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Unexploded Ordnance Desk Based Study with Risk Assessment

Project: **Hywind Offshore Wind Farm**

Client: **Xodus Group**

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Project Developer	Statoil

Ordtek Limited, OrbisEnergy, Wilde Street, Lowestoft, Suffolk, England, NR32 1XH
+44 (0)1502 509345 enquiries@ordtek.com www.ordtek.com

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Executive Summary

Background

Hywind Scotland (HWS) will be a pilot floating offshore wind project deploying up to 5 turbines that will be on a floating foundation anchored to the seabed. There may also be a requirement for a small amount of seabed infrastructure additional to the anchors. A single export cable from the project which will come ashore in Peterhead, Aberdeenshire. Statoil is the developer. The site is located in the area known as *"Buchan Deep"*, with a depth of water between approximately 93m – 120m. The HWS main site AOI is split by the Forties to Cruden Bay oil pipeline.

Unexploded ordnance (UXO) residue from World War One (WWI), World War Two (WWII) and post-war dumping of explosive ordnance (EO) presents a potential risk to the development. Nevertheless, the UXO hazard can be managed safely and at best value to the project through a comprehensive understanding of the risks involved, the natural environment and the project development phases.

Xodus Group has provided Ordtek with an Area of Interest (AOI) for this desk-based study that encompasses the proposed turbine platform and an area of sea around it, totalling 45.29km^2, together with the export cable route and a buffer of ± 250m either side, totalling 11.85km^2.

In this study we consider both wider regional and, where the information is available, site specific historical factors to determine a baseline UXO hazard level within the HWS AOI. We match this baseline to the likely development operations to be carried out in the AOI and assess the potential risk to the project from UXO.

We identify the dump sites, official and unofficial, the EO legacy of two World Wars and the modern military exercises that could potentially contaminate the HWS AOI with UXO, both now and during the full life cycle of the project. We also examine the likelihood of EO migrating from outside the area into the site.

UXO Hazards

There were substantial mine laying operations – both German and British, buoyant and ground mines – during both World Wars with minefield clearance of only limited effectiveness after each period of conflict. There is a strong possibility, therefore, that mines could be found within the Site. The accumulation of evidence points to mines presenting statistically the biggest risk to project activity but it is also possible that other types of EO may also be encountered.

Rationalising this data, the study identifies what we consider to be the ordnance types that present the main UXO hazard to the Project. We outline both the factors that determine the likelihood of encountering these UXO items and the causes and Project activities that could lead to an inadvertent detonation, with consequential damage to equipment or injury to personnel. The UXO items, in order of likelihood of encounter, are:

- German and British Buoyant Mines
- Torpedoes/Depth charges
- Naval Projectiles (Shells) / Rockets
- Aircraft Bombs/Depth Bombs/Rockets

Ordtek considers the UXO threat items most likely to be encountered in the HWS AOI are German WWI and British WWII moored mines that have sunk to the seabed. Possible charge weights vary from 50kg-350kg but are most likely to be between 90kg-227kg. The typical diameter of the buoyant mines likely to be present in the AOI is 0.84 to 1.01m.

Smallest UXO Item for ALARP Sign-Off

Accordingly the smallest hazard item that needs to be mitigated for an ALARP sign-off is the German WWI Type II contact sea mine. This consists of a 0.80m "egg-shaped" casing manufactured from steel, with a total weight of 322kg (excluding any floating devices or sinkers). The mine contained a 131kg charge of wet gun cotton. Assuming that this item can be successfully detected and identified within the survey datasets, larger objects will also be detectable.

While the possibility of finding smaller items of UXO in the area of interest cannot be discounted, the risk posed by them is very small. The evidence is that the probability of encountering small arms ammunition, HE naval shells and small bombs is low. It is also highly unlikely that any disturbance, other than direct and substantial impact would lead to detonation; even then the probability is that an explosion would not occur. The same argument can be made for larger air dropped munitions, with a similarly low probability of encounter and subsequent detonation.

Risk Mitigation and Geophysical Survey

Although strategically, 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 concludes that *the risk from UXO to the proposed development ranges from Low to Moderate* and that mitigation is required to reduce the risk to ALARP.

Ordtek have studied the geophysical data acquired by MMT in 2013 and considers it to be of sufficient quality to mitigate the UXO risk ahead of the specified geotechnical activities. The MBES and SSS data is high quality and will allow recognition of potential hazard items on the seabed. Even though the magnetometer data was acquired at low resolution (due to height and coverage), it is adequate for mitigation at this stage. In light of this review, the developer and its contractors should adopt the following cascading procedure to mitigate the risk:

- Stage 1 - Grade the geophysical anomalies and identify those that are Potentially UXO.
- Stage 2 - Assign a suitable safety distance around the "Potential" UXO anomalies. Any anomalies that model as UXO, should be avoided by a sufficiently safe distance.
- Stage 3 - All exploratory positions should be relocated on geophysical survey lines and grab samples should be taken where there is full data coverage.
- Stage 4 - For due diligence purposes, an ALARP certificate should be issued to the geotechnical contractor to evidence the risk management process and highlight any operational constraints.

A similar process will also be required ahead of the engineering phase but there will be the additional requirement for a higher resolution magnetometer survey ahead of the export cable installation.

UXO Migration

Given the degree and potential for UXO contamination on this project, it is possible that further EO could migrate into the site once the wind farm is operational, although we consider the probability very low. Depending on the degree of maintenance work and the time lapsed from the original geophysical survey there may be the requirement for additional risk mitigation. However this will need to be evaluated on an individual basis. The developer should consult a UXO specialist to conduct a risk assessment and explore the options available for disposal. There are too many variables involved in such a scenario to make a rigid strategy at this stage.

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Abbreviations and Acronyms

ALARP	As Low As Reasonably Practicable
dGPS	Differential Global Positioning Systems
EO	Explosive Ordnance
EOD	Explosive Ordnance Disposal
ERW	Explosive Remnants of War
GIS	Geographical Information System
HE	High Explosive
HSE	Health and Safety Executive
JSEODOC	Joint Service Explosive Ordnance Disposal Operations Centre
KHz	Kilohertz
Kg	Kilogram
Kv	Kilovolt
Km	Kilometre
M	Metres
MCM	Mine Countermeasures
mm	Millimetres
NEQ	Net Explosive Quantity
NGR	National Grid Reference
Nm	Nautical Mile
PLGR	Pre Lay Grapnel Run
ROV	Remotely Operated Vehicle
RN	Royal Navy
QA/QC	Quality Assurance/Quality Control
SOP	Standard Operating Procedure
SSS	Side Scan Sonar
SQRA	Semi Quantitative Risk Assessment

TNT	Trinitrotoluene
UK	United Kingdom
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
WWI	World War One
WWII	World War Two

1 Introduction

1.1 Project Description and Background

Hywind Scotland (HWS) will be a pilot floating offshore wind project deploying up to 5 turbines that will be on a floating foundation anchored to the seabed. There may also be a requirement for a small amount of seabed infrastructure additional to the anchors. A single export cable from the project which will come ashore in Peterhead, Aberdeenshire. Statoil is the developer. The main array site is located in the area known as “Buchan Deep”, with a depth of water between approximately 93m – 120m. The HWS main site AOI is split by the Forties to Cruden Bay oil pipeline.

Unexploded ordnance (UXO) residue from World War One (WWI), World War Two (WWII) and post-war dumping of explosive ordnance (EO) presents a potential risk to the development. Nevertheless, the UXO hazard can be managed safely and at best value to the project through a comprehensive understanding of the risks involved, the natural environment and the project development phases.

Although we have no evidence of such an occurrence in the immediate area, the explosive remnants of war (ERW) occasionally lead to inadvertent detonations in European waters, causing damage to equipment and the death of personnel. Most recently, three Dutch fishermen lost their lives in 2005, when a WWII bomb exploded on board their fishing vessel after having been hauled aboard in fishing nets.

Such explosions are an increasingly rare event and the UXO hazard can be managed safely and at best value to the project through a comprehensive understanding of the risks involved, the natural environment and the project development phases.

For the purposes of this document, UXO is specified as the hazard and will be defined as "all ordnance and explosives contamination" including discarded or dumped, fired and/or unfired munitions.

Ordtek Limited (Ordtek) has been appointed as UXO consultants to Xodus Group for the HWS Offshore Wind Farm. Xodus Group has provided Ordtek with an Area of Interest (AOI) for this desk-based study that encompasses the proposed turbine platform and an area of sea around it, totalling 45.29km^2, together with the export cable route and a buffer of ± 250m either side, totalling 11.85km^2.

We have been commissioned to undertake a study to determine the potential presence, type and risk from UXO within the main development site and wider area of interest. In the study we consider both wider regional and, where the information is available, site specific historical factors to determine a baseline UXO hazard level within the AOI. We match this baseline to the likely development operations to be carried out and assess the potential risk to the project from UXO.

We identify the dump sites, official and unofficial, the EO legacy of two World Wars and the modern military exercises that could potentially contaminate the HWS AOI with UXO, both now and during the full life cycle of the project. We also examine the likelihood of EO migrating from outside the area into the site.

This study will focus on three key components:

- **UXO Desk Based Study with Risk Assessment -** A desktop study of the risk of encountering munitions, UXO, dumped chemical warfare agent and other dangerous objects and substances at or near the sites.
- **Methodologies for UXO Detection -** An assessment of which methods will be most suitable for locating the identified hazard items - as input to future geophysical survey planning.
- **UXO Risk Mitigation Strategy -** Recommendations for a general UXO strategy for the site. This must include:
    - A description of the regulation and legislation which applies to offshore work where risk from UXO or similar may be expected
    - A discussion whether the ALARP principle may be applied and whether any legal or regulatory requirements exist that need to be taken into account when deciding or whether the risk is reduced to ALARP
    - An assessment and description of the necessary procedures to follow if UXO is moved or cleared.

2 UXO Assessment Methodology

2.1 Research

In this desk based study we have considered both wider regional and, where the information is available, site specific historical factors for the purpose of determining a baseline UXO hazard level.

Our research has focussed on the following:

- Military history of the area
- Official and unofficial munitions dumping sites
- Military weapon ranges and training areas
- Potential migration of dumped munitions
- Wrecks of vessels or aircraft that may have a legacy of UXO contamination
- Defensive and offensive minefields laid by both the German and British military forces
- Evidence of aerial warfare, including bombing, depth charge and torpedo deployment
- Evidence of naval surface and subsurface warfare and engagements

Information and data from a wide variety of sources has been collated to inform the study and risk assessment. The principal sources have been:

- UK Hydrographic Office (UKHO)
- The National Archives, London
- Royal Navy Historical Archive, Portsmouth
- British Ministry of Defence, Air Historical Branch, RAF, Northolt
- Pertinent authoritative British and German publications
- Web based archives
- Internal database
- Federal Maritime and Hydrographic Agency (BSH) in Hamburg;
- Naval Office of the German Federal Armed Forces, Division Geo 1, Underwater Data Centre, Rostock

The extent of information presented within this study does not represent the full volume of Ordtek's research or all documentation obtained. The purpose of this document is to serve as a valid operational risk assessment, not as a detailed historical treatise. Our research has drawn on the most convenient and reliable sources, cognisant of the need to limit cost and delay to the client. Nevertheless, the data presented is complete and appropriate for risk assessment purposes and fully in line with current best practice.

Should the client require further details of any particular aspect or issue raised within the following paragraphs, it can potentially be provided as an addendum to this report on request.

2.2 UXO Hazard and Risk Assessment

Our research for this study has identified numerous UXO sources that have the potential to contribute to contamination in the area. We have reviewed the baseline data and made an assessment of what we consider to be the most likely UXO hazard items in the AOI, including the most likely types that could be encountered, the probability of encountering them as well as the risk and consequences of detonation.

Having identified areas likely to have been contaminated by UXO, the study assesses the likelihood of munitions being present in the OWF development site or migrating along the seabed into it, together with the likelihood of detonation if the UXO is disturbed during cable laying, anchor handling and other installation development work.

For completeness we have considered all activities past and present that could have contributed to UXO contamination. However, military archives and data sources, particularly older ones, are often very limited in both accuracy and detail. Determining specific and complete evidence of the amount of EO dumped, laid, fired or dropped, live or inert is very rarely possible. Accordingly, with the data available to us, it is impossible to quantify precisely the levels of EO that may be encountered across the proposed works area. Our risk assessment therefore is based on the data that is available, extrapolated to fill information gaps using similar situations from other sites, and built on ALARP principles using the expertise, judgement and high level of experience of our specialist analysts.

In addition to the three key components of the study outlined in paragraph 1.1 above, we also recommend the smallest hazard item that needs to be mitigated for an ALARP sign-off. It is worth noting at the outset that this is the German WWI Type II contact sea mine. This item consists of a 0.80m "egg-shaped" casing manufactured from steel, with a total weight of 322kg (excluding any floating devices or sinkers). It contained a 131kg charge of wet gun cotton. Assuming this mine can be detected successfully and identified within the survey datasets, larger objects will also be detectable.

It is important to confirm the smallest threat item, not only to ensure the UXO risk has been reduced to ALARP, but also for grading the geophysical targets. Setting the grading criteria too low is likely to result in a significant number of geophysical anomalies presented in the dataset.

3 UXO Focused Historical Research

3.1 Military History and UXO Hazard Findings – Overview

In the North Sea, UXO contamination is the result of various activities. In the environs of the HWS site, it is principally the legacy of WWI and WWII German buoyant minefields. However, German bombing, submarine operations, naval surface conflict, modern military training exercises and munitions dumping have all played a part in potentially contaminating the HWS site. This desk based study will consider all these possible sources of UXO contamination.

3.2 Potential Sources of UXO Contamination

This section of the study identifies the principal potential sources of UXO contamination in the AOI, and summarised in Table 3.1. It is possible that there may be others that were either never recorded or for which records have been lost.

Positional information drawn from historical documents, for activities such as mine-laying, should always be treated with caution. The navigational equipment in use at the time was rudimentary compared to systems available today and inherent errors were compounded in transmission and exacerbated by the fog and tension of war. This is particularly true for visual reports of enemy dropped ordnance.

Sunken moored mines are the items of UXO most likely to be found in the AOI and the accumulation of evidence is that these will pose the greatest risk to the HWS development.

Source of Potential UXO Hazard	Findings
British, German & American Buoyant Minefields WWI	Many thousands of buoyant mines were laid by the British and Americans during WWI in a northern anti-submarine barrage between Norway and the Orkneys. These frequently broke free from their moorings and drifted large distances before finally sinking. The Germans laid mines by surface vessel in the Moray Firth and a number of fields by submarine along the Scottish north east coast. They laid three small submarine-laid offensive minefields in the vicinity of Peterhead.
British Minefields WWII	During WWII, the British laid an extensive defensive buoyant mine barrier the length of the East coast of the UK. The nearest mine lines are recorded as being a few miles (c. 7nm) further out to sea than the HWS site but, given the inherent navigational limitations of the laying vessels and the tendency for mines to break free and drift, it is quite possible British buoyant mines could have found their way into the AOI.
German Minefields WWII	There are no recorded German buoyant or ground minefields on this part of the UK coast. However, there is anecdotal evidence of "parachute mines" being used during the bombing of Peterhead, so it is possible, although we consider it very unlikely, that German ground mines could be encountered in the HWS AOI.

Source of Potential UXO Hazard	Findings
Submarine and Surface Ship Torpedo Attacks/ Depth Charges/Rockets	German and British submarines operated in this area during both World Wars. Two of the wrecks in Buchan Deep are fishing vessels sunk by German submarines in 1917. Submarine torpedoes often missed their target and sank to the seabed and in 2011, a local fishing vessel trawled up a torpedo warhead off the Peterhead coast. German submarines are also very likely to have come under attack from Allied aircraft, with depth charges and rockets. Consequently, these could be present in the AOI.
Naval Projectiles	Ships being attacked from the air defended themselves. Consequently, any size of projectile could be encountered, but most are likely to be small; sub-5kg NEQ. The majority of exchanges of fire in the North Sea with large calibre weapons took place in WWI.
Aerial Bombing / Jettisoned Bombs/ Rocket Attacks	Peterhead was bombed heavily during WWII. Bombs are recorded as falling short of their target and into the sea. Aircraft, both German and Allied, also frequently jettisoned bombs into the sea if they had suffered damage. German planes routinely attacked the convoys and other vessels using the swept coastal shipping route past Peterhead. Consequently, a wide variety of air-dropped EO could be found within the AOI. This could vary from rocket warheads of <5kg to large H.E. bombs of 2000kg or more. However, given the distance offshore of the HWS OWF site, the density and therefore probability of encounter due to project activities of these items of EO will be very low.
Shipwrecks	There are two wrecks of military significance within Buchan Deep and the AOI. These are both Fishing Vessels sunk by German submarine by gunfire in 1917. They do not present a UXO hazard.
Military Practice and Exercise Areas	There are no current military practice areas near the AOI. The closest is the Drums Firing Range 40 km to the South West and the range boundary extends only 2.4km seawards from the coast. It is used mostly for small arms training. There are no former military or naval training areas close to the AOI. However, some *ad hoc* training evolutions in the local region, taken over a period of several decades is very probable; including live firing of small arms, naval gunfire (typically up to 105mm) and possibly larger anti-submarine weapons.
Explosives/Munitions Disposal	The nearest recorded dump site is the disused “East of Aberdeen”, marked on the chart, and is approximately 25nm from the AOI. The EO dumped is believed to be Conventional Munitions. The precise nature and types of munitions has not been recorded. There is no evidence of Chemical Weapon agents being dumped close to HWS.

Table 3.1 - Summary of historical research and potential sources of UXO hazard.

3.3 Sea Mines

Mines are generally classified by their position in the water and their method of firing (actuation).

3.3.1 Buoyant Mines

The first and the most commonly employed in WWI, but also extensively deployed in WWII, is the buoyant mine, which is designed either to float just below the surface, tethered to the seabed by a mooring wire and sinker (anchor), or to drift with the ocean currents. Buoyant mines consist of a spherical or ovoid casing with a charge weight of typically 40kg - 250kg of High Explosive (HE), taking up approximately a third of their volume. They are most commonly actuated by contact with the target, using either mechanical switch horns to close a battery-powered firing circuit or “Hertz” horns. The latter are also known as “Chemical Horns”. A Hertz horn consists of a soft lead or copper sheath enclosing a glass phial of acid at the base of which is a dry battery cell. On contact with a target vessel, the glass phial breaks, releasing the acid to act as the battery cell’s electrolyte, which then provides power to the mine’s detonator. The increased danger a Hertz horn presents over a switch horn is that it does not rely on a battery, which will discharge over time, but can provide power to the detonator indefinitely.

Figure 3.1 - Hertz (Chemical) Horn

Other variants of moored mines, were the Antenna Mine, an anti-submarine contact mine that used the current generated by two dissimilar metals rubbing together to fire, and the Magnetic mine, an “influence” mine that was actuated by the small electro-magnetic current generated when a target vessel’s moving magnetic field cut the mine’s internal coiled rod sensor.

Drifting mines are not particularly effective as an anti-ship weapon – their value lay in the fear and disruption they caused – and were not often employed. However, hundreds of thousands of moored mines were laid during the two world wars. A moored mine frequently became a drifting mine when its cable parted due to the wear and tear of wave motion. In accordance with the Hague Convention of 1905, mines breaking free from their moorings are required to self-neutralise but, in reality, either by design or malfunction, early mines often remained active. They continued to be a danger to shipping and to civilians, if swept ashore. Most eventually sank, often a considerable distance from where they were originally laid. Consequently, estimating the risks posed in any particular area by the mines laid either defensively or offensively during the two world wars is exceptionally difficult. So many were laid that a general assumption is that buoyant mines could be present in any area of the North Sea.

3.3.2 Ground Mines

Although they were in existence towards the end of WWI, ground mines were neither very effective nor common at that time. However, from 1939 onwards, both British and German influence ground mine technology advanced rapidly.

The influence Ground Mine, as its name suggests, is designed to lay on the seabed. It can be laid by surface vessel, submarine or aircraft, and it is most commonly cylindrical in shape. It has a single or a combination of magnetic, acoustic and pressure sensors to detect the influence “signature” of passing target vessels. To be close enough to create sufficient damage to its target, a ground mine must be laid in relatively shallow water; generally not more than 70m but more usually around 30m or less. For the same reason, and because the mine does not have to float, the size of the main charge is considerably bigger than in a buoyant mine, typically 300kg-750kg. Both Germany and Britain had versions that could be fitted with direct impact bomb fuses in addition to magnetic and acoustic firing circuits.

British ground mine casings were generally made of steel and subject to corrosion over time unless they became buried in hypoxic sediment. The mines relied on batteries to power sensors and firing circuit; these will now be discharged and the mine will not function as designed. Charge weights were between 227kg-499kg, except for two specialist mines that had much smaller net explosive quantities (NEQs) of 45kg and 91kg. The British continued to develop ground mines throughout the war, starting with AMKs I-IV in the early years, finally progressing to the AMk IX by 1945.

WWI German ground mines were made of aluminium and superbly engineered, with reliable *Rheinmetal* fuses and, consequently, are frequently found in excellent condition after decades in the water. German air dropped “parachute” mines are likely to be found intact and the mines could function as designed if sufficient battery power was available. However, their batteries will have discharged. Many variants were fitted with booby traps and anti-disturbance devices; some of these relied on battery power, some employed mechanical inertia designed to operate on impact with a cocked-striker initiator, some had clockwork delay mechanisms and others relied on human intervention; all could be in a very sensitive condition and could function if disturbed.

3.3.3 Minefields

The North Sea was very heavily mined, both defensively and offensively, during both World Wars.

Many thousands of buoyant mines were laid by the British and Americans during WWI in a northern anti-submarine barrage between Norway and the Orkneys. These frequently broke free from their moorings and drifted large distances before finally sinking.

During WWI, the Germans laid mines by surface vessel in the Moray Firth and a number of fields by submarine along the Scottish north east coast. There were three in the vicinity of Peterhead, all relatively small (see Appendix 3).

MF No.	No. of mines	Distance to HWS main AOI (approx.)	Distance to Export Cable
57	3	26km	18km
58	6	27km	21km
97	18	22km	9km

Table 3.2 – German WWI submarine laid minefields

Although we have no evidence to be certain, these mines were most probably Type II contact mines. They consisted of a 0.80m "egg-shaped" casing manufactured from steel, with a total weight of 322kg (excluding any floating devices or sinkers). The main charge was 131kg of wet gun cotton.

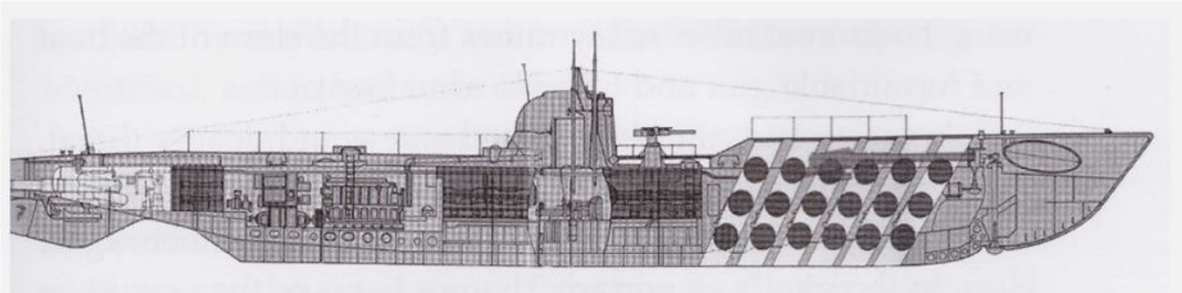


Figure 3.2 – German UC.II mine-laying U-Boat

There are no recorded German WWII buoyant or ground minefields on this part of the UK coast, although they were laid in considerable numbers further south – off the Humber, for example. However, there is anecdotal evidence of "parachute mines" being used during the bombing of Peterhead, so it is possible, though we consider it very unlikely, that German ground mines could be encountered in the HWS AOI.

No British WWI minefields are thought to have been laid in the vicinity of the HWS AOI.

Fig 3.3 – Type II Mine

During WWII, the British laid an extensive buoyant mine barrier the length of the East coast of the UK. Minefield maps show this as being a few miles further out to sea (circa 7nm) to the east of the HWS site (see Appendix 4). Records show that the nearest mine line, designated SN16G, contained 280 Mk XVII contact mines but there were a total of 5,000 mines laid in the portion of the East Coast Barrier in vicinity of Buchan's Deep. The minefields consisted of a mixture of Mk XVII, Mk XIV and Mk XV (switch/Hz horns) and MkXX (antenna) mines.

Minefield	Number Laid	Type
SN12	2092	XIV,XV,XVII,XX (372 XIV, XV units)
SN13	2090	XX/XVII/XIV (570 XIV/XVII units)
SN15A	1778	XX/XVII
SN16A	314	XX/XVII
SN16B	313	XX/XVII
SN16C	314	XX/XVII
SN16D	280	XVII
SN16E	280	XVII
SN16F	280	XVII
SN16G	280	XVII

Table 3.3 – British WWII minefields in the Buchan Ness region

Although there were no minefields laid directly within the HWS AOI, given the very large numbers of buoyant mines deployed throughout the region and their propensity to break free and drift with ocean and tidal currents over long distances before finally sinking to the seabed, it is possible that sunken buoyant mines could be found in the AOI. However, unless they have been completely covered in hypoxic sediment, these will now be severely corroded. Both the risk of encounter and inadvertent detonation from HWS activities is very small.

During WWII, British ground mines were used almost exclusively as an offensive weapon. They were dropped by aircraft, coastal forces mine layers, motor torpedo boats and submarines in shallow enemy controlled waters, causing significant disruption to seaborne logistic traffic and stretching German mine clearance forces. We have no evidence of British ground mines laid near the HWS AOI.

3.3.4 Minesweeping and Mine Clearance Operations

It is appropriate to mention the minesweeping and other mine clearance efforts that went on after both World Wars.

Minesweeping was the standard method for clearing moored mines during WWI and WWII and in the immediate post-war period. The technique used special abrasive wires, latterly with explosive cutters attached, that were towed behind one or more ships. These sweep wires cut the mine's mooring cable and, once free of its sinker, the mine would either self-destruct (in accordance with the Hague Convention 1905) or could be sunk by gunfire.

Minesweeping continued well after the armistice in November 1918 with 55 different flotillas still operating in June 1919. The British searched over 40,000 square miles until November 1919. At the end of the war when great efforts had to be made to clear the sea of mines, it was observed that about 85% of the mines laid had "disappeared" due to various causes and only a small fraction could be found and eliminated.

Many reports refer to the "clearance" of barrier minefields after WWI. The term here should not be confused with what is understood by the modern usage of the word clearance, which includes removal of the UXO threat completely, usually by countermining.

Minesweeping was not effective against mines that had already broken free and sunk to the seabed. And while minesweeping removed the threat for surface vessels and submarines, the practice of sinking them with gunfire has left a significant legacy hazard to modern seabed operations. The mine sinkers (anchors) also present solid targets for modern sonars and magnetic sensors that have to be identified and discounted, increasing the effort and time required for the survey of a contaminated area.

Directly following the end of WWII a major effort was made to clear areas of international water where minefields had been laid during the conflict. In addition to mechanical (wire) minesweeping, influence (magnetic and acoustic) equipment and techniques were developed to counter both the residual and emerging influence ground mine threat. These for the most part were asset intensive and not particularly effective.

Figure 3.4 - LL Magnetic Minesweeping

Despite the mine clearance efforts, in the years immediately after the war, ships routinely continued to hit mines and sink with loss of life. Between May 1945 and the end of 1957, 159 ships were hit by mines in the North Sea. The last incident, we have record of, was in 1960: the *SS Marmara* was severely damaged when it strayed out of the compulsory shipping channel in bad weather and hit a mine. Since then, UXO has been regularly encountered during fishing, dredging, mine counter measures and diving operations; providing strong evidence that there is still a substantial legacy of UXO in the Southern North Sea, which potentially includes the HWS site.

3.4 Torpedoes/Depth Charges

Although mines, given the numbers that were laid, undoubtedly present the most likely threat to HWS project activities, the area saw a considerable amount of other naval action in both world wars. Other EO, such as torpedoes and depth charges may be encountered.

Submarines, both German and British operated in this area during both World Wars. Two of the wrecks in Buchan Deep are fishing vessels sunk by German submarines in 1917, in this case by gunfire, but the U-boats also used torpedoes. There are four other ships in the general area that are recorded as having been sunk by U-Boat torpedoes in 1918. There are four more that were sunk in the same way at the beginning of the Second World War, in 1939. These wrecks are shown in Table 3.3 later in this section.

Torpedo fusing was often unreliable and it is quite possible that other attacks took place, unrecorded, when the torpedo failed to function or missed its target and sank to the seabed. Recently, in 2011, a torpedo warhead was trawled up by a local fishing vessel off the Peterhead coast.

German submarines were very likely to come under attack from Allied aircraft, with depth charges and rockets. We have no direct evidence of anti-submarine operations taking place in the HWS AOI site itself, either during WWI or WWII, but it is likely that unexploded torpedo warheads and depth charges are present in the region.

The WWI torpedoes used were probably of the “wet heater” type; steam driven, with kerosene as fuel and compressed air providing oxygen for combustion. Warheads of around 250kg were detonated by means of a direct impact or magnetic fuse. The standard German WWII torpedo was the electrically driven G7e, with a 280kg warhead.

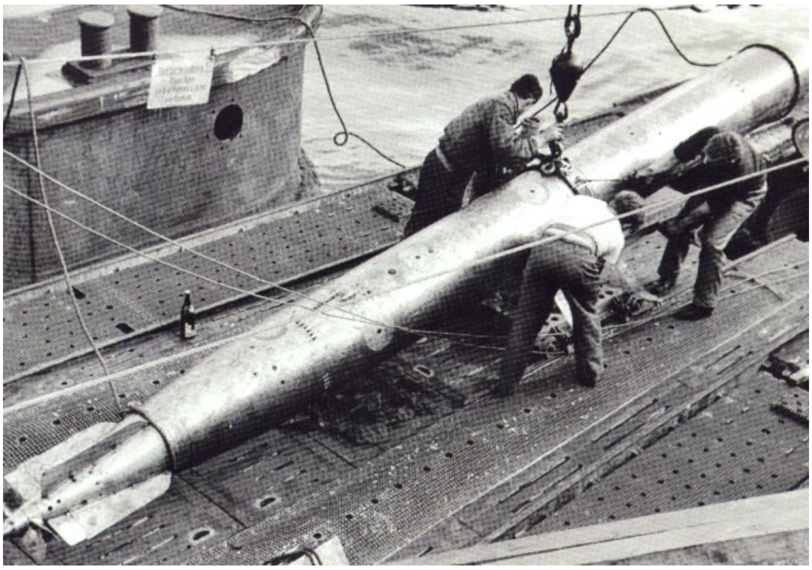


Figure 3.5 – German G7e electrically driven torpedo

A number of different types of depth charges and depth bombs could have been used in the area, with an NEQ in the range of 50kg-200kg. These all would have been thin-cased and consequently subject to severe corrosion in the intervening years. They would have fired by a hydrostatic fuse or perhaps an impact bomb fuse with a delay.

3.5 Naval Projectiles

The majority of exchanges of fire with large calibre weapons took place in WWI; the most notable being the Battles of Jutland, Helgoland Bight and Dogger Bank, much further to the South East. However, many naval engagements took place throughout the North Sea and the coast of the UK, not all were recorded. Any size of projectile could be encountered, but most are likely to be small; sub-5kg NEQ. Early naval projectiles were filled with Picric Acid, or a derivative such as Lyddite and later Shellite. Later WWII fillings were typically, Amatol, TNT and RDX. Charge weights were generally less than 10% of the overall weight of the projectile, so even the largest 16 inch shells contained an NEQ of only around 20kg of HE, and while these would present the greatest projectile hazard, the overall risk to HWS activities from naval projectiles is considered extremely small.

3.6 Air Dropped Bombs and Rockets

Almost any category of bomb, particularly German, could be encountered in the HWS AOI. Air dropped ordnance will come from two sources:

- The result of attacks on shipping, where the EO missed its target; these weapons are likely to have been armed and will present a UXO risk.
- Bombs jettisoned by aircrew in an emergency on the way to or from an inland target. These bombs may or may not have been armed on release. For risk assessment purposes, it must be assumed that they were armed.

Peterhead was bombed heavily during WWII. Bombs are recorded as falling short of their target and into the sea. Aircraft, both German and Allied, also frequently jettisoned bombs into the sea if they had suffered damage. German planes routinely attacked convoys and other vessels using the coastal shipping route that ran past Peterhead (some of these are recorded as shipwrecks in Table XX). Consequently, a wide variety of air-dropped EO could be found within the AOI. Bombs dropped and rockets fired from fighter bomber aircraft are likely to be in the region of 5kg-50kg NEQ; those destined for inland raids but jettisoned over the sea could be considerably larger; up to 2,000kg and more. However, given the distance offshore of the HWS OWF site, the density and therefore probability of encounter due to project activities of these items of EO will be very low.

British and German bombs could be fitted with several kinds of fuses, including singly or in combination: impact, long delay and anti-disturbance. However, any anti-disturbance fuse that relied on a power source is now highly unlikely to function. Moreover, the majority of mechanical fuses or pistols will have been subject to significant corrosion and are also unlikely to function as designed. Nevertheless, it cannot be discounted that some may be in an extremely sensitive state.

3.7 Military or Explosives Related Shipwrecks

There are two wrecks of military significance within Buchan Deep, one of them within the HWS AOI. These are both FV sunk by German submarine by gunfire in 1917. They do not present a UXO hazard.

There are many other wrecks in the wider region that were sunk as a result of military action. Representative samples are listed below in Table 3.4 to show the range of EO that was used and therefore could be present in the HWS AOI.

Date	Vessel	Position	How Sunk	Remarks
23/03/17	SS Egenaes (Norwegian cargo vsl)	10nm east of Peterhead	Gunfire/Shelled	Sunk by U-45 (Hubert Aust)
30/04/17	FV Argo (British steam trawler)	15nm ESE from Buchan Ness Light House ***(inside the HWS AOI)***	Gunfire/Shelled	Sunk by UB-22 (Karl Wacker)
19/05/17	FV Winward Ho (British steam trawler	3nm South from Peterhead	Mine	Sunk by UC-40 (Alfred Arnold)
29/06/17	Manx Princess	57°33.089'N 001°16.010'W ***(within Buchan Deep)***	Gunfire / Shelled	Sunk by UC-33 (Martin Schelle)
21/01/18	SS Adolf Meyer (Swedish Collier)	Southeast of Peterhead	Mine	Sunk by UC-58 (Karl Vesper)
12/02/18	SS St Magnus (Defensively armed British passenger cargo vessel)	3nm NNE from Peterhead	Torpedo	Sunk by UC-58 (Karl Vesper)
28/03/18	HMS Tithonous (auxiliary cruiser/ex passenger vsl)	50nm East of Aberdeen	Torpedo	Sunk by UB-72 (Friedrich Träger)

17/09/18	SS Muriel (British cargo vessel)	3.5nm NE of Peterhead	Torpedo	Sunk by UC-58 (Kurt Schwartz)
01/12/39	SS Mercator (Finnish Cargo vessel)	57°23.983'N 001°36.541'W	Torpedo	Sunk by U-21
01/12/39	SS Arcturus (Norwegian cargo ship)	57°27.00'N 001°36.13'W	Torpedo	Sunk by U-31
16/02/41	HMT Ormonde (British minesweeper)	57°22.432'N 001°40.282'W	Air Raid	Attacked and sunk by enemy bombs 7nm from Cruden Scar, Peterhead
27/09/40	SS Port Denison (British cargo vessel)	57°22.432'N 001°40.282'W	Air Raid / Air launched torpedo	Torpedoed and sunk by German aircraft whilst in convoy
03/11/40	SS Kildale (British cargo ship)	57°22.432'N 001°40.282'W	Air Raid	Bombed and raked by MG fire in Coastal Convoy WN-29
05/04/41	SS St Clement	57°17.265'N 001°50.992'W	Air Raid	Bombed by aircraft Kirkwall to Aberdeen. Position approximate.
26/02/45	Beaufighter TFX NV414 (British aircraft)	North Sea near Peterhead	Anti-aircraft fire	Damaged attacking convoy at Arendal (Norway). Crashed into sea on return flight.
14/04/45	U-1206 (German submarine)	57°18.242'N 001°39.823'W	Bombed / Scuttled	Bombed by British aircraft, damaged and scuttled

Table 3.4 – Military related wrecks within the local area

Many merchant as well as naval vessels sunk in WWI and WWII contained munitions. Similarly, aircraft that were shot down, or otherwise had to ditch into the sea, also had unexpended ammunition and other EO. There is evidence that munitions could spill and be thrown clear from a sinking ship or become exposed as the vessel broke up on the seabed, and in due course migrate away from the original site. But the risk of EO contamination is generally less in the vicinity of wrecks (compared with munitions dump sites) as the ordnance typically remains contained and immobile within the structure of the sunken vessel.

From a UXO threat perspective, unknown wrecks should be avoided. It is anticipated that for geophysical survey (and subsequent operations) such wrecks will be avoided anyway.

3.8 Ordnance Disposal/Dumping

3.8.1 Background

For several decades after the World Wars, large volumes of chemical and conventional munitions were disposed of at sea. At the time, with public safety as a guiding principle, such disposal was considered best practice. The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention, 1972), ratified by many countries, now prohibits the disposal at sea of wastes, including munitions. The North Atlantic Treaty Organization (NATO, 1996) states that one of the most outstanding examples of cross border contamination is the disposal of large quantities of chemical warfare agents into the Baltic Sea, North Sea, and the Irish Sea. These discarded munitions are now a significant hazard to offshore projects including cable laying and foundation installations on renewable projects.

The two World Wars left a legacy of enormous quantities of munitions requiring disposal. The process had to be completed quickly and safely. Given the technical limitations of the time, it became clear that sea dumping was the only practical method of disposing of the bulk of the munitions. Other nations reached the same conclusion and sea dumping became the internationally accepted method of munitions disposal. Sea dumping continued until 1972 when the UK adopted the London Convention on the Disposal of Wastes at sea and the Oslo Convention on the prevention of Marine Pollution in the North East Atlantic.

3.8.2 Dumping Sites Near the HWS AOI

The nearest recorded dump site to HWS is the disused "East of Aberdeen", marked on the chart. It is approximately 25nm from the AOI. The EO dumped within it is believed to be Conventional Munitions, with no Chemical Warfare agents. However, the precise nature and types of munitions has not been recorded.

It can be assumed that the vast majority of large munitions deposited at the site were packaged robustly and dumped unfused. There is no reason to believe therefore that they will become unstable or present a hazard even if accidentally disturbed. However, the state of corrosion of all munitions could vary from very little to completly degraded away and therefore it is not possible to predict the condition of all types of EO in and around the dumping areas.

Anecdotal evidence has recorded occasional unexplained explosions in the vicinity of some dump sites. No definite evidence of spontaneous detonation of dumped conventional munitions exists, but any explosive ordnance which contained Shellite or Lyddite (highly sensitive picric acid based explosives) is far more likely to spontaneously detonate when disturbed than, for example, TNT filled munitions. This could arise if they were subject to an impact when the structure of a container collapsed or if they were struck by other items of ordnance falling onto them.

Picric acid is known to have an aging problem through which metal picrates form, e.g. iron picrate. Such metal picrates are extremely sensitive energetic materials that can be initiated very easily. Shellite and Lyddite was a common WWI filling for large shells, including naval projectiles.

Migration of EO from this site due to tidal stream and sediment movement into the AOI is considered highly unlikely. However, movement due to fishing vessels (trawler nets) is possible. Unrecorded, unofficial dumping in Buchan Deep cannot be discounted; particularly as it is an obvious deep basin near to land.

3.9 Military Practice and Exercise Areas

There are no current military practice areas near the AOI. The closest is the Drums Firing Range 40 km to the South West and the range boundary extends only 2.4km seawards from the coast. It is used mostly for small arms training.

There are no former military or naval training areas close to the AOI. However, some ad hoc training evolutions in the local region, taken over a period of several decades is very probable; including live firing of small arms, naval gunfire (typically up to 105mm) and possibly larger anti-submarine weapons. Without evidence, it is impossible to quantify any risk that UXO from these activities may present. Our view is that it is statistically insignificant when compared to other types of UXO that could be encountered.

3.10 Chemical Weapons

We have found no evidence of the dumping of Chemical Warfare (CW) agents near enough to HWS to present a hazard.

4 UXO Hazard Analysis

4.1 Probability of Encountering UXO in the HWS Site

4.1.1 General

Throughout the life of the project, the more activity in the HWS OWF that interacts with the seabed, the greater the probability of encountering UXO. It follows that for any given density of UXO and amount of project activity within the site area, the probably of encounter will be increased by or be proportional to:

Survey

- Any geotechnical survey technique that disturbs the sediment
- The total area of disturbance as a proportion of the site area

Cable Installation and PLGR

- The swept path of any plough or the PLGR x the number of runs as a proportion of the total site area

WTG Platform Installation and Seabed Infrastructure

- Penetration into the sediment of jack-up barge legs
- The number of times a barge repositions in the same location
- The total instances of penetration of the sediment (4 legs x repetition x number of WTG) as a proportion of the total site area

Anchor Deployment

- The number of vessel anchoring operations across the life of the wind farm
- The sum of the swept path across the sediment of all anchor cables as vessels yaw as a proportion of the total site area
- Penetration into the sediment of platform anchors

4.1.2 Hazard UXO

There were substantial mine laying operations – German and British, buoyant and ground mines – during both World Wars with minefield clearance of only limited effectiveness after each period of conflict. It must be assumed that there is a strong possibility that mines will be found within the Site. The accumulation of evidence points to sunken buoyant mines presenting statistically the biggest risk to project activity, but it is also possible that other types of EO may also be encountered. Table 4.1 below summarises those items of EO that could be present in the HWS OWF Main Array site. A rationale is outlined in the paragraphs below.

4.1.3 British and German Buoyant Mines

We have shown previously that the region was very heavily mined, both defensively and offensively, by the British and the Germans in both World Wars.

Contemporary minefield records show that there were 3 German WW1 buoyant minefields relatively close to the HWS AOI (Appendix 3). The main platform site is within about 5nm of the British WWII East Coast mine barrier (Appendix 4).

Given the very large numbers of buoyant mines deployed during WWI and WWII and their propensity to break free and drift with ocean and tidal currents over long distances before finally sinking to the seabed, it is very possible one or more could be present in the HWS site.

4.1.4 German Ground Mines

There is no evidence of the deliberate laying of German ground mines in HWS, however, there remains a very small possibility that German ground mines could be encountered.

4.1.5 Torpedoes and Depth Charges

We described a number of typical examples of torpedo attacks carried out from surface ships, submarines and aircraft earlier. German submarines are known to have operated extensively in the area and it is certain that some of them came under depth charge attack. There are also a number of wrecks in the general area that were sunk by torpedo (Table 3.4). A torpedo warhead was trawled up by a local fishing vessel in 2011. It is possible therefore that depth charges and/ or torpedoes could be present in the HWS AOI.

4.1.6 Naval Projectiles

The majority of surface action took place much further to the south east. It is unlikely, therefore, that large calibre naval projectiles will be found in the AOI. However, ships being attacked from the air defended themselves. Consequently, anti-aircraft, projectiles could be encountered, but most are likely to be small (sub-5kg NEQ) and will not present a significant threat to envisaged project activities.

4.1.7 Air Delivered Bombs

The presence of aircraft bombs of all types at HWS, whether jettisoned deliberately or by accident post-raid or used offensively against shipping, is possible. However, the density within any specific area is likely to be very low and therefore probability of encounter, while cannot be discounted, will be small.

4.1.8 Munitions Dumping

It is considered highly unlikely that any EO has migrated into the HWS site from the only known dumpsite in the region (East of Aberdeen).

4.2 Hazard Items Potentially within the HWS OWF Site

Having taken into consideration the evidence outlined in previous sections of this study, the following generic ordnance groups are considered to be potential hazards at HWS.

UXO Hazard	Justification
British Buoyant Sea Mines	Potentially present on this site, given the very large numbers deployed in the region in the East Coast Barrier.
German Buoyant Sea Mines (WWI)	Known small minefields relatively close by. Potentially present on this site, given the unreliability of their moorings and tendency to break free and drift long distances before sinking.
German Ground Mines	No direct evidence of use in or near HWS but extensively deployed further down the coast. Could be present, but unlikely.
Depth Charges	German submarines are known to have operated in the area and attacked by ship and aircraft. There is no direct evidence but there is a remote possibility DC could be present.
Torpedoes	Plenty of evidence of torpedo attacks and ship sinking in the general area. Recent recovery of a torpedo warhead by a local fishing boat. Potentially present within the HWS AOI.
Artillery/Naval Projectiles	Could be present on the HWS AOI, in small numbers.
Air Delivered Bombs	Could be present, but the density of UXB in any particular area is probably very small.

Table 4.1 - UXO that could be encountered at HWS OWF.

5 Environmental Conditions

5.1 Bathymetry

To date, Ordtek has not had access to any bathymetric survey data. However, the Admiralty chart shows that the main site is located in the area known as “Buchan Deep”, with a depth of water between approximately 93m – 120m. The HWS main site AOI is split by the Forties to Cruden Bay oil pipeline.

The proposed export cable path shelves steadily upwards towards Peterhead, meeting the 20m contour line only about 400m from the shore, when it then rises rapidly to the rocky beach. The export cable track crosses a spoil ground centred on 57°31.0’N 001°42.6W approximately 1.7nm from Peterhead harbour.

5.2 Seabed Conditions, UXO Migration and Burial

The tidal stream sets NNE and SSW along the coast. The south-going stream begins 2 hours before, and the north-going stream 3½ hours after, high water at Dover, with a maximum rate at springs of 2½ knots. According to the Admiralty Chart, the seabed varies from Sand to Gravel. At this stage, without access to bathymetry survey data, the depth of the sediment and currents at seabed level are unknown. The navigational chart suggests that within the AOI the seabed is relatively firm and complete burial of UXO due to initial impact is unlikely, even for heavy items such as large aircraft bombs and ground mines. However, subsequent UXO burial due to scouring and sand migration is possible. Once covered by sand or sediment, UXO will usually remain close to the surface, within 0.5m – 1.0m. Over time, as further sediment movement occurs, items of UXO will occasionally re-appear. Therefore, depending on the capability of the sonar and the frequency used, bigger items of ordnance, such as mines and large bombs should still be detected during a comprehensive sonar survey. This detectability is obviously a function of burial depth and size. Buried smaller items are unlikely to be detected by SSS and magnetometry will be needed.

Although the general downward slope of the seabed into the AOI would assist movement, migration into the site of large new items of EO once the AOI has been cleared of UXO is considered unlikely, unless inadvertently dragged there by fishing vessel.

6 UXO Risk of Detonation

6.1 Overview

The risk that UXO could be initiated if encountered during the construction works will depend on its condition, how it is found and the energy with which it is struck. Most UXO does not necessarily become less dangerous with age and could still function as designed if disturbed. Furthermore, it is possible that seawater may have degraded certain types of munitions over time leaving them in a more sensitive state. The early mines used by both Allied and Axis forces mainly used lead chemical horns, which contain a wet cell battery activated by the crushing of the lead horn. These will continue to be an effective power source until the wires to the detonator corrode.

The movement of vessels and implementation of non-intrusive surveys would not result in the initiation of ordnance through influence alone. Initiation would only result from either direct impact or shock/vibration.

6.2 Likelihood of Detonation

In the following section of this report, we will conduct a Risk Assessment for HWS project activities against the types of UXO likely to be encountered on the site. Conventionally, "Risk" is the product of the likelihood of an event happening and the severity of the consequence. In this instance, the "event" is the detonation of an item of UXO caused by some project activity.

The likelihood of this specific event happening is also the product of two factors: the probability of encountering the UXO and the probability of its detonating. We examined the probability of encountering different types of EO from potential sources within the study area at paragraph 4.1. This section looks at the risk of detonation from the main hazard UXO against typical OWF Project activities that might lead to that detonation.

6.3 Factors Affecting the Risk of Detonation

Before a weapon can detonate, a sequence of events must happen, called the *Explosive Train* (also known as the *Firing Train*), which starts with the removal of any safety measures and culminates in the detonation of the main charge of high explosive.

The accidental detonation of an item of UXO that has lain undisturbed on the seabed for several decades is a rare event, even when subjected to quite a heavy shock such as being struck by a cable, plough or dragged by a ship's anchor. However, UXO can also be very unstable and will detonate if the right combination of circumstances occur.

Most HE weapons have four principal components: a fuse (the part of the weapon that initiates function), a safe and arm mechanism/unit (often contained within the fuse), a detonator and a main charge. Additionally, larger weapons such as mines and heavy bombs have a booster charge (also known as the primer) between the detonator and the main filling, to give the detonation shock wave sufficient energy to ensure the weapon's complete detonation.

The detonator is filled with a Primary explosive, such as Lead Azide, which is extremely sensitive to stimuli such as impact, friction, heat or static electricity and a relatively small amount of energy is required for its initiation. The detonator's purpose is to trigger the larger main charge. This is made of much less sensitive Secondary Explosive and requires substantially more energy to be initiated but is relatively safe to store and transport. The safe and arm system ensures that the detonator and main charge remain separated and the firing chain broken until the weapon is clear of its carrier/launcher and is in a position to function as designed.

Although it may not actually be the case, when UXO is encountered, it must always be assumed that the explosive train is intact: that is, all safety measures have been removed and the detonator is in contact with the main charge.

The UXO could be caused to detonate several ways: if the detonator is struck accidentally with sufficient force or is subjected to heat, static charge or friction; if a fuse containing a temporarily jammed cocked striker is jarred and the striker is released; similarly if a seized clockwork mechanism restarts; or if the sensitive iron picrates associated with a picric acid filled munitions are subjected to friction, heat or are knocked.

The risk of accidental detonation will become greater if the UXO is either deliberately or accidentally removed from the water and allowed to dry out. In addition to the danger of iron picrates, some HE can exude metallic azides and salts that, once they dry out, are extremely sensitive.

Nevertheless, the main filling is inherently stable and such a detonation is a rare event, even when UXO has been subjected to robust handling, for example when a bomb is caught up in a dredger head or ship's anchor. And, moreover, most UXO – particularly EO that has lain on the seabed for several decades – will have been the subject of significant corrosion to its casing and to any mechanical moving parts. It is extremely rare for UXO found on the seabed to function as intended; detonation will almost always be the result of unusual and vigorous kinetic stimuli.

6.4 Causes of Detonation during HWS OWF Activities

From the previous paragraphs it can be seen that for a detonation to occur, the UXO must be in a sensitive state and a certain set of conditions satisfied. It is evident from the many items of UXO that are recovered from building sites, farmers' fields, anchor flukes, fishing nets and dredger buckets every year that these conditions are hardly ever met and an accidental detonation is unusual. It would be foolish however to be complacent and the UXO risk should be managed safely and at best value to the project through a comprehensive understanding of the risks involved, the natural environment and the project development phases.

The potential for UXO to be initiated if encountered during project operations will depend on its condition and the energy with which it is struck or moved, or if it is subjected to friction or excessive heat. The movement of vessels and implementation of non-intrusive surveys will not result in the initiation of ordnance through influence alone.

The most likely cause of UXO detonation would be a blow from heavy equipment; an anchor or cable, leg of a jack-up barge or cable plough for example, or if the UXO was dragged across the seabed and struck a solid object such as a boulder. There is also the possibility that an item, particularly a smaller piece of EO, such as a naval projectile or small aircraft bomb, could be caught in the flukes of an anchor and inadvertently lifted to the surface creating a potential hazard for exposed personnel and soft-skinned equipment.

Many activities through the life cycle of the HWS project could cause an item of UXO to detonate unexpectedly. Some typical potential activities are:

- Geotechnical investigation and geophysical survey: intrusive survey of the sediment or towfish flies to the seabed.

- WTG Platform installation: anchor handling.
- Cable installation: ploughs, tools and PLGR work along the routes.
- Support Vessel activity: anchor and cable deployment and dragging.
- All of the above for through-life maintenance of the WTG.

6.5 Risk of Detonation of Specific EO Types

6.5.1 Buoyant Mines

Today, if encountered both WWI and WWII buoyant mines will be found situated on the seabed, often partially buried in the sediment. The mine casings will be heavily corroded. Chemical (Hertz) horns may still be capable of functioning but internal wiring and firing mechanisms are unlikely to be effective. Switch horn mines require power from an internal battery and these will no longer function. The explosive filling is likely to be stable if undisturbed but the mine may still detonate if appropriate criteria are met. Charge weights are between 145-227kg.

6.5.2 German Ground Mines

WWII German ground mines were very well engineered, with casings of corrosion-resistant aluminium and fuses made by *Rheinmetal*. They are very liable to be found intact. The mines could still function as designed if sufficient battery power was available. However, the batteries will have discharged. Many variants were fitted with booby traps and anti-disturbance devices; some of these relied on battery power but some used clockwork mechanisms and some mechanical inertia devices designed to operate on impact, such as the cocked-striker, all of which could be in a sensitive condition and function if disturbed.

6.5.3 Artillery and Naval Projectiles

The possibility of encountering HE Naval and artillery projectiles in the HWS site is considered relatively low. Typically, they will be around 5kg NEQ, but less than 25kg, and consequently present minimal threat to vessels and equipment. Any fusing will be corroded and unlikely to function as designed. However, as relatively small items, they could become wedged in the flukes of an anchor and be brought to the surface, presenting a blast and fragmentation hazard to exposed deck-hands. WWI projectiles were filled with Picric Acid, and derivatives, that could be in a sensitive state.

6.5.4 Torpedoes

As with most UXO, torpedo warheads are liable to be stable if undisturbed but remain a potential hazard, particularly if after launch from the torpedo tube, safety détentes have been removed and the firing train is complete; that is, the detonator is married to the booster and main charge within the warhead.

6.6 Detonation Effects - HWS Project Vessels, Structures & Personnel

The consequence (severity) of UXO detonation will depend on the charge weight (NEQ), its proximity to the vessel, structure, equipment or person and its susceptibility to shock damage (robustness).

Unlike in air, for UXO deeper than about 10 metres, fragmentation does not pose a hazard from a detonation underwater. The effect that causes damage to structures and vessels is shock transmitted through the seabed and water column. Surface vessels and submarine equipment are also susceptible to the rapid expansion of gaseous products known as the “bubble pulse”; in this instance damage is caused by a lifting and whiplash effect that can break the back of a ship. Once it reaches the surface, the energy of the bubble is dissipated in a plume of water and the detonation shock front rapidly attenuates at the water/air boundary.

The most widely used parameter for describing shock severity is the shock factor value. This value is a shock input severity parameter that is a function of charge weight and charge distance (stand-off from the ship). For vessels, terms used are Hull Shock Factor (HSF) and Keel Shock Factor (KSF). A small explosive charge close to a vessel can give the same HSF as a larger one further away, although the pressure characteristic and damage mechanism may be different.

Shock damage to the hull area of a vessel can vary quite appreciably, depending on the charge size, orientation and proximity to the hull. If the charge is located directly or almost directly underneath and/or close to a vessel, the bubble collapse onto the ship's hull and the whipping caused by the bubble pulse will contribute to the damage.

In simple terms, the larger the UXO charge weight and the closer it is to any given structure, vessel, equipment or person, the more damage it may cause. A deep draft vessel is at more risk of damage than a shallow draft one operating in the same depth of water. A vessel is more at risk at Low Water than at High Water.

The effects of the detonation of an explosive charge underwater are complex and subject to many varying factors. If required, Ordtek can provide more information on the science of the response of surface ships to underwater explosions. No attempt will be made in this study to quantify the damage that could occur to vessels, structures or equipment from the inadvertent detonation of threat UXO.

7 UXO Risk Assessment

7.1 Key Terms

"Hazard" is a source of potential harm or a situation with the potential to harm or damage. For the purposes of this report the hazard will be termed as "UXO". This is an overarching term which may include all munitions and/or explosive items that have been dumped, fired or unfired.

"Risk" is the calculation of two principal elements:

(1) The likelihood that a hazard may occur (= probability of encountering UXO x probability of detonation).

(2) The consequence (severity) of the hazardous event.

7.2 Risk Assessment Data

Important Data For Risk Assessment Purposes	
Source - Main Hazards (in order of likelihood of encounter)	• British and German Buoyant Mines • Torpedoes • Naval Projectiles (Shells) and Rockets • Aircraft Bombs
Pathway - Classification of Work Activities	• Geotechnical investigation • Installation of cable using open excavation techniques, PLGR • WTG Platform installation that interacts with the seabed • Anchor handling operations
Site conditions	• Dynamic sands
Receptor - Entities at Risk	• Personnel, equipment and project programme
Tolerability of Risk	• Risk level should be reduced to ALARP
Inherent Risk Controls by Contractor	• Follow best practice and Project H&S plan • In-house UXO Risk Management procedure followed and benchmarked against other projects in the region • Specialist UXO risk assessment conducted • All known obstacles to be avoided or investigated

Table 7.1 - Key factors to be used in the risk assessment

7.3 Risk Assessment Matrix

Ordtek uses the following matrix to quantify the risk, each generic UXO hazard is assessed for severity and likelihood of occurrence. This model is generally considered best practice for assessing risk in the marine environment, although it has been modified where required to ensure it is UXO centric.

		Hazard Severity				
		1 = Negligible Negligible injury or impact on equipment with no lost work	**2 = Slight** Minor injury or damage requiring treatment or repair	**3 = Moderate** Injury leading to lost time incident	**4 = High** Involving single death and serious damage to equipment	**5 = Very High** Multiple deaths and/or sunk vessel
Likelihood of Occurrence	**1 = Very Unlikely** A freak combination of factors would be required for a UXO initiation to result	**1 = L**	**2 = L**	**3 = L**	**4 = L/M**	**5 = L/M**
	2 = Unlikely A rare combination of factors would be required for a UXO initiation to result	**2 = L**	**4 = L**	**6 = L/M**	**8 = M**	**10 = M/H**
	3 = Possible Could happen if sensitive UXO exists but otherwise unlikely to occur	**3 = L**	**6 = L/M**	**9 = M**	**12 = M/H**	**15 = H**
	4 = Likely Not certain to happen but sensitive UXO may exist and density may be above average resulting in an accident	**4 = L/M**	**8 = M**	**12 = M/H**	**16 = H**	**20 = H**
	5 = Very Likely Almost inevitable that an UXO initiation would result due to the type and density of UXO	**5 = L/M**	**10 = M/H**	**15 = H**	**20 = H**	**25 = H**

Table 7.2 - UXO Risk Assessment Matrix

7.4 Risk Assessment Results

Our Risk Assessment for the HWS AOI is presented in Table 7.3 below. Note that ***the Risk is calculated before any mitigative actions have been adopted - i.e. it is the risk in the HWS AOI as it stands now.*** Our judgement is that implementing the Risk Mitigation Strategy recommended by Ordtek (Section 11), together with an appropriate UXO disposal strategy, will reduce the Risk to ALARP. It assumes that the embedded mitigative actions adopted as best practice by the construction industry are in place; in this case that the appropriate survey and UXO disposal strategies should be implemented before intrusive activities are undertaken.

For risk assessment purposes, a number of generic ordnance classifications have been grouped. This is justifiable as the probability of encounter, potential for initiation and NEQ are sufficiently similar.

Risk Calculation prior to the implementation of mitigation:

Risk Assessment Results				
Development Stage	**Generic Ordnance Category**	**Likelihood of Occurrence (Encounter and Detonation)**	**Hazard Severity**	**Result**
Geophysical Investigation (non-intrusive) (Consequence to equipment)	British and German Buoyant Mines	1	3	3 – Low
	Torpedoes and Depth Charges	1	3	3 – Low
	Naval Projectiles (<5kg NEQ) and Rockets	1	1	1 - Low
	Aircraft Bombs	1	3	3 - Low
Geotechnical Investigation (core sampling and CPT) (Consequence to equipment)	British and German Buoyant Mines	2	3	6 – Low / Moderate
	Torpedoes and Depth Charges	2	3	6 –Low / Moderate
	Naval Projectiles (<5kg NEQ) and Rockets	1	2	2 - Low
	Aircraft Bombs	2	3	6 – Low / Moderate
Export Cable Installation (Risk increases in shallower water – figures assume worst case <30m) (Consequence to equipment)	British and German Buoyant Mines	2	3	6 – Low / Moderate
	Torpedoes and Depth Charges	2	3	6 –Low / Moderate
	Naval Projectiles (<5kg NEQ) and Rockets	1	2	2 - Low
	Aircraft Bombs	2	3	6 – Low / Moderate
WTG Platform Installation Anchor Handling **(120m water)** (Consequence to seabed equipment)	British and German Buoyant Mines	2	3	6 – Low / Moderate
	Torpedoes and Depth Charges	2	3	6 - Low / Moderate
	Naval Projectiles (<5kg NEQ) and Rockets	1	1	1 - Low
	Aircraft Bombs	2	3	6 – Low /Moderate

Operation and Maintenance	British and German Buoyant Mines	1	2	2 - Low
	Torpedoes and Depth Charges	1	2	2 - Low
	Naval Projectiles (<5kg NEQ) and Rockets	1	1	1 - Low
	Aircraft Bombs	1	2	2 - Low
Boat Traffic **(120m water)** (Consequence to boat and inboard machinery and equipment)	British and German Buoyant Mines	1	1	1 - Low
	Torpedoes and Depth Charges	1	1	1 – Low
	Naval Projectiles (<5kg NEQ) and Rockets	1	1	1 - Low
	Aircraft Bombs	1	1	1 - Low
Boat Anchors (Consequence to anchor and cable)	British and German Buoyant Mines	2	3	6 – Low / Moderate
	Torpedoes and Depth Charges	2	3	6 - Low / Moderate
	Naval Projectiles (<5kg NEQ) and Rockets	1	1	1 - Low
	Aircraft Bombs	2	3	6 – Low /Moderate
Unprotected Personnel **(120m water)** (assumes small items of UXO have inadvertently been brought to the surface)	British and German Buoyant Mines	1	1	1 – Low / Moderate
	Torpedoes and Depth Charges	1	1	1 – Low / Moderate
	Naval Projectiles (<5kg NEQ) and Rockets /small bombs	1	5	5 – Low / Moderate
	Aircraft Bombs	1	1	1 – Low
Unprotected Personnel **(<30m water)** (assumes small items of UXO have inadvertently been brought to the surface)	British and German Buoyant Mines	2	4	8 – Moderate
	Torpedoes and Depth Charges	2	3	6 – Low / Moderate
	Naval Projectiles (<5kg NEQ) and Rockets /small bombs	2	5	10 –Moderate / High
	Aircraft Bombs	2	3	6 – Low / Moderate

Table 7.3 - UXO Risk Assessment Table

8 UXO Risk - Summary of Key Findings

8.1 Summary

This detailed desk based study has considered the development operations to be carried out within the HWS AOI, which included the main WTG site and the export cable route, in order to assess the potential risk to the project from UXO. We have conducted an in-depth historical research into both regional and, as far as possible, site specific factors. In doing so, we have made use of national and military archives to gather relevant information, as well as pertinent authoritative British and German publications, web-based archives and our own extensive internal knowledge database.

Within the study area, we have identified the dump sites, official and unofficial, and the EO legacy from two World Wars and modern military exercises with the potential to contaminate the HWS site with UXO, both now and during the full life cycle of the project. We have also considered the likelihood of EO migrating from outside the area into the site.

Rationalising this data, we have identified what we consider to be the ordnance types that present the main UXO hazard to the project. We have outlined the factors that determine the likelihood of encountering these UXO items and the factors and project activities that could lead to an inadvertent detonation with consequent damage to equipment or injury to personnel. These items in order of likelihood of encounter are

- German and British Buoyant Mines
- Torpedoes / Depth Charges
- Naval Projectiles (Shells) / Rockets
- Aircraft Bombs

From the evidence we have found, Ordtek considers the UXO threat items most likely to be encountered in the HWS AOI are German WWI and British WWII moored mines that have sunk to the seabed. Possible charge weights vary from 50kg-350kg but are most likely to be between 90kg-227kg. The typical diameter of the buoyant mines likely to be present in the AOI is 0.84 to 1.01m.

Accordingly the smallest hazard item that needs to be mitigated for an ALARP sign-off is the German WWI Type II contact sea mine. This consists of a 0.80m “egg-shaped” casing manufactured from steel, with a total weight of 322kg (excluding any floating devices or sinkers). The mine contains a 131kg charge of wet gun cotton. Assuming that this item can be successfully detected and identified within the survey datasets, larger objects will also be detectable.

While the possibility of finding smaller items of UXO in the area of interest cannot be discounted, the risk posed by them is very small. The evidence is that the probability of encountering small arms ammunition, HE naval shells and small bombs is low. It is also highly unlikely that any disturbance, other than direct and substantial impact would lead to detonation; even then the probability is that an explosion would not occur. The same argument can be made for larger air dropped munitions, with a similarly low probability of encounter and subsequent detonation.

9 UXO and the Legal Framework

9.1 Construction Industry Duties and Responsibilities

Certainly in the UK, there is no specific legislation covering the management and control of the UXO risk to the offshore construction industry (especially outside the 12 nautical mile (nm) boundary) but issues regarding health and safety are addressed under a number of regulatory instruments. In our experience, this is generally the case across Europe, only on-land and near-shore areas of Germany does the law specifically address UXO as a workplace hazard. Dealing with the risk of explosives and UXO in these areas falls under federal responsibility and law. Each Federal Republic has the responsibility to administer its own policies and protocols related to explosives and UXO risk management. Prior to development there is often the mandatory requirement to undertake a detailed risk assessment to determine the level of mitigative actions required.

In view of the lack of specific legislation in the majority of Europe outside the 12nm limit, our considered opinion is that European Union (EU) law, specifically that concerned with the protection of workers from work-place hazards, will apply in a similar way to the UK.

In practice the regulations below impose a responsibility on the construction industry to ensure that they discharge their obligations to protect those engaged in ground engineering operations (such as cable installation) from any reasonably foreseeable UXO risk.

- The Health & Safety at Work Act (1974) - The Act places a duty of care on an employer to put in place safe systems of work to address, as far as is reasonably practicable, all risks (to employees and the general public) that are reasonably foreseeable.
- Construction Design and Management (CDM) Regulations (2007) - This legislation defines the responsibilities of all parties (primarily the Client, the CDM Coordinator, the Designer and the Principal Contractor) involved with works.
- Corporate Manslaughter and Corporate Homicide Act (2007) - This Act now enables the prosecution of companies (and other organisations) where there has been a gross failing, throughout the organisation, in the management of health and safety with fatal consequences. If UXO causes a fatality and there has been a gross failing, the act will apply.

9.2 ALARP

Many regulatory authorities, including the UK's Health & Safety Executive (HSE), require that operational risks should be within acceptable limits and be deemed “as low as reasonably practicable" (ALARP), this is also the case with UXO.

Determining that UXO risks have been reduced to ALARP involves an assessment of the UXO risk to be avoided, an assessment of the effort (in terms of money and time) involved in taking control measures to avoid or mitigate that risk, and a comparison of the two facets. The graph at *Figure 9.1* demonstrates how ALARP is measured.

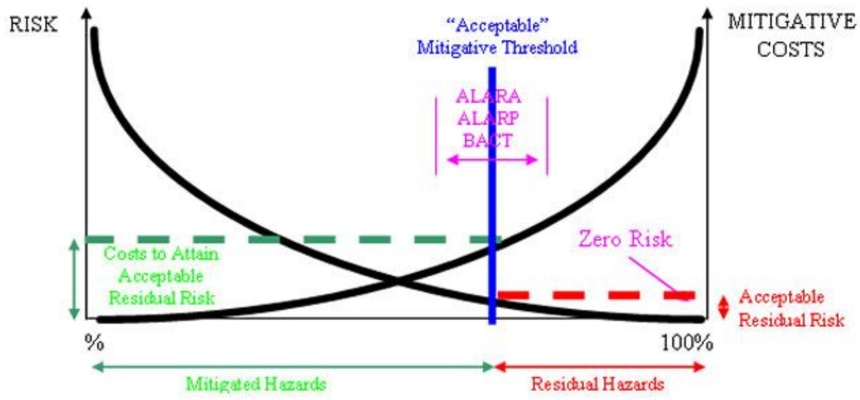


Figure 9.1 - Determining risk are ALARP by measuring Cost versus Effort (Reference - Riskope http://infocenter.oboni.net/tolerability.php)

To demonstrate that risks are ALARP, a suitably qualified entity (usually a UXO specialist) must show that enough has been done to reduce risks. In cases where the risks are well-defined, it is sufficient to show that recognised "good practices" have been implemented. In more complex situations, i.e. where the industry or technology is new, to demonstrate risks are ALARP, one should show that all reasonably practicable risk reduction measures have been implemented, and that all other measures that could be implemented are shown to be unjustified.

Risk criteria may be defined by national regulations, corporate guidance and well-established industry standards.

Developers and principal contractors retain overarching responsibility for UXO (and other) safety systems on the project. Typically as there is a lack of direct legislation, these parties will rely on UXO specialists to ensure that UXO risks to the project, equipment and personnel are deemed to be ALARP.

9.3 Best Practice for UXO Risk Management

Through previous engagement on renewable projects in the UK and Europe, Ordtek is acutely aware of the standards and guidance that needs to be adhered to when managing UXO risk. This includes working in line with the guidance and research provided by the Health & Safety Executive (HSE) and other National suppliers of best practice.

- Construction Industry Research & Information Association (CIRIA) – UXO A Guide for the Construction Industry (reference number C681)
- Maritime and Coastguard Agency (MCA)
- British Marine Aggregate Producers Association (BMAPA)
- Health & Safety Executive (HSE)

However where no official guidance exists (i.e. such as addressing risk in the offshore environment), Ordtek will work within its proprietary framework (see *Figure 9.2*) and Standard Operating Procedures (SOPs).

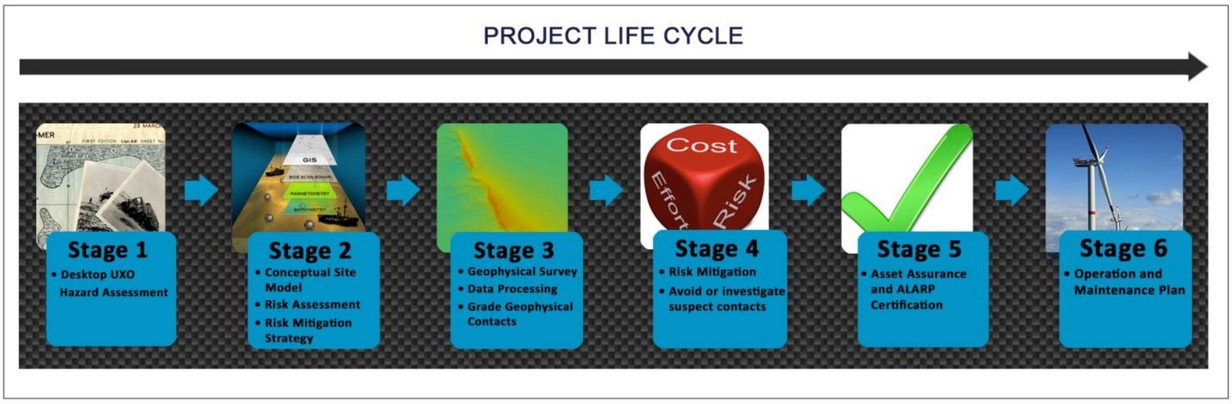


Figure 9.2 - Ordtek's UXO Risk Management Framework

10 Strategic Risk Management

10.1 Overview

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

- Accepted by all parties and no further proactive action is taken
- Avoided by not undertaking the activities at risk
- 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 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 development ranges from Low to Moderate and that mitigation is required to reduce the risk to ALARP. To achieve this standard a geophysical survey should be undertaken to identify large NEQ items of UXO, while the smaller UXO may be dealt with by reactive mitigative measures adopted during the installation phase of the project.

It should be considered that the risk from UXO could never be considered "zero" in the offshore environment, as there is always the potential for UXO migration through natural sedimentation and transportation.

11 Recommended Risk Mitigation Strategy

11.1 Survey Rationale

The smallest significant hazard item identified from the historical research is the German WWI Type II moored contact mine. In order to mitigate the risk of encountering this item (and larger items of UXO), we recommend that a "UXO specified survey" is undertaken. This includes coverage of areas where interaction with the seabed is expected during project development activity.

11.2 Geotechnical Investigation and Benthic Sampling

Ordtek has been informed that the ground investigation will comprise core samples and CPT from a dynamically positioned (DP) vessel. In addition benthic grab sampling will be undertaken across the site. Ordtek have studied the geophysical data acquired by MMT in 2013 and it is considered to be of sufficient quality to mitigate the UXO risk ahead of these specific investigative activities. The MBES and SSS is high quality and will allow recognition of potential hazard items on the seabed. Even though the magnetometer data was acquired at relatively low resolution, it is adequate for mitigation at this stage.

In light of this review, the developer and its contractors should adopt the following cascading procedure to mitigate the risk:

- Stage 1 - Grade the geophysical anomalies and identify those that are Potentially UXO.
- Stage 2 - Assign a suitable safety distance around the "Potential UXO" anomalies. Any anomalies that model as UXO, should be avoided by a sufficiently safe distance.
- Stage 3 - All exploratory positions should be relocated on geophysical survey lines and grab samples should be taken where there is full data coverage.
- Stage 4 - For due diligence purposes, an ALARP certificate should be issued to the geotechnical contractor to evidence the risk management process and highlight any operational constraints.

11.3 Offshore Construction Phase – Anchor Handling and Cable Installation

11.3.1 Geophysical Survey

Ordtek recommends, as with best practice, that a suitability specified geophysical survey is conducted ahead of the engineering layout, together with a suitable working space (for jack up barges for example). Any geophysical anomalies modelling as the potential UXO hazard items should then be highlighted for further consideration.

The output from the 2013 geophysical survey indicates a challenging environment to identify UXO using acoustic solely methods of detection. For example mega-ripples are present that have the potential to bury UXO. In addition numerous boulders are recorded which will may have the characteristics of UXO in both SSS and MBES datasets. Therefore for cable installation a magnetometer survey should be specified along the final route to cover where the cable will be installed.

11.3.2 Geophysical Anomaly Management - Design Engineering Stage

Any geophysical anomalies that are not definitively confirmed as UXO, can be avoided by a suitably safe distance, making the assumption that the item remains stable and will not be disturbed. In accordance with the ALARP principle, the installation could then proceed with a *de minimis* risk of encountering UXO. However notice should be given to the safety exclusion zones around the geophysical contacts. Unless these contacts are investigated and confirmed as not UXO related, they should be considered a potential hazard.

11.3.3 Offshore UXO Risk Management

To conform with best practice, installation contractors should also adopt the following UXO risk management and mitigation actions:

- Obtain the ALARP sign-off certificate for each installable asset. Input the geophysical contacts to be avoided into the on-board navigation system.
- Establish the location of known wreck sites especially those highlighted in this desk study. Avoid these locations by at least 100m.
- Ensure the project team are aware of their internal UXO policy including key support numbers
- Hold a copy of this risk assessment on-board the vessel.
- Brief all personnel on the potential UXO risk.
- Hold a UXO specialist on-call in the event of a suspect item being discovered unexpectedly.

11.4 Operation and Maintenance of the Wind Farm

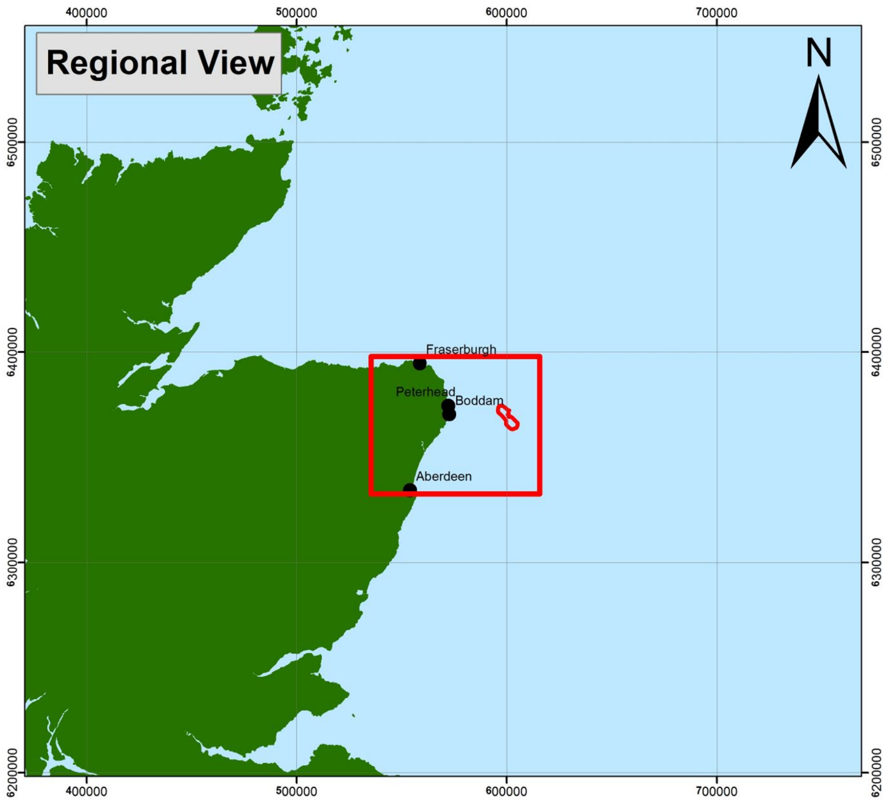
Given the degree and potential for UXO contamination on this project, it is considered possible that munitions may migrate within the boundary of the site once the wind farm is operational. Depending on the degree of maintenance work and the time lapsed from the original geophysical survey there may be the requirement for additional risk mitigation. However this will need to be evaluated on an individual basis.

Should items (or suspect items) of UXO be encountered during any upgrade and/or maintenance work, specific risk management advice must be sought and implemented to address this potential risk. In such circumstances the developer should consult a UXO specialist to conduct a risk assessment and explore the options available for disposal. There are too many variables involved in such a scenario to make a rigid strategy at this stage.

ORDTEK

Appendix 1

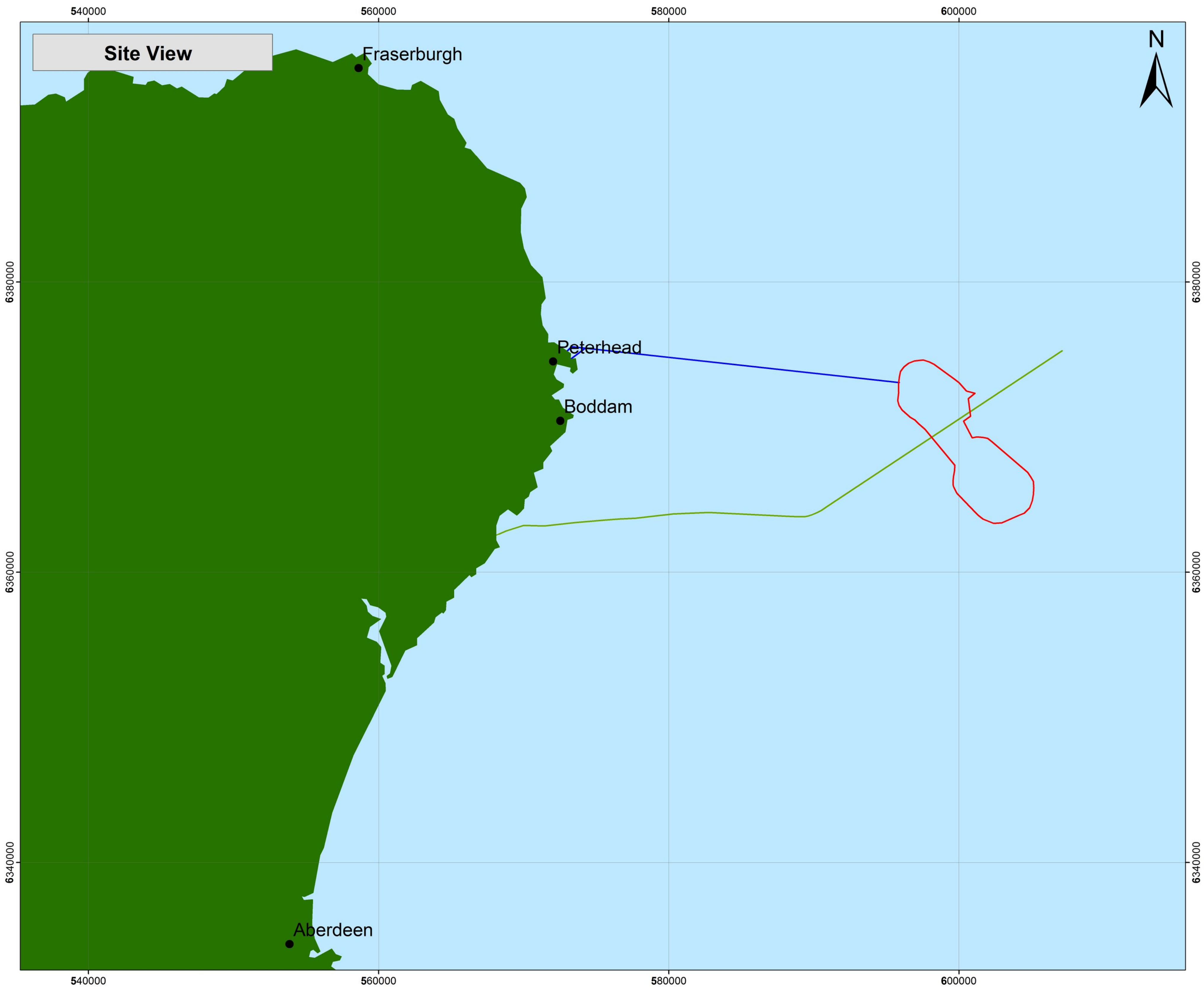
Hywind Scotland Offshore Wind Farm Location



Legend for Site View

Red box	Hywind Survey Area
Blue line	Approximate Export Cable Route
Green line	Forties to Cruden Bay Oil Pipeline

0 2,500 5,000 10,000 15,000 20,000 Meters



Consultant

ORDTEK — Excellence in Unexploded Ordnance Risk Management

Developer

xodus GROUP

Statoil

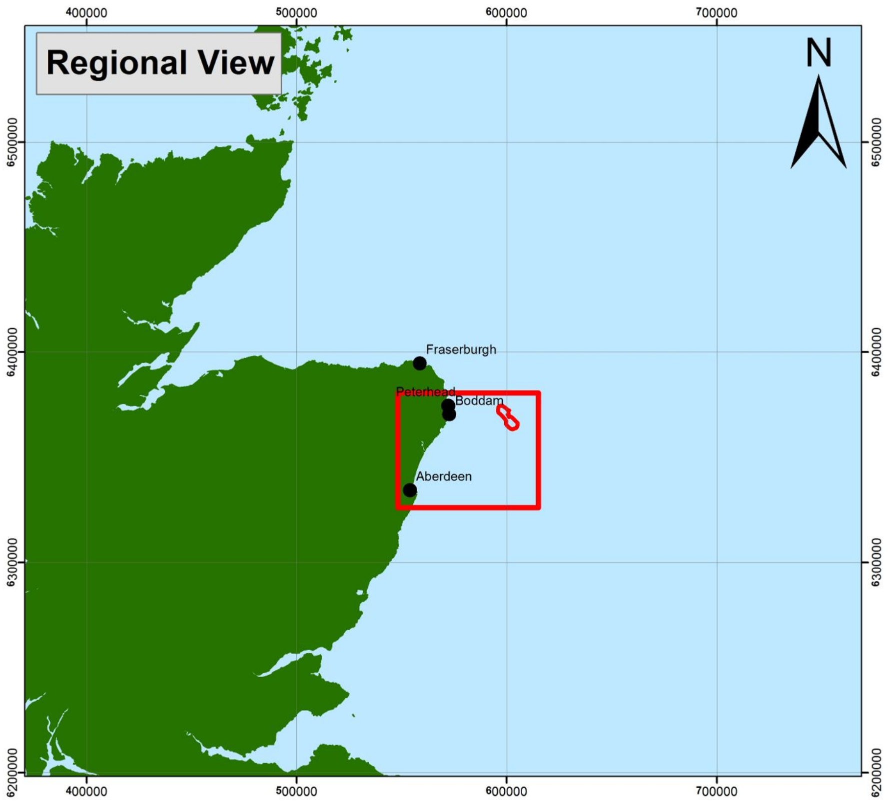
Drawing Title

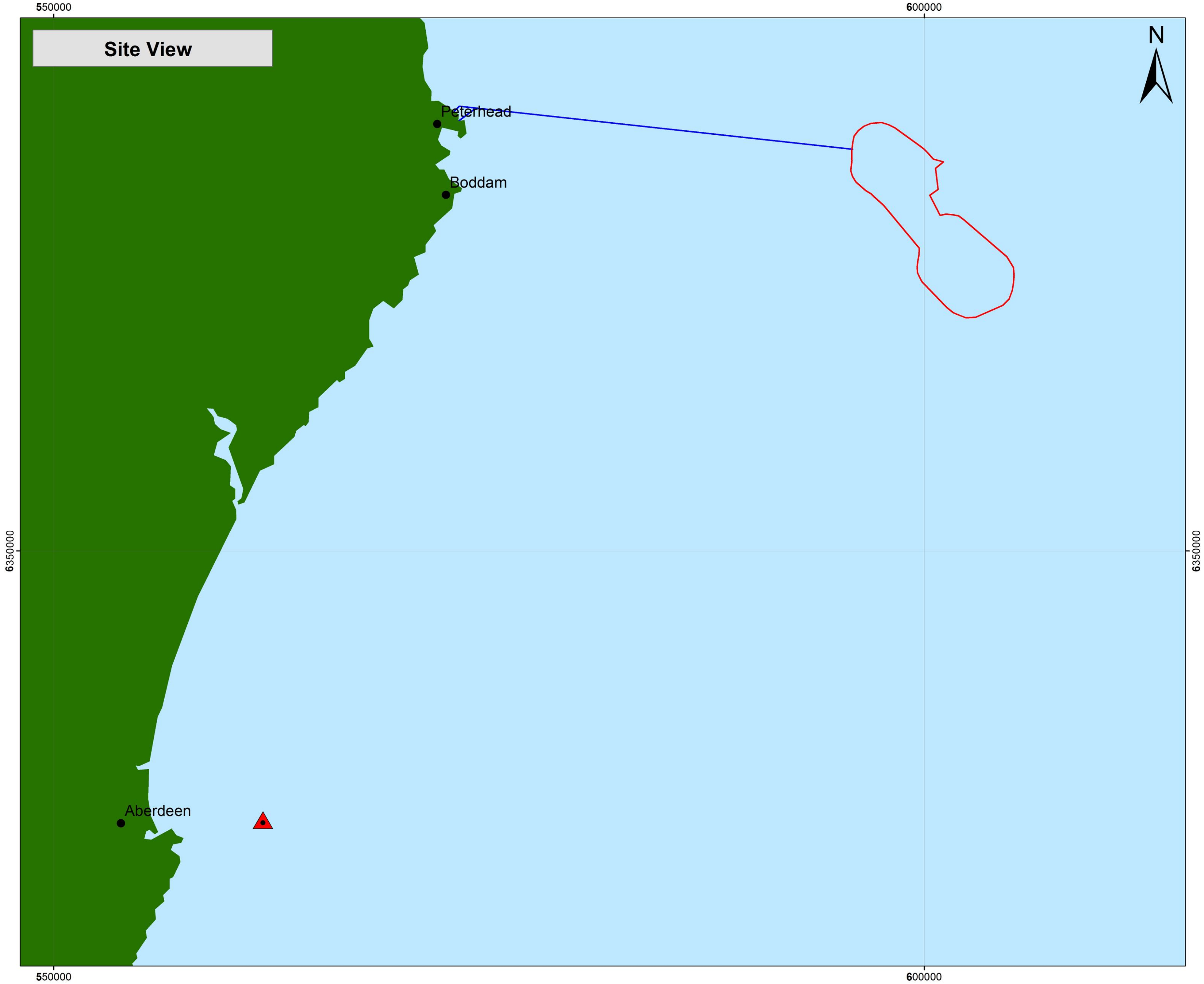
Hywind Offshore Wind Farm Site Location

Projection: UTM Zone 30N Geodetic Datum: WGS84	Hywind Offshore Wind Farm	
	Drawn By: KA	Checked by: AC
JM5035 - 01	Date: 3rd July 2013	Version 1.0

Appendix 2

Munitions Dump Sites





Legend for Site View

Hywind Survey Area

Approximate Export Cable Route

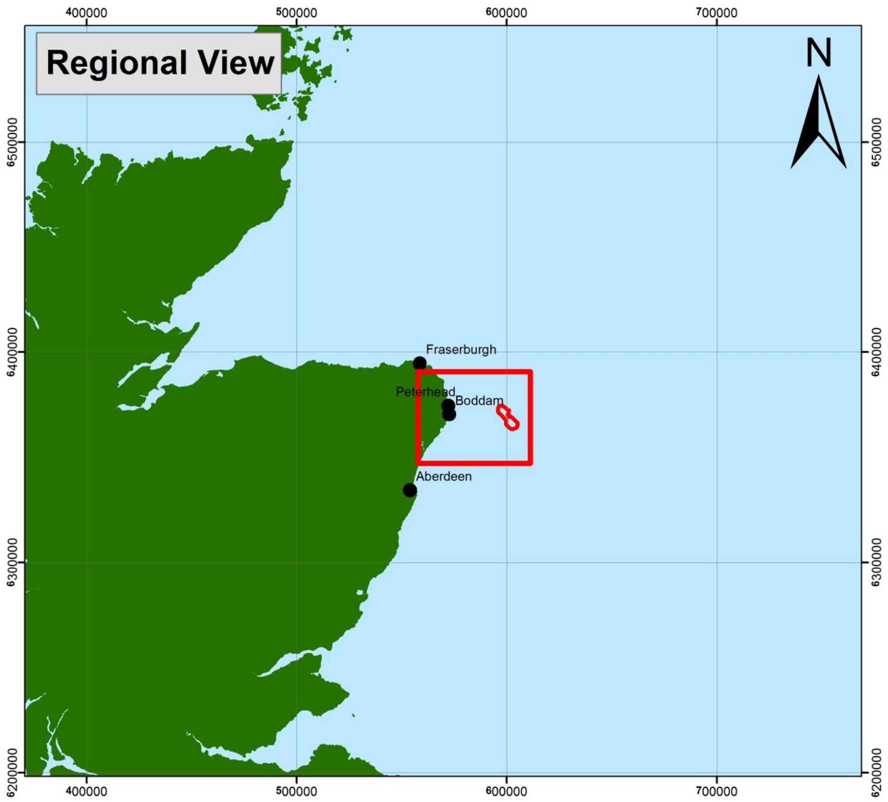
East of Aberdeen Munition Dump Site

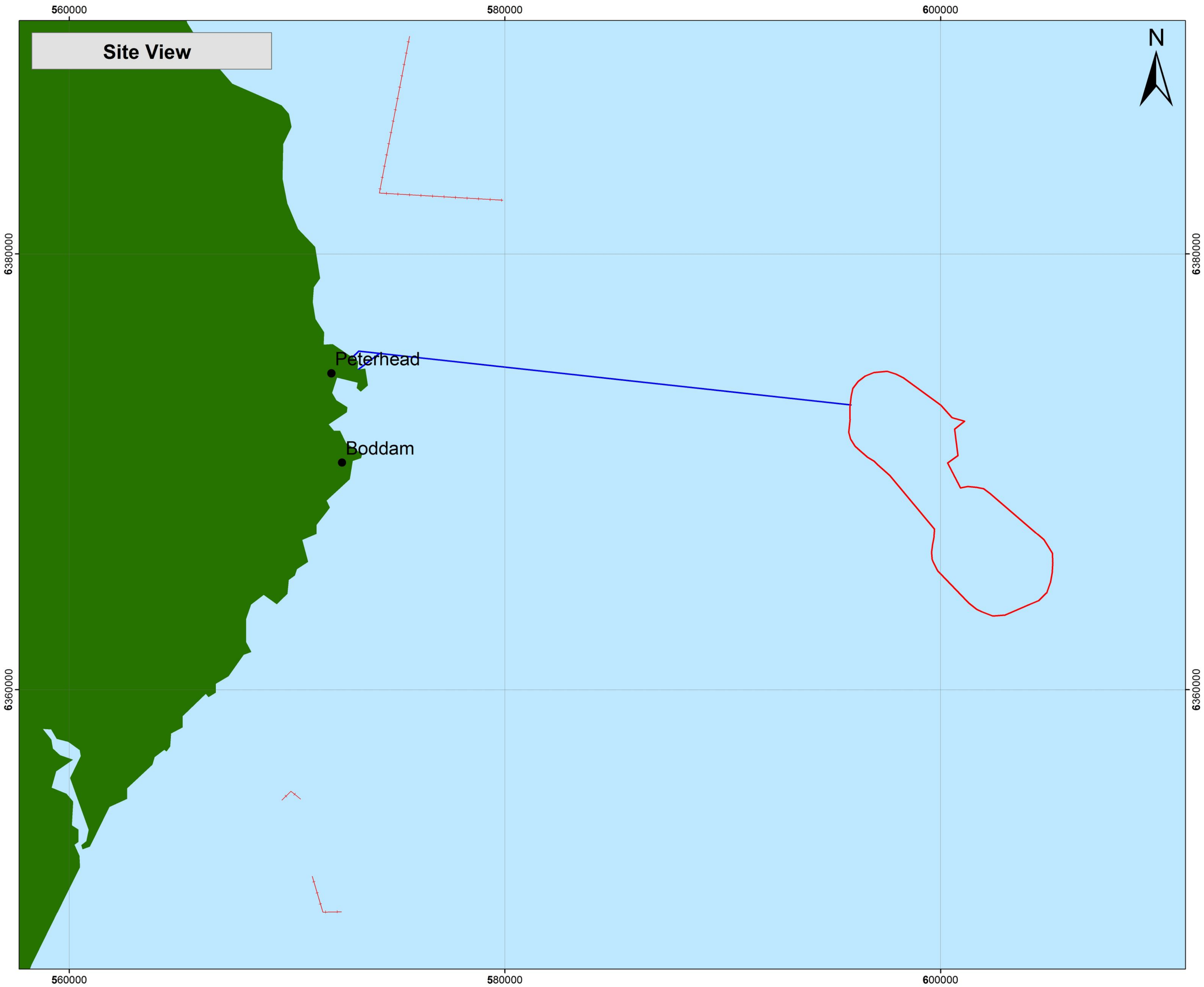
0 2,500 5,000 10,000 15,000 20,000 Meters

Consultant	Developer	Drawing Title	Projection: UTM Zone 30N Geodetic Datum: WGS84	Hywind Offshore Wind Farm	
ORDTEK Excellence in Unexploded Ordnance Risk Management	xodus GROUP Statoil	**Hywind Offshore Wind Farm Munition Dump Site**		Drawn By: KA	Checked by: AC
			JM5035 - 02	Date: 3rd July 2013	Version 1.0

Appendix 3

German WWI Minefields





Legend for Site View

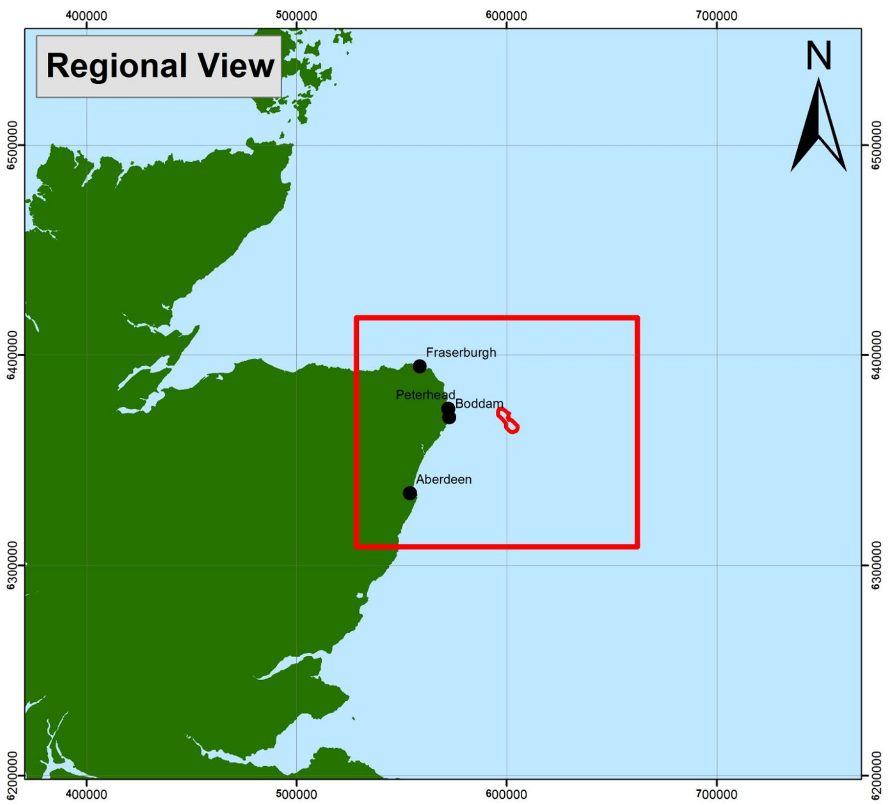
- WWI German Mine Lays
- Hywind Survey Area
- Approximate Export Cable Route

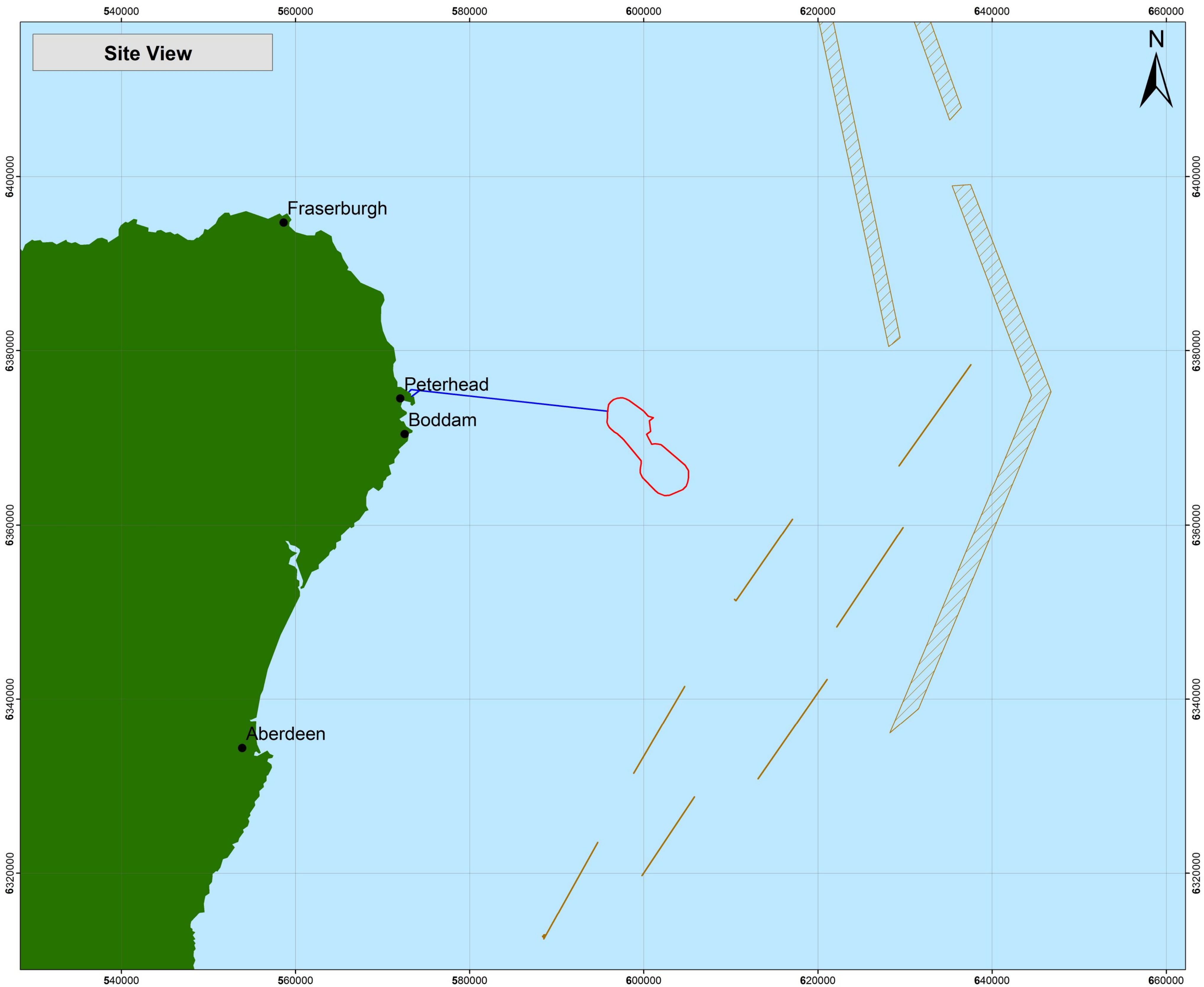
0 2,500 5,000 10,000 15,000
Meters

Consultant	Developer	Drawing Title			
ORDTEK Excellence in Unexploded Ordnance Risk Management	xodus GROUP Statoil	**Hywind Offshore Wind Farm** **WWI German Mines**	Projection: UTM Zone 30N Geodetic Datum: WGS84	Hywind Offshore Wind Farm	
				Drawn By: KA	Checked by: AC
			JM5035 - 05	Date: 3rd July 2013	Version 1.0

Appendix 4

British WWII Minefields





Legend for Site View

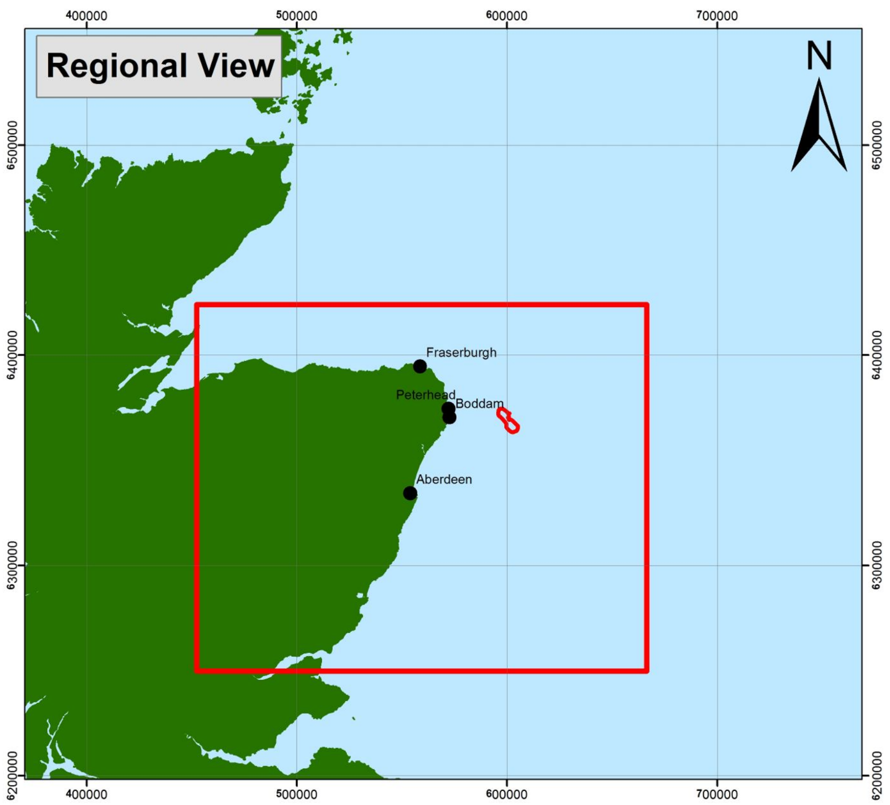
- Hywind Survey Area
- Approximate Export Cable Route
- WWII British East Coast Mine Barrier - Shallow Mines
- WWII British East Coast Mine Barrier - Shallow Mines

0 5,000 10,000 20,000 30,000 40,000
Meters

Consultant	Developer	Drawing Title		
ORDTEK Excellence in Unexploded Ordnance Risk Management	xodus GROUP Statoil	**Hywind Offshore Wind Farm WWII British Mines**	Projection: UTM Zone 30N Geodetic Datum: WGS84	Hywind Offshore Wind Farm
				Drawn By: KA / Checked by: AC
			JM5035 - 03	Date: 3rd July 2013 / Version 1.0

Appendix 5

Modern Military Training and Exercise Areas



Legend for Site View

Hywind Survey Area

Approximate Export Cable Route

Modern Military Training and Exercise Areas

Firing Range

0 10,000 20,000 40,000 60,000 Meters

Consultant	Developer	Drawing Title		
ORDTEK Excellence in Unexploded Ordnance Risk Management	xodus GROUP Statoil	Hywind Offshore Wind Farm Modern Military Training & Exercise Areas	Projection: UTM Zone 30N Geodetic Datum: WGS84	Hywind Offshore Wind Farm
				Drawn By: KA / Checked by: AC
			JM5035 - 04	Date: 3rd July 2013 / Version 1.0

Appendix 6

Descriptions of Typical Examples of Threat UXO (Matrix)

We have shown in the main body of the report that the North Sea saw a considerable amount of action over two World Wars, consequently almost any type of EO could be encountered in the area. However, we have also shown that the probability of encountering some is higher than others. The table below shows typical examples of the main items of UXO that might be present within the HWS AOI.

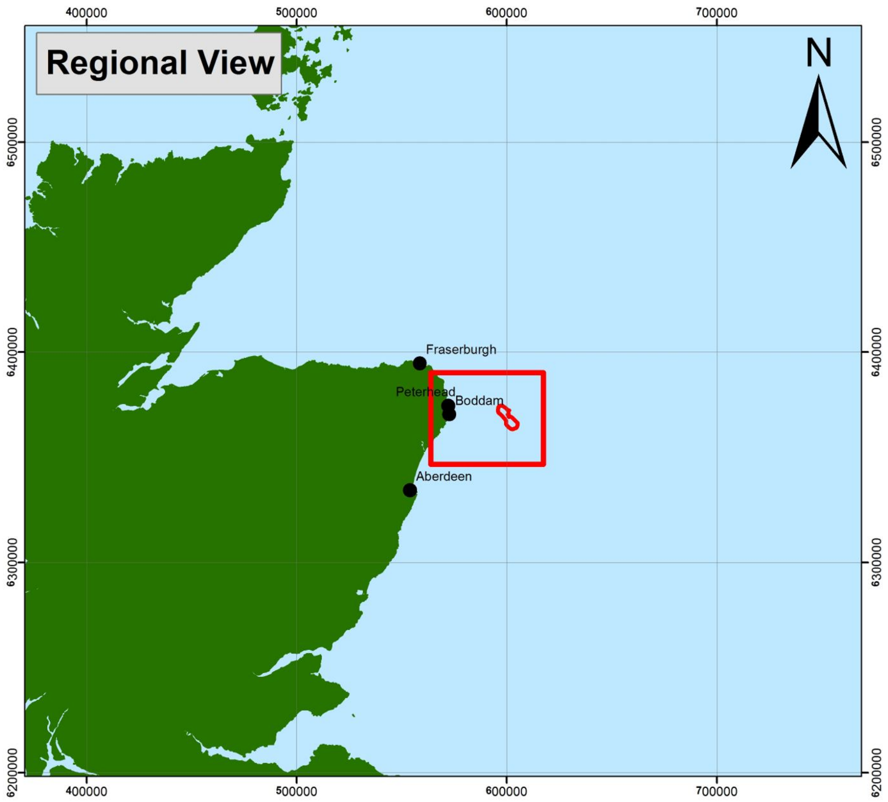
Military Designation	Nationality	Shape	Type	Features	NEQ	Dimensions
Mines						
Type II	German	Ovoid ("egg-shaped")	Moored Contact	Equipped with 5 Hz horns	131kg of wet gun cotton	0.80m diameter
EMA and EMB	German	Ovoid	Moored Contact	Equipped with five Hz Horns. Deployed with base mooring unit. Surface or submarine laid.	163kg or 220kg	Both had similar casing 1.17m long x 0.863m in diameter.
EMC	German	Spherical	Moored Contact	Equipped with seven Hz Horns. Deployed with base mooring unit. Surface laid.	300kg	1.2m in diameter.
UMB	German	Spherical	Moored Contact	Improved moored contact mine with five Hz and three switch horns.	41kg	0.84m in diameter.
Mk XIV	British	Ovoid	Moored Contact	Equipped with 11 mainly Hertz Horns. Used in both WWI and WWII.	145kg or 227kg	1.02m in diameter
Mk XV	British	Ovoid	Moored Contact	Equipped with 11 mainly Hertz Horns. Used in both WWI and WWII.	145kg or 227kg	1.02m in diameter
Mk XVII	British	Ovoid	Moored Contact	Equipped with 11 switch Horns. Used in WWII.	145kg or 227kg	1.02m in diameter

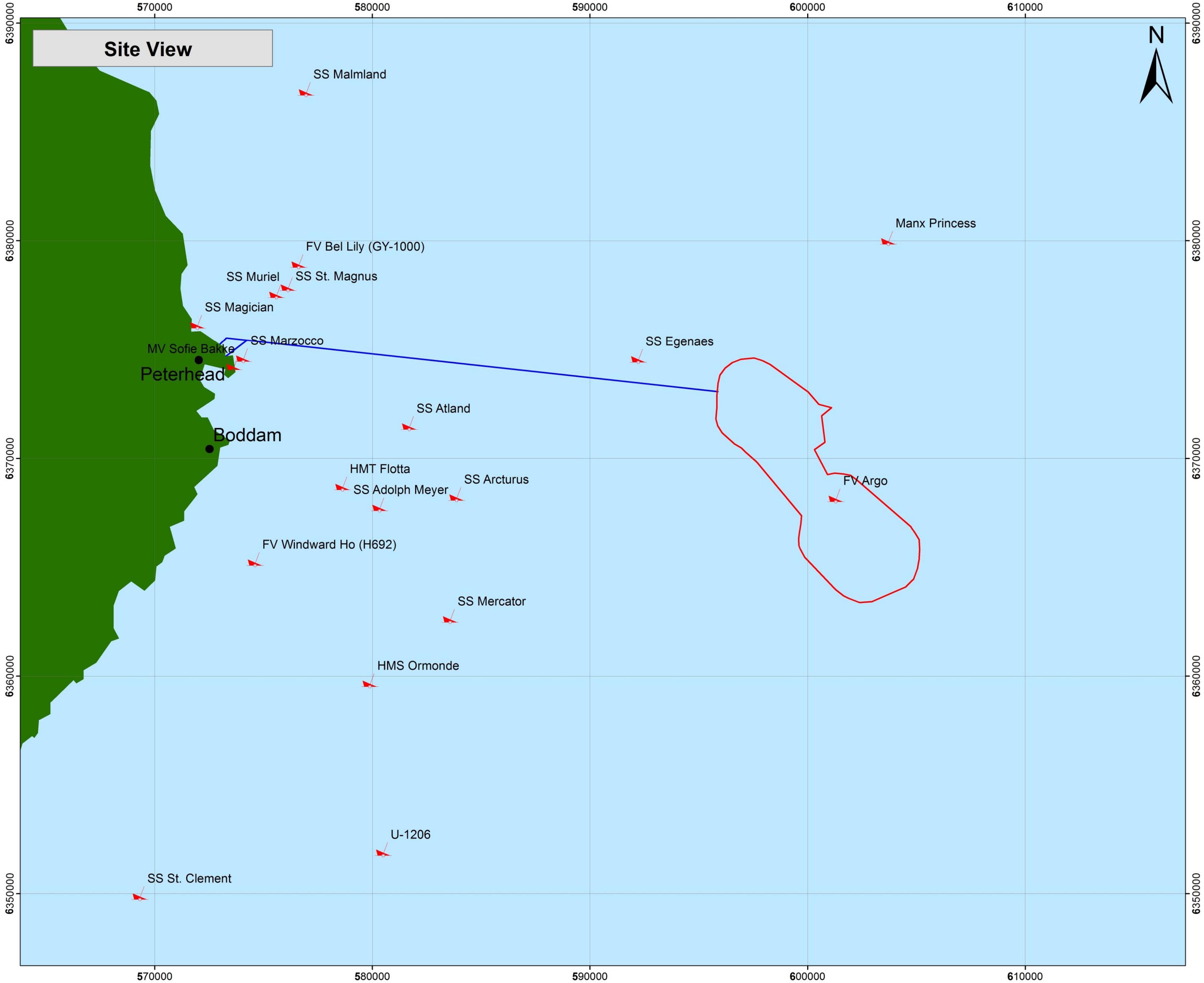
Military Designation	Nationality	Shape	Type	Features	NEQ	Dimensions
Mk XX	British	Ovoid	Moored contact (antenna)	Equipped with 4 switch horns and phosphor bronze antenna	145kg or 227kg	1.02m in diameter
Torpedoes						
Naval Torpedo (multiple combinations of warhead and fusing)	German	Cylindrical	Impact or Magnetic	Some fitted with Whiskers, Wet Heater propulsion	235kg-295kg	21 inch diameter (533mm) Length 7.162m
Luftwaffe Torpedo	German	Cylindrical	Impact or Magnetic	Wet Heater	200kg	45cm diameter Length 4.8m
Torpedo MkVIII	British	Cylindrical	Impact or Magnetic	Air/Steam powered	340kg or 365kg	21 inch (533mm) diameter Length 6.579m
Torpedo MkXII	British	Cylindrical	Impact	Air/steam powered	176kg	45cm diameter Length 4.95m
Bombs						
500lb MC Bomb	British	Parallel sides with ogival nose	Impact/delay	Tail or Nose pistol or fuse	95kg, 100kg, 105kg	Diameter 32.7cm Body Length 1.041m
1000lb MC Bomb	British	Parallel sides with ogival nose	Impact/delay	Tail or Nose pistol or fuse	215kg, 226kg, 238kg	Diameter 45cm Body Length 1.33m
500lb MC	US	Parallel sides with ogival nose	Impact/delay	Tail or Nose pistol or fuse	126kg	Diameter 0.36m Body length 1.2m
1000lb MC	US	Parallel sides with ogival nose	Impact/delay	Tail or Nose pistol or fuse	260kg	Diameter 0.48m Body length 1.37m
250kg SC	German	Parallel sides with ogival nose	Impact/delay	Transverse fusing	130kg/145kg	Diameter 0.368m Body length 1.2m

Military Designation	Nationality	Shape	Type	Features	NEQ	Dimensions
500kg SC	German	Parallel sides with ogival nose	Impact/delay	Transverse fusing	220kg	Diameter 0.46m Body length 1.45m

Appendix 7

Military Related Wrecks





Legend for Site View

Hywind Survey Area

UXO Related Wrecks

Approximate Export Cable Route

0 2,500 5,000 10,000 15,000 Meters

Consultant	Developer	Drawing Title		
ORDTEK Excellence in Unexploded Ordnance Risk Management	xodus GROUP Statoil	**Hywind Offshore Wind Farm Military Related Wrecks**	Projection: UTM Zone 30N Geodetic Datum: WGS84	Hywind Offshore Wind Farm
				Drawn By: KA / Checked by: AC
			JM5035 - 05	Date: 3rd July 2013 / Version 1.0