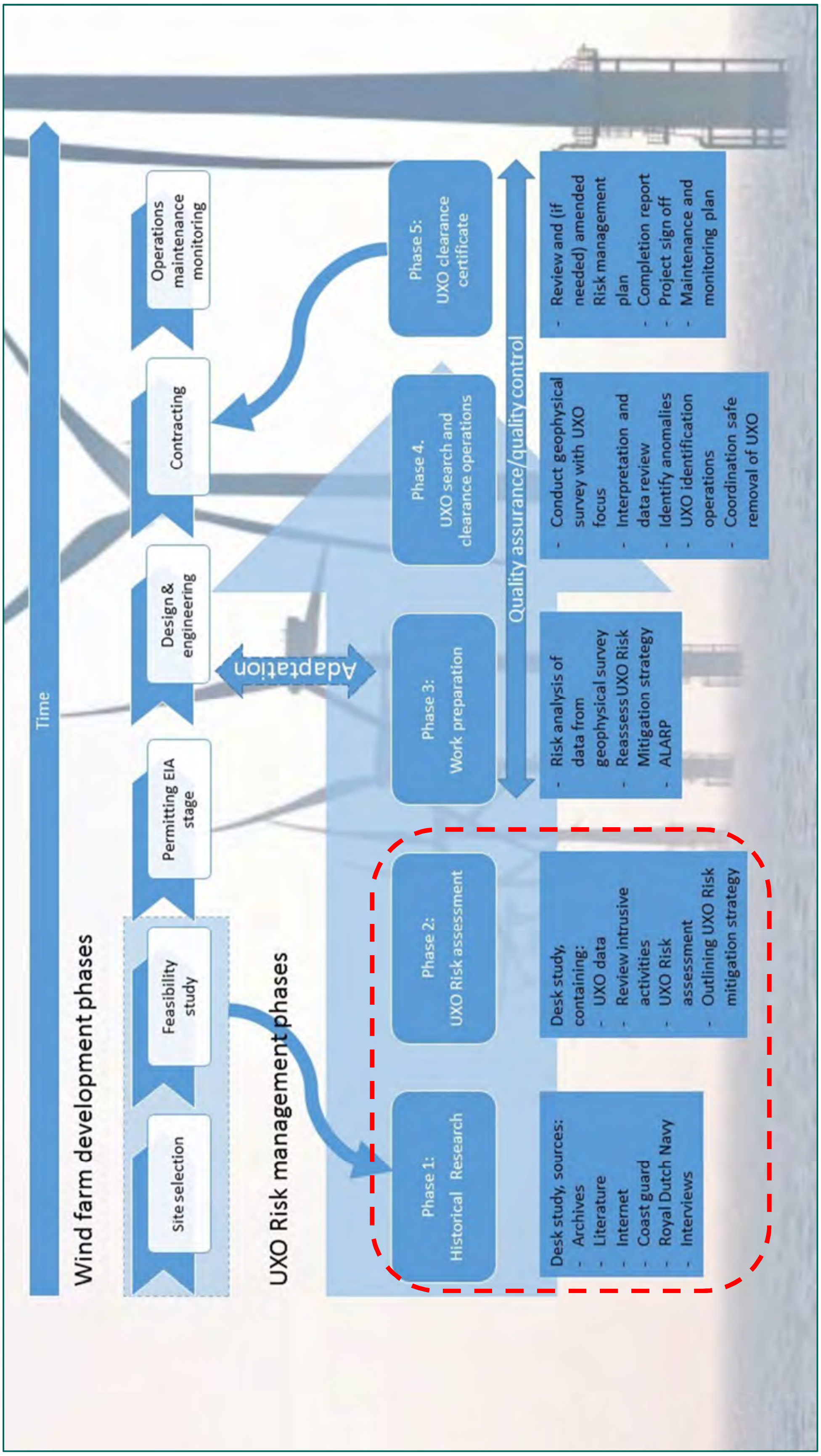
  The conducted historical research has shown that several calibres of aerial bombs, naval mines, depth charges and torpedoes could be present within the investigation area. The possible effects of a detonation on vessels, equipment, personnel, and surroundings may form an intolerable risk. This means mitigation measures are required to reduce the risks to ALARP. It is recommended to It is recommended to investigate the possible presence of UXO by performing a UXO geophysical survey prior to any intrusive works. The mitigation measures consist of UXO survey, identification of potential UXO objects, re-routing or re-location of cables and structure if possible and disposal of UXO items if required.

  Evaluating the results of the SQRA, it is assessed that the 250 lbs Air Dropped Bomb is deemed the smallest ferrous threat item for an ALARP sign-off. The ferrous weight of these bombs can range from 50 kg to 83 kg dependent on the make, modification and type of munition. Assuming these items can be successfully detected and identified within the geophysical datasets, larger objects will also be detectable. Magnetometry is generally considered the most reliable and common method of UXO geophysical survey. The provisional magnetometer (MAG) threshold is set on 50 kg ferrous mass. This threshold is also sufficient to detect ferrous naval mines which are likely to be present in the area. The risk also posed by the possible presence of depth charges and torpedoes will be mitigated sufficiently by applying the recommended threshold value.

Annexes

18 ANNEXES

ANNEX 1 UXO RISK MANAGEMENT PHASES (IMAGE)



ANNEX 2 UXO FIGURES

Naval mines

E-Mine

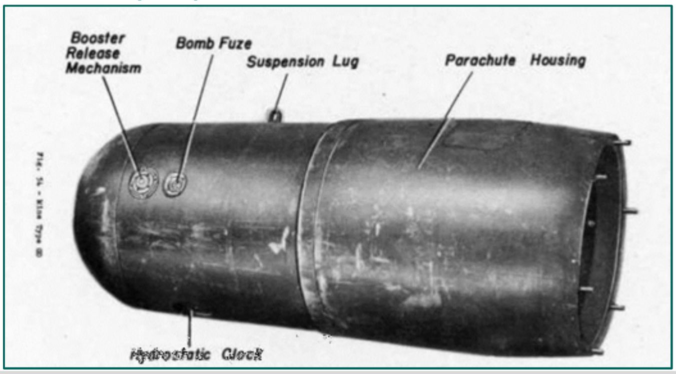
Characteristics

Utilised in (conflict): World War I

Nationality: German

Type: Moored contact mine

Luftmine A (LMA)



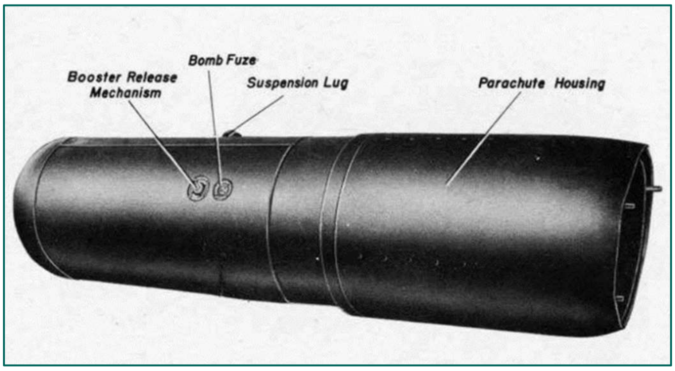
Characteristics

Deployed in (conflict): World War II

Nationality: German

Type: Magnetic ground mine. Later fitted with acoustic or acoustic/magnetic triggers.

Luftmine B (LMB)



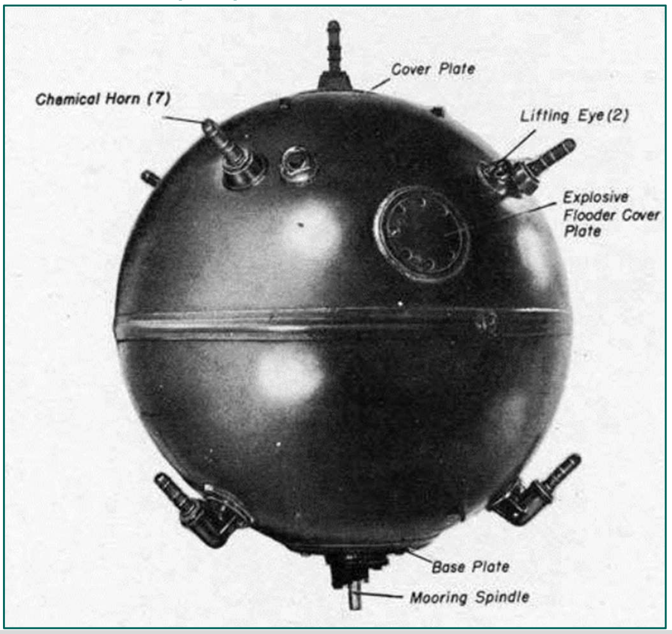
Characteristics

Deployed in (conflict): World War II

Nationality: German

Type: Magnetic and acoustic ground mine. Late in 1944 some were fitted with pressure/acoustic triggers.

Einheitsmine C (EMC)



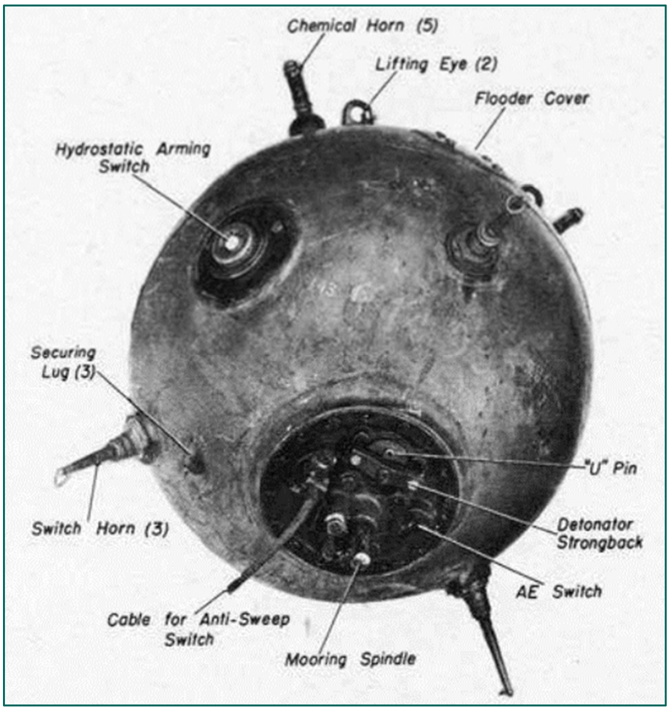
Characteristics

Deployed in (conflict): World War II

Nationality: German

Type: Moored contact mine.

Ubootmine B (UMB)



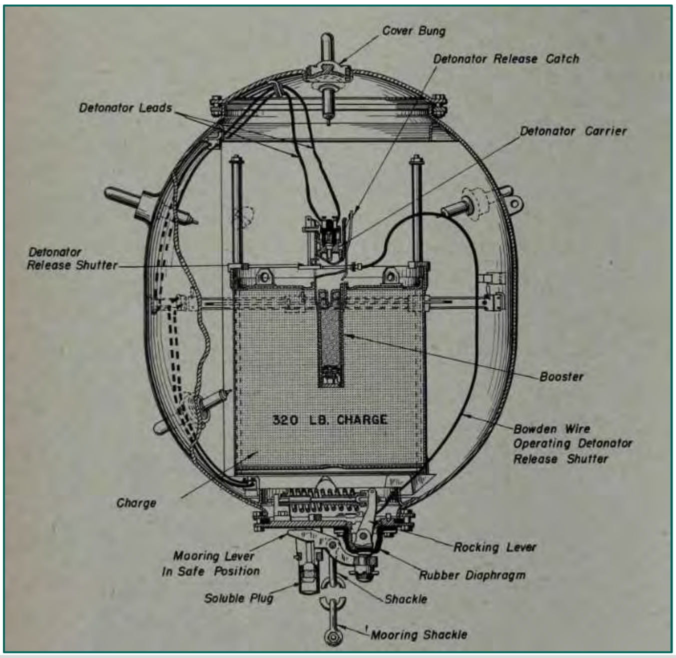
Characteristics

Deployed in (conflict): World War II

Nationality: German

Type: Moored contact mine.

Mark XIV



Characteristics

Deployed in (conflict): World War II

Nationality: British

Type: Moored contact mine.

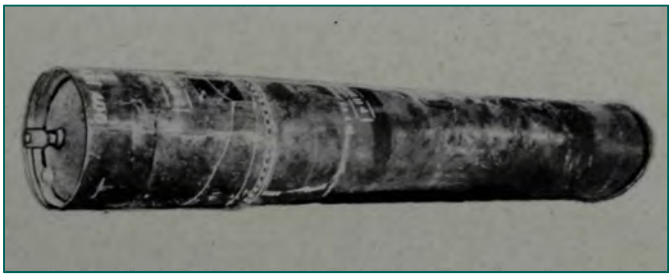
Mark XVII

See Mark XIV mine

Characteristics

Same as Mark XIV mine. The main exception is that the Mark XVII is fitted with 11 switch horns.

A Mark I-IV



Characteristics

Deployed in (conflict): World War II

Nationality: British

Type: magnetic, induction of acoustic ground mine.

Aerial bombs

Characteristics

Deployed in (conflict): World War II

Nationality: British, US

Type: GP, MC, HC, fragmentation, demolition

Torpedoes

Characteristics

Deployed in (conflict): World War II

Nationality: British

Type: 18 inch, Aircraft launched

Depth Charges

Characteristics

Deployed in (conflict): World War II

Nationality: British

Type: Mk. VIII & MK XI

ANNEX 3 LITERATURE

For this research the following literary sources are consulted:

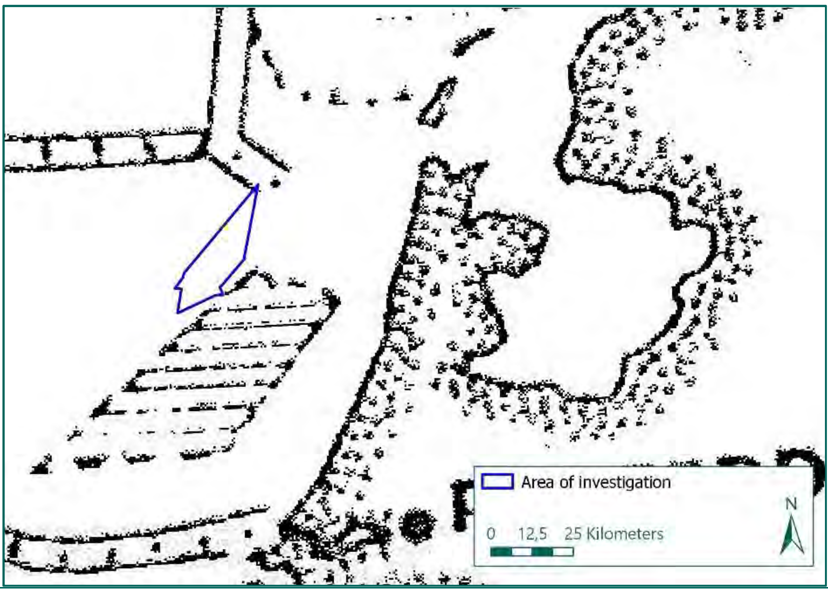
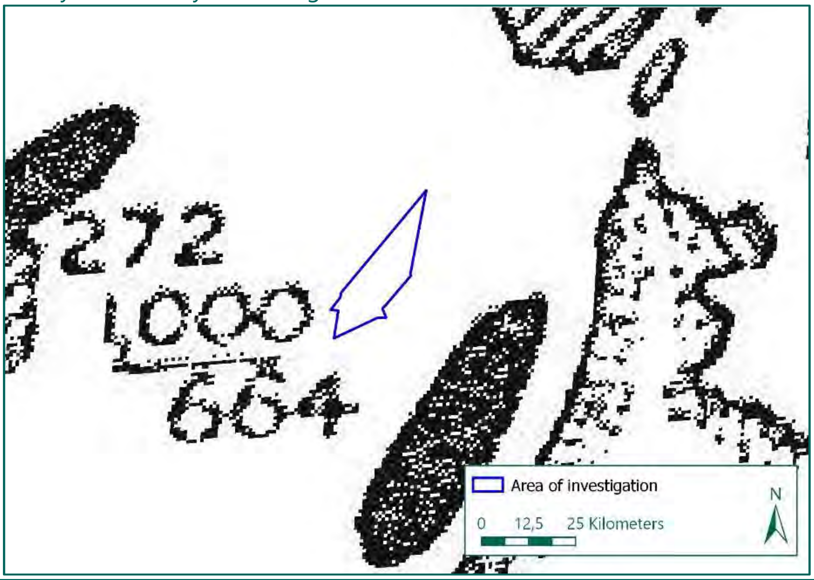
Abbreviation	Author	Title	Relevant
BEZ 1&2	Bezemer, K.W.L.	*Geschiedenis van de Nederlandse Koopvaardij in de Tweede Wereldoorlog* (2 dln.; Amsterdam).	Yes
BOW	Bowyer, Ch.	*Coastal Command at War* (1979).	Yes
BRO	Brongers, D.	*Op tegengestelde koersen. De kustvaart in oorlogstijd* (Deventer 1996).	Yes
BUR	Burg, G. van	*Oorlogsstorm over zee en havens. IJmuiden 1939-1946* (Schoorl 1995).	Yes
CRO	Crossley, J.	*The Hidden Threat. The story of mines and minesweeping by the Royal Navy in World War I* (South Yorkshire 2011).	Yes
DDH	Dienst der Hydrografie	*HP39. Wrakkenregister Nederlands Continentaal Plat en Westerschelde.* (Den Haag 2014).	Yes
DIS	Dissel, A. van e.a.	*De Nederlandse koopvaardij in oorlogstijd* (Amsterdam 2014).	Yes
DUR	Durrieu, A. e.a.	*Atlantic Wall. Its most incredible remains*	Yes
HAR	Harff, P. and Harff, D.	*Bergen (NH) 1940-1945. Bergen en Bergen aan Zee. Duitse bezetting, Atlantikwall en gevolgen voor de inwoners* (Bergen 2016).	Yes
KUR	Kurowski, F.	*Seekrieg aus der Luft. Die Deutsche Seeluftwaffe im Zweiten Weltkrieg* (Herford 1979).	Yes
MID	Middlebrook, Ch.	*The Bomber Command War Diaries. An operational reference book 1939-1945* (Leicester 1996).	Yes
MVL	Ministerie voor Luchtvaart	*Coastal Command speurt, beschermt, valt aan* (London, z.j.).	Yes
NES	Nesbit, R.C.	*The Strike Wings. Special Anti-Shipping Squadrons 1924-45* (London 1995).	Yes
RON	Rondèl, C. en Dalenberg, C.	*Ach ja, de LUA* (Hoorn 2007).	Yes
SCH	Schroeder, W, Kutzleben, K. von	*Minnenschiffe. Marinekleinkampfmittel* (1974).	Yes
SGLO	Studiegroep Luchtoorlog	*Crash database. Dutch Air War Studygroup. http:www.verliesregister.studiegroepluchtoorlog.nl*	Yes
VER	Verbeek, J.R.	*Kustversterkingen 1900-1940* (Wassenaar 1988).	Yes
WEI	Weiß, H.,	*Luftkrieg über Holland 10-15 Mai 1940* (unpublished manuscript).	Yes
ZWA 1&2	Zwanenburg, G.J.,	*En Nooit was het Stil. Kroniek van een Luchtoorlog* (2 dln. & supplement; Oldemarkt).	Yes

Table 20: Reference to literature.

In the following tables the information about relevant war events are reproduced per period.

Pre-war period and the First World War 1914-1918

During the second half of the 19th century and the 20th century tension were rising in Europe. Most countries were increasing their military expenses by producing weapons, cannons and shells. The great powers at the time were divided in two blocks. Great-Britain, France and the Russian Empire were joined into the Triple Entente. The German Empire together with the Austrian-Hungarian Empire and Italy formed the Triple Alliance. Italy left the Alliance in 1915, instead came the Ottoman Empire. Both alliances assured military support for its own members. The assassination of the Austrian-Hungarian crown prince Franz Ferdinand on the 28th of June 1914 in Sarajevo eventually lead to the outbreak of the First World War. The Netherlands were neutral during this war.

Date / year	Event	Source	Page
1914-1918	Mined areas during the First World War. The East Coast Swept Channel. Patrolled regularly by trawlers, this provided a safe route for coastal traffic. The system was extended to cover all coastal passages around the British Isles. Naturally, the German-laid minefields off the British coast were a hazard for German raiders as well as for British commerce. 	CRO	55
	British, German and American mines laid during the war. The German minefields are in black, whereas the allied fields are shaded. The underlined figures are numbers of allied mines, and other figures are numbers of German mines. With their vastly greater resources, the Allies laid far more mines in the latter part of the war, placing them strategically where they would effectively trap the maximum numbers of U-boats. German mines were placed mainly close to headlands where ships would make landfalls and around the approach to major ports. From 1916 onwards, most of the German mines were laid by submarines, whereas the Allies were able to use surface ships, especially fast destroyer-minelayers, to operate close to enemy coasts. The chart gives an idea of how dangerous minelaying and minesweeping operations were as both enemy and friendly mines might be laid in the same areas. 	CRO	62
August 1914	The German government announced already in August 1914, they would probably have to lay mines in front of enemy harbours. In October 1914, the British government declared a certain area in the North Sea as mined area, but	BEZ	24

Date / year	Event	Source	Page
	a small route will remain open. During the war, more and more allied and German mines were laid in different parts of the North Sea, which were declared as a war zone or dangerous zone by the belligerent parties. Mainly moored contact mines were laid. These mines were not dangerous anymore as soon as they were loose. This was the intention although the reality was different. During the war, 6,000 mines washed ashore on the Dutch coast. Most mines were British (4,981 against 431 German, 81 French and more than 500 mines from unknown origin). Many of these mines did explode.		
2 November 1914	England declared the whole North Sea as war zone. Sea routes near the British coast were forbidden in order to force merchant ships to follow a route through the Channel. This provided the British Navy to February the cargo. This decision made the Germans think about using U-boats to attack allied shipping.	BEZ 1	18
End of 1916	At the end of 1916 a total of 29 Dutch ships were sunk by mines. About one third of the mines were laid by U-boats.	BEZ 1	25
February 1917	Till the February U-boat war in February 1917, mines were the main threat to Dutch merchant ships. After 1 February 1917, the amount of Dutch ships destroyed increased fast. In total, 38 Dutch ships were sunk by German U-boats. Sometimes with torpedoes, then with artillery or charges.	BEZ 1	24, 26
1918	Mines, of course, remain deadly irrespective of peace treaties or armistices. No fewer than 240,000 mines were scattered about the seas, some in their original position, some having dragged their moorings and settled in a new location, and some drifting freely. These constituted a major danger to shipping after the end of the war. To clear them up an international committee was formed, which included most belligerent and neutral countries, and was eventually joined by the defeated powers. This was called the International Mine Clearance Committee (IMCC) and was organized principally by the Royal Navy. All members carried out mine clearance activities and reported regularly to the IMCC, who issued regular charts and updates showing safe areas and known danger zones. The main part of the clearance work was divided between the maritime nations, Germany being responsible for sweeping Heligoland Bight, France the waters off the French and Belgian coasts, America the Northern Barrage and the UK, most of the rest, working through a new organization called the Mine Clearance Service. The service was manned mainly by Royal Navy personnel and fishermen and consisted of 14,500 men and 700 officers at its peak. A particular danger when clearing dense fields was what was known as 'counter mining'. This occurred when exploding one mine would set off others in the vicinity – possibly dangerously close to the sweeper involved. Normally, deep fields were left until last, as they did not constitute a serious danger to shipping, but sometimes some of the mines were laid incorrectly and finished up close to the surface. It was determined to skim of any of these shallow mines first, and the sweep began in the normal way. The intensive mining of the eastern North Sea also contributed to Germany's to such an extent that it could not even undertake exercises safely, the British offensive mining campaign contributed to the collapse of fleet discipline and hence to the popular revolt against the Kaiser's government, which resulted in the Armistice.	CRO	149-160

Table 21: Overview war events during the First World War, 1914-1918.

Interwar period 1919-1939

After the devastated and damaged areas of WWI were rebuild, rural fields were brought back into cultivation and remainders of the war, like UXO, were cleared to a certain extent. Nowadays it is known that many tons of UXO were dumped, e.g. in the North Sea. During the interwar period, as the economies developed, construction and infrastructural works took place. During the 1930's international tensions rose again and many countries anticipated by building defence works.

Date / year	Event	Source	Page
1939	The last mine catastrophe in 1939 was a ship which ran on a Dutch mine. Short before and shortly after the outbreak of war, the Royal Dutch Navy laid minefields with moored mines in front of the Dutch coast. One minefield, ‘Schulpengat Buiten’, was situated in front of de kop van Noord-Holland, between Den Helder and Callantsoog. The minelayer Willem van der Zaan laid 98 and 97 mines on 3 and 22 September 1939. The minefield was expanded on 11 April 1940 with a new row of 95 mines. On 9 December 1939, a ship ran on one of those mines.	BEZ 1	137

Table 22: Overview war events during the interwar period, 1919-1939.

The Second World War 1940-1945

After the German invasion of Poland on the 1st of September 1939, France and Great-Britain declared war with Germany. For about six months, different countries mobilized their armies but the fighting was very limited. In April 1940 Germany invaded Denmark and Norway. About one month later, on the 10th of May 1940, the German army invaded The Netherlands, Belgium and the Grand Duchy of Luxembourg. France was also invaded. From July 1940 till October 1940 the German Luftwaffe waged war over the North Sea and the British air space. Between 1941 and the first half of 1943 little movement was seen on the western front. This changed with the allied landing in Italy (3rd of September 1943) and the landings on the Normandy beaches (6th of June 1944).
It would take the allied forces in Western Europe about ten months to liberate large parts of Europe and to enter German to force an unconditional surrender.

Date / year	Event	Source	Page
1940-1945	Ships had to deal with certain dangers. First, mines and later allied airplanes that attacked ships with bombs and machine guns. Fishing trawler from IJmuiden, who were fishing relatively close near the shore, could encounter mines and torpedoes in their fishing nets. They could also be attacked by planes.	BUR	53
Jan – 10 May 1940	During the last 4 months, no less than 16 merchant vessels were lost. 10 were struck by torpedoes, 4 ran on a mine, 1 was sunk by an aerial attack and 1 was hit by naval guns. Furthermore, 4 fishing trawlers were lost; 2 by mines, 1 by an aerial attack and 1 was shelled.	BEZ 1	144
9-10 May 1940	Die 27 Flugzeuge der 9. Fl. Div. legten ingesamt 46 Luftminen der typen LM/A und LM/B in die Gewässer vor Rotterdam, die „Alte“ Maas, bei Heinoort, vor Hoek van Holland, vor Vlissingen und Oostgsat sowieso vor IJmuiden und Den Helder.	WEI	N/A
10 May 1940	The Luftwaffe dropped magnetic mines in front of the Dutch coast. The Nieuwe Waterweg was not suitable for shipping anymore. German magnetic mines were also dropped in front of IJmuiden harbour. With the help of British minesweepers, it was tried to clear the routes, but soon new mines were dropped.	DIS	22-23
13 May 1940	The British HMS Princess Victoria laid a large minefield in front of the Dutch coast. It existed of 236 mines and was situated 5 miles out off the coast of Castricum. This minefield covered British operations in near the Belgian and Dutch shore.	BUR	22
14 May 1940	Luftwaffe. Mines. 23 Heinkels He-115’s 106 and 12 Ju-88’s took off for minelaying. In total 24 LM/A en 24 LM/B mines were dropped in the sea zone near Texel, Den Helder and IJmuiden.	ZWA 1	28
28 May 1940	Coastal Command. Offensive patrols by 9 Swordfishes and 8 other Swordfishes to attack 3 MTB’s 60 km WNW van IJmuiden and 6 MTB’s near Ameland. No results were reported.	ZWA 1	41
27 June 1940	A Blenheim bomber of 235 Squadron crashed into the North Sea north-north west of Egmond/Noordwijk.	SGLO	T0732
12/13 July 1940	Coastal Command. Six Swordfishes laid mines near IJmuiden.	ZWA 1	60

Date / year	Event	Source	Page
11 September 1940	9 Blenheims on sea sweep and ports reconnaissance; 1 aircraft bombed a convoy off Dutch coast.	MID	81
4 October 1940	A Beaufort of 42 Squadron crashed in the North Sea off IJmuiden.	SGLO	T0858A
8 October 1940	Coastal Command. 2 Beauforts on 'Rover-patrol' between IJmuiden and the Eems. One Beaufort spotted a flak ship near IJmuiden and another 16 km west off Terschelling. Due to technical failure, the torpedo of this Beaufort fell into the sea 22 km SW off Texel.	ZWA 1	113
18 October 1941	Mines washed ashore on different places (the next day, 12 mines were encountered on the beach near Egmond).	BUR	71
23/24 October 1940	Coastal Command. 4 Swordfishes laid mines off IJmuiden.	ZWA 1	123
27 October 1940	9 Blenheims on sea and coastal sweeps. Ships attacked off Dutch coast. No losses.	MID	99
	Bomber Command. 7 Blenheims on 'Roving Commission'. A Blenheim attacked a small cargo ship near IJmuiden, but bombs fell 60 meters short.	ZWA 1	125
	Twee Beauforts 'Rover' from Borkum to Texel. One Beaufort spotted two cargo ships near IJmuiden. A torpedo attack was unsuccessful.	ZWA 1	125
11 January 1941	Bomber Command. 9 Blenheims carried out the following attacks. On a convoy of six ships 22 km west off Den Helder, Rotterdam harbour, airfield Haamstede, Flushing harbour, four E-boats 8 km west of IJmuiden etc.	ZWA 1	147
14 January 1941	2 Blenheims; 1 bombed a ship off Dutch coast but scored no hits. No losses.	MID	117
17 January 1941	Coastal Command. Four Beauforts escorted by three Blenheims attacked 12 km west off IJmuiden a convoy of four cargo ships and three flak ships. Hits were scored on two cargo ships, also near misses were scored.	ZWA 1	148
19 January 1941	Coastal Command. A Blenheim, on patrol along the Dutch coast, spotted 25 km NW off IJmuiden a non-escorted convoy of five ships. A dive attack was carried out against the last ship, but no hits.	ZWA 1	149
1 February 1941	3 Blenheims; 1 aircraft bombed a ship off the Dutch coast but scored no hits. No losses.	MID	119
18 March 1941	Coastal Command. A Blenheim attacked 70 km NW off IJmuiden, with 2 small bombs, a fishing trawler. Near misses.	ZWA 1	171
22 March 1941	6 Blenheims on coastal sweep. 1 aircraft attacked a convoy off Holland. No aircraft lost.	MID	137
	Bomber Command. Six Blenheims on ships. 15 ships in a convoy near IJmuiden were spotted. One Blenheim attacked. Bombs fell across one of the ships.	ZWA 1	172-173
24 March 1941	9 Blenheims on coastal sweeps. 1 fishing vessel was sunk off the Dutch coast. 1 aircraft lost.	MID	138
25 March 1941	5 Blenheims off Holland and the Frisian Islands. Convoy attacked and 1 ship claimed as hit. No aircraft lost.	MID	138
26 March 1941	Bomber Command. Twelve Blenheims on anti-shipping patrol off the Dutch coast. Three attacked a steam trawler of 4 to 500 ton. Others Blenheims attacked various small ships during a low-level attack. Near misses were scored. The attacks took place between IJmuiden and Texel.	ZWA 1	174
	Coastal Command.	ZWA 1	174
29 March 1941	4 Blenheims off Belgium and Holland. 1 aircraft attacked a tanker heavily defended by Flak ships.	MID	139
6 April 1941	14 Blenheims to Belgian and Dutch coasts. Shipping and harbours were attacked. No losses.	MID	141
	Bomber Command. Blenheims strike IJmuiden. IJmuiden reports 13 bombs on two separate strikes.	ZWA 1	177

Date / year	Event	Source	Page
7 April 1941	A Blenheim bomber of 139 Squadron crashed into the North Sea, 25 km west of IJmuiden. The bomber was hit by German anti-aircraft and shot down by a German fighter.	SGLO	T0982
14 April 1941	16 Blenheims attacked Leyden and Haarlem power stations. 14 Blenheims on shipping patrols; a convoy off Holland was bombed. 1 Blenheim lost.	MID	144
18 April 1941	20 Blenheims and 6 Hampdens on operations to enemy coasts. A convoy off Holland was bombed and barges containing troops were also attacked. 1 Blenheim and 1 Hampden lost.	MID	146
25 April 1941	Bomber Command. Four Blenheims strike Blast furnaces. Ground reports 14 bombs.	ZWA 1	188
30 April 1941	13 Blenheims on sweeps of Dutch and German coasts. 3 aircraft attacked a convoy off Holland. The defences of the convoy – 8 Flak ship escorts for just 1 tanker, together with an Me 110 air cover – illustrate how the recent Blenheim operations forced the Germans to increase their protection of coastal shipping. 1 Blenheim was shot down attacking this convoy and another badly damaged; no hits were scored on the tanker.	MID	149
7/8 May 1941	Bomber Command. One Blenheim attacked a 300 ton ship 7 km off IJmuiden. A direct hit was scored.	ZWA 1	194
10/11 May 1941	Minor Operations: 18 Blenheims to the Dutch coast	MID	154
13 May 1941	Coastal Command. A Blenheim attacked a trawler of 800 ton with bombs and cannon and four other trawlers 40 km west of IJmuiden.	ZWA 1	200
14 May 1941	Coastal Command. Three Beauforts on 'Rover' patrol along the Dutch coast spotted 25 km WNW off IJmuiden a convoy of five merchant ships and two escorting vessels. One Beaufort attack a 5,000 ton ship with a torpedo. Afterwards, thick black smoke was spotted.	ZWA 1	200
23 May 1941	20 Blenheims on coastal sweeps. 1 ship was hit off Holland. No losses.	MID	157
27 May 1941	14 Blenheims on shipping sweeps off Holland and Germany.	MID	158
7 June 1941	Bomber Command. One Blenheim attacked a ship of 5 to 6,000 ton in a convoy near IJmuiden. Two hits were scored and the ship was left burning on its side. Another Blenheim successfully attacked a 5,000 ton ship in the same convoy. The ship was hit and started burning.	ZWA 1	206
16 June 1941	25 Blenheims on coastal sweeps off Holland and Germany. Several ships were attacked including a trawler well out to sea and suspected of being a radio warning ship. One of the Blenheims attacking this ship was so low that it hit the trawler's mast and crashed into the sea. 3 Blenheims were lost on this day.	MID	163
21 June 1941	23 Blenheims on coastal sweeps and a *Circus* operation to St-Omer airfield. The airfield was bombed and a ship attacked off the Dutch coast. 1 Blenheim was lost.	MID	165
29 June 1941	Coastal Command. A Blenheim attacked a convoy of seven ships from 2 to 4,000 ton, 28 km NNW off IJmuiden.	ZWA 1	216
5 July 1941	14 Blenheims on coastal sweeps off the Frisians and Holland.	MID	171
7 July 1941	20 Blenheims on coastal sweeps. Aircraft of 105 and 139 Squadrons made an attack on a convoy off Holland and hit 2 ships but lost 3 aircraft.	MID	172
12 July 1941	A Blenheim bomber of 107 Squadron was shot down during an attack on ships, 40 km west of Den Helder. The bomber crashed into the North Sea off IJmuiden.	SGLO	T1106
14 July 1941	Bomber Command. 8 Blenheims intercepted a convoy 13 km N off IJmuiden. 4 Blenheims attacked a 6,000 ton ship and hit it. Two others attacked a 3,000 ton ship and reported a hit. Another Blenheim reported a hit on an escorting vessel of 1,500 ton. All ships were claimed to be destroyed.	ZWA 1	228
16 July 1941	5 Blenheims carried out sweeps off the Dutch coast without loss.	MID	181
2 August 1941	Bomber Command. 1 Blenheim attacked two small trawlers 5 km west off IJmuiden but the bombs missed their targets.	ZWA 1	237

Date / year	Event	Source	Page
14 August 1941	26 Blenheims on coastal sweeps over a wide area. Ships off the Dutch coast and in Boulogne docks were bombed. 1 aircraft lost.	MID	192
	Bomber Command. 31 Blenheims to five ships off the Dutch coast. One attacked a fishing trawler 52 km SW off IJmuiden and anther Blenheim attacked a drifter 65 km NNW off IJmuiden, but bombs were overshot. Three other Blenheims attacked a steam trawler 50 km west off IJmuiden and two drifters and a trawler 65 km NW of IJmuiden. Near misses were scored. Results were not observed.	ZWA 1	239
16 August 1941	Bomber Command. One Blenheim attack from 15 meter high a watch ship 10 km NW off IJmuiden. The bombs missed the target, that was strafed afterwards.	ZWA 1	244
18 August 1941	Bomber Command. One Blenheim attacked 52 km NW off IJmuiden a trawler of 2 to 300 ton. Due to the attack the rear end fell off and the ship sank within 45 seconds.	ZWA 1	245
21 August 1941	A Spitfire of 130 Squadron crashed into the North Sea near IJmuiden.	SGLO	T1223A
	A Spitfire of 130 Squadron crashed into the North Sea, 20 km west of IJmuiden.	SGLO	T1213B
26 August 1941	Bomber Command. Six Blenheims attacked 37 km north off IJmuiden eight control ships of 500 ton each. One was sunk, two others were hit. One Blenheim missing.	ZWA 1	247-248
7 September 1941	12 Blenheims on shipping attacks off the Dutch coast. 2 ships were hit and sunk or severely damaged. 2 Blenheims lost.	MID	200
11 September 1941	23 Blenheims on shipping sweeps from Holland to Norway. A convoy off Holland was attacked without success. No aircraft lost.	MID	202
12 September 1941	11 Blenheims on sweeps off the Dutch coast. 1 ship was hit. No aircraft lost.	MID	202
14 September 1941	12 Blenheims on sweep off the Dutch coast. Ships were attacked but not hit. No losses.	MID	203
20 October 1941	8 Blenheims on sweep of Dutch coast. 1 Flak ship was attacked off Terschelling, with either a hit or a near miss. No Blenheims lost.	MID	211
21 October 1941	Bomber Command. 17 Blenheims, 9 for ships near Ameland and the German islands and 8 with fighter escort for ships near Texel. Attacks were carried out 8 km west of IJmuiden on a convoy of seven or eight ships from 1 to 4,000 ton, escorted by flak ships.	ZWA 1	278
26 October 1941	8 Blenheims on a sweep off the Dutch coast. Ships were attacked but not hit. 1 Blenheim lost.	MID	214
27 October 1941	6 Blenheims on sweeps off the Dutch coast. A convoy was attacked but no results were seen. 2 Blenheims lost.	MID	214
11 November 1941	A Hudson and a Beaufort of Coastal attacked a 900 ton ship 18 km west off Den Helder. Direct hits caused the ship to sink within four minutes.	BUR	55
29 November 1941	Coastal Command. About 14.20 hour, three Beauforts took off for ships near the Dutch coast. One Beaufort carried out an attack on a ship escorted by four torpedo boats, about 18 km off IJmuiden. Ships near Dutch coast. Results were not observed due to heavy anti-aircraft artillery.	ZWA 1	298
9 December 1941	4 Stirlings to Germany but only 1 aircraft bombed ships off the Dutch coast. No aircraft lost.	MID	225
First half 1942	During the first half of 1942, airplanes laid more than 4,000 mines of various types (magnetic and acoustic) in the sea routs along the Dutch Coast. This forced the German Navy to sweep the safe passages between known minefields for every convoy. Also escorting ships were equipped with minesweeping gear.	BUR	88

Date / year	Event	Source	Page
6 January 1942	Coastal Command. A Hudson on patrol along the Dutch coast attacked about 18.18 hours a 1,000 ton ship 20 km NNW off IJmuiden. Results were not observed.	ZWA 1	319
19 January 1942	Coastal Command. A patrolling Beaufighter saw 35 km NNW off IJmuiden small armed vessels. An attack with cannon was carried out on one ship, resulting in white smoke.	ZWA 1	321
22 January 1942	A Beaufighter of 248 Squadron crashed into the North Sea near IJmuiden.	SGLO	T1392
29 January 1942	Coastal Command. A Beaufighter on recce attacked 15 miles north off IJmuiden a 300 ton ship with cannon. Hits on the deck.	ZWA 1	323
16 February 1942	8 Bostons, of 88 and 226 Squadrons, commenced the first regular operations with this new type of day bomber. They searched for German shipping off the Dutch coast without success or loss.	MID	236
11 March 1942	The KW. 26 AAFJE, an in 1915 constructed ship of 140 ton, was lost after running on a mine. The ship was situated about 24 miles NNW off IJmuiden.	BUR	55
8 April 1942	4 Bostons on a sweep off the Dutch coast. A ship was bombed but not hit. No aircraft were lost.	MID	254
17/18 April 1942	Coastal Command. A Hudson attacked a 4,000 ton ship 16 km west off IJmuiden. Results were not observed.	ZWA 1	345-346
18 April 1942	A Hudson of 407 Squadron crashed into the North Sea, 16 km west off IJmuiden.	SGLO	T1485A
17 July 1942	16 Wellingtons on cloud-cover raids to Emden (9 aircraft) and Essen (7 aircraft). Only 3 aircraft from the Essen force bombed and machine-gunned a convoy off the Dutch coast. Only near misses were achieved by the bombs. No aircraft lost.	MID	286
5/6 August 1942	Minor Operations: 57 aircraft minelaying off France, Holland and Germany.	MID	293
9/10 August 1942	Coastal Command. Eleven Swordfishes laid mines along the Dutch coast between IJmuiden and Texel. Seven were successful, one dropped a mine on a different position, another returned early due to motor problems. Two aircraft were missing.	ZWA 1	393
13/14 August 1942	Minelaying. 36 aircraft to many locations along the German and Dutch coasts. 1 Stirling lost.	MID	295
6 September 1942	Bomber Command. One Mosquito to IJmuiden. Strike executed from a height of 15 meters, four 500 lb. HE dropped.	ZWA 1	399
11 September 1942	11.20 hours, British and German MTB were fighting each other just north of IJmuiden. According to a German report, fourteen German boats of S-boat A were involved. One British ship was severely damaged and was entered by German soldiers.	BUR	90
9 November 1942	A Hudson of 320 Squadron crashed into the North Sea off IJmuiden.	SGLO	T1905A
25 November 1942	1 Wellington bombed ships off the Dutch coast.	MID	326
	Coastal Command. 16.00 hours, twelve Hudsons were sent for an attack on a convoy, which was reported by a Spitfire near Hoek van Holland and heading north. Eight Hudsons attacked north off IJmuiden a convoy. A direct hit was observed on the front deck of a 2,000 ton ship and caused a big explosion. Another bomb was possibly also a direct hit, near misses were scored on two other ships. Four Hudsons did not attack.	ZWA 1	426
3/4 January 1943	Minor Operations: 39 Wellingtons and 6 Lancasters minelaying off the French and Dutch coasts	MID	341
29 January 1943	A Spitfire of 118 Squadron crashed into the North Sea, 15 km north west of IJmuiden.	SGLO	T2017
5/6 March 1943	A Stirling bomber of 214 Squadron crashed in the North Sea, 30 km north-north west of IJmuiden.	SGLO	T2098

Date / year	Event	Source	Page
8/9 April 1943	A Wellington of 300 Squadron crashed into the North Sea, 20 km west of IJmuiden.	SGLO	T2182
3 May 1943	A Ventura of 487 Squadron crashed into the North Sea, 19 km west of IJmuiden.	SGLO	T2248
23/24 May 1943	A Lancaster bomber of 57 Squadron crashed into the North Sea, 40 km west of Egmond.	SGLO	T2359
25/26 May 1943	A Stirling bomber of 90 Squadron crashed into the North Sea, 70 km west of Alkmaar.	SGLO	T2381
11/12 June 1943	A Halifax bomber of 405 Squadron crash landed into the North Sea, 80 km west of IJmuiden.	SGLO	T2421
	A Lancaster bomber of 83 Squadron crashed into the North Sea, 40 km west of Alkmaar.	SGLO	T2425
21/22 June 1943	A Wellington bomber of 300 Squadron crashed into the North Sea, 65 km west of IJmuiden.	SGLO	T2517
23/24 August 1943	A Lancaster bomber of 115 Squadron ditched into the North Sea, 20 km west of Castricum, due to battle damage.	SGLO	T2851
1 September 1943	Heading from Rotterdam to Hamburg, the Baloeran ran on a mine just north of IJmuiden. The ship was stranded and later destroyed by British airplanes and MTB during the night of 19-20 September 1943.	BEZ 1	176
15/16 September 1943	Coastal Command. One out of six Hampdens on anti-shipping, torpedoed a passenger ship 2 miles off IJmuiden. Results were unobserved.	ZWA 2	82
19 October 1943	The vessel *Strassburg*, a German liner of 17.000 tons, was sunk by 236 and 254 squadron, Coastal Command, off IJmuiden.	NES	259
31 December 1943 / 1 January 1944	There were no bomber operations on New Year's Eve; 2 Stirlings laid mines off the Dutch coast and returned safely.	MID	462
27/28 January 1944	Berlin. 515 Lancasters and 15 Mosquitoes. The German fighters were committed to action earlier than normal, some being sent out 75 miles over the North Sea from the Dutch coast. Extensive operations were carried out in support of the Berlin raid. 80 Stirlings and Wellingtons flew to the Dutch coast and laid mines there	MID	465-466
16/17 March 1944	3 Stirlings minelaying off the Dutch coast.	MID	480
29 March 1944	A Boeing B-17 bomber of 91 Bomb Group crashed into the North Sea, 50 km west off IJmuiden.	SGLO	T2559A
½ April 1944	34 Halifaxes minelaying off the Dutch coast	MID	489
7/8 April 1944	12 Halifaxes minelaying off the Dutch coast.	MID	490
18 April 1944	A P-38 of 20 Fighter Group crashed in the North Sea, 35 km west of IJmuiden.	SGLO	T3600
26/27 April 1944	16 Halifaxes and 6 Stirlings minelaying off the Dutch coast and in the Frisians	MID	498
	Three Stirlings laid fifteen mines off IJmuiden.	ZWA 2	224
	Coastal Command. 00.19 hrs. A Wellington on armed recce in Den Helder area attack a convoy of three carriers 12 miles NNW off IJmuiden. Five 500 lbs MC were dropped. Results from the first two bombs were unobserved, the others felt across one of the ships and caused an orange flash and smoke.	ZWA 2	205
27/28 April 1944	Three Stirlings laid fifteen mines off IJmuiden.	ZWA 2	224
15/16 May 1944	Coastal Command. 03.52 uur. An Avenger attacked a small carrier, 8 miles north off IJmuiden. Four 250 lbs bombs were dropped from 1,400 ft.	ZWA 2	214
28/29 April 1944	Bomber Command. A Stirling laid five mines off IJmuiden.	ZWA 2	225

Date / year	Event	Source	Page
29/30 April 1944	Bomber Command. In the Netherlands Nederland a Halifax laid four mines off IJmuiden.	ZWA 2	225
31 May / 1 June 1944	Bomber Command. A Halifax laid four mines off IJmuiden.	ZWA 2	227
8/9 June 1944	Bomber Command. A Stirling laid five mines off IJmuiden.	ZWA 2	233
15/16 June 1944	Bomber Command. A Stirling laid six mines off IJmuiden.	ZWA 2	239
6/7 July 1944	4 Stirlings minelaying off the Belgian and Dutch coasts.	MID	537
15 July 1944	The V 1412 was sunk by 2 British MTB west off IJmuiden.	BUR	116
August 1944	By August 1944, the Germans had been forced to cease sending convoys by day along the Dutch coast. The toll taken by the allied air forces had become too heavy. The only possible tactic was to sail the convoys by night., in short hops from port to port, sheltering in heavily defended harbours during the long daylight hours. In response, Coastal Command tried to attack the convoys at night, employing the Torbeaus of the Strike Wings. These squadrons were joined by two bomb-carrying squadrons based at Bircham Newton in Norfolk, the Wellingtons of 524 Squadron and the Avengers of 855 (Fleet Air Arm) Squadron. During moonlit nights these aircraft would roam along the Dutch coast on patrols called Rovers, taking off singly at set intervals and seeking 'targets of opportunity'. On dark nights, they would sometimes adopt more evolved tactics, known as Operation Gilbeys. These were combined bombing and torpedo attacks, and the method had been worked out as early as January 1944, based on experiments carried out by the Torbeaus of 254 Squadron at North Coates. The tactics of Operation Gilbey involved the extensive use of flares. The Beaufighter could carry only four flares but the Wellingtons could carry as many as seventy as well as a load of 500 lb medium-capacity bombs. The Wellingtons, equipped with Gee radar and ASV (anti-surface vessel) radar, would hunt along the Dutch coast and try to locate a convoy.	NES	181-182
1 September 1944	The Tilly, a German minelayer of 146 tons, was sunk by 254 Squadron, Coastal Command, off IJmuiden.	NES	264
15 September 1944	A Spitfire of 229 Squadron crashed into the North Sea, 48 km west off IJmuiden.	SGLO	T4025
5 December 1944	A P-51 D of 479 Fighter Group crashed into the North Sea, 25 miles off Egmond.	SGLO	T4746
1945	Mines have continued to evolve since 1918. During the Second World War mines dropped from aircraft and laid by ships formed an important part of British and German strategy. Magnetic and acoustic mines, as well as conventional contact mines, were used by both sides, and increasingly sophisticated systems were used for mine clearance.	CRO	160

Table 23: Overview relevant events during the Second World War, 1940-1945.

Post-war period

Like the interwar period, countries began to rebuild. As a part of this reconstruction defence works and remaining UXO were cleared. Also, the sea was cleared of mines.

Date / year	Event	Source	Page
1955	Anti-aircraft artillery exercise camp at Den Helder.	RON	61

Date / year	Event	Source	Page
			

Table 24: Overview post-war period.

ANNEX 4 MARINEMUSEUM, NOORDZEELOKET EN DIENST HYDROGRAFIE

Marinemuseum

This Annex contains the information which is derived from the maps and charts of the Royal Netherlands Navy. Figure 31 shows the area of investigation projected on the NEMEDRI 227 mine map.

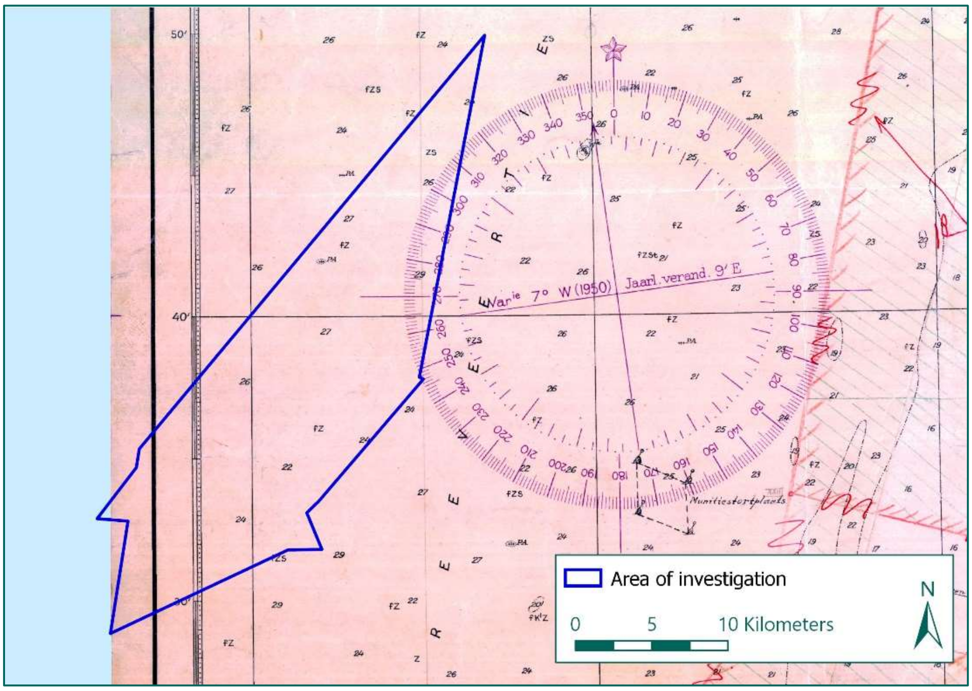


Figure 31: Extract of NEMEDRI 226 mine map (28 September 1949). The entire coast, except for the harbour entrance of IJmuiden, was considered a danger area. The area of investigation is situated outside the scope of the NEMEDRI map.

Noordzeeloket

The North Sea Desk ('Noordzeeloket') is a cooperation between different departments of the Dutch Government that deal with the North Sea. This desk can be consulted at: https://www.noordzeeloket.nl. The website contains the map 'Military Use'. Figure 32 shows this map. The area of investigation does not see any military use.

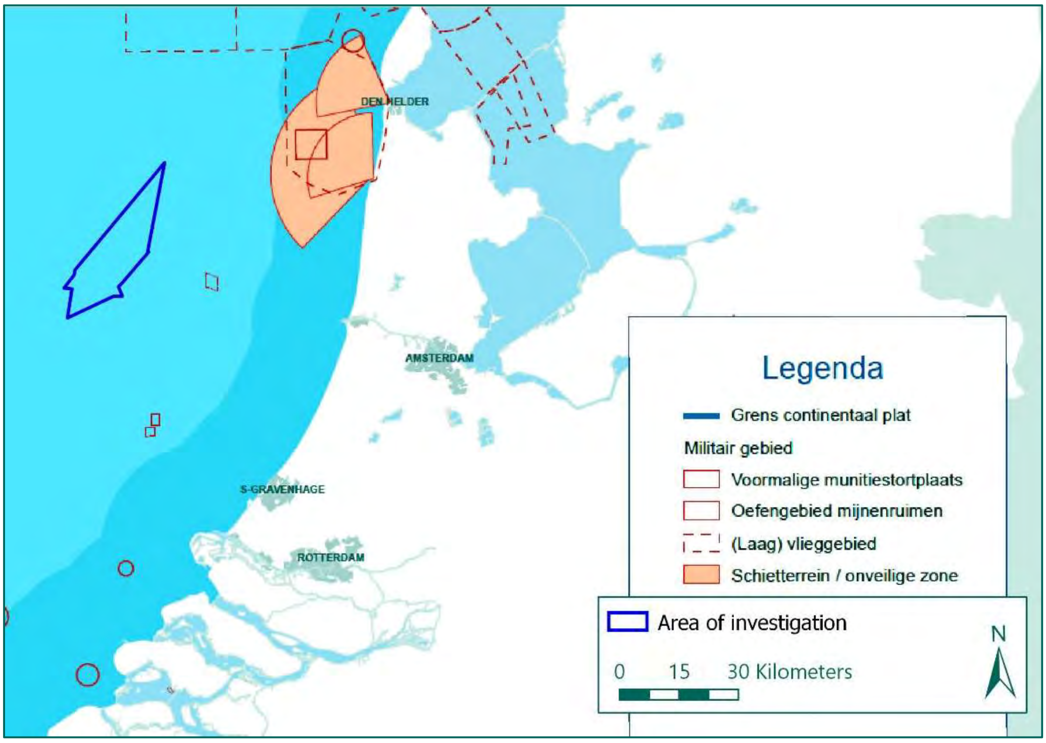


Figure 32: Extract of the map Military Use.

Dienst Hydrografie Defensie & Wrakkenregister

REASeuro ordered the Sea chart *DKW1801: Noordzeekust. De Panne tot Den Helder* from the Hydrographic Service of the Royal Netherlands Navy. This chart is shown in Figure 33. No relevant information for this investigation is shown on the map.

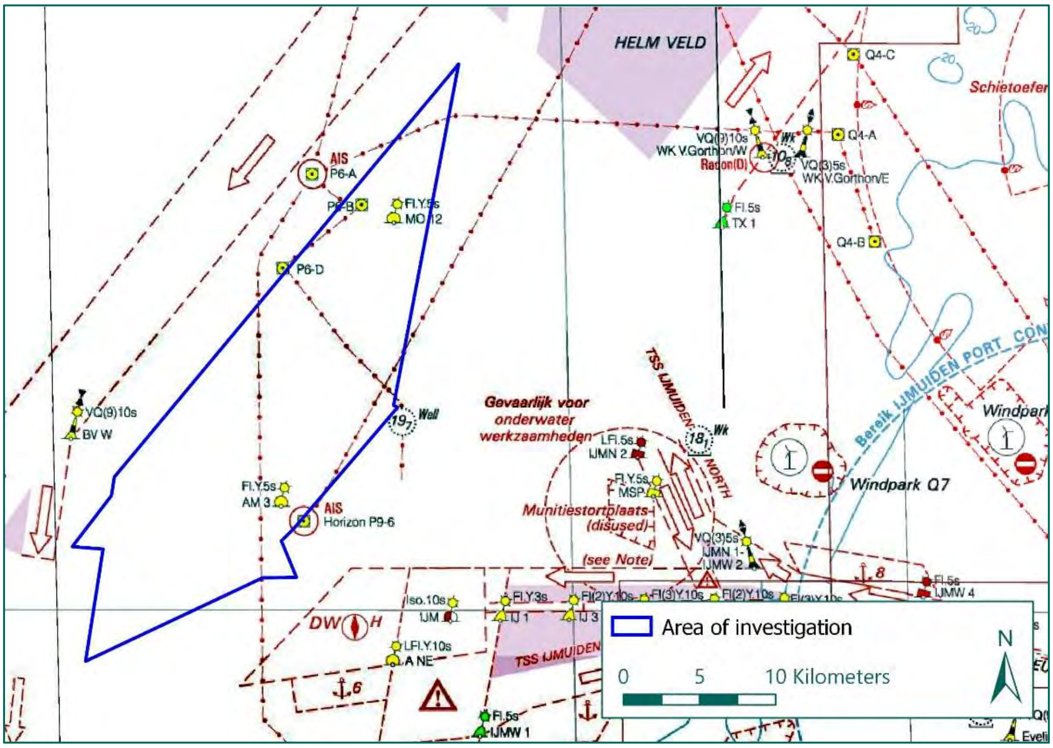


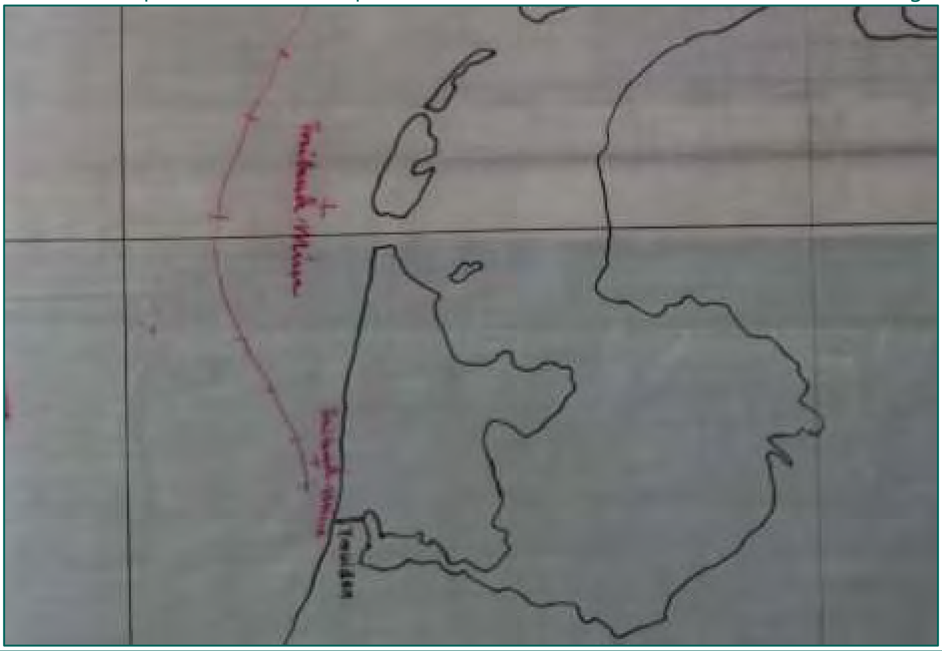
Figure 33: Extract from the Sea chart DKW1801: Noordzeekust. De Panne tot Den Helder.

ANNEX 5 BUNDESARCHIV-MILITÄRARCHIV, FREIBURG

REASeuro has conducted archival research 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. The destruction wreaked upon Germany during World War II destroyed large parts of the archival material, leading to large 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 5 Admiralstab der Marine / Seekriegsleitung der Kaiserlichen Marine	
RM 5/4721k	Streuminen": Minenverseuchung, Verluste durch Minenlegen. Bd. 2 Dez. 1914-Juni 1915 Kartenanlagen.
Relevant. Map shows an area suspected to be mined in front of the Dutch coast during the First World War. 	

RM 7 Seekriegsleitung der Kriegsmarine	
RM 7/86	Heft II: Lageübersicht Westraum/Nordsee.- Kriegstagebuch Teil B II. 15. Okt. 1941 – 31. Dez. 1943

Relevant. The records refer to British aerial and naval attacks, give information about mine clearance in front of the Dutch coast. Examples are given:

- Lageübersicht Westraum vom 15. – 31 März 1942.
  - Ein geleiter Erzdampfer ("Islande") lief nahe Hoek van Holland auf eine Mine, konnte aber eingeschleppt werden.
  - Küstenbatterien beschossen am 21 März abende vor der holländische Küste in Gebiet zwischen Hoek van Holland und Scheveningen geortete Ziele.
- Vom 1. – 15 März 1943.

Minenräumerfolge:

Während der Berichtszeit wurden im Gebiet des BSN insgesamt 95 Minen geräumt, davon
84 ELM/I und
11 ELM/A.
Der größte Teil dieser Minen wurde vor den Westfriesischen Inseln, vor Ymuiden und Den Helder, ein weiterer Teil vor Borkum und der kleinere Rest im Gebiet der Deutschen Bucht geräumt.
Die 12. Vp.-Flottille hat vom 23.2. - 2.3. 97 treibende Minen abgeschossen.

Minenlage:

Die großen Räumerfolge auf den Geleitwegen der Nordsee, vor der holländischen Küste und dem Kanal sind auf die erheblich günstigere Wetterlage in der Berichtszeit gegenüber dem Monat Februar zurückzuführen. Andererseits hat der Gegner diese günstige Wetterlage dazu benutzt, hauptsächlich mit Flugzeugen eine stärkere Verminung dieser Wege vorzunehmen.
Die starke Verminung vor Ymuiden, Den Helder und Boulogne deutet darauf hin, daß der Feind diese Häfen als Stützpunkte für unsere Streitkräfte ausschalten will. Sie beweist andererseits, daß diese Gegenden

- Vom 16 März – 15 April 1943.

Minenräumerfolge:

Jnsgesamt 157 Minen geräumt.
38 Mark 19 mit Ziehleine aus dem verseuchten Gebiet vor Scheveningen.
Bei den übrigen Minen handelt es sich hauptsächlich um Grundminen. Sie wurden vor der holländischen Küste und auf den Geleitwegen vor den West- und Ostfriesischen Jnseln geräumt.

Feindberührungen:

Am 12.4. Pos.-Boote vor Ymuiden Gefecht mit engl. S-Booten. Treffer auf 2 S-Boote.

Luftangriffe:

Am 10.4. M 3406 vor Ymuiden von 4 engl. Jägern angegriffen.

Am 15.4. Luftangriff auf M 3412 zwischen Den Helder und Ymuiden.

Verluste und Beschädigungen:

Am 27.3. M 82 westl. Scheveningen Ate- Minentreffer. Boot mit eigener Kraft eingelaufen.

- Vom 16 -30 April 1943.

Feindberührungen:

Am 17.4. vor Ymuiden Gefechtsberührung der Vorp. Pos. mit feindlichen S-Booten.

Am 18.4. Gefecht der Vorp.Boote auf Pos. Schweveningen mit 8 feindlichen S-Booten. Hierbei 1 S-Boot (" Adonis") versenkt, ein weiteres wahrscheinlich, 2 beschädigt.

Am 29.4. Sicherungs-Pos. Ymuiden Gefecht mit feindl. S-Booten. 1 S-Boot versenkt, 1 S-Boot in Brand geschossen. VP

Luftangriffe:

Am 16.4. bei Ymuiden Angriff von 2 Spitfire auf M-Boote 3403, 07, 09, 12.

Am 18.4. Tagesangriff von 20 Bombern und 20 Zerstörern auf Geleit von Hoek nach Elbe vor Den Helder. Hierbei norwegischer Dampfer " Hoegh Carrier" (4906 BRT) durch T-Treffer gesunken. M 201 beschädigt. 2 Abschüsse.

Verluste und Beschädigungen:

Am 18.4. vor Den Helder norwegischer Dampfer " Hoegh Carrier" (4906 BRT), Ladung Kohle, durch T-Treffer vom Flugzeug gesunken.

Am 21.4. dänischer Dampfer " Catja Lau " (1224 BRT), Ladung Koks, vor Ymuiden Grundminentreffer. Beschädigt nach Ymuiden eingeschleppt.

Am 28.4. VP 1408 durch T-Treffer vom S-Boot vor Ymuiden gesunken.

Luftangriffe:

Am 14.5. Angriff von 12 Flugzeugen auf 3 Boote der 34. Minensuchfl. bei Ymuiden und Angriff auf Hochofenwerk Ymuiden.

- Vom 1-30 Juni 1943.

Luftangriffe:

18.6. Fliegerangriff auf VP-Pos. bei Ymuiden, Boote Personalschäden.

- Vom 1-15 Juli 1943.

Minenräumerfolge:

44 Minen wurden in der ersten Monathälfte auf den/Geleit-Wegen in der Nordsee und auf den West-und Nordfriesischen Jnseln geräumt.

Luftangriffe:

8.7. Ein Abschuß bei Den Helder.
Zweimaliger Angriff auf HS-Boote vor Den Helder durch 2 Feindflugzeuge.
1 Abschuß durch Mar. Flak.
Angriff auf Vlissingen.
1 Abschuß.

Verluste und Beschädigungen:

Kraft Cuxhaven eingelaufen.
5.7. Holl. Fischkutter " Scheveningen 140 " (250 BRT) NW Ymuiden durch Minentreffer gesunken.

Feindberührungen:

Jn der Nacht vom 5. zum 6.7. westl. Den Helder Gefecht zwischen 34. Msfl. und feindl. S-Booten. Die Angriffe wurden abgewehrt.

- Vom 16-31 Juni 1943.

Feindberührungen:

25.7. 0119 Uhr 34. Msfl. xGr.Ymuiden Gefecht mit feindl. S-Booten in Höhe Nord-Wijk. 1 S-Boot versenkt, 3 weitere in Brand geschossen.
0243 Uhr erneutes Gefecht mit feindl. S-Booten und 34. Msfl. und VP-Booten 13/14 bei Ymuiden. 2 Boote in Brand geschossen.

Verluste und Beschädigungen:

20.7. VP 805 durch Min.Det. ...
23.7. Jm S-Boots-Gefecht vor Ymuiden R 107, 103, 87 schwer beschädigt.
Fischereifahrzeug "KB 158" zwischen Ymuiden und Den Helder nach U.W. Det. gesunken.
... mit feindl. Gun-Booten nördl. Vlie

- Vom 1-15 September 1943.

Gefechte mit S-Booten setzten erst am 14. ein. An diesem Tage gingen um 0213 Uhr ein M-Boot zwischen Ymuiden und Scheveningen durch Torpedo-Treffer eines feindlichen S-Bootes verloren. Am 15.9. 0115 Uhr kam es vor Ymuiden zwischen Vorpostenbooten und S-Booten und 2 Stunden später zwischen R-Booten und S-Booten zu ergebnislosen Gefechten, bei denen der Feind sich durch Anwendung von Nebel und eines neuartigen Brandsatzes der deutschen Waffenwirkung entzog.

RM 7/172	Heft VI: Minenkriegführung Kriegstagebuch Teil C VI Bd. 13. Sept. 1939 – 21. Jan. 1941

- 15 Oct 1940
  Map shows British minefields in front of the Dutch coast.

Holländisch-belgische Küste:

- 26 Juni 1940. Englische magnetische Minen.

c) Ijmuiden:
im seewärtigen Halbkreis (Radius 1 sm) um
52°28'N 4°33,1' O

- 19 September 1940. Englische Minensperren.

19.9.40 Englische Minensperren:
a) Ijmuiden:
vom Punkt 52°33'00"N 4°28'18" O in Richtung
280° 6,1 sm
(bereits durch Beuteseekarte bekannt)

b) Ijmuiden:
im Umkreis von 3 sm um 52°42'N 4°10' O

c) Scheveningen:
im Seegebiet begrenzt durch die Punkte:
1) 52°06'30"N 4°05'48" O
2) 52°04'00"N 4°06'48" O
3) 52°00'30"N 3°59'30" O
4) 52°03'06"N 3°58'48" O
(bereits durch Beuteseekarte bekannt)

RM 7/174	Heft VI: Minenkriegführung Bd. 3 3. Jan. 1942 – 11. Jan. 1945

Relevant, records show that three ships of the German Maas Fleet were damaged as a cause of a British aerial attack with bombs or torpedoes.

RM 7/175	Heft VI: Minenkriegführung Anlage zum Kriegstagebuch Teil C VI und C XV Jan. – 3. Apr. 1945

Relevant. A table gives an overview of cleared ground mines in 1944 and early 1945.

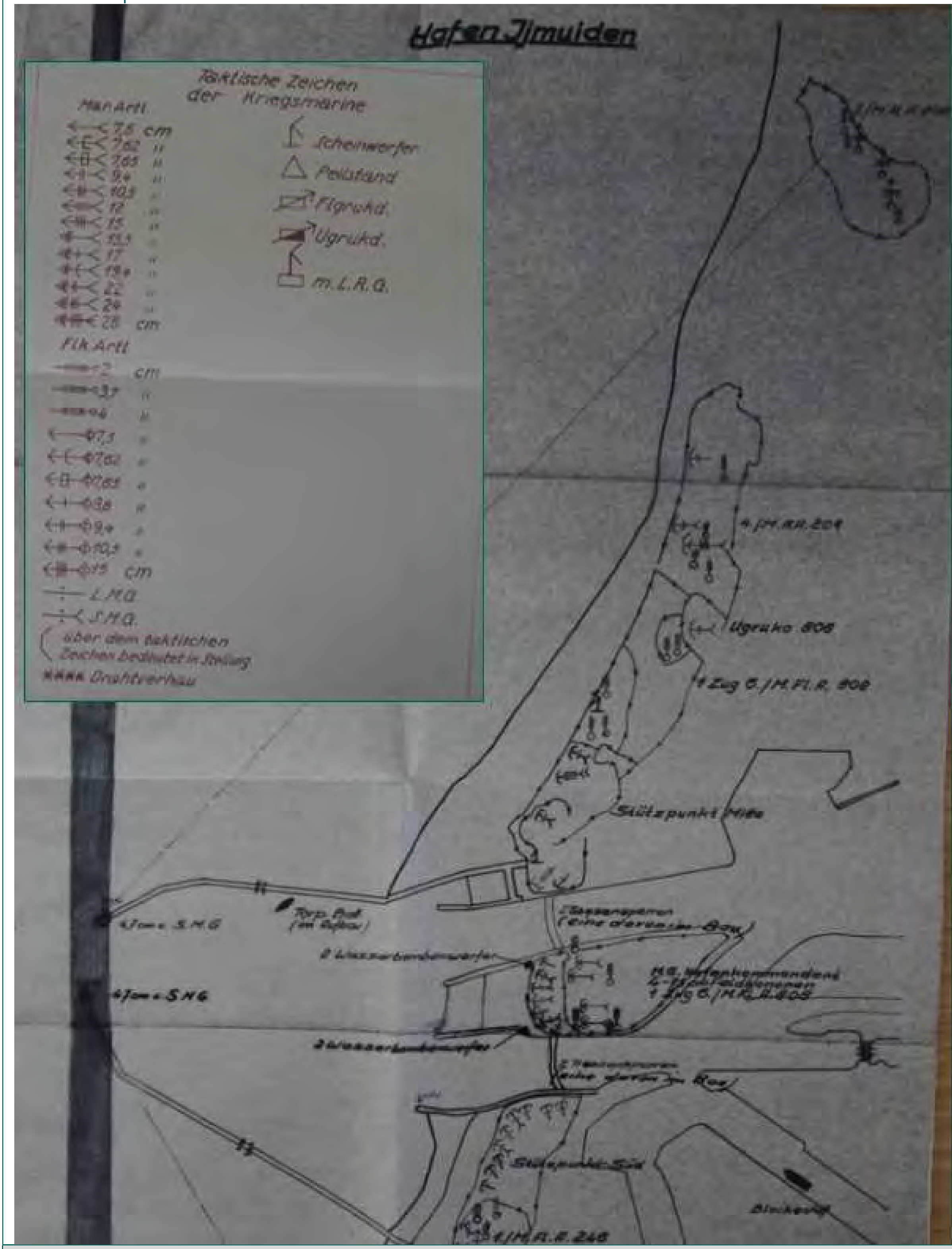
Räumung von Grundminen 1944 :

CVI

onat :	Ostsee:	Nordsee:	Norwegen:	Westraum:	Ägäis:	Donau:
nuar	24	79	--	71	11	--
bruar	88	124	--	75	24	--
ärz	157	163	--	226	3	--
ril	235	353	--	157	2	--
i	431	254	--	380	2	--
ni	175	182	--	520	8	82
li	135	79	--	131	4	60
ugust	192	40	5	128	2	72
September	219	18	3	--	2	33
Oktober	209	29	18	--	4	10
ember	74	22	20	--	-	--
zember	117	13	22	--	-	--
1 9 4 5 :						
Januar	122	7	21	--	-	--
Februar	185	57	35	--	-	--

RM 35-I Marinegruppenkommando Ost / Nord der Kriegsmarine	
RM 35-I/267	Minen, Allgemein Minensperren Nordsee

	10. Aug. 1940 – 1. Okt. 1943
Relevant, minelaying reports on which the maps in ZA 5 are based.	
RM 35-I/277	Minenlage Nord (M.L.N.) 1. Mai 1942 – 1. Okt. 1943
Relevant. Maps show coastal defences.	



ZA 5 Deutscher Minenräumdienst (German Minesweeping Administration)	
ZA 5/27	(Im Kriege geworfene Minensperren in der Ost- und Nordsee etc.)

Relevant. Map indicating the locations of German naval minefields. The minefields C.47 and C.48 are relevant for the area of investigation.

ZA 5/28	Minenkarten, Deutsches Hydrographisches Institut (Großformat) 1960 Deutsche Minensperren des Zweiten Weltkrieges 1939 – 1945.- Erläuterungen zu den Minenkarten

Relevant, this record contains information about the clearance of German naval minefields.

- May 1960.

Sperren-Bezeichnung	Minen-Anzahl, Typ	Bemerkung
C 35	340 LMB	
C 45	72 "	
C 47	160 EMC	nichts gefunden
C 48	160 "	32 EMC geräumt, Ende 1945

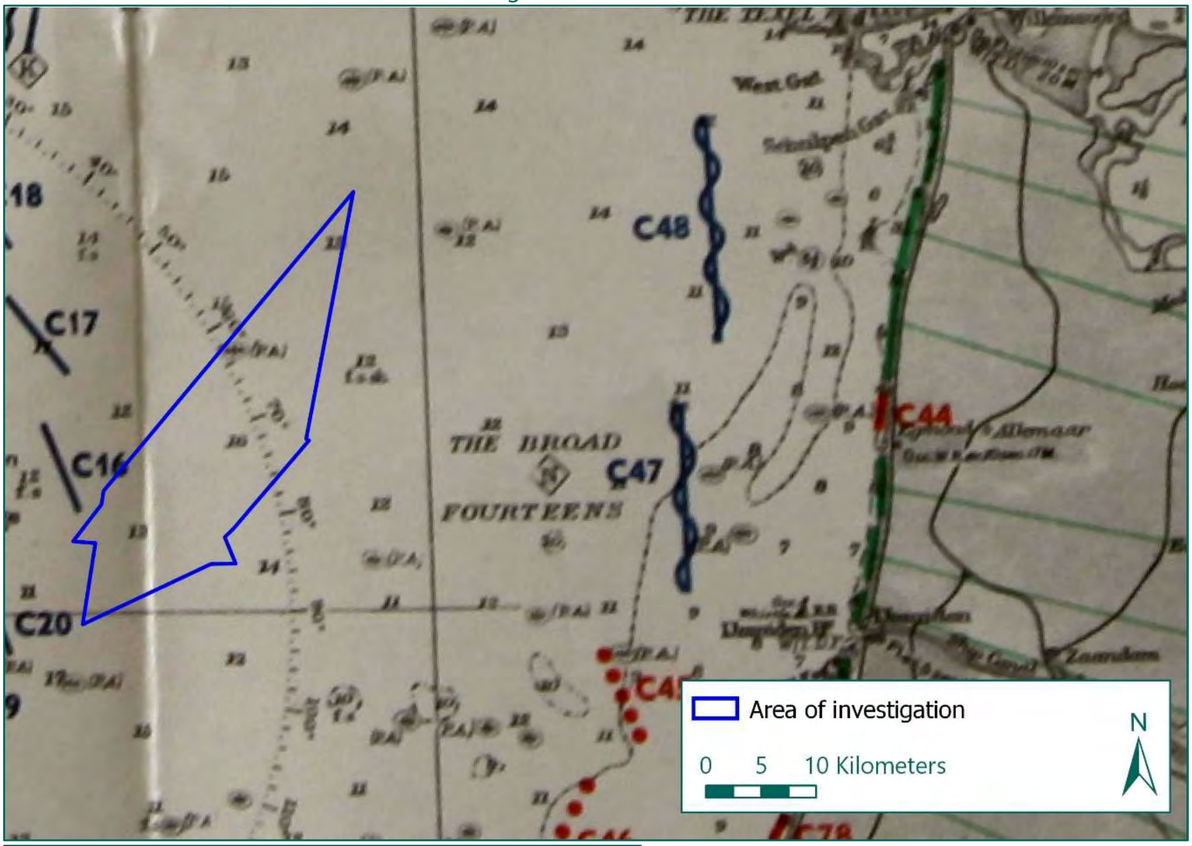
ZA 5/44	Summary of Enemy Minelaying, The Admiralty, United Kingdom (Großformat)

Relevant, the record gives an overview of the German minefields.

ZA 5/48	German Minelaying 1939 – 1945, Hydrographic Department of the Admiralty (Minenkarten, Großformat) 1945 Chart C: The North Sea.- Southern Sheet (1:754400)

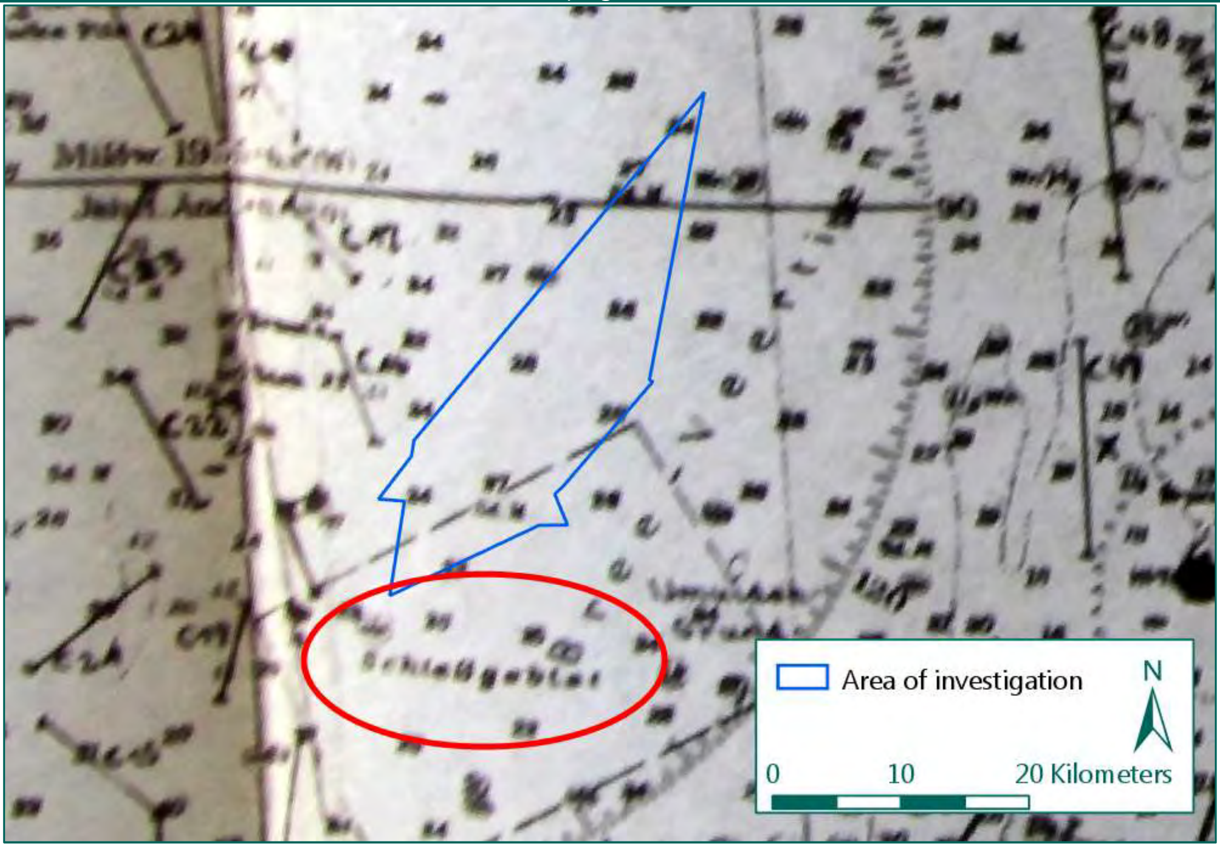
ZA 5 Deutscher Minenräumdienst (German Minesweeping Administration)

Map indicating the locations of German naval minefields. Minefield numbers refer to ZA 5/44. No German minefields were situated near the area of investigation.

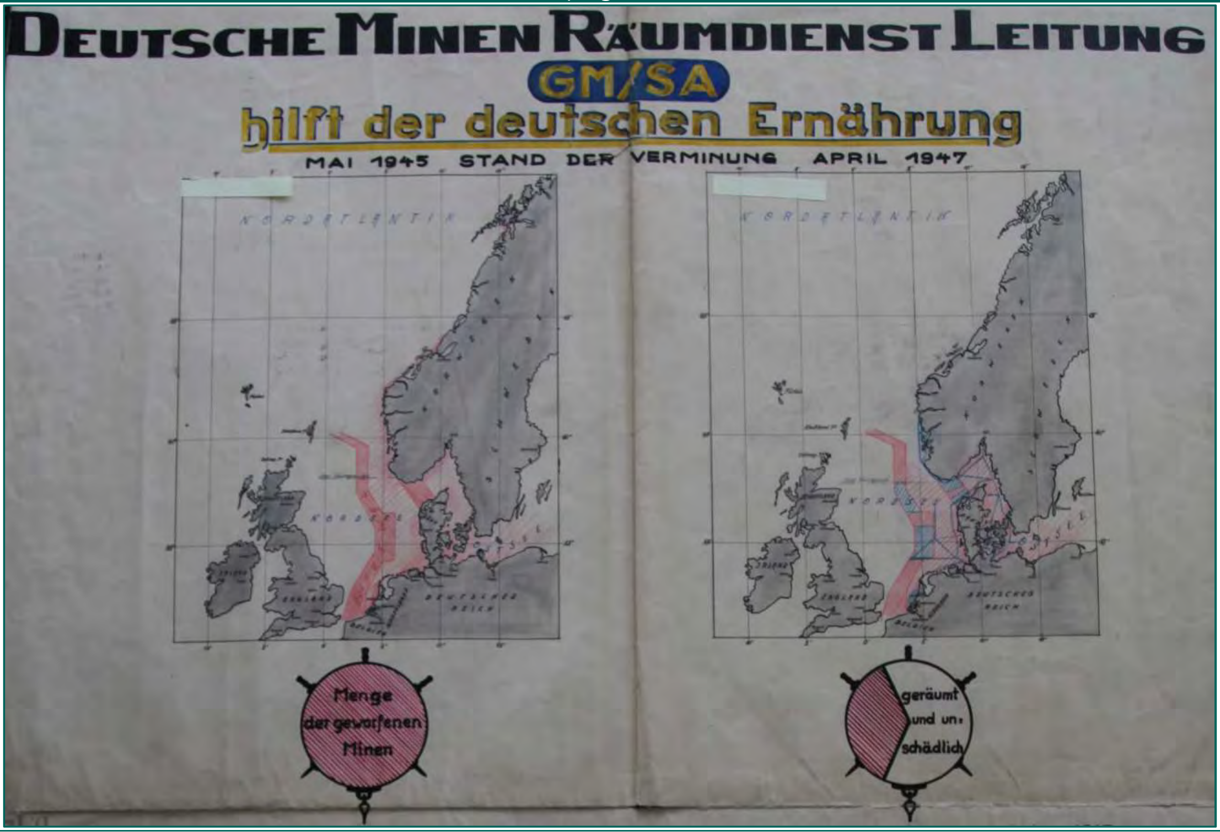


The minefields are geographically positioned on the contemporary map in GIS, based on the information from this chart.

ZA 5/62	Die Nordsee.- Südblatt

ZA 5 Deutscher Minenräumdienst (German Minesweeping Administration)	
 Relevant, chart indicates German shooting range.	
ZA 5/66	Stand der Verminung
Relevant, shows the progress during the post-war clearance of naval mines.	

ZA 5 Deutscher Minenräumdienst (German Minesweeping Administration)



ANNEX 6 THE NATIONAL ARCHIVES, LONDEN

A variety of records of the British Royal Air Force, Royal Navy (Admiralty) and War Cabinet were consulted. The results are presented in this Annex.

Royal Air Force

The British Royal Air Force (RAF) undertook numerous maritime operations, including minelaying and attacks on shipping.

AIR 14: Air Ministry: Bomber Command: Registered Files
Information on airborne minelaying.

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 December 31 1941. No known ship losses are mentioned in or nearby the area of investigation.

General overview of amounts of mines laid by Bomber and Coastal Command:

1. Seamining operations have been carried out by aircraft of Bomber Command during the whole of this period and by aircraft of Coastal Command until the end of December 1941. By the end of April 1942 Bomber Command had laid 2324 mines and Coastal Command laid in the period in which they operated 365 mines.

Overview of mines laid by Coastal Command

GARDEN.	PLANTED BY BOMBER A/C.	PLANTED BY COASTAL A/C.	TOTAL PLANTED.	GERMAN SHIPS.	SHIPS OF OTHER NATIONALITY.	TONNAGE.
TEXEL		25	25.	1		1,000
IJMUIDEN		20	20			

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

Bomber Command minelaying offensive 1 Jan. 1944 – 30 April 1944.

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

AIR 14: Air Ministry: Bomber Command: Registered Files
Information on airborne minelaying.

Bomber Command. Minelaying 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.

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.

AIRCRAFT MINELAYERS

Operations: Routine laying between DUTCH COAST and CHENAL DU FOUR.

AREA	CODE WORD	MINES AND SETTINGS	
DUTCH COAST	TREFOIL	A. Mk. IV	Lives limited
LE HAVRE	SCALLOPS	A. Mk. IV	to
CHERBOURG	GREENGAGE	A. Mk. IV	8 days.

AIRCRAFT MINELAYERS (See Note A)

Operations: I. Y-22 onwards
Routine laying to continue, with special laying as indicated below:-

AREA	CODE WORD	MINES
LE HAVRE CHERBOURG	SCALLOPS GREENGAGE	A. Mk. VI (D.410 & G.706)
IJMUIDEN HOOK W. SCHELDT	WHELKS)See IRIS FIVE)Note IRIS TWO) A	A. Mk. VI (D.410 & G.706)

AIR 14: Air Ministry: Bomber Command: Registered Files Information on airborne minelaying.
Position of Gardening fields:

DUTCH COAST (Q.Z.X.772) - TREFOIL
An area bounded:-

(a) on the north by latitude 52°52' N.,

(b) on the east by the 5 fathom line,

(c) on the south by latitude 52°38' N.,

(d) on the west by longitude 04°29' E.

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.

- Not relevant, the area of investigation is situated over 13 kilometres from the closest Gardening field.

AIR 15: Air Ministry and Admiralty: Coastal Command: Registered Files Information on airborne minelaying.	
AIR 15/267	Minelaying Areas, 1942 Oct. 1944 Dec.

This record contains information about the allied Gardening operations. This operation is about the dropping of mines by plane in various sea zones. Three zones lie in the vicinity of the area of investigation:

- "Limpets 2" (S. Texel)

All the waters suitable for mining bounded as follows:-

On the North by latitude 53° 04' N

On the East by the five fathom line

On the South by latitude 53°00' N

On the West by longitude 04°30' E

- "Whelks" (IJmuiden)

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

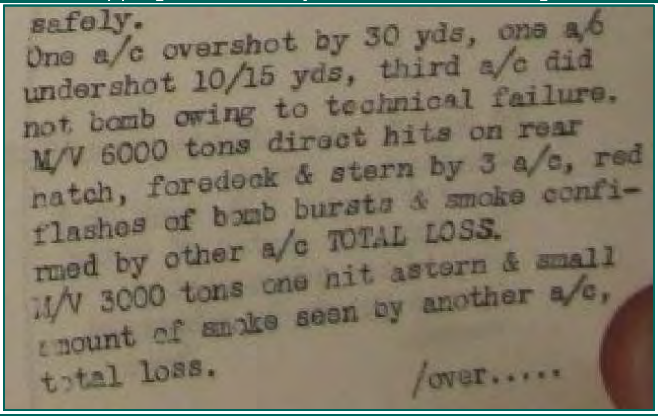
52° 28' 00" N

04° 33' 06" E

- "Trefoil" (between Texel and IJmuiden

AIR 15: Air Ministry and Admiralty: Coastal Command: Registered Files Information on airborne minelaying.	
The area bounded as follows:- (1) On the North by Latitude 52° 52' N. (2) On the East by the 5 fathom line. (3) On the South by Latitude 52° 38' N. (4) On the West by Longitude 04° 29' E. Not relevant, the area of investigation is situated over 13 kilometres from the closest Gardening field.	
AIR 15/772	Sea Mining Sheets Nos. 1-200 Vol 1, 1940 Apr.- 1941 July
Not relevant, contains information of Gardening operations, which took place over 13 kilometres from the area of investigation.	

AIR 24: Air Ministry: Bomber Command Attacks on shipping in the vicinity of the area of investigation.	
AIR 24/230	RAF Bomber Command Operations Record Book, April 1941.
• 6 April 1941. Cargo ship 2,000 tons beached on sandbank 52° 48'N, 04° 38'E bombed by three Blenheims with 10 x 250 lbs. 4 x 250 bombs undershot by 20 yards. 2 x 250 bombs just missed starboard bow. 4 x 250 by 10 yards.	
AIR 24/231	RAF Bomber Command Operations Record Book, May 1941.
• 6 May 1941. Two Blenheim bombers attacked two 50-ton Trawlers (Dutch Markings) 52° 52'N, 03° 53'N with 8 x 250 lbs. 1 aircraft bombs overshot. Other results not seen. No damage to either boat. • 6 May 1941. One Blenheim bomber attacked one or two 1,600-ton cargo ships, 52° 54'N, 04° 40'E, with 4 x 250 lbs bombs. Believed undershot, no damage seen.	
AIR 24/232	RAF Bomber Command Operations Record Book, June 1941.
• 15 June 1941. One Blenheim attacked M/V about 5/6,000 tons escorted by flak ships at 52° 54'N, 04° 32'E, with 2 x 500 lbs bombs SAP and 4 x 25 lbs incendiary bombs. Bombs seen to fall and make glancing hits on port side of bow. Intense fire from all ships prevented further observation.	
AIR 24/233	RAF Bomber Command Operations Record Book, July 1941.
• 12 July 1941. 4 Blenheims bombed a 1,000 ton trawler 52° 58'N, 04° 10'E with 16 x 250 lbs bombs SAP. Bombs from 3 a/c overshot and undershot. The fourth a/c bombs fell alongside ship 5 -10 yards to port. • 12 July 1941. 100 ft. sailing vessel (believed reporting vessel) 52° 32'N, 03° 58'E, attacked by one Blenheim with 4 x 250 bombs SAP and 0,4 tons incendiary bombs. Bombs overshot by 5 – 10 yards. Vessel also machine gunned. • 14 July 1941. 8 Blenheims bombed Convoy off IJmuiden 52° 53'N, 04° 33'E with 32 x 250 lbs bombs SAP and 36 x 25 lbs bombs.	

AIR 24: Air Ministry: Bomber Command Attacks on shipping in the vicinity of the area of investigation.


safely.
One a/c overshot by 30 yds, one a/c
undershot 10/15 yds, third a/c did
not bomb owing to technical failure.
M/V 6000 tons direct hits on rear
hatch, foredeck & stern by 3 a/c, red
flashes of bomb bursts & smoke confi-
rmed by other a/c TOTAL LOSS.
M/V 3000 tons one hit astern & small
amount of smoke seen by another a/c,
total loss. /over.....

AIR 24/234	RAF Bomber Command Operations Record Book, August 1941.

- 18 August 1941. Two Blenheims bombed a trawler of approx.. 100 tons, 52° 49’N, 04° 25’E, with 4 x 250 lbs bombs SAP. Considered two bombs very closes misses. Vessel M/C.
- 19 August 1941. Trawler 200-300 tons, 52° 37’N, 03° 48’E, attacked by one Blenheim with 4 x 250 lbs bombs SAP and 0,4 tons incendiaries. Undershot. Periscope seen later.
- 27 August 1941. 31 x 600 ton vessels 52° 49’N, 04° 38’E, were attacked by three Blenheims with 6 x 500 lbs bombs SAP and 10 x 25 lbs incendiaries. Smoke seen from one vessel after attack & believed incends. Found their mark. Results from other two a/c unobserved but believed their bombs over-shot.

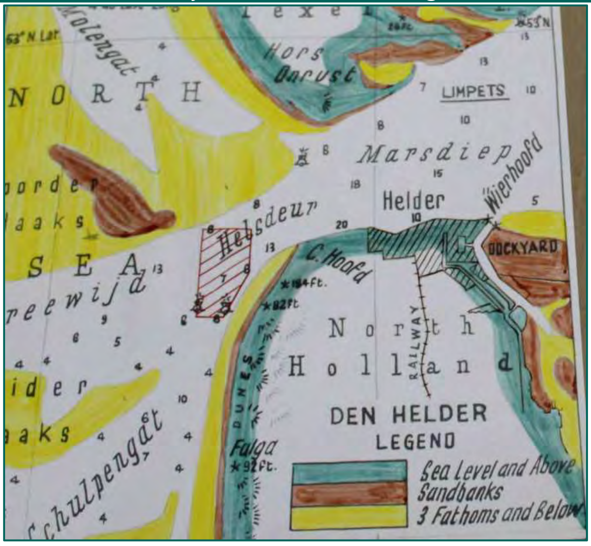
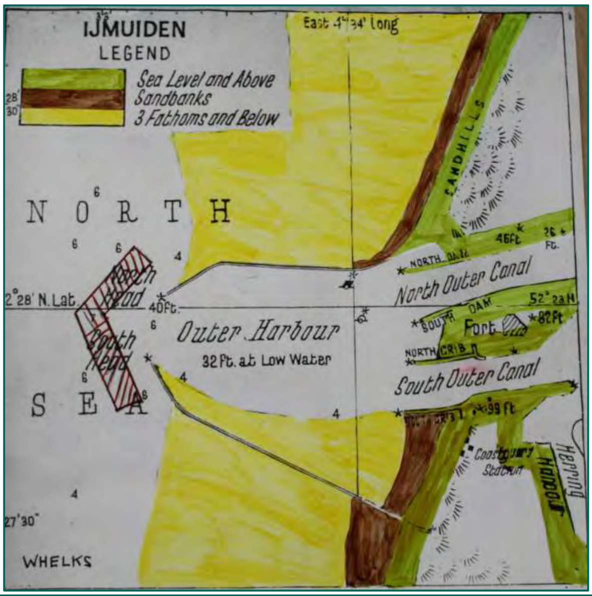
AIR 24: Air Ministry: Coastal Command	
AIR 24/407	H.Q.C.C. Narrative 1943 Sept.-Oct.

- 19 October 1943. 27 A/C. A/C on shipping strike. Sighted the M/W Strassbourg with at least one armed tug and armed trawler, one M-Class minesweeper and one TLC (probable) in attendance. Six aircraft of 236 attacked with a total of 48 R/P’s and cannon; the remaining aircraft with cannon only. Three of the R/P aircraft each fired a salvo of 8 R/P at the M/W from 5-600 yards. The fourth fired a salvo at the armed trawler. The fifth fired 8 R/P’s in pairs at the M/V at 4/500 yards, and the sixth fired one pair at the M/W at 600 yards. (…) Vessel also received cannon strikes all over the decks and superstructure. (…) The armed trawler was damaged by cannon fire. One of the Beaufighters is missing and several other received damages.

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 Jun – 1941 July.

Relevant, Gardening charts of fields near the area of investigation.

Limpets:

AIR 40: Air Ministry: Directorate of Intelligence and Related Bodies: Intelligence Reports and Papers
 Whelks: 

War Cabinet

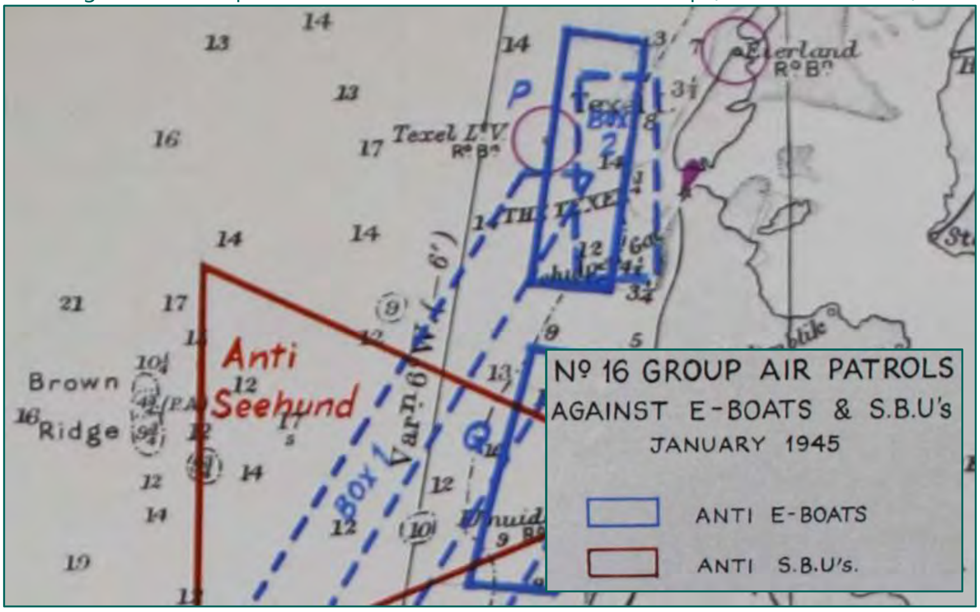
CAB 101: War Cabinet and Cabinet Office: Historical Section: War Histories (Second World War), Military.	
CAB 101/324	Air Offensive Against Enemy Shipping and Bomber Command Minelaying Operations, 1 September 1944 – 5 May 1945
Reports on air offensive operations against enemy shipping and minelaying operations holding several sections on aerial attacks off the Dutch coast and aerial attacks on the E-boat shelters in IJmuiden. No specific locations are mentioned, but a narrative illustrated with tables shows the general results of the British attacks, for example in September-December 1944:	

CAB 101: War Cabinet and Cabinet Office: Historical Section: War Histories (Second World War), Military.

Summary of the Air Offensive against Enemy Shipping
September to December, 1944

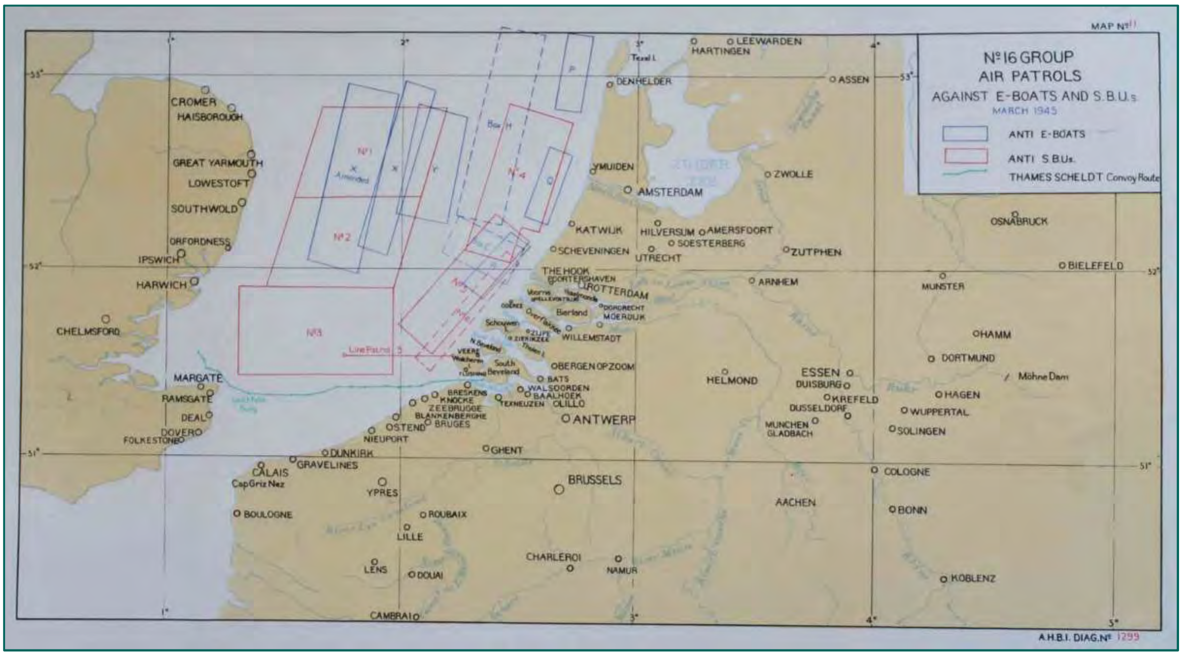
Month	Aircraft Sorties	Attacks made	Enemy vessels sunk		Enemy vessels damaged		Air-craft lost
			No.	Tonnage	No.	Tonnage	
September	1,916	557	41	16,061	2	3,886	24
October	1,267	270	15	13,659	3	10,029	12
November	1,154	204	12	13,927	7	18,078	11
December	1,330	251	10	20,417	13	46,532	21
Totals	5,667	1,282	78	64,064	25	78,525	68

A chart gives a more specific overview where actions of 16th Group (Coastal Command) took place:



January 1945

February 1945



March 1945

CAB 101: War Cabinet and Cabinet Office: Historical Section: War Histories (Second World War), Military.

April 1945

Admiralty

The Admiralty was responsible for the Royal Navy. Documents from the admiralty include documentation on minelaying, minesweeping and naval combat.

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 dangerous area in the European waters due to mining, August 1945

Chart indicating dangerous area in the European waters due to mining, March 1946

ADM 1: Admiralty, and Ministry of Defence, Navy Department: correspondence and papers

The report includes a list of ships sunk by mines in the post-war period:

Dutch Lugger (name unknown)	?/10/45	Off Dutch Coast	Sunk	*Thought to have entered dangerous area in fog.*
Norwegian BETTY (2,450 tons)	12/3/46	Off Ymuiden	Damaged	*Outside swept water.*

ADM 234: Admiralty, and Ministry of Defence, Navy Department: Reference Books

ADM 234/560	British mining operations 1939-1945: Vol 1.

This record contains information about the British offensive minelaying of the coast of Holland.

Operation “CBX”, 10 May 1940

Operations “CBX2” and “CBX3”, 16 May 1940

ADM 234: Admiralty, and Ministry of Defence, Navy Department: Reference Books	

Operations "CBX2" and CBX3". 16th May 1940

Having carried out two lays in the East Coast Barrier and reloaded at Immingham, the 20th Destroyer Flotilla, now reinforced by two more ships, was detailed to lay additional fields off the Netherlands coast as follows:

a. Operation "CBX2". INTREPID and IMPULSIVE (40th Division) to reinforce "CBX".

b. Operation "CBX3". EXPRESS, ESK and IVANHOE (39th Division) to lay a field off the Hook of Holland.

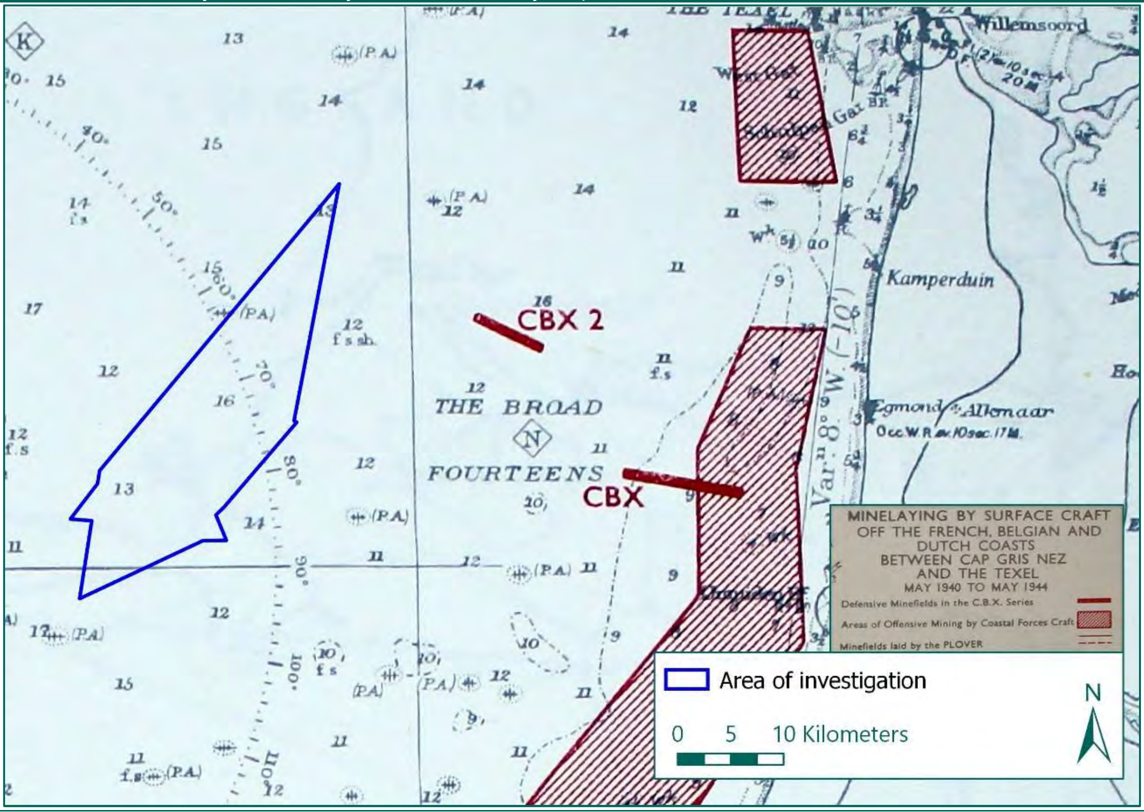
The operations were to be carried out on the night of 15th/16th May and discretion was given to the Senior Officer of each Division to vary the actual position of the lay, should local conditions prevent close approach to the Netherlands coast.

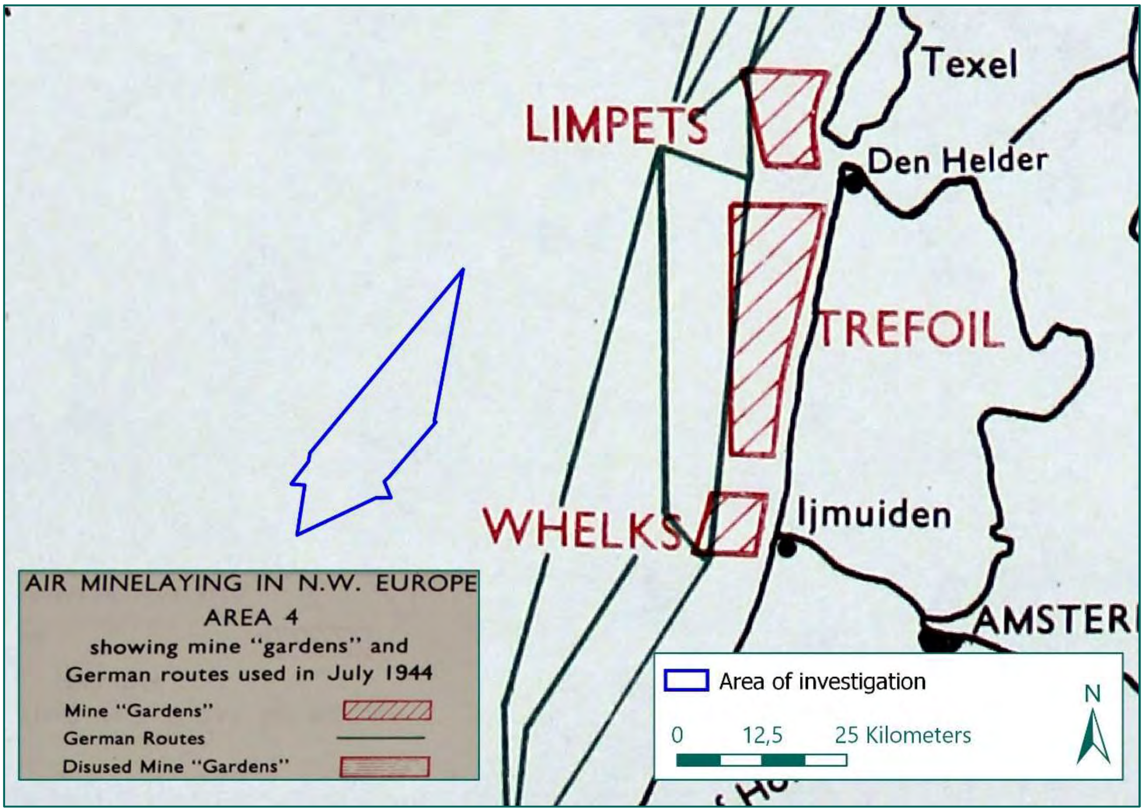
The Flotilla left Immingham at 1525 on 15th; shortly afterwards the IMPULSIVE reported boiler defects and had, eventually, to be ordered to return to harbour. The remaining ships proceeded south, taking departure from the South Lemon buoy at 2028 and heading thence for their respective laying areas. The 39th Division was not detected by the enemy and, between 0041 and 0134 on 16th, laid 164 Mk XIV/XVII units along a zig-zag line extending for 15 miles in a mean direction 258° from position 52°05.1'N, 04°04.8'E. Mines were laid in groups of five, at intervals of approximately half a mile and at a depth of eight feet, ships laying in the order ESK (60), IVANHOE (60), EXPRESS (44). The INTREPID was not so lucky and was shadowed by aircraft intermittently from 2300. The Commanding Officer considered that in the clear conditions his mines must have been visible on deck and that his intentions were therefore known. In these circumstances he decided to lay his field further from the coast than planned, and at 0015 if no aircraft was then in contact. This condition was fulfilled and, between 0016 and 0028 on 16th, the INTREPID laid 60 Mk XIV/XVII units along a zig-zag line extending for 3.5 miles in a mean direction 114° from position 52°42.2'N, 04°06.3'E: depth eight feet. On completion all four ships returned to Immingham.

Relevant, the CBX 2 minefield was situated in the area of investigation. Other allied minefields were planted closer to the coast.

ADM 234/561	British mining operations 1939-1945: Vol 2.
Annex to Vol 1, containing maps, plans, tables and charts. The following images are relevant to the area of investigation.	

ADM 234: Admiralty, and Ministry of Defence, Navy Department: Reference Books	

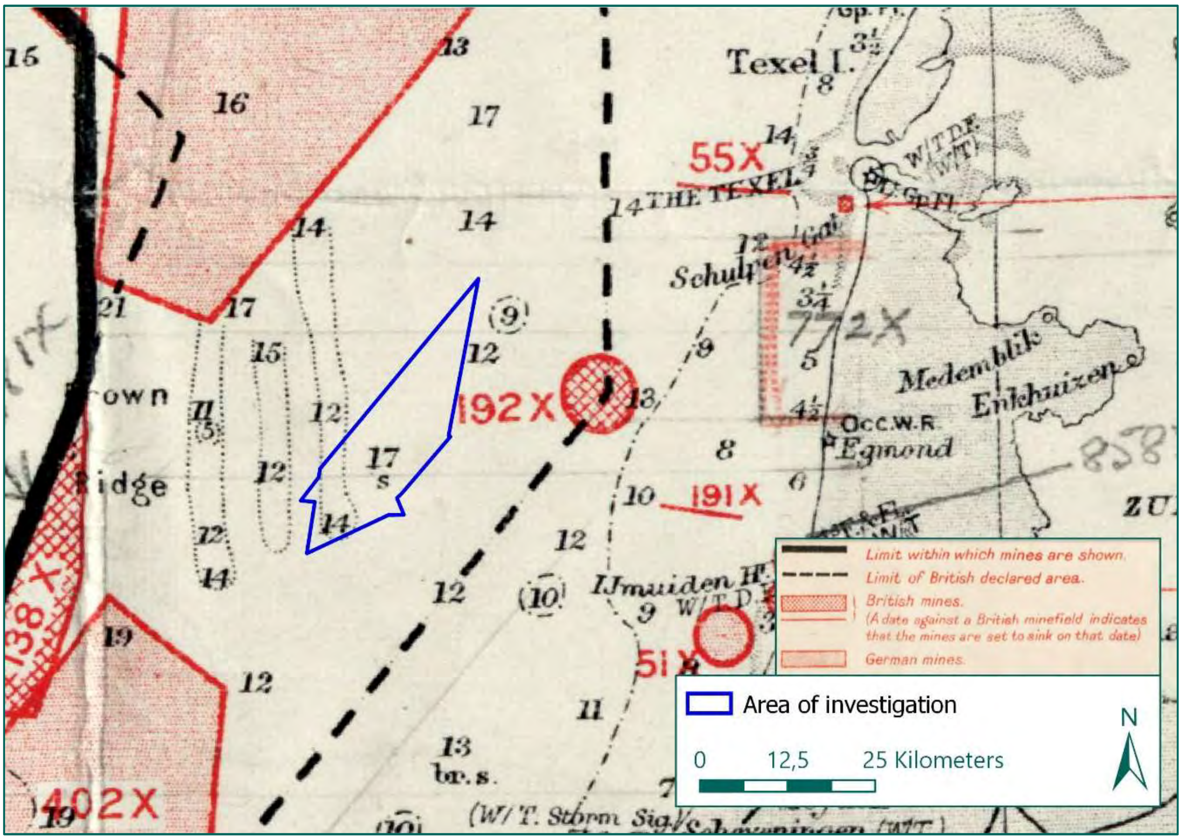




Relevant,according to the maps above, the area of investigation was situated outside major shipping routes and minefields.

ADM 239/304	North Sea: chart 736 showing position of British and German minefields

ADM 234: Admiralty, and Ministry of Defence, Navy Department: Reference Books



Relevant, area of investigation is situated outside known minefields.

ANNEX 7 NATIONAL ARCHIVES AND RECORDS ADMINISTRATION

The National Archives and Records Administration (NARA) have been consulted to obtain more information on aerial attacks in and near the area of investigation. The United States Army Air Force (USAAF) was responsible for heavy daylight bombardment on occupied territory. IJmuiden was bombed by USAAF aircraft as well. Besides information on USAAF missions, the NARA contains information intelligence shared by their British counterparts, including military intelligence photographic information and strike reports. The following record groups were consulted in the NARA:

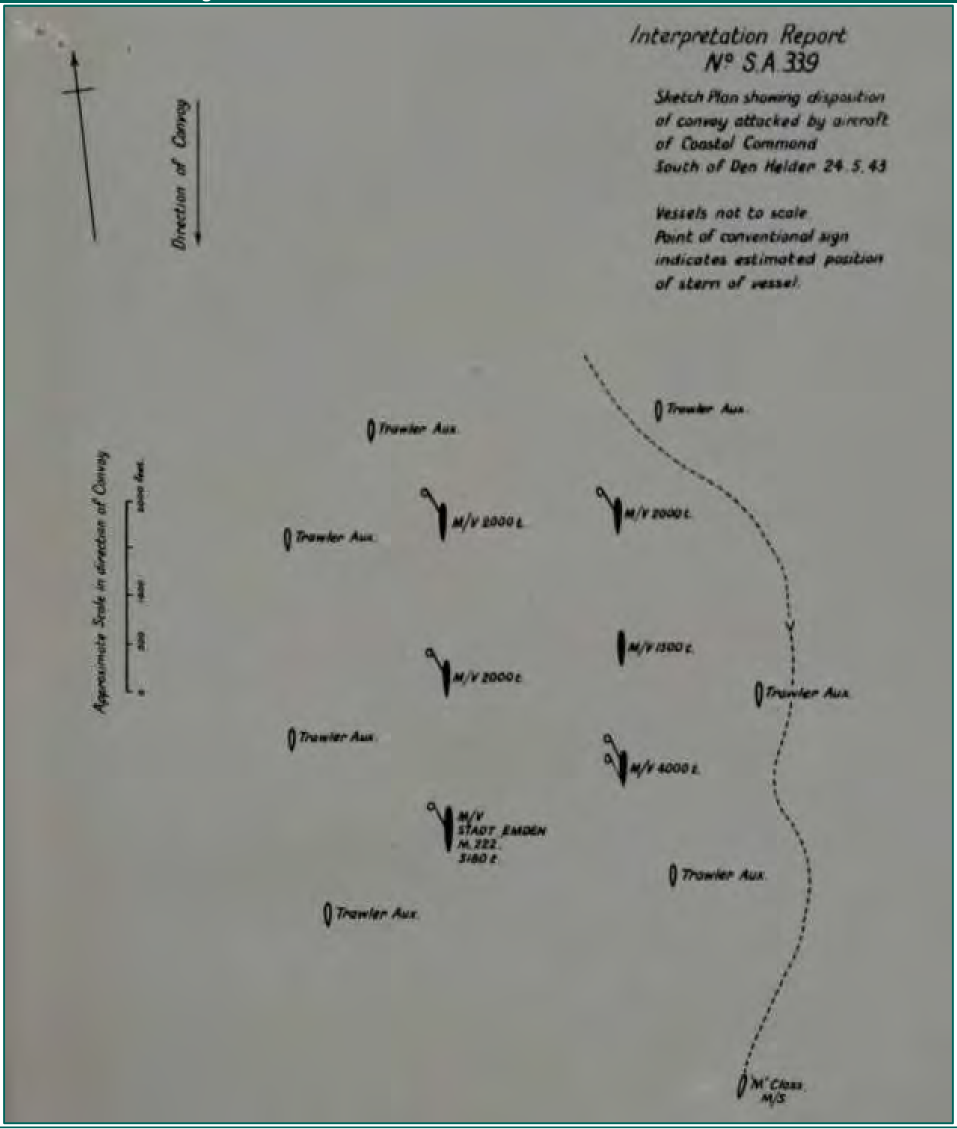
- Record Group 18: Mission Reports.
  World War II combat operations records ("Mission Reports"). These documents contain information on USAAF missions including bombing altitude, aircraft velocity and the deployed munitions.
- Record Group 243: Strategic Bombing Survey.
  Records of the European Survey 1934-1947. Details flight information and statistics for the Strategic Bombing Survey, a survey conducted to evaluate the effectiveness of the RAF and USAAF bombing campaign.
- Record Group 341: Military Intelligence Photographic Interpretation.
  Military intelligence interpretation reports of the Reconnaissance Branch, 1942-56. Interpretation reports of aerial photos taken during or short after air strikes. The analyses yield information on results of British and American air strikes.
- Record Group 373: Records of the Defense Intelligence Agency.
  Aerial Photographs. The aerial photo archive contains thousands of reconnaissance photos taken by US aircraft or captured from the Third Reich after the war.

Of these record groups RG 341 yielded relevant results.

Record Group 341: Military Intelligence Photographic Interpretation *Aerial attacks during which bombs struck the water are shown*
Entry 217, box 30 Report of an attack on a German convoy, sailing southbound southwest of Den Helder. The attack was carried out with 250 lbs G.P. bombs, cannons and torpedoes.

Record Group 341: Military Intelligence Photographic Interpretation

Aerial attacks during which bombs struck the water are shown



ANNEX 8 EOD: UXO-ENCOUNTERS AND –DISPOSAL

The area of investigation is situated 12 Nautical Miles west of the Dutch coast. REASeuro utilises different sources that give an indication about encountered and cleared UXO in the North Sea:

- Dutch Coastguard Archive Records.
- OSPAR Commission.

Dutch Coastguard Archive Records

Since the Second World War, the Dutch fishing fleet have at times experienced weekly encounters with UXO within their fishing nets. To compensate fisherman for the loss of income due to UXO, a deficiency payments regulation was introduced. These payments caused some fisherman to deliberately fish for UXO when fishing was poor. As a consequence, large amounts of UXO were reported each year. These UXO were subsequently rendered safe by the Dutch Naval EOD (Explosive Ordnance Disposal). This situation eventually led to the abolishment of the compensation. In the period that followed, no UXO incidents were reported. However, this does not mean that UXO were not encountered. Fisherman encountering UXO simply dumped the items back overboard. This often led to some extremely dangerous situations and to an uncontrolled migration of UXO.

On April the 6th 2005 three crewmembers of the vessel OD-1 'Maarten Jacob' (a trawler) were killed when an air dropped bomb detonated on the deck of the vessel. This event led to an increase of the threat awareness amongst fisherman and also led to a change in government policy regarding the handling of UXO encountered by fisherman. The Dutch Coastguard implemented the current "Bijstands- en bijdrageregeling". The aim of this regulation was to reduce the risks attached with encountering of UXO as much as possible. The regulation provides guidelines for fisherman and professional support from the Coastguard and EOD. To prevent fisherman from dumping the UXO a financial compensation scheme was implemented.
After the tragic event with the OD-1 a detailed registration is kept regarding encountered UXO in the North Sea. Up to November 2016, in total 1,656 UXO were reported to the coast guard, Royal Netherlands Navy and other authorities. The Royal Netherlands Navy Mine Counter Measures Service destroyed 1,237 of the reported UXO, 412 could not be found.[47]

Within a distance of 2,7 NM (5 km) surrounding the cable routes several items of UXO have been reported since April 2005. The coordinates of the reported UXO which are presented in Table 25 and are rendered in Figure 344. The UXO encountered were destroyed and are no longer present.

ETRS89		UXO Type	ETRS89		UXO Type
Lat.	Long.		Lat.	Long.	
52,61817	3,74725	Unknown	52,58709	3,62207	Aerial bomb
52,62517	3,75203	Unknown	52,53078	3,5698	Unknown
52,62367	3,76192	Aerial bomb	52,52504	3,63807	Aerial bomb
52,66693	3,73903	Depth charge	52,53078	3,5698	Unknown
52,72492	3,65808	Moored mine	52,51182	3,51997	Unknown
52,62403	3,67788	Aerial bomb	52,5027	3,66667	Aerial bomb
52,6172	3,6459	Aerial bomb	52,503	3,79117	Depth charge
52,63065	3,5114	Aerial bomb	52,47217	3,52717	Aerial bomb
52,58709	3,62207	Aerial bomb	52,45	3,56667	Artillery shell
52,53078	3,5698	Unknown	52,43597	3,54952	Aerial bomb
52,52504	3,63807	Aerial bomb			

Table 25: Reported UXO types within 2.7 NM (= 5 km) of the cable routes.

[47] Source: http://www.kustwacht.nl/nl/explosieven.html, overview dated November 28, 2016

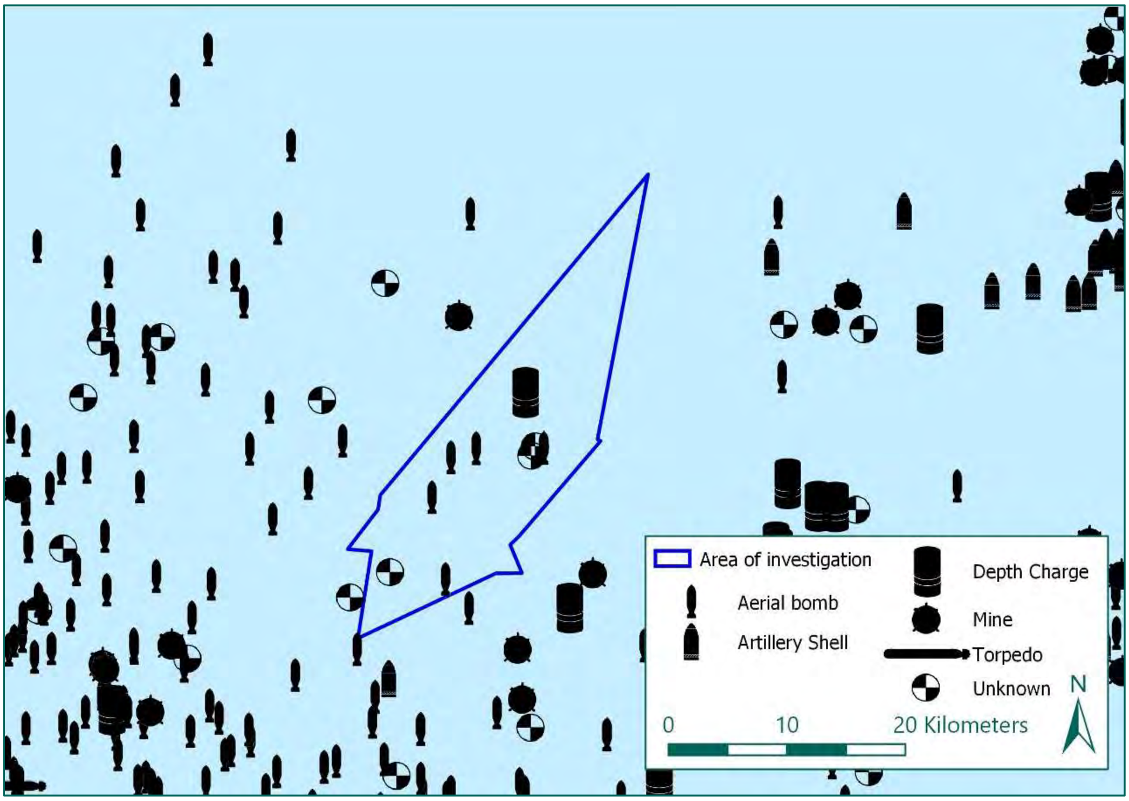


Figure 34: Locations of encountered UXO.

OSPAR Commission

OSPAR is the mechanism by which 15 governments and the European Union cooperate to protect the marine environment of the North-East Atlantic. Since 1972 the OSPAR Convention has worked to identify threats to the marine environment and has organised, across its maritime area, programmes and measures to ensure effective national action to combat them. One of the Policy Issues of the OSPAR Convention is to report encounters with conventional and chemical munitions in the OSPAR maritime area. These encounters are kept in a database[48]. The munition encounters from 1999 till 2014 surrounding the cable routes are rendered in Figure 35. Table 26 contains the encounters within 5 km of the cable routes. Some of these encounters have overlap with the Dutch Coastguard Archive Records, see above. Despite this overlap, the OSPAR encounters indicate one extra conventional and an unknown encounter within the wind farm zone.

ETRS89		UXO Type	ETRS89		UXO Type
Lat.	Long.		Lat.	Long.	
52,45	3,566667	None, boulder with metal wire	52,5871	3,6221	Unknown conventional
52,472167	3,527167	Torpedo	52,6028	3,5195	Unknown conventional
52,5118	3,52	Unknown conventional	52,6172	3,6459	Unknown conventional
52,5027	3,6667	Unknown conventional	52,6182	3,7473	Unknown conventional
52,503	3,7912	Unknown conventional	52,6237	3,7619	Unknown conventional
52,525	3,6381	Unknown conventional	52,624	3,6779	Unknown conventional
52,5308	3,5698	Unknown conventional	52,6669	3,739	US 250 LBS nr29
52,5118	3,52	Unknown conventional	52,7249	3,6581	Unknown conventional
52,5482	3,5308	Unknown conventional			

Table 26: Reported UXO by OSPAR between 1999 and 2014 within 2.7 NM (= 5 km) of the cable routes.

[48] This database can be consulted at http://odims.ospar.org/layers/?limit=100&offset=0.

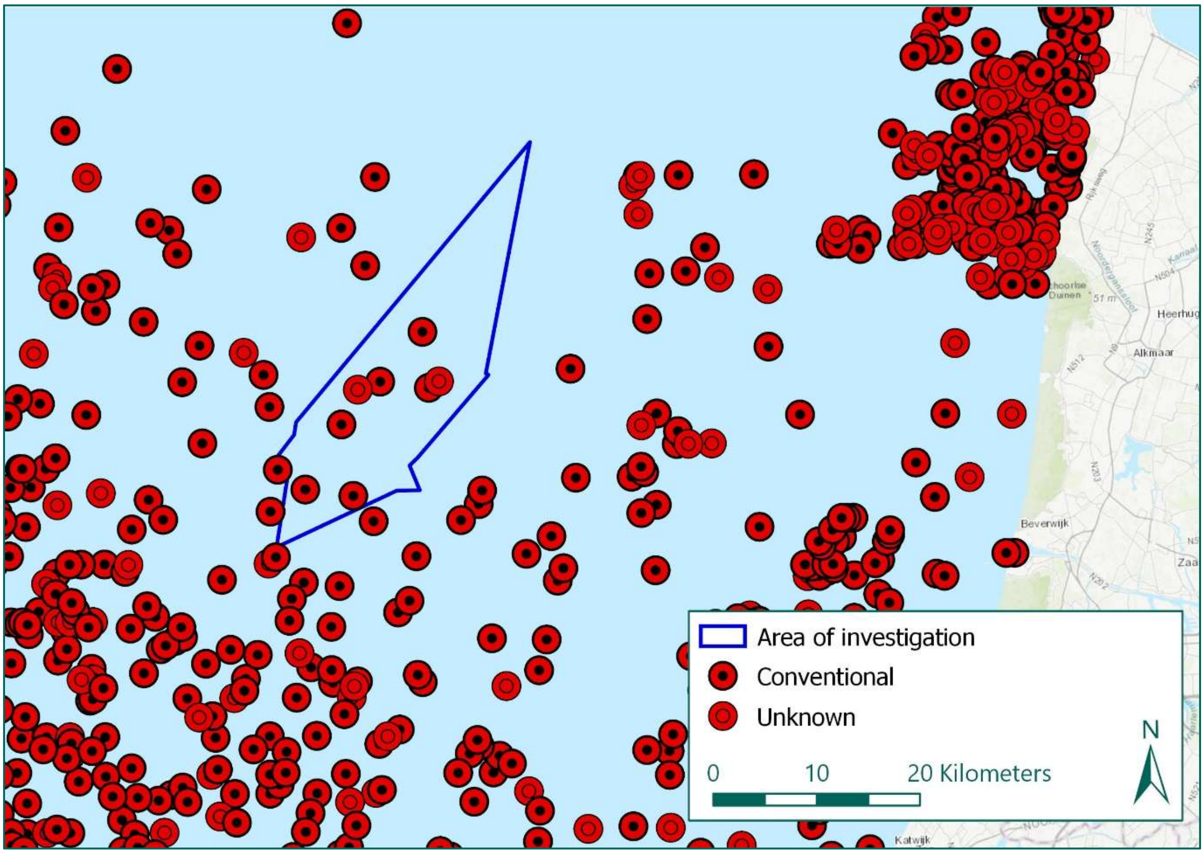


Figure 35: Locations of encountered munitions.

ANNEX 9 PREVIOUS RESEARCH

It is known to REASeuro that previous UXO-related research has been conducted in the recent past. The relevance of this earlier research for the current area of investigation is described in this Annex.

Nr.	Author	Date / document code	Title
1.	Saricon	27th January, 2016 / 15S175-VO-03	Vooronderzoek Conventionele Explosieven Potentiële Zandwindlocaties Noordzee / Preliminary UXO Research Potential Sand Source Locations North Sea
2.	REASeuro	12th February, 2016 / HKZ_20160212_REASeuro_ UXOdesk-study_EvBerg_V2_F	Site data Hollandse Kust (zuid) wind farm zone. Unexploded Ordnance (UXO) – Desk Study
3	REASeuro	20170705_SDHKNWFZ_REASeuro_UXO Desk Study_EvdBerg_V2_F	Site Data Hollandse Kust (noord) Wind Farm Zone
4	REASeuro	9th February, 2018 / RO-170286 20180102_Desk Study_V2_D	UXO Desk Study Unexploded Ordnance Hollandse Kust (noord) Export cables routes
5	REASeuro	RO-180062 Desk Study HKW versie 1.0	Hollandse Kust (west) Export cables routes

Table 27: Previous research.

1. Saricon, 27th January, 2016

In 2016 Saricon Safety & Risk Consultancy conducted a historical UXO research for potential sand source locations in the North Sea, in front of the Dutch coast. The locations lie approximately 10 kilometres (= 4,5 NM) out of the coast, in front of Den Helder, Callantsoog and the isle of Texel, just north of the HKNWFZ, see Figure 36.

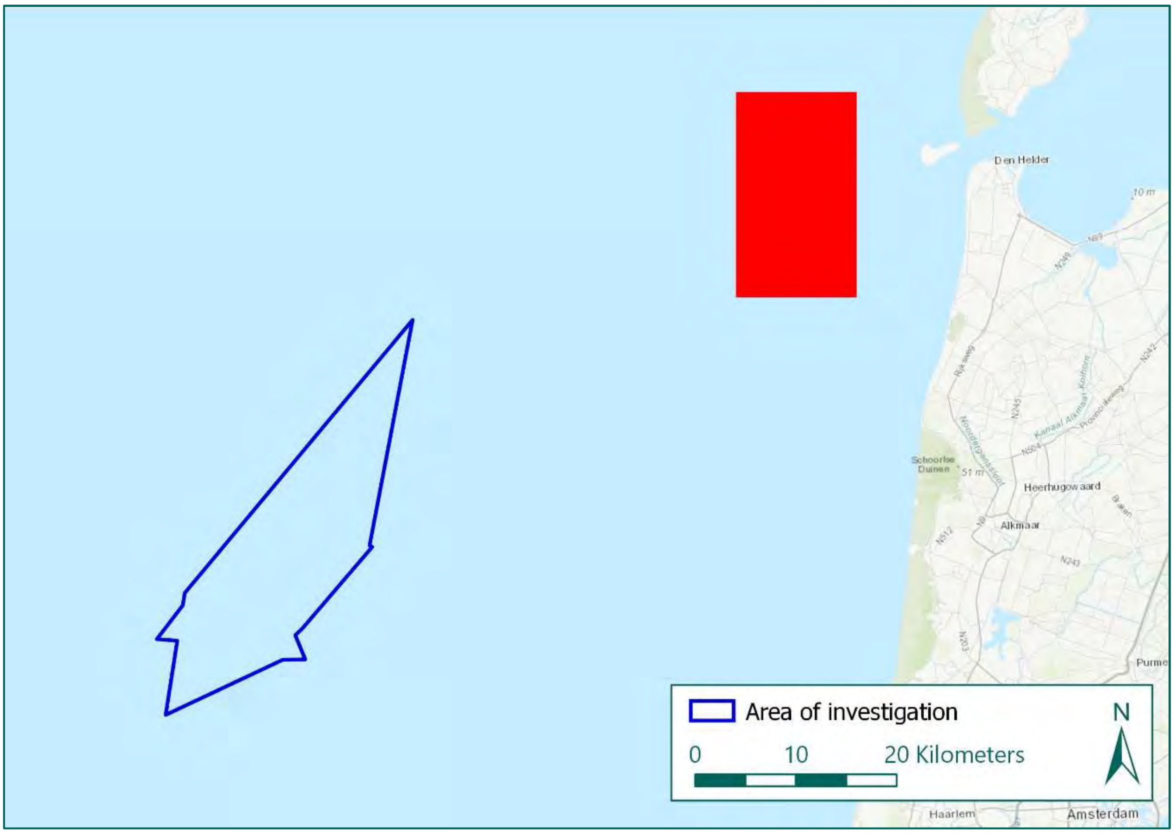


Figure 36: Area of investigation and sand source locations (red square).

Based upon historical sources, Saricon reports the presence of the following UXO in the sand source location:

- Presence of fired artillery shells, due to coastal guns;
- Presence of British and German naval mines, due to laying and clearance of minefields;
- Presence of aerial bombs, due to jettisons at sea;
- Presence of rockets, aerial bombs, depth charges and torpedoes, due to allied aerial attacks on German ships and convoys.

2. REASeuro, 12th February 2016

In 2016 REASeuro completed a desk study for the Hollandse Kust (zuid) Wind Farm Zone. This wind farm zone lies over 18 km (= 10 NM) south of the cable routes, see Figure 37.

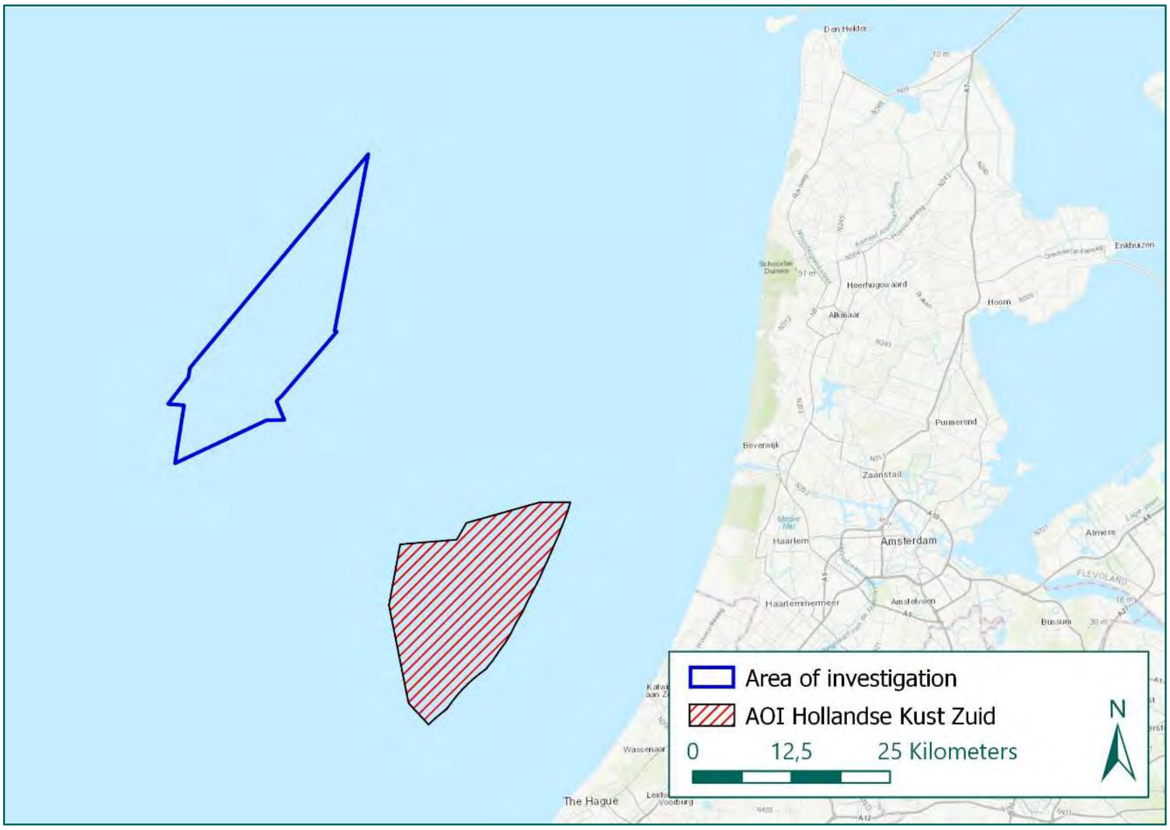


Figure 37: Hollandse Kust (zuid) Wind Farm Zone AOI.

The desk study for Hollandse Kust (zuid) Wind Farm Zone consults different historical sources to recover possible relevant war related events. The following events are discussed in the report:

- Naval mines (German and British).
- Naval warfare.
- Aerial attacks and jettisons.
- Airplane crashes and ship wrecks.
- Ammunition dump.
- Post-war UXO clearance.

Due to the mentioned war related events, it is expected that UXO could have remained within the complete wind farm zone. It concerns naval mines (and destruction charges), aerial bombs, depth charges, torpedoes, and artillery shells.

3. REASeuro, 5th July 2017

In 2017 REASeuro conducted research for the Hollandse Kust (noord) Wind Farm Zone (HKNWFZ).

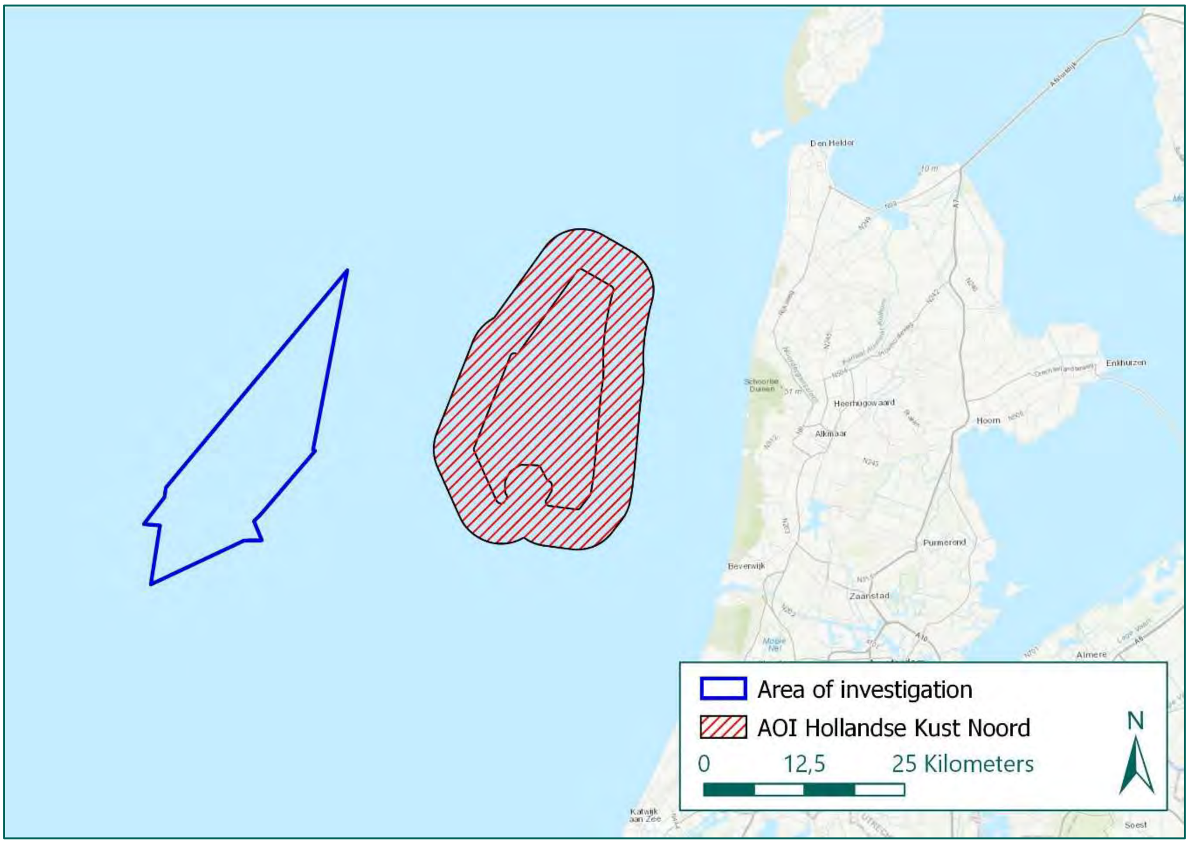


Figure 38: Area of investigation of HKNWFZ.

Based on consulted historical sources, the following UXO may be present in the HKNWFZ:

UXO type	Likelihood of presence	Remarks
Allied HE Bombs	Certain	The area of investigation is located near flight paths of allied bombers. If a plane was badly damaged or under attack, it was common for the crew to jettison their bombs in order to assist their evasion attempts or before landing at their home bases. Allied planes carried out various attacks on ships, convoys and submarines. Air-dropped high explosive (HE) bombs could be present anywhere within the area of investigation. Bombs have been found since 2005 within the vicinity of HKNWFZ.
Naval mines	Probable	The site overlaps with several WWI and WWII minefields. It concerns allied and German mine fields. Despite post-war mine clearance operations, ships still encountered mines and sunk in the post war period. Since 2005 several mines have been encountered in the vicinity of the site.
Artillery shells	Certain	After World War II, some areas in the North Sea were designated for military use by the Dutch Army. A large anti-aircraft shooting area has overlap with HKNWFZ. Since 2005 various shells were encountered within the shooting areas.
	Remote	Prior to WWI coastal guns were already present at the Dutch coast. It concerns Dutch and German coastal guns and anti-aircraft guns. Coastal guns rarely fired in this part of the North Sea. The anti-aircraft artillery however was frequently used.

UXO type	Likelihood of presence	Remarks
		Because of the range of the anti-aircraft artillery, it is less likely that unexploded shells ended up in the area of investigation.
Torpedoes	Remote	There is some evidence for aerial and naval attacks with torpedoes, but no specific information was found for HKNWFZ.
Depth charges	Feasible	Naval and aerial attacks on submarines were carried out with depth charges. No specific information was found for HKNWFZ, but since 2005 some depth charges were encountered in and near the wind farm zone.

Table 28: Summary of types and calibres of UXO likely to be present in the HKNWFZ AOI.

4. REASeuro, 9th February, 2018

In February 2018, REASeuro conducted a UXO desk study for the Hollandse Kust Noord Export Cable route options.

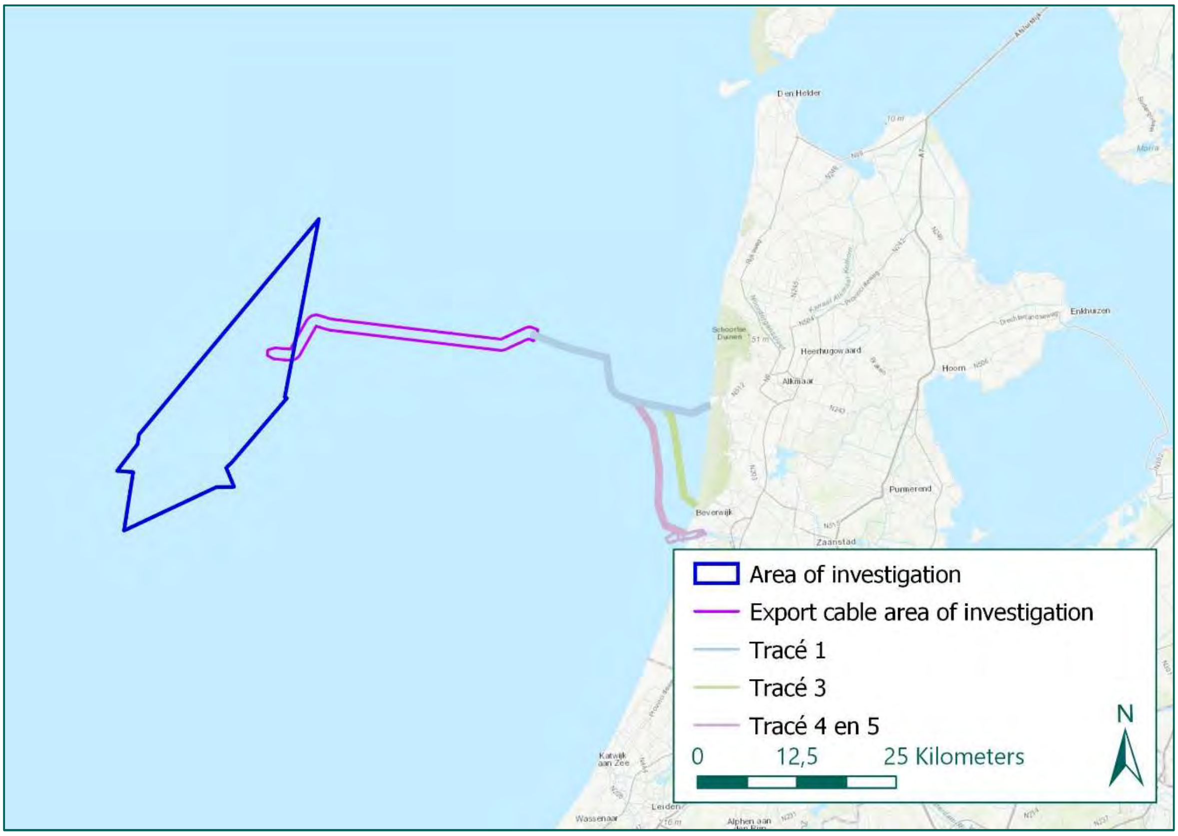


Figure 39: Areas of investigation HKNWFZ export cables.

The following UXO may be encountered in the different cable route options:

Cable route option 1				
Type of UXO	Calibres	Likelihood of presence	Confidence level	Remarks
Aerial bombs	All possible calibres, including but not limited to 4, 25, 30, 40, 100, 250, 500, 1,000 lbs	Certain	High	Information on attacks on shipping and jettisons in the vicinity available. Encountered UXO from aerial bombs reinforce this conclusion.
Rockets	3 inch air-to-ground with 60 lbs SAP warhead	Feasible	High	Evidence of attacks on shipping

Cable route option 1				
Type of UXO	Calibres	Likelihood of presence	Confidence level	Remarks
Naval mines (coastal)	KMA	Probable	Very high	Cable route directly crosses a KMA minefield.
Naval mines (contact)	EMC E-Mine	Probable	High	Cable route does not directly cross minefields with contact mines, but UXO encounters indicate an increased chance of migrated contact mines from the minefields in the vicinity.
Naval mines (ground)	A Mark I-IV A Mark VI Mark XVII	Certain	Very high	Cable route directly crosses minefield laid by aircraft and surface vessels.
Naval mines (LMB)	LMA LMB	Remote	Very high	No LMB minefields nor any encounters of LMB mines near the cable route option.
Artillery shells (Flak)	Possible calibres include 2 cm, 3.7 cm, 5 cm, 7.5 cm, 8.8 cm, 10.5 cm (German)	Probable	High	The large amount of flak and how often the guns fired render the presence of the UXO from AAA probable.
Artillery shells (coastal artillery)	Possible calibres include 7.5 cm and 28 cm (Dutch), and 10.5 cm, 12 cm, 15 cm and 17 cm (German)	Remote	High	While an important part of coastal defence, these guns rarely fired.
Artillery shells (post-war target practice)	20 mm, 40 mm	Probable	High	Decades of target practice may have led to the presence of UXO of these calibres.
Aircraft cannon shells	20 mm (different types including incendiary, HE, AP)	Feasible	High	Evidence of attacks on shipping in the direct vicinity of the cable route.
Torpedoes	Unknown	Remote	Moderate	Evidence of aerial attacks with torpedoes on shipping in the wider vicinity.
Depth charges	Unknown	Feasible	Moderate	Evidence of aerial attacks with depth charges on shipping in the wider vicinity. UXO from depth charges encountered near the cable routes.

Table 29: Summary of types and calibres of UXO likely to be present within cable route option 1.

Cable route option 3				
Type of UXO	Calibres	Likelihood of presence	Confidence level	Remarks
Aerial bombs	All possible calibres, including but not limited to 4, 25, 30, 40, 100, 250, 500, 1,000 lbs	Certain	High	Information on attacks on shipping and jettisons in the vicinity available. Encountered UXO from aerial bombs reinforce this conclusion.
Rockets	3 inch air-to-ground with 60 lbs SAP warhead	Feasible	High	Evidence of attacks on shipping
Naval mines (coastal)	KMA	Probable	Very high	Cable route directly crosses a KMA minefield.
Naval mines (contact)	EMC E-Mine	Probable	High	Cable route does not directly cross minefields with contact mines, but UXO encounters indicate an increased

Cable route option 3				
Type of UXO	Calibres	Likelihood of presence	Confidence level	Remarks
				chance of migrated contact mines from the minefields in the vicinity.
Naval mines (ground)	A Mark I-IV A Mark VI Mark XVII	Certain	Very high	Cable route directly crosses minefield laid by aircraft and surface vessels.
Naval mines (LMB)	LMA LMB	Remote	Very high	No LMB minefields nor any encounters of LMB mines near the cable route option.
Artillery shells (Flak)	Possible calibres include 2 cm, 3.7 cm, 5 cm, 7.5 cm, 8.8 cm, 10.5 cm (German)	Probable	High	The large amount of flak and how often the guns fired render the presence of the UXO from AAA probable.
Artillery shells (coastal artillery)	Possible calibres include 7.5 cm and 28 cm (Dutch), and 10.5 cm, 12 cm, 15 cm and 17 cm (German)	Remote	High	While an important part of coastal defence, these guns rarely fired.
Artillery shells (post-war target practice)	20 mm, 40 mm	Probable	High	Decades of target practice may have led to the presence of UXO of these calibres.
Aircraft cannon shells	20 mm (different types including incendiary, HE, AP)	Feasible	High	Evidence of attacks on shipping in the direct vicinity of the cable route.
Torpedoes	Unknown	Remote	Moderate	Evidence of aerial attacks with torpedoes on shipping in the wider vicinity.
Depth charges	Unknown	Feasible	Moderate	Evidence of aerial attacks with depth charges on shipping in the wider vicinity. UXO from depth charges encountered near the cable routes.

Table 30: Summary of types and calibres of UXO likely to be present within cable route option 3.

Cable route option 4/5				
Type of UXO	Calibres	Likelihood of presence	Confidence level	Remarks
Aerial bombs	All possible calibres, including but not limited to 4, 25, 30, 40, 100, 250, 500, 1,000 lbs, 4,250 lbs, 4,500 lbs, 12,000 lbs	Certain	Very high	Direct information on bombing runs on IJmuiden harbour and attacks on ships near it increase the likelihood of presence. Besides these specific attacks, the chance of remanence of UXO from jettisons is present.
Rockets	3 inch air-to-ground with 60 lbs Semi-Armour-Piercing (SAP) warhead	Feasible	High	Evidence of attacks on shipping in the direct vicinity of the cable route.
Naval mines (coastal)	KMA	Negligible	Very high	This cable route option does not cross a KMA minefield. KMA mines only show limited mobility, rendering the chance of migration very low.
Naval mines (contact)	EMC E-Mine	Probable	High	Cable route does not directly cross minefields with contact mines, but UXO encounters indicate an increased chance of

Type of UXO	Calibres	Likelihood of presence	Confidence level	Remarks
				migrated contact mines from the minefields in the vicinity.
Naval mines (ground / allied)	A Mark I-IV A Mark VI Mark XVII	Certain	Very high	Cable route directly crosses minefield laid by aircraft and surface vessels.
Naval mines (ground / German)	LMA LMB	Probable	Very high	Several LMA and LMB mines were dropped directly on this cable route option, in the vicinity of the harbour entrance, increasing the chance significantly.
Artillery shells (Flak)	Possible calibres include 2 cm, 3.7 cm, 5 cm, 7.5 cm, 8.8 cm, 10.5 cm (German)	Certain	High	The largest amount of flak was positioned at IJmuiden. The guns fired very often, rendering the likelihood of presence of UXO from AAA certain.
Artillery shells (coastal artillery)	Possible calibres include 7.5 cm and 28 cm (Dutch), and 10.5 cm, 12 cm, 15 cm and 17 cm (German)	Remote	High	While an important part of coastal defence, these guns rarely fired.
Artillery shells (post-war target practice)	20 mm, 40 mm	Probable	High	Decades of target practice may have led to the presence of UXO of these calibres.
Aircraft cannon shells	20 mm (different types including incendiary, HE, AP)	Feasible	High	Evidence of attacks on shipping in the direct vicinity of the cable route.
Torpedoes	Unknown	Remote	Moderate	Evidence of aerial attacks with torpedoes on shipping in the wider vicinity.
Depth charges	Unknown	Feasible	Moderate	Evidence of aerial attacks with depth charges on shipping in the wider vicinity. UXO from depth charges encountered near the cable routes.

Table 31: Summary of types and calibres of UXO likely to be present within cable route option 4/5.

5. REASeuro, 18th April 2018

In April 2018, REASeuro conducted a UXO desk study for the Hollandse Kust West Export Cable routes. The study was commissioned by TenneT.

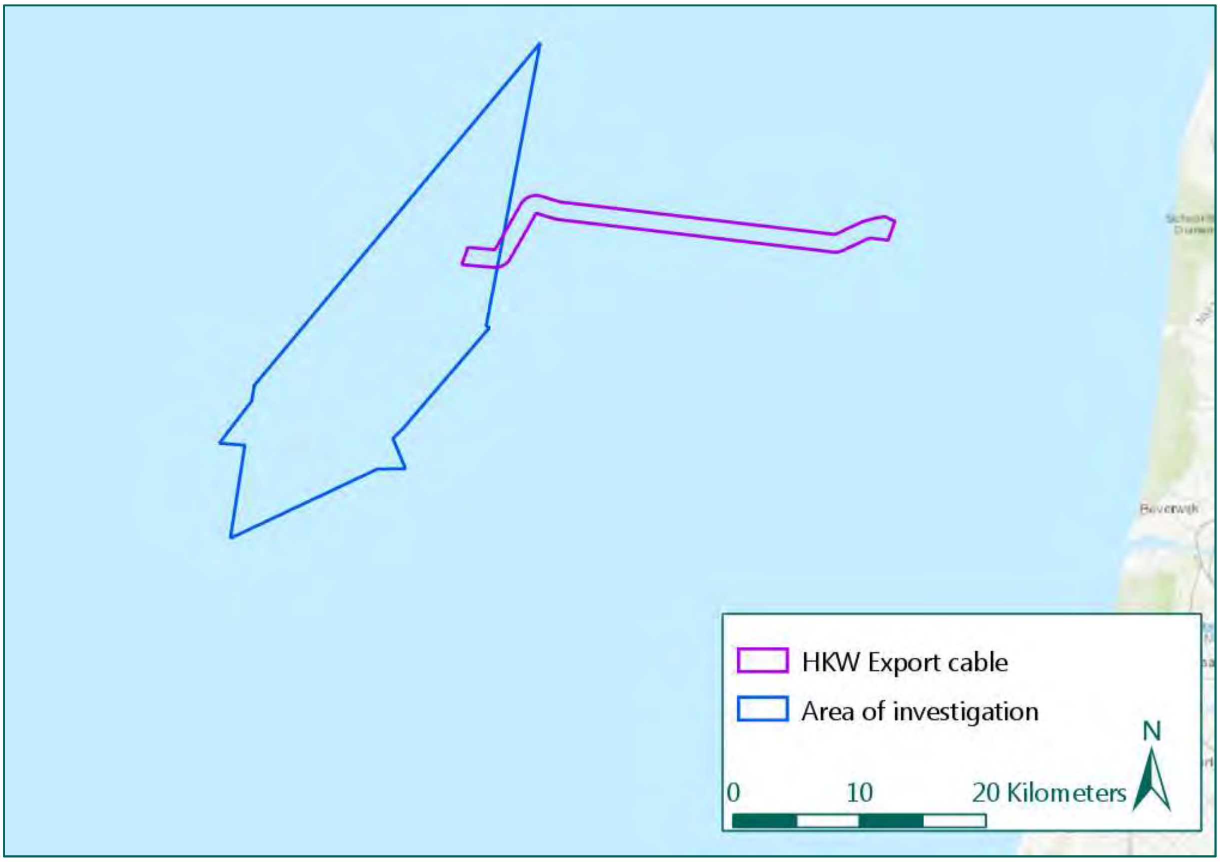


Figure 40: HKW Export cable.

The following UXO may be encountered in the export cable route:

Type of UXO	Calibres	Likelihood of presence	Confidence level	Remarks
Aerial bombs	All possible calibres, including but not limited to 4, 25, 30, 40, 100, 250, 500, 1,000 lbs	Certain	High	Information on attacks on shipping and jettisons in the vicinity available. Encountered UXO from aerial bombs reinforce this conclusion.
Rockets	3 inch air-to-ground with 60 lbs SAP warhead	Feasible	High	Evidence of attacks on shipping
Naval mines (contact)	EMC E-Mine	Probable	High	The export cable routes lie in the vicinity of a large WWI minefield and two WWII minefields. UXO encounters indicate an increased chance of migrated contact mines from the minefields in the vicinity.
Naval mines (ground)	Mark XIV Mark XVII	Probable	Very high	Cable route directly crosses minefield laid by aircraft and surface vessels.
Naval mines (non-ferrous)	LMA LMB	Negligible	Very high	No LMB minefields near the area of investigation. One (assumed) LMB encounter by fisherman.
Artillery shells (Flak)	Possible calibres include 2 cm, 3.7 cm, 5 cm, 7.5 cm, 8.8 cm, 10.5 cm (German)	Remote	Very high	The area of investigation lies outside the range of coastal Flak positions. Only shells from Flak ships could be left behind. This renders the presence of UXO from AAA remote.

Type of UXO	Calibres	Likelihood of presence	Confidence level	Remarks
Artillery shells (coastal artillery)	28 cm (Dutch)	Remote	High	While an important part of coastal defence, these guns rarely fired. Only the range of the 28 cm gun overlaps with part of the investigation area.
Artillery shells (post-war target practice)	20 mm, 40 mm	Negligible	Very high	The area of investigation lies outside of the range of the used calibres.
Aircraft cannon shells	20 mm (different types including incendiary, HE, AP)	Feasible	High	Evidence of attacks on shipping in the direct vicinity of the cable route.
Torpedoes	Unknown	Remote	Moderate	Evidence of aerial attacks with torpedoes on shipping in the wider vicinity.
Depth charges	Unknown	Remote	Moderate	Evidence of aerial attacks with depth charges on shipping in the wider vicinity. UXO from depth charges encountered near the investigation area.

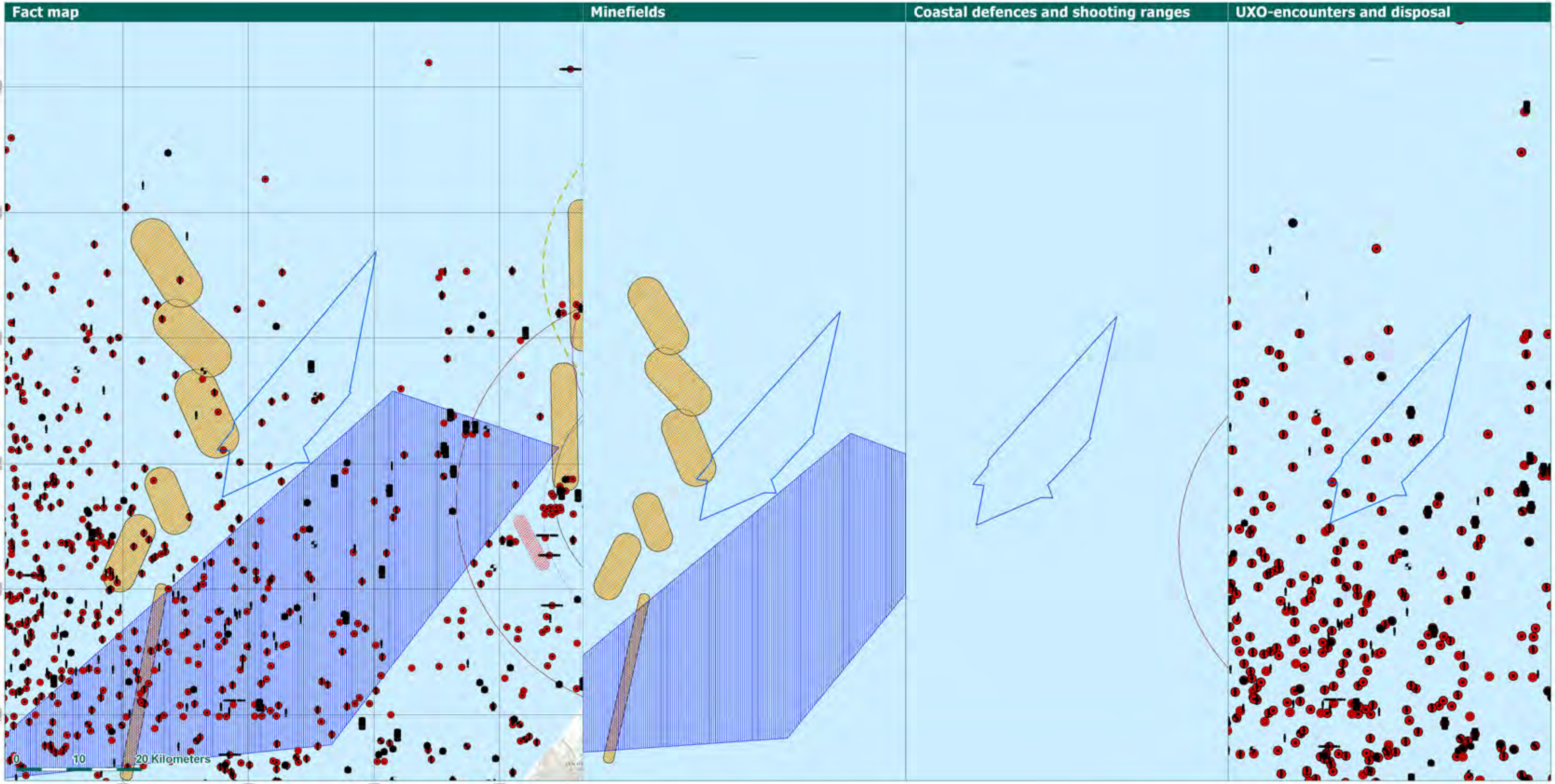
Table 32: Summary of types and calibres of UXO likely to be present within the export cable route.

ANNEX 10 FACT MAP

REASeuro

Site Data Hollandse Kust (west) Wind Farm Zone

Fact map



Area of investigation

Coastal defences and shooting ranges

- 12 cm coastal gun
- 15 cm coastal gun
- 17 cm coastal gun
- 28 cm coastal gun
- Post-WWII shooting range

Minefields

- Minefield (E-Mine)
- Minefield (EMC)
- LMB

Coast guard encounters

Cleared UXO

- Aerial bomb
- Artillery Shell
- Depth Charge
- Mine
- Torpedo
- Unknown

OSPAR encounters

- Conventional
- Unknown

Site Data Hollandse Kust (west) Wind Farm Zone

Fact map

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Drawing by:	M. van Lelieveld	28-02-2018	Drawing no:
Checked by:	L. Arlar	28-02-2018	73065-RVO-01-01
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The information in this document is valid at the time of publishing (see month/year). Updates will be published on the website https://offshorewind.rvo.nl/ at the relevant sitemap (Hollandse Kust (zuid)/Hollandse Kust (noord)/Hollandse Kust (west)), General Information, submap Revision Log and Q & A. In the Revision Log is indicated which versions are the latest and what the changes are in relation to previous versions. The documents can be found at the relevant sites, indicated in the Revision Log.

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