moray offshore renewables ltd

Environmental Statement

Technical Appendix 5.8 A - UXO Threat and Risk Assessment

Telford, Stevenson, MacColl Wind Farms and associated Transmission Infrastructure Environmental Statement

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APPENDIX 5.8 A

Final Version 2.0

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Appendices and Annexes

Appendices

Acronyms and Abbreviations

ALARP	As Low As Reasonably Practicable
CIRIA	Construction Industry Research and Information Association
BD	Bomb Disposal
BDO	Bomb Disposal Officer
BMAPA	British Marine and Aggregate Producers Association
dGPS	Differential Global Positioning Systems
EO	Explosive Ordnance
EOD	Explosive Ordnance Disposal
ERW	Explosive Remnants of War
GIS	Geographical Information System
HE	High Explosive
HMX	High Molecular (mass) RDX
HSE	Health and Safety Executive
IB	Incendiary Bomb
JSEODOC	Joint Service Explosive Ordnance Disposal Operations Centre
KHz	Kilohertz
Kg	Kilogram
Km	Kilometre
lb	Pound (weight)
LSA	Land Service Ammunition
M	Metres
MCM	Mine Countermeasures
MDA	Mine Danger Area
MCA	Maritime and Coastguard Agency
MoD	Ministry of Defence
MORL	Moray Offshore Renewables Ltd
mm	Millimetres
NaREC	New and Renewable Energy Centre
NEQ	Net Explosive Quantity
NGR	National Grid Reference

Nm	Nautical Mile
RDX	Research Department (composition) ‘X’
ROV	Remotely Operated Vehicle
RN	Royal Navy
QA/QC	Quality Assurance/Quality Control
SAA	Small Arms Ammunition
SI	Site Investigation
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

Executive Summary

Purpose

Items of Unexploded Ordnance (UXO) are regularly encountered along the northern coast and rarely become inert or lose their high explosive effectiveness with age. There is therefore, a risk that UXO could be encountered at the Moray Firth Offshore Wind Farm.

Cathie Associates Limited (Cathie Associates), on behalf of Moray Offshore Renewables Ltd (MORL), has commissioned 6 Alpha Associates Limited to conduct a detailed UXO desk based study for this wind farm development.

Aim and Objectives

The aim of this document is to address the initial stages of the UXO risk management process by providing a holistic overview of the UXO threats and risks for both the marine and land components of the entire operation. In commissioning 6 Alpha as the project's UXO consultant, MORL intends to:

- Discharge its duty of care to those involved in the development of the project site;
- Ensure that it takes appropriate "best practice" measures to manage all of the risks posed by the UXO threat;
- Protect the development itself from the risks of UXO blight and in doing so protect its investors, investment and reputation;
- Identify UXO risk areas (subject to available information), in order to avoid or manage UXO risks;
- Procure the most time efficient and cost effective means of managing and mitigating the UXO risk.

Therefore, the report will cross reference and account for relevant statutory instruments *vis-à-vis* UXO risk (with which clients will have to comply), including Heath and Safety at Work legislation as well as the Corporate Manslaughter and Corporate Homicide Act of 2007 and common law liabilities. Additionally, and in particular, the report will explain how and why the Construction Design and Management (CDM) Regulations 2007 apply as does CIRIA's *UXO – A Guide for the Construction Industry*, (the latter providing the first UK "good practice guide", helping developers and the construction industry to deal with UXO).

The report will describe the potential for UXO encounter, the risks that may be posed as a result, as well as how those risks can be reduced to As Low As Reasonably Practicable (ALARP), at best value. In this way we anticipate that MORL will be able to both satisfy and discharge their liabilities concerning corporate governance and UXO risk management through the provision of appropriate levels of project safety.

Land UXO Threat and Risk (Annex A to the main report)

During WWII the study site was mostly devoid of residential or commercial properties and accordingly there were no primary bombing targets. Accordingly there was a very low level of Luftwaffe bombing during WWII. There are only three notable dates where bombing incidence occurred.

Under the threat of German invasion in the summer of 1940, the creation of a defensive 'coastal crust' represented one of the largest construction projects of the war in Britain. Hundreds of miles of beaches were closed to the public and fortified with barbed wire, minefields and gun emplacements. There was one such minefield located to the north of the study site. The northern extent of the minefield was the mouth of the River Wanabech, while the southern boundary is not specified.

When dealing with beach minefields there are a number of inherent concerns by the success of WWII clearance operations. Firstly, the very high rates of clearance during the war may have caused some mines to be missed and secondly, there is commonly a recorded discrepancy in the numbers of mines that were laid to those that were cleared. In many areas along the north east coast these factors have resulted in mines being discovered post WWII.

Across the site the UXO risk profile varies. Moderate Risk has been assigned to the areas of the beach where the minefield was installed. The remaining areas of the site have been assessed as Low Risk.

Marine UXO Threat and Risk

In terms of UXO threat, this report will demonstrate that the UXO threat is primarily the result of munitions and weaponry employed during WWI and WWII; this includes, in priority order: sea-dumped explosives/munitions, shipwrecks and sea mines. The report will summarise this threat and will present a Semi Quantitative Risk Assessment (SQRA) concerning UXO and the effects that they may have upon personnel and the construction work that they are expected to undertake.

Conclusions

The report concludes that whilst there is a risk posed by UXO to the project, the risk level does vary with both the proposed activity and its location within the development zone. Such risks are not uncommon and have been encountered on a high proportion of wind farm developments in the North Sea.

The UXO risks can be managed throughout the construction phase in general (and the foundastion, inter-array and export cable installation phases in particular). By employing the proven risk management techniques, which have been described general (and in section 12.3.2 in particular), those risks can be managed and reduced to ALARP, at best value.

The potential presence of UXO and the associated hazard it might pose should not be considered a barrier to wind farm development.

Land Risk Mitigation Recommendations

6 Alpha have recommended that the following actions are required to address the UXO risk on land:

All Works across the Entire Site

1. Documentary procedures to be taken in the event of a suspicious find;

2. Brief all personnel involved with the intrusive works on the potential risk of an associated UXO discovery.

Eastern Area

1. Non-intrusive magnetometer survey of areas ahead of subsurface construction activities, the whole area does not need to be searched.

2. Avoid or investigate any geophysical anomalies that model as potential items of UXO.

3. If required 6 Alpha can support the project with UXO survey procurement and operational QA/QC. On receipt of satisfactory method statements, technical specifications and results from the survey contractor, 6 Alpha can sign off the works to state that the risk has been reduced to ALARP

Marine Risk Mitigation Recommendations

6 Alpha have therefore recommended that the following actions are required to address the UXO risk. This table should be read in conjunction with the "probability of UXO encounter map" at *Appendix 11*.

UXO Probability Encounter Rating	Grading	Action Required ahead of Intrusive Works	Associated Additional Costs Low → High
1-2	**Remote - Possible**	Areas defined as "background residual risk". Use, wherever possible, existing geophysical datasets for UXO risk reduction. Define smallest UXO threat items, interpret the datasets for contacts similar to UXO and avoid during future works. **6 Alpha Deliverable** - Client's must accept that this is not a 100% survey coverage for UXO, although if conducted by 6 Alpha the risk will be reduced to ALARP.	
3-4	**Likely - Highly Likely**	Areas which display a specific significant threat, there are three options for dealing with the risk in these areas: • **Option 1** - Conduct a UXO Specific Geophysical Survey and avoid targets. This survey should be designed to match the defined UXO threat and provide 100% coverage of specific threat area; • **Option 2** – Relocate works to areas with a grading of 1 or 2; • **Option 3** – If target avoidance not possible conduct either diver investigation or ROV inspection, which may discount the item or lead to UXO disposal. **6 Alpha Deliverable** - Once the UXO risk reduction actions have been successfully implemented and subject to our own QA/QC measures, 6 Alpha will sign-off the UXO risk as ALARP.	
5	**Almost Certain**	6 Alpha would strongly suggest avoiding these areas, and relocation work. As the costs associated reducing the risk to ALARP are likely to be considerable.	

1 Introduction

1.1 Overview

Cathie Associates Limited (Cathie Associates), on behalf of Moray Offshore Renewables Ltd (MORL), has commissioned 6 Alpha Associates Limited (6 Alpha) to conduct a detailed Unexploded Ordnance (UXO) desk based study for the Round 3 – Zone 1, Moray Firth Offshore Wind Farm (the project's location is depicted at *Appendix 01*).

Items of UXO are regularly encountered along the northeast coast, as has been confirmed by a variety of Royal Navy clearance tasks and associated media reports. UXO rarely becomes inert or loses its effectiveness with age. Over time, trigger mechanisms (such as fuzes and gaines) can become more sensitive and therefore more prone to detonation. This applies equally to items that have been submersed in water and/or lodged within the seabed. It is possible that the generation of significant kinetic energy over a short duration, which might be created by marine engineering (such as site investigation boreholes, foundation installation or cable trenching), could cause an inadvertent detonation of sensitive UXO.

In order to enable early site investigation works to be undertaken, 6 Alpha have already delivered two abbreviated UXO Risk Assessment reviews (which were dated on 2nd and 13th November 2010), ahead of this formal threat and risk assessment. The purpose of this document is to address Stage 2 of the overarching UXO Marine Risk Management process by providing a holistic overview of the UXO threats and risks for the entire marine component of the operation. This includes employing background research and factual data, which has been provided *inter alia* by (client engaged) third parties, and upon which we have relied.

1.2 Background

In commissioning 6 Alpha as the project's UXO consultant, MORL intends to:

- Discharge its duty of care to those involved in the development of the project site;
- Ensure that it takes appropriate "best practice" measures to manage all of the risks posed by the UXO threat;
- Protect the development itself from the risks of UXO blight and in doing so, protect its investors, investment and reputation;
- Identify UXO risk areas (subject to available information), in order to avoid or manage UXO risks;

- Procure the most time efficient and cost effective means of managing and mitigating the UXO risk.

2 Report Methodology

2.1 Structure

This study consists of a desk-based collation and review of readily available documentation and records relating to the possibility of encountering UXO and/or dangerous Explosive Ordnance (EO) related paraphernalia, within the study area. This study methodology is based on best practice for UXO risk assessment.

Certain information obtained by 6 Alpha may be either classified or restricted material, or may otherwise be considered confidential to 6 Alpha. Therefore summaries of such information have been provided. Please note that our appraisal partly relies on the accuracy of the information contained in these and other third party documents and that 6 Alpha will, in no circumstances, be held responsible for the accuracy of such third party information or data supplied.

In agreement with Cathie Associates, the following facets will be covered within this report:

- The entire scope of the proposed wind farm project has been considered;
- All sources of potential UXO threat will be considered including those within and outside of the concession boundary, because UXO outside of the boundary can migrate (though the action of tides and currents) into it;
- The history of the region has been considered, incorporating data from the abbreviated UXO Risk Assessment reviews;
- Relevant modern military records have been researched and presented;
- Wartime activities have been researched and presented;
- The holistic UXO threat has been considered, including the types that could be encountered, the probabilities of encountering them as well as exposing their potential mechanisms and risks of detonation;
- An outline assessment of how UXO interacts with the natural environment and conditions has been made;
- The risks regarding UXO have been assessed;
- A semi-quantitative risk assessment (SQRA) has been undertaken employing 6 Alpha's "Azimuth ©" proprietary risk model;
- The consequences of an inadvertent High Explosive (HE) detonation has been considered;

- Conclusions have been drawn;
- Recommendations, and an overview risk mitigation strategy has been presented.

The detailed UXO risk assessment for the landfall element of the export cable has not been commissioned however 6 Alpha can provide that in the form of a separate off-the-shelf study (see www.6alpha.com/bombsearch).

2.2 Sources of Information

The sources of information consulted for this report include:

- Royal Navy (Northern Diving Unit), Scotland;
- The National Archives, Kew;
- Naval Historical Centre, Portsmouth;
- UK Hydrographic Office, Taunton;
- 6 Alpha's "Agility Database ©" which contains historic maps, aerial photographs and records;
- Development boundary supplied by Cathie Associates.

2.3 Standards, Guidance and Best Practice

In producing this document 6 Alpha has consulted the most relevant published guidance and best practice. It should be noted that some of these sources may *prima facie*, not appear to be distinctively relevant to this project/study but, in the absence of specific guidance concerning the management of UXO for the offshore renewable industry, the following sources of guidance are considered most applicable:

- 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).

2.4 Joint Service Explosive Ordnance Disposal Operations Centre, UK

According to Joint Service Explosive Ordnance Disposal Operations Centre (JSEODOC – collocated with one of the British Army's Bomb Disposal Regiments at Didcot, Oxfordshire), UXO discovered during wind farm related operations have presented a problem in the recent past. However, and as yet, there is no clear guidance as to what actions should be taken to mitigate the risk nor in what circumstances the Ministry of Defence (MoD) might respond. JSEODOC have in the past, directed 6 Alpha to the BMAPA guidance employed for mitigating UXO risk during dredging operations, although this only partly addresses the UXO risk in a wind farm situation.

In summary the pertinent points gathered from the JSEODOC are:

- There is no legal obligation on the Royal Navy (RN) to respond to UXO incidents outside the UK's 12 nautical mile (Nm) limit;
- Each reported UXO find would be risk assessed on a case by case basis;
- The RN response will depend upon the perceived risk and their commitments to other operations;
- If commercial operations are active in an area where there is a "reasonably foreseeable" risk from UXO, then commercial Explosive Ordnance Disposal (EOD) consultancy and/or contracting support should be arranged. However, in terms of offshore cable laying and foundation installation especially, there is no clear indication as to which areas might have a "reasonably foreseeable" UXO risk. (For dredging operations, by comparison, UXO is (generally), evenly distributed over the seabed and thus the associated risk is often cleared and delivered as part of the operating license.

3 UXO Risk and Legal Position

3.1 Introduction

6 Alpha believe our clients need to have a coherent view of what the law is likely to require concerning potential UXO risk, not only to discharge both statutory and tortuous legal duties, but also to protect those that might exposed to UXO risks in the marine environment.

The consideration of the legal position *vis-à-vis* UXO risk on this project is substantively based upon the principles and guidelines employed to assist the UK's Health and Safety Executive (HSE) in its judgment that duty-holders have to reduce risks to As Low As Reasonably Practicable (ALARP).

6 Alpha's interpretation of the HSE guidelines concerning UXO has not been subject to formal legal scrutiny or any form of legal test, nor has been endorsed (formally or informally) by the HSE. Nonetheless we believe that it is accurate and founded upon significant empirical legal research and UXO project management experience.

Ultimately however, it is for the courts to decide whether or not duty-holders have complied with the law, both national, European Union and/or international. The following legal interpretation, the subsequent UXO risk assessment and associated risk mitigation measures upon which they are founded, aim to discharge legal duties in relation to the ALARP principal in general and its applicability to UXO risk in particular.

3.2 Appropriate Legislation, UXO Guidelines and ALARP Application

In the construction/civil engineering arena (in the UK), relevant statutory instruments (with which clients will have to comply) are in general, likely to encompass Heath and Safety at Work legislation (namely the 1974 Act and 1999 Regulations), as well as the Corporate Manslaughter and Corporate Homicide Act of 2007.

Clients also face a common law liability (for negligence and a potential breach of duty) if reasonable steps are not taken to identify and appropriately ameliorate risk posed by UXO.

Additionally, and in particular, the Construction Design and Management (CDM) Regulations 2007 apply as does CIRIA's *UXO – A Guide for the Construction Industry*, the latter providing the first UK "good practice guide", helping developers and the construction industry to deal with UXO. Whilst CIRIA's guide is concerned with UXO risk on land, the same generic principles apply to construction activities in the marine environment, where 6 Alpha's programme and project managers also have extensive experience.

In terms of dealing with UXO hazards and risks, we believe that by applying broad HSE's guidelines in term of risk assessment, risk treatment and risk management together with our own UXO expertise, enables our clients to comply with UK statutory and common law. In addition, if and when this is employed as a legal and technical benchmark (including outside UK territorial waters or overseas), it is also likely to meet with any other reasonable legislation, guidance and standards that might be encountered.

3.3 Determining that UXO Risk has been reduced to ALARP

Determining that UXO risks have been reduced to ALARP involves an assessment of the **UXO risk** to be avoided, of the **sacrifice** (in money, time and effort) involved in taking control measures to avoid or mitigate that risk, and a **comparison** of the two. A diagrammatic representation for meeting with ALARP is presented at Figure 3.3.

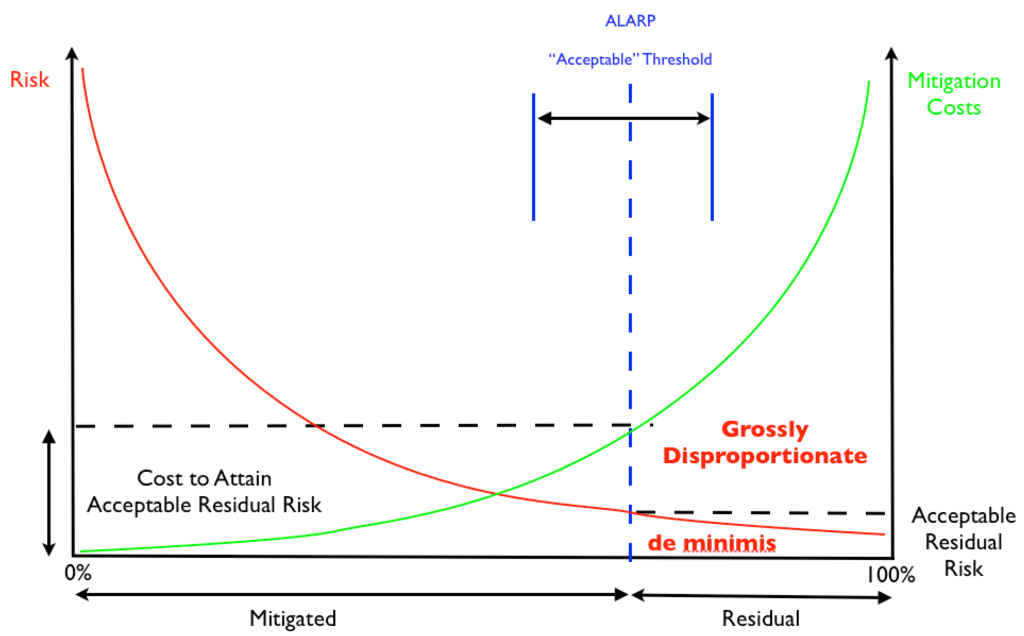

Figure 3.3 – Meeting with the ALARP

This process can involve varying degrees of rigor that will depend on the nature of the UXO hazard, the extent of the risk and the control measures to be adopted. The more systematic the approach, the more rigorous and more transparent it is to any regulator and other interested parties. The greater the initial levels of risk under consideration, the greater the degree of rigor that might be required of the arguments purporting to show that those risks have been reduced to ALARP.

In terms of UXO risk, it is clear that it may present a significant hazard (as death or deaths may be caused), and that the UXO threat should be described and the UXO risk determined in an open, systematic, rigorous, consistent and transparent way. Similarly, risk control measures should therefore be adopted to demonstrate that the risk has been reduced to ALARP, which can, in accordance with the law (be assessed by addressing the UXO risk and sacrifice, and comparing the two).

3.4 UXO Risk Tolerance

6 Alpha have made certain assumptions about MORL and their individual and collective tolerance for the acceptance of UXO risk. Our assumptions include that there are three interrelated elements to be considered:

- **Corporate Governance** – is the system by which companies are managed and controlled. It is assumed that MORL adhere to the highest international standards of corporate governance. Discharge of corporate responsibility is expected to be on risk-based criteria and it is expected that MORL will have in place a framework for managing risk for good governance. It is anticipated that safety and risk management are integrated in the business culture.
- **Risk Management** – MORL will expect the highest standard of risk and safety management to be applied to this project. MORL will have a risk management system in place for responding to business, programme and project risks. Any risks posed by UXO will have to be assessed based upon probability and consequence criteria. High rated UXO risks will have to be avoided or otherwise mitigated not only in accordance with the law but also with best proactive risk management guidelines. MORL will not only rely upon 6 Alpha's professionalism and independence to identify UXO risks but also to design appropriate UXO risk management solutions in accordance with the law in general and the ALARP principle in particular; and to warrant that the UXO risk mitigation contractors responsible for the subsequent execution of those works, perform to appropriate quality and best practice standards.
- **Safety** – we assume that safety will be the highest priority for MORL on this project. Personnel safety will assume the highest priority; the protection and preservation of equipment, property and the environment, whilst highly important, will remain subservient to personnel safety.

4 Moray Firth Offshore Wind Farm

4.1 Background

MORL have been awarded the exclusive rights to develop offshore wind farm sites within the Crown Estate's Round 3 Offshore Wind zone for Moray Firth, (and see Appendix 1), which aims to deliver 1.4 – 1.5GW (target capacity), of offshore wind power.

4.2 Site Definition

The zone is located on the Smith Bank in the Moray Firth, off the northeast coast of Scotland and covers an area of 520 Km^2. It is located approximately 25 km southeast of the Caithness coast and has water depths ranging form 30-60 m.

4.3 Site Considerations

The client has divided the site into two development zones: east and west, (and see Appendix 2).

5 Proposed Intrusive Works

5.1 Marine Site Investigation

As part of the initial concession survey, as is good practice in all offshore renewable projects, geophysical and/or geotechnical work has been undertaken at this development.

5.1.1 Geophysical Survey

In terms of geophysical survey, the methodology generally employs remote and direct sensing (eg swathe bathymetry, sub-bottom profiling (aka “pinger”), and Side Scan Sonar (SSS)), all of which use the reflection or refraction of energy sources to generate data that can be interpreted to provide a “picture” of the seabed. Whilst it might be theoretically possible that some of these energy sources could initiate very sensitive marine explosive ordnance, it is considered practically impossible to do so. Furthermore, there is no evidence of historic UXO in the marine environment (or elsewhere), being initiated by conventional methods of marine geophysical survey.

5.1.2 Geotechnical Survey

Marine geotechnical survey methods (eg Bore-Holing (BH) and Cone Penetrometry (CPT) techniques), employ kinetic energy to invasively penetrate the sea-bed. Such techniques are capable of initiating UXO, especially if it comes in to direct contact wit the leading edge of the equipment.

Similarly, some platforms employed (eg jack-up barges) may deploy legs which also deliver significant kinetic energy and which themselves might also initiate UXO.

5.2 Marine Cable Installation

It is expected that an export cable will connect the wind turbine array to the Scottish mainland; in addition there will be a number if inter array cables between the turbines. Given empirical evidence it is conceivable that potential interaction with UXO may occur during the following installation operations:

5.2.1 Pre-Lay Grapnel Run (PLGR)

PLGRs are used to prove that the route is clear of disused cables or scrap. It will involve towing a heavy grapnel iron(s) along the route and may encounter UXO that is either shallow buried or on the seabed surface. In such circumstances, and depending upon the types of UXO that might be encountered and their position on (or in) the sea bed, the PLGR might be considered as a method of partially ameliorating UXO risk, in advance of subsequent intrusive engineering works (especially cable trenching and foundation installation).

5.2.2 Cable Trenching

Cable trenching is often employed to lay, and to concurrently bury the export cable. Although cable plough will often be preceded by a PLGR, the cable installation operation can be conducted by a variety of installation methodologies, which will be influenced primarily by water depths and seabed conditions. Cable ploughs can generate significant forces, which are considered sufficient to initiate sensitive items of UXO that they encounter directly.

5.2.3 Cable Jetting

Cable jetting is often employed to install inter-array cables, especially where there is a mobile seabed or relatively soft sediment, which would not require a plough to bury the cables. Water jetting is considered a more benign and less aggressive installation methodology (as compared with cable ploughing), and therefore be less likely to inadvertently initiate UXO.

5.2.4 Deployment of Barge Anchors

In areas where the water depth is less than 10m a cable plough may be deployed from a moored cable-laying vessel. Anchors are required to stabilise the vessel and to give it sufficient counter-force to plough in the cable. The anchor spread will facilities this and the anchors will generally be positioned using a tugboat.

5.3 Wind Turbine Installation

5.3.1 Foundations

Although the wind turbine foundation design has not been confirmed at this early stage of the project, they are expected to be either monopiles, suction bucket, gravity base structure, pin piles or similar. Whatever type is selected, a specialist vessel employing significant kinetic energy is usually employed to install them.

Whatever foundation techniques are employed the key factor, concerning UXO risk, is the resultant kinetic energy employed which, regardless of technique, might be sufficient to initiate any UXO in the immediate vicinity.

Once the foundation design has been scoped, perhaps at the conceptual engineering phase 6 Alpha will be in a better informed position to advise about the nature of the potential risks risk that might be encountered and how they might be ameliorated.

5.3.2 Scour Protection Systems

It is expected that the wind turbine foundations will require some form of anti-scour protection system in the form of either static or dynamic rock armour. Rock is usually emplaced after turbine installation works and inter array cabling work is complete. The type and extent of anti-scour protection depends upon the soil and sea conditions and type of foundations employed; other types may be employed that will involve interaction and intrusion into the seabed. Subject to the type and installation method employed and the associated kinetic energy is generated, it might also be considered sufficient to initiate UXO.

6 Sources of UXO Contamination - Marine

6.1 General

6 Alpha have undertaken detailed archive research to support this project, and after analysing the datasets it is envisaged that there are six principle potential sources of UXO contamination that may influence the project, which are presented at Table 6.1.

Study Area	Area Bombed	Axis Minefields	Allied Sea Minefields	Military Training Ranges	Munitions Related Shipwrecks	Munitions Disposal
All Zones	**Yes**; allied aircraft attacked at least one U Boat in the region – but outside of the project boundary - sinking it with depth charges on 26th June 1944. It is known that axis aircraft bombed allied shipping in this region in 1939 and 1940.	**Yes**; mine laying in the region in WWI. HMS Lynx was sunk by an Axis mine in 1915. Axis mine-laying in WWII not recorded; sporadic mine laying by U-Boat and air likely.	**Yes**; 463 mines were laid in WWI (1916) within 20Nm of the site to counter U-Boats. Approx, 5,600 mines were laid in WWII (1940-42) within 30Nm-46Nm of the site to counter U-Boats (and general invasion).	**Yes**; WWII RN, Army and RAF training ranges (torpedoes, AAA and bombing respectively). Current; Army and RAF training ranges (incl. SAA firing; UXO Dmls (latter land); gunnery; missiles; torpedoes; air to air firing.	**Yes**; there are 7 ship wrecks in the region. 6 of them were sunk by either mines, torpedoes; gunfire or bombing. 4 of them are within the site boundary. Once wreck (HMS Lynx) contains some UXO & it is located on the periphery of area.	**Yes**; sea mines were cleared post WWII. It is suspected that some sea mines may remain in place in the general region because clearance techniques were ineffective and uncertain. Mines may have migrated to site.

Table 6.1 – UXO threats to the Study Areas (within 500m of the Site)

The details of all summarised UXO threats are described in detail subsequently.

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6.2 British Military Activities (20th Century to Current)

6.2.1 WWII Armament and Training Areas

The range areas employed in WWII have been geo-referenced from historical data sets; they are presented at *Appendix 03* and summarised in table 6.2.1.

Range Number	Name	Facility	Distance (to the Main Array Site)
N233	Fearn (Sandwick Bay)	Royal Navy - Anti Aircraft Artillery (AAA) - Light	27 Nm (50Km)
N220	Moray Firth North	Royal Navy - Torpedo Running From Aircraft	Encroaches
N229	Moray Firth South	Royal Navy - Torpedo Running From Aircraft	2Nm/4Km
A318	Strathlene Links	Army - (AAA) - Heavy and Light	9Nm/17Km
127A	Spey Bay	RAF - Live Bombing	2Nm/9Km

Table 6.2.1 – WWII Armament Training Areas in Proximity of the Project
(Distances are Approximate and measure to the nearest edge of the concession boundary).

Because of its encroachment into the south-west corner of the main array site, Range N220 is considered potentially significant, because of the threat posed by air delivered torpedoes. Similarly, ranges N229 and 127A are in relatively close proximity (approximately 2Nm/4Km and 5Nm/9Km respectively) and it is considered possible that high NEQ items of UXO may have migrated to site (especially iron bombs from 127A, which is the closest to the periphery of the site). Clearly, the direction of the export cable route may also have a significant bearing upon sorts of UXO threats that might be posed, especially if the route passes through a former armament range.

Generally, the other armament training areas (N233 and A318) are considered less significant sources of threat to the main array site because:

- Most live or practice items are considered too far away (between 17 – 50Km) to have drifted to site in significant numbers;
- Those that might drift are considered to be in sufficiently small numbers to present a low level of threat.
- The ordnance is generally sufficiently small (in terms of NEQ) to present a low level of threat;
- A proportion of UXO that might be generated may be of training (rather than live) natures, thus some may be relatively benign.

6.2.2 Current Armament and Training Areas

The current armament and training areas have been geo-referenced from current data sets; they are presented at *Appendix 04* and summarised in table 6.2.2.

Range Number	Name	Facility	Distance (to the Main Array Site)
X5072	Binhill	Army – Firing	19Nm (35Km)
X5819	Old Wick	Army – Firing	12Nm/22Km
D702	Fort George	Army – Firing & UXO Demolition	40Nm/74Km
DS809(S)	Moray Firth - South	RAF: High and Low Angle Gunnery (ground to ground): Air to Air firing; Air General; Air to Surface Firing; HM Ships: non-firing exercises, practice and trials; Pilotless Target Aircraft; Torpedo Firing.	9Nm/17Km
DS809(C)	Moray Firth - Central	RAF: High and Low Angle Gunnery (ground to ground); Air to Air firing; Air General; Air to Surface Firing; HM Ships: non-firing exercises, practice and trials; Pilotless Target Aircraft; Torpedo Firing.	Encroaches
D712C	Northern MDA	Air Combat Training; High Energy Manouvers.	2.2Nm approx.
D703	Tain	RAF; Practice Bombing (up to 1,000lb); Strafe up to 30mm; Rocket Projectiles; (On Land: Small Arms; General Purpose Machine Gun (GPMG - Sustained Fire); EOD Demolitions).	9Nm/17Km
D807	Moray Firth	RAF: Bombing; Firing; Radar Training Buoy.	Encroaches

Table 6.2.2 – WWII Armament Training Areas in Proximity of the Project
(Distances are Approximate and measure to the nearest edge of the concession boundary).

Because of their significant encroachment into the central region the site D807 and D809S are considered potentially significant, not only because of their encroachment but also because of the threat posed by the employment RAF weapons generally (including gunnery and torpedo firing).

Whilst ranges D809S and D807 have been employed for similar purposes (the former range especially), they are considered sufficiently far enough away to pose a reduced degree of UXO threat (and *de facto* risk).

Clearly, the direction of the export cable route may also have a significant bearing upon types of UXO threats that might be posed by the other ranges in this category, especially as the cable reaches landfall.

6.2.3 Munition / Explosives Disposal

Although both chemical and conventional munitions were extensively dumped at sea off the UK coast following WWI and WWII, our research has not discovered any specific evidence for munitions dumping either within or close to the concession boundary.

Whilst the locations of some of these areas are well known (as are the type and numbers of munitions deposited), in other areas there are problems concerning accuracy of types and numbers dumped. This inaccuracy has been incurred because of a combination of factors including; inadequate record keeping, the dumping of items outside designated official dumping areas; and, to an extent, the movement of munitions post dumping as the result of tidal flow.

6.3 Allied Sea Minefields

A naval mine is a self-contained explosive device placed in the water to destroy ships and/or submarines. They are fused so that they are detonated by the close proximity (or in some cases contact with) a ship. Naval mines can be employed offensively, to hamper enemy shipping and e.g. lock it into it's harbour; or defensively, e.g. to protect Allied shipping and create "safe" movement zones. A figure, showing a range of WWI and WWII "marine UXO threats", including deep sea mines off the Scottish Coast is presented and geo-referenced from historical data sets at Appendix 05 (6 Alpha UK Map).

6.3.1 WWI Minefields

In 1915 the east coast of Scotland was subject to U-Boat attack; natural headlands were a favoured U-Boat hunting ground because such features not only enabled easier navigation but also provided plentiful opportunities to attack unescorted allied shipping. As a result barrier minefields were laid to defend against such attacks.

Records of mine laying from WWI are relatively poor (as compared with the quality and accuracy of those from WWII), but according to official Royal Naval records, in excess of 69,000 British mines were deployed a defensive barrier, in deep water (i.e. between 45ft (13m) and 240ft (73m)), off the Scottish coast (but at distances in excess 35Nm from the project boundary).

Closer to shore (as depicted and geo-referenced from historical data sets at Appendix 06), up to 463 sea mines were laid in June 1916 in three minefields, which were located off Lybster, Tarbtness and Lossiemouth. The WWI minefields are located approximately 10Nm to 20Nm to the west of the concession boundary.

6.3.2 WWII Minefields

As a result of Axis sea mining activity, proposals were made in November 1939 to mine the North Sea. These proposals considered the likely effect on fishing as well as the requirement to provide mine-cleared sea-channels for British, Dutch and Belgian shipping. The WWII minefields are located approximately 30Nm to 46Nm the east of the concession boundary (as depicted and geo-referenced from historical data sets at Appendix 07). In comparison with WWI records the details of mine lays in WWII are more comprehensive, and the details of each mine lay is summarised in *Table 6.3.2*.

Mine Lay Number (Date Month/Year)	Number of Mines (Approx Length)	Mine / Sinker	Depth Below Chart Datum (feet/meters)
PA1A (Jan 1940)	240 (6Nm)	H2/ VIII	78-79 feet (24m)
PA2B (Mar 1940)	330 (8.5Nm)	H2/ VIII	90 feet (27m)
PA3C (Mar 1940)	150 (3.8Nm)	H2/ VIII	90 feet (27m)
PA4D (Mar 1940)	180 (17Nm)	H2/ VIII	86 feet (26m)
SN12 (Aug 1940)	2092 (52Nm)	MXIV/XV & XX/XVII	10-12 feet (4m)
SN15A (Jan 1942)	1778 (45Nm)	XX/XVII	7-11 feet (3m)
SN15B (Jan 1942)	842 (20Nm)	XX/XVII	10 feet (3m)

Table 6.3.2 – WWII Mine Lays in the Moray Firth

6.3.3 Mine Clearance

Historical Admiralty mapping confirms that minefields that had been situated off the north-eastern British coast were cleared post-WWII, and there was a significant sea-mine clearance operation undertaken by both Allied and German Navies, who attempted to clear their respective minefields. Whether all those mines that were recorded as being laid, were *de facto* recovered during clearance, could not be confirmed (it should be noted that 100% clearance of minefields, even with today's technology, is not always achievable).

The clearance operation was undertaken by one of two methods:

- Using two minesweepers, a sweep-wire (with a serrated edge and an “otter” or “kite” to keep the sweep wire at the required depth), was laid into the water and both ends were attached to a winch at the stern of each ship. The sweep-wire was towed by both vessels over a mined area and, when connected to the “mooring stay” of a moored mine, the ships momentum would then force the stay to the serrated edge of the sweep wire, which cut it. The mine would then (usually), float to the surface for disposal;
- An alternative method was to use one ship only with the sweep wire attached to an oropesa float (to keep the sweep wire away from the ships), and the wire would then cut the mooring stay of the mine (as described above). The untethered mine would then (usually) float to the surface for disposal.

6.3.4 Mine Clearance Analysis

Mine disposal was often by rifle fire however, on occasions, the rifle bullet only penetrated the outer casing of the mine, which allowed water to ingress and it would then sink and come to rest on the sea bed; an explosive hazard thus remained. Some historical sources suggest that up to 70% of sea mines were not recovered after WWII; based upon that (worst case) statistic, approximately 340 WWI mines and up to 3,900 WWII mines might not have been cleared.

Whilst wartime sea mines undoubtedly pose a potential residual hazard, it is not possible to say how many - if any - might be located with the concession boundary. Certainly, not all of the mines were laid close to the concession boundary (especially the longer minefield lays i.e. SN15A and SN12, which also contained the highest number of mines). Discounting, for purposes of simple analysis, SN15A and SN12 (which were the furthest away and therefore would have the longest distance to migrate west), then up to 1200 WWII mines, plus 340 WWI mines, - total 1540 mines - may have remained in the region (i.e. up to 30Nm away) post WII clearance.

6.4 Aerial Bombing Campaign

6.4.1 Overview

Limited bombing occurred during WWI, as the main German threat in the marine environment were U-Boats. With the development of aircraft and air delivered weaponry, aerial bombardment became an important phase prior to any possible invasion during WWII. During the early stages of the war, Britain was continuously bombed between 1940 and 1943. Strategic targets along the coastlines of Britain included ports, docks, shipping lanes and power stations.

6.4.2 Shipping Lanes, Sea Convoy Routes and Ports

The east coast ports were important commercially and, as WWII progressed, they achieved strategic importance for the transport of coal, as well as for fishing (which was considered key to helping feed the UK's wartime population). A military lesson learned during WWI was implemented, namely the gathering of merchant ships into convoys for protection. Notwithstanding the Royal Navy's attempts to protect convoys, they were regularly attacked from the air. The Luftwaffe also dropped thousands of HE bombs on these convoys and regularly targeted other vessels as the opportunity arose. Details concerning this site are described more specifically at 6.5 below.

6.4.3 Tip and Run

Given that the RAF occupied a number of airfields in the area during WWII, it is likely that they were attacked and/or that air-to-air battles also occurred over the region. Some of those battles may have which resulted in allied and enemy aircraft jettisoning all or part of their payloads i.e. *inter alia* medium and large capacity, UXBs (a tactic known as "Tip and Run"), either in an attempt to escape their pursuers, or to quickly offload weapons from damaged aircraft, before returning to base. Although records of these events are poor, the threat of encountering jettisoned munitions in the sea must be considered an unquantifiable risk, when assessing the background UXO threat for all areas in the North Sea in general and for the Moray Firth in particular.

6.4.4 Defensive Anti Aircraft Artillery (AAA)

There were two types of AAA battery deployed during WWII; heavy and light. These weapons were deployed on the ranges along the east coast.

Heavy batteries were static and usually sited in the same position for the duration of the war. They deployed either 4.5 or 3.7 inch guns in groups of 2, 4, 6 or 8 guns per battery. Typically heavy battery was divided between two sites each with four guns and up to several miles apart. The 4.5 inch gun could fire a HE shell (weighing approximately 25kg and fitted with either a barometric or time fuze) 8 miles in 50 seconds. The 3.7 inch gun had a similar ceiling height but smaller calibre shell, again with barometric or time fuzes.

The light batteries were deployed with the 40mm Bofors gun. This weapon could fire up to 120 x 40mm HE shells per minute to approximately 6,000ft; the shells were designed to explode on impact with enemy aircraft. These batteries were not static and could be moved easily to new positions by truck when required.

The Royal Navy and Army both had WWII AAA ranges in the region (at Sandwick bay and Strathlene Links respectively), the details of which have been presented separately at paragraph 6.2.2. Given the proximity of RAF and other military bases in the region during WWII, AAA fire will have been directed at Axis aircraft as they approach over land and sea. If AAA shells failed to explode or strike an aircraft they would eventually fall back to land or sea, settling on the seabed in the latter case, presenting a potential UXO hazard

Naval and merchant vessels are also commonly equipped with various types of deck guns to protect themselves against enemy air attack. If projectiles or AAA fire missed the target, then they could fall into the sea (or over land), and may still present a potential UXO hazard.

Records of land and sea based AAA training and defensive activities of this activity are scant and therefore AAA UXO should be considered as a part of the residual "background" UXO risk.

6.5 Shipwrecks / Downed Aircraft

Shipwrecks in the zone indicate/confirm that the following military activity has taken place within the project boundary:

- Aerial bombing;
- Both Allied and Axis sea mine laying;
- Naval combat utilising torpedoes;
- Additionally, the specific deployment of Allied depth charges been recorded outside the project boundary).

Both merchant and naval vessels that were sunk in WWII may have contained munitions. Empirical evidence has shown that munitions did spill from the ships as they sank and subsequently broke-up. Similarly, aircraft that were shot down or otherwise had to ditch into the sea, may have also contained munitions. In general, the risk of munitions contamination is somewhat reduced in the vicinity of wrecks (as compared with munitions dump-sites), because the munitions within the body of wrecks generally remain enclosed and immobile. However, it may be possible that some might have been thrown clear of the vessel as it sank or they could become exposed and migrated as the wrecks gradually broke up.

There are number of wrecks that may potentially impact upon the project; there is specific evidence that 7 ships were sunk by variously, gunfire, bombing, torpedo and sea mines, near the site boundary (3 wrecks are within the boundary and two are on its periphery); their locations have been and geo-referenced from historical data sets and are presented at *Appendix 8*) and they are summarised in table 6.5:

Wreck Name	Date Sunk	Vessel Type	Weapons Employed (to sink vessel)	UXO Threat?
Sunbeam	1915	Sailing/ Transport	U-Boat attack; captured at first instance and sunk by deck gun subsequently	Not Known
SS Minsk	1940	Supply Ship Steamer Transport	U-Boat attack employing torpedo and deck gun	Not Known
HMS Lynx	1915	Her Majesty's Ship Steamer Destroyer	Axis sea mine – broke vessel in two before or during sinking. (Any munitions therefore might have spilled from wreck).	3 No 4 inch guns; AA Gun; 2 No Torpedo Tubes (Number of associated munitions on board - not known)
Active	1939	Fishing Vessel Trawler	Air launched torpedo attack	Not Known
Llanishen	1940	Steamer Cargo	Bombed– thus air delivered iron bomb – likely to have been 250Kg	Not Known
Carisbrook	1915	Steamer Cargo	U-Boat attack; captured at first instance and sunk by deck gun subsequently	Not Known
Not Known	Not Known	Steamer (Possibly Cargo)	Not Known	Not Known

Table 6.5 – WWI and WWII Wrecks in the Moray Firth

Regardless of the type of weapons system employed to attack the ships it is unlikely that any vessel was sunk in the first exchange of fire and it is entirely feasible that a number of exchanges of fire would have preceded a successful attack. As a result many of the weapons systems employed are likely to have missed the target at first instance. As a result there may also be UXO in the regions of the wrecks.

Standard project procedures are to avoid shipwrecks for both technical and legal reasons, however given the nature of how some of these vessels were sunk, the potential UXO "avoidance zone" should be set at 500m radius (see recommendations section for further comment on this issue, together with an option for potentially reducing this distance).

7 Explosive Threat Items

7.1 General

Having established potential contamination sources, the following generic ordnance groups are considered likely to present a threat to the proposed development. Clearly, some varieties of UXO are likely to be more common within the project area than others. The table at *Appendix 9* provides a schedule of dimensions and explosive quantities for the main threat items.

7.2 Weapon Fill Materials

7.2.1 High Explosives (HE)

A HE compound detonates at rates ranging from 1,000m to 9,000m per second, and may be subdivided into two explosives classes, differentiated by their respective sensitivity:

- **Primary Explosives** – are extremely sensitive to mechanical shock, friction and heat to which they will respond by burning rapidly or detonating. Examples include mercury fulminate and lead azide. This characteristic makes them unsuitable to use as base (i.e. main-fill) explosives in military ordnance. Sensitivity is an important consideration in selecting an explosive for a particular purpose, e.g. the explosive in an armour-piercing projectile must be relatively insensitive, or the shock of impact would cause it to detonate before it penetrated the target.
- **Secondary Explosives** – are relatively insensitive to shock, friction and heat. They may burn when exposed to heat in small-unconfined quantities, although the risk of detonation is always present (especially when they are confined and/or are burnt in bulk). Dynamite, TNT, RDX and HMX are classed as secondary high explosives, which are commonly used as, base explosives in military ordnance. PETN is the benchmark compound; those explosives that are more sensitive than PETN are classed as primary explosives.

7.2.2 Low Explosives

A low explosive is usually a mixture of a combustible substance and an oxidant that decomposes rapidly (in a process akin to very rapid burning and known as deflagration).

Under normal conditions, low explosives undergo deflagration at rates that vary from a few centimetres per second to approximately 400m per second. Low explosives are normally employed as propellants, included in this group are e.g. gun-powders, pyrotechnics and illumination devices such as marine markers or flares.

7.2.3 Propellants

In ballistics and pyrotechnics, a propellant is a generic name for those chemicals used for propelling projectiles (e.g. artillery shells or mortars) from a weapon system.

Propellants are always chemically different from high explosives (as compared with those used in munitions for “target effect” for example), as they are not designed to release their energy as quickly and as a result do not produce a blasting/shattering effect (such an effect would damage or destroy the weapon platform e.g. gun/howitzer or mortar).

However, some explosive substances can be used both as propellants and as “burster charges”, (e.g. gunpowder), and some of the ingredients of a propellant may be similar to those employed to make explosives. If bulk propellants are confined and burn very rapidly the result can be similar to that witnessed by a (small) high explosive charge. Propellants therefore, remain highly dangerous and can come in various forms e.g. powder or thin sticks and can be contained in pre-formed containers or bags.

A very typical propellant burns very rapidly but controllably and non-explosively, to produce thrust (generated by rapidly expensing gas, generating pressure), and thus accelerating a projectile/rocket from a weapons platform. In this sense, common or well-known propellants include:

- Gun propellants, such as:
    - Gunpowder (black powder);
    - Nitrocellulose-based powders;
    - Cordite;
    - Ballistite;
    - Smokeless powders.
- Compounds, which may be mixed with a solid oxidiser (such as ammonium perchlorate or ammonium nitrate), or a rubber (such as HTPB or PBAN), or a powdered metal (commonly aluminium).

7.3 Artillery Projectiles

Artillery projectiles may be classified and grouped as follows:

- **HE –** High Explosives (HE) are designed to cause damage by combination of high explosive blast and fragmentation;
- **Fragmentation** – designed to be used primarily against personnel;
- **AP and SAP** Armour Piercing (AP) and Semi-Amour Piercing (SAP) shells are always base fuzed and are generally designed for the attack of lightly armoured vehicles, concrete emplacements dug outs etc. they are not intended for heavily armoured targets.
- **Smoke** – Used for the production of smoke screens; various fillings are used, the most common being white phosphorous;
- **Illuminating** – designed to illuminate an area or specific target at night; a burning flare is suspended from a small parachute to provide an intense white light;
- **Practice** – commonly a solid shot fitted with a so-called "spotting charge" which gives an indication of where it lands.

7.4 Torpedoes

Torpedoes were utilised by a range of vessels including submarines and the surface fleet. Unlike sea mines (which are a "mass-weapon" system deployed in order to strike an opportunity target), torpedoes were usually specifically targeted (i.e. fired and/or guided to a known target) rather than deployed in mass.

The guidance systems used in torpedoes are often sophisticated and include homing systems reliant upon *inter alia* acoustic signature. Any power supply in WWII torpedoes is considered expended, and it is therefore highly unlikely that any residual current in fact exists, or that a tiny amount which may still exist, could not still be sufficient to enable the torpedo to function as originally intended.

Whilst it is possible that unexploded torpedoes might be encountered, it is anticipated that their potential discovery is likely to be less frequent than other naval weapons e.g. sea mines.

7.5 Sea Mines

7.5.1 General

Sea mines (which were employed by both sides engaged in WWI and WWII), were designed either to be buoyant or to sink; the former variety tended to be moored but if they were not initiated (or cleared at the end of the war), then they often sank and drifted on the seabed with tides/weather.

Some British mines could be programmed to self neutralise, often by sinking themselves and allowing the ingress of salt water to render the firing circuit inoperable. Although self-neutralising sea mines could not function today as originally designed, the detonators and HE charges remain intact; they are dangerous. Official records also state that not all of the mines had the “sterilisation plugs” fitted to enable self-neutralisation.

Additionally, the detonators in mines are, by design, made from a sensitive explosive compound (often picric-acid based), which remains susceptible to shock to this day, although exposure to saltwater does not generally increase this sensitivity. All WWII vintage sea mines are filled with HE (usually ammonium nitrate and TNT compositions e.g. ammonal or minol), which often remains in sufficiently good condition to detonate, to this day; thus they are dangerous.

7.5.2 Fuzing

Sea mines can be armed with complex fuzing and initiation mechanisms, which fall into 3 main categories:

- **Hydrostatic Fuzing** – A valve that detects the difference in water pressure (i.e. generated by a passing vessel). Some sophisticated German WWII mines had this type of fuzing and were used in the North Sea;
- **Magnetic Fuzing** – A fuze that detects a displacement of the ambient magnetic field, normally by the introduction of a ferrous metal object (such as a passing vessel);
- **Sonar Fuzing** – Based upon a similar principle as radar (i.e. “Doppler Shift’), whereby any “positive shift” (i.e. closing), underwater sonar signal to the sea mine, is interpreted as a potential target vessel and therefore the arming sequence is initiated.

The older generation of moored sea mines were, more commonly, designed to function upon contact with a ship or vessel. The externally mounted chemical horns (or spikes), consisted of a lead outer sheath, which contained two, separated, chemical ampoules. Upon contact, the external horn would crumple, thereby crushing the ampoules and allowing the chemicals to mix. The resultant mixture would immediately produce either an electrical charge or combustion, forming the basis for an explosive chain-reaction and the detonation of its bulk high explosive.

7.5.3 German Influence Mines

After completing their initial mine campaigns, the German military sought to exploit the potential value of so called “influence mines”, which could be laid by aircraft. The mine was fabricated from aluminum and was cylindrical in shape with a rounded nose. Originally designed as a magnetically triggered sea mine, the two (German) designations were Luftmine A (LMA) and Luftmine B (LMB), which were 500 kg and 1,000 kg masses and 1.7m and 2.6m long, respectively. They were in fact modified land mines, which could be easily modified for deployment by surface craft. Although LM series mines had a range of different initiation devices, the basic design appears to have changed little throughout WWII.

When used as parachute mines they were armed by a clockwork fuze mechanism (although such mechanisms are considered highly unlikely to be working order today, the HE in the adjacent fuzes remain sensitive and potentially, highly dangerous).

They were very widely used by the Germans during WWII with devastating results. The firing system was most commonly initiated by magnetic influence, but acoustic types were also used, sometimes in combination with magnetic influence (i.e. both influences were required to initiate the mine). Later in WWII, water-pressure sensing initiation systems were also developed.

The primarily disadvantage of employing air delivered varieties of influence mines against shipping, was their low rate of descent which was deliberately retarded by parachute; (otherwise they may have broken up upon (un-retarded) impact with the water). It was therefore very difficult to emplace them with any accuracy, eg into shipping lanes. To enhance delivery accuracy, the mines had to be dropped from a relatively low altitude, which made the deploying aircraft more vulnerable to anti-aircraft fire. These problems were probably the main reason for the Luftwaffe’s development of the BM mine series, the first variant of which was dropped in the same manner as a conventional HE bomb ie in free-fall without any retarding features.

7.6 Depth Charges

The depth charge was designed to counter the threat posed by submarines/U-Boats. The generic design resembles a drum containing HE with a hydrostatic fuze, which initiated the main charge at a preset depth (as a result of water pressure). They were fired from the stern or sides of ships (or a combination of both). As the war progressed, the Royal Navy introduced the so-called “Hedgehog” and “Squid” systems, which enabled their depth charge to be fired forward from the bow the ship (which were also known as forward throwing charges).

Depth charges varied in size (from 55Kg to 300Kg) and consequently the mass of HE of explosive changed to suit the type of target being attacked. Towards the end of WWII the RN were using a “Mark X” depth charge, which contained 1000kg of explosives; they were fired from tubes mounted on the decks of war-ships.

7.7 German Air-Delivered Weapons

7.7.1 Iron Bombs

Generally, most iron (i.e. air –delivered) bombs are of similar generic construction, consisting of a steel container, a fuze or fuses either located in the nose/tail of the bomb or located laterally (though sometimes in combined locations), and a stabilizing device (i.e. the bomb “tail” to aid accurate aerodynamic flight from the aircraft to the target). The steel container (i.e. the bomb body) contains either the HE content (or other contents e.g. sub-munitions).

Iron bombs are designed in broadly similar shapes (with some variations to ogive shape/angle), but in a much wider variety of masses, depending on the intention of the bombing mission and the targets. Iron bombs are generally categorised as follows;

- **General Purpose** – Designed, as the name suggests, to attack a variety of targets and they normally contain an explosive content of approximately 50% of the overall mass of the bomb.
- **Armour Piercing** – Designed to create a mechanically driven entry point in the target prior to detonation, in order to maximise the consequent blast and fragmentation effect. Bunker busting systems, anti-shipping, anti-armoured fighting vehicle and counter-tunnel systems are good examples of the tactical deployment of armour piercing bombs. In general, only 30% of the overall mass contains HE with the remaining 70% made up of steel (in order to maximise penetration and any subsequent fragmentation effect). Armour piercing bombs are always fitted with tail-fuzes.
- **Anti-Submarine** – As the name suggests, primarily designed to attack known underwater targets. These types of bombs are always equipped with a tail fitted hydrostatic fuse and 85 – 90% of the overall mass consists of HE.
- **Incendiary** – These are normally constructed of a thin metal casing containing a thermite (manganese/aluminium) compound. Generally, once the compound is

exposed to oxygen, an instantaneous combustion takes place with the heat generated reaching in excess of 800°C. These bombs were often targeted against high concentrations of industry, general urban development and shipping.

- **Fragmentation** – Fragmentation bombs are normally deployed to maximise the secondary effects of an explosion. The bomb is generally constructed from thick (sometimes segmented), steel, designed to for maximum fragmentation effect. Fragmentation bombs are generally deployed against “soft” unprotected targets.

The larger size high-explosive varieties, were used against shipping i.e. 1,000kg mass and greater, (compared with the smaller bombs (e.g. 50 kg and 250 kg variants), which were often used during “carpet-bombing” campaigns on land).

8 UXO Seabed Penetration, Burial and Migration

8.1 General

When assessing the potential for ordnance to penetrate either the ground or the sea-bed, it is essential to rely on just an empirical, or statistical or arithmetical formula. Experience has shown that a realistic penetration depth is best estimated by considering a blend of the above approaches supplemented by accounts of Explosive Ordnance Disposal Tasks (and thus empirical evidence), wherever possible in the same geographical region and using the same environmental conditions as are expected for the theoretical case.

8.2 Seabed Migration

Munitions can migrate across the seafloor, the main factors concerning the degree of movement concern *inter alia*; the strength and direction of hydrodynamic currents; the overall shape of the weapon (influencing the degree to which UXO are free to move without obstruction); weapon protrusions such as fins and lugs (the latter being employed for suspension from the aircraft in flight); and the UXO position on the seabed (e.g. in either sediment, gradient or a seabed recess), which could significantly impede movement.

After prolonged exposure to saline water and the action of sea, some munitions can break-up or be otherwise rendered ineffective as high explosive devices; others are still discovered (today), in excellent condition. Additionally, munitions tend to gather in seabed depressions (they roll in, but tidal action often has insufficient momentum to roll them out again). In some areas of the North Sea high concentrations of UXO may gather in such natural seabed “sinks”.

8.3 Seabed Burial

Empirical evidence has shown that it is possible for UXO that initially lie on the seabed, to become subsequently buried within the “offshore” environment. This occurs especially where substantial tidal and environmental factors impact seabed conditions e.g. when there are high sedimentation rates, and thus UXO movement (into a seabed depression), and subsequent concealment. Storms and/or exceptional tidal flows could significantly alter the topography of the seabed, and although items of UXO are usually very dense, if they are not moved (as they might during strong tidal flows), they may be concealed easily with the sequential passing of tides and associated sediment movement/deposition.

When establishing the options for UXO risk mitigation it is important to ascertain the level of potential sediment cover in areas of proposed works, and seabed mobility. On this project areas in the near shore zone (where the export cable is expected to run) are likely to have only limited amounts of sediment cover, with the rockhead being exposed in some areas. Within the array zone seabed mobility is not known although sand wave peaks appear to be small. However it appears that there may be up to 1m of relatively soft sediment over the majority of the array zone.

Clearly, in such circumstances, smaller munitions are more likely to be completely buried (such as AAA or projectiles rather than the larger items of UXO (such as sea mines and iron bombs).

8.4 Seabed Penetration

The presence of a body of water will have a considerable effect on the conventional and expected penetration depth (into the seabed) for air dropped bombs. Bombs behave uniquely as they enter a body of water and their velocity is reduced significantly before the bomb comes into contact and attempts to penetrate the seabed. As a guideline and subject to specific UXO and geotechnical factors, the maximum penetration of a 500kg bomb is unlikely to exceed 1m below seabed level, when at least 10m of water is present (at the time the munition was delivered).

9 UXO Detonations

9.1 Initiation Scenarios

In 'normal' conditions at sea, UXO does not usually spontaneously explode. Ordinarily, high explosive requires the input of a significant amount of energy (usually kinetic energy) to create the conditions for detonation to occur. Although the British Geological Society seismological records suggest that there were 47 spontaneous detonations of dumped munitions in the Beauforts Dyke dumping grounds, between 1992 and 2004, it is possible that these were the result of munitions deteriorating in the salt-water environment (which is in itself unlikely) and/or becoming more sensitive to shock with age (which is more likely).

Notwithstanding this, in the event of UXO discovery within the construction environment, there are a number of potential initiation mechanisms; they are:

- **Direct Impact**; onto the main body of the munition e.g. from the PLGR, jack up barge leg or cable plough;
- **Friction Impact**; initiating the (more sensitive) fuze explosive caused by a number of construction related activities (for example impact from an excavator bucket, piling, or trenching equipment);
- **Over Pressure**; caused by piling that may initiate a hydrostatic fuzed munition (where present and in proximity).

During the 1980's British Royal Navy clearance divers were informed, by technical experts from North Atlantic Treaty Organisation (NATO), that WWII-era munitions, which relied on a capacitor in the firing system, would not retain enough electrical charge to function as designed. Therefore very old items, which rely on magnetic or acoustic fuzing to initiate them, are not considered a threat, although direct impact to these items may generate enough kinetic energy to cause a detonation.

9.2 Detonation Variables

The consequences of munitions detonation have been the subject of a number of studies. It is generally accepted that these consequences depend upon:

- The size of the item and its Net Explosive Quantity (NEQ).
- The proximity of the item to vulnerable equipment (and/or other structures).
- The type of explosive and/or fill (e.g. high explosive, incendiary, or specialist).
- Location of the item which may be:

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   - Floating on the body of water (buoyant mines only);
   - On the seabed;
   - On the surface;
   - Partially buried;
   - Totally buried.
- The construction and structural strength of any vessel, equipments or structures near the site of an explosion.

9.3 Underwater High Explosive Detonations

9.3.1 Underwater Detonation Hazards

When an item of UXO detonations underwater there are four main hazards:

- Fragmentation;
- Blast;
- A pulsing and rising gas bubble;
- A shockwave.

9.3.2 Direct Effects of Ordnance Detonation

If a significantly large high explosive item of UXO detonates underwater (e.g. after close contact with pile, jack up barge leg or trenching equipment), then the effect is very similar to that experienced at the surface. A high order detonation causing blast and fragmentation would certainly destroy mechanical equipment or significantly damage (shatter or buckle) part of a cable plough, for example.

9.3.3 Effect of Explosive Shockwave and Gas Bubble on Supporting Vessels

If a mine or a bomb detonated underwater at some distance from the underside of a floating vessel, fragmentation is not a primary consequence. On detonation of a high explosive charge the explosive gasses rapidly form a rising spherical bubble. The momentum imparted to the water in the early stages enables the water to expand until the pressure in the bubble is far less than the hydrostatic pressure of the surrounding water. A violent contraction therefore takes place, followed by a second expansion (almost as rapid as the first), which may be followed by further expansions and contractions.

Each expansion causes a pressure wave that is propagated outwards throughout the water in all directions. As water is highly incompressible the maximum pressure in the initial shockwave is very much higher than would occur in either the ground or in air (but the peak pressure is of much shorter duration). Although these shockwaves become gradually weaker as the bubble rises, the origin of those shockwaves (i.e. centre point of the rising bubble) is often closing with the intended target (i.e. the underside of a floating ship), and therefore it still has sufficient energy to cause considerable shock wave damage at significant distance from the point of initiation. It is possible that the energy could be sufficient to damage and sink a vessel.

10 UXO Risk Assessment Factors

10.1 Source – Pathway – Receptor

The threat in this instance must be considered in light of the proposed operations, the intrusive related activities, as well as the impact on key receptors such as personnel, key installations, high-value equipment and the environment.

10.1.1 Source

6 Alpha has considered that the threat is primarily the result of munitions and weaponry used during WWI and WWII, generated through sea and air battles as well as defensive mine laying, resulting in a a variety of potential natures of UXO and/or spilled munitions. A secondary source is post WWII range activities, although a modern day rages tend to employ drill munitions which conation little or no HE (they tend to contain more benign spotting charges which indicate the point of impact).

10.1.2 Pathway

The pathway is described as the route by which the hazard reaches the site personnel. Given the nature of the site, the pathways could be generated during:

- Geotechnical investigation;
- PLGR;
- Marine cable trenching (jetting or ploughing);
- Laying barge anchors;
- Foundation Installation.

10.1.3 Receptors

Sensitive receptors on this site would include:

- Site Investigation Crews.
- Construction Workers/Engineers.
- High-value Equipment.
- Ships/vessels
- Third party shipping/vessels in the immediate vicinity – Note extended safety distances for detonations underwater apply (for reasons we have articulated above).

- Infrastructure and people located along the coastline (close enough to be harmed UXO if was inadvertently detonated). This only expected when approaching shore eg in beaching an export cable.

11 Semi-Quantitative Risk Assessment

11.1 Overview

In undertaking a series of Semi-Quantitative Risk Assessments (SQRA) across the project, we have employed the technical data associated with the items presented within this report and the proposed operation. The following sections outlines transparently the methodology and calculations used in conducting the SQRA for the project. Risk assessment tables are presented separately at *Appendix 10 abc*.

11.2 Risk Rating

For the purposes of this report, Risk (R) is a function of **Probability** of occurrence (P) and **Consequence** of occurrence (C), where R = P x C. In each case, the Probability and Consequence of the identified threats has been assessed on a scale of 1 to 5. (Where 1 = Very Low, & 5 = Very High) based on expert judgement. These ratings are multiplied together to create Risk scores with a maximum of twenty-five. This allows relative weighting and comparison of risk across the project. Colour coding is provided for ease of use, grouping figures in Green as Low Risk, in Yellow as Medium Risk and Red as High Risk.

Probability							
Very High	**5**	5	10	15	20	25
	4	4	8	12	16	20
Medium	**3**	3	6	9	12	15
	2	2	4	6	8	10
Very Low	**1**	1	2	3	4	5
		1	**2**	**3**	**4**	**5**
		Very Low		Medium		Very High
				Consequence		

Table 11.2 – Risk Matrix

11.3 Risk Rating Criteria

It is important that the numerical values assigned to the potential probability and impact of a risk match the risk tolerance of the Client. Table 11.3 outlines the risk rating rationale that has been applied in this analysis:

Risk Rating (P x C)	Grading	Risk Appetite (Tolerance)	Action Required
1-5	**Low**	Tolerable or Partly Tolerable	Little/No specific Risk Mitigation Required. Situation should be monitored. Reactive UXO risk mitigation required during operations, but overall, residual risks are carried.
6 - 12	**Medium**	Intolerable	Advance Mitigation Measures should be considered. Situation should be monitored. Risks to be mitigated subject to the mitigation being reasonable, practical and affordable. Note: High Consequence or High Probability that score as Medium Risk events should be afforded the same status as Highly Intolerable but assessed on a case-by-case basis.
15 - 25	**High**	Highly Intolerable	Risk Mitigation Measures should / will be implemented. All risks to be mitigated.

Table 11.3 – Risk Tolerability Table

The risk levels are used to determine the level of mitigation (see *Appendix 10*) required to reduce the risk to conform with the ALARP principle. In producing the risk mitigation strategy the risk levels are benchmarked against the various degrees of tolerability (shown in Table 11.3 above), in order to determine what degree of risk is considered acceptable.

11.4 Definition of Consequence and Probability

As is accepted practice in formalised Risk Management, the Risk Rating scales are dimensionless, allowing the user to apply these methods to any desired terminology in order to fit their discrete needs.

11.4.1 Consequence

If the key consequence is financial, then 5 on this scale should equate to the amount of money that will either, stop the contract, close the operation, exceed agreed budget or any other defined critical financial figure. The scale then sub-divides that amount into 5 equal portions down to zero financial impact.

If the key impact figure is the loss of a vessel, then 5 on the scale is equal to total loss of the vessel as an operational asset, and the sliding scale represents vessel operational efficiency loss i.e. 1 = loss of 0% to 20% operational efficiency, while 5 = loss of 81% to 100% operational efficiency.

If the critical impact figure is loss of 50% of operational efficiency, then the scale represents loss of between 0% and 50% in 5 equal steps. This can be applied to any number of scenarios.

The critical consequence associated with UXO however is that associated injury or death. Both are considered unacceptable and therefore such circumstances should be avoided or the risk appropriately managed or otherwise mitigated to ameliorate such a consequence.

11.4.2 Consequences Specific to the Moray Firth Offshore Wind Farm

The detonation consequence assessment assigns a site-specific consequence level to any potential UXO that may be encountered at the site. This is achieved by combining the UXO impact distance from sensitive receptors, the Net Explosive Quantity (NEQ) of the item and, where applicable, the average water depth range (assumed here to be in the region of 45-60m). A rating system for assigning impact levels has been derived based on the expected effects of a detonation event on each of the receptors identified in the project consequence matrix is presented at Table 11.4.2. The expected impacts are ranked from 1 (no significant effect) to 5 (major widespread effects / catastrophic).

Impact Level	*NEQ*	**Expected Consequences**			
		Human Health	**Plant and Equipment**	**Vessels**	**Environment**
1	*Low Explosive <10kg & High Explosives <5kg*	Injury requiring medical treatment	No noticeable effect	No noticeable effect	Minor disturbance
2	*High Explosive 5-15kg*	Lost time injury < 3 days	Slight superficial damage	Slight superficial damage	Significant disturbance
3	*High Explosive 15-50kg*	Serious debilitating injury	Minor component replacement repair	Repairs - non-structural	Moderate damage to habitats.
4	*High Explosive 50-250kg*	Localised fatalities	Significant component replacement repair	Repairs – structural	Moderate damage to habitats. Some long term effects.
5	*High Explosive >250kg*	Multiple fatalities over extended area	Unit destruction	Localised structural failure and collapse	Localised destruction of habitats. Moderate long-term effects.

Table 11.4.2 – Consequence Matrix

11.4.3 Probability

The Probability scale is simply the assessed likelihood of an event-taking place. If units are required, then the scale frequently used on Project Risk Registers may be utilised.

11.4.4 Specific to the development of the Moray Firth Offshore Wind Farm

Based on 6 Alpha’s significant experience of assessing the probability of UXO contamination, it is not always possible to present an accurate statistical (or purely quantitative) measure, simply because the base data is largely qualitative i.e. it is drawn form a variety of different historical and environmental sources.

However, 6 Alpha’s semi-quantitative approach blends together professionally informed judgements made upon empirical, qualitative evidence and introduces a transparent statistical approach which has be successfully employed on a variety of land and marine sites where the environmental context remains relatively constant and the quantity and type of munitions employed, together with expected failure rates, is recorded.

For this purposes of this study the probability levels presented in the matrix at *Table 11.4.4*, (which is specifically tied to the probability of encounter chart presented separately at Appendix 11), which have been employed together to chart and to code the overarching probability ratings for this specific project:

Probability Level	Probability of Encountering UXO	Example seen at Moray Firth
1	Remote	Not seen on this project
2	Possible	Residual background risk based on WWI and WWII activities
3	Likely	Convoy routes which experienced enemy bombing
4	High Likely	Historically Live Bombing Range
5	Almost Certain	Shipwrecks contain munitions

Table 11.4.4 – Probability Matrix

6 Alpha have collated, reviewed and analysed the historical data presented in our desk study and conducted a separate assessment based on the levels in *Table 11.4.4* to produce a chart that demonstrates “probability of UXO encounter” (*Appendix 11*). The chart is an important tool not only in informing the subsequent and associated risk management process but also in helping to reduce risks to As Low as Reasonably Practicable (ALARP), because it visually displays areas as false colours, showing which might require UXO risk mitigation as well as others which might be avoided.

However, there are some limitations associated with practical employment of this chart. Primarily, it should not be used as a “risk chart” as it does not incorporate the construction activities that might be associated with a UXO “encounter”. Moreover, it does not consider the complete threat (i.e. net explosive quantity (NEQ) and fuzing) posed by any particular item. Therefore, this chart cannot address the causing and initiation, nor the likely consequences; therefore it only informs one part of the risk process (i.e. part of the probability element); it does not address potential types of encounter nor the potential consequences.

The UXO threat locations and safety buffering have been produced by digitising *inter alia* historical Naval records and/or plotting coordinates provided by third parties. It is possible these activities may have generated a number of inherent inaccuracies. Primarily because much of this data was gathered in a wide variety of circumstances, by different agencies, to different standards, over a long time-frame, some of that data may not be accurate or as detailed as 6 Alpha would like. Nonetheless, this data is the best that can be obtained and although 6 Alpha have relied upon it, we are not responsible for any inaccuracies that it might contain.

Notwithstanding this, 6 Alpha have taken all reasonable care to ensure that all base data employed is as accurate as possible and any potential inaccuracies have been taken into consideration in the final “probability” buffering. Moreover, UXO buffer areas also take into consideration potential for drift/movement since the time of UXO placement.

12 Recommended Risk Mitigation

12.1 Overview

In view of the UXO risk in this region and the proposed engineering works, 6 Alpha has designed the following mitigation strategy to reduce the risk to a level that conforms with the legal ALARP principle. This strategy has been developed in order to fully address the UXO risk across the entire development site (exempt export cabling which has not been specifically considered at this stage), whilst working within critical operational and time limitations.

6 Alpha believes that avoidance of potential risk items is the key to successful UXO risk management in this environment. By adhering to robust procedures and operational guidelines the impact to the ongoing development can be significantly reduced. We recommend that due to the nature of the sinking of some of these vessels, a baseline avoidance zone of 500m radius should be set around shipwrecks, for both technical and legal reasons.

However, 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. Therefore 6 Alpha recommend that the time between any proactive mitigation works and the proposed construction works is minimised (within reasonable operational constraints).

12.2 Quality Assurance / Quality Control

Given the scope of the overall strategy and the need to undertake real-time decisions during various phases of the project, 6 Alpha recommend that a QA/QC UXO Specialist is deployed to oversee key elements of the UXO risk mitigation work. 6 Alpha's view is that given the significant cost and potential implications on site associated with undertaking UXO risk mitigation measures, the presence of a QA/QC representative is essential in order to ensure quick informative decisions are made concerning the UXO Risk Management tactics (and potential strategy impact), and then report those findings directly to the client, wider project team and relevant authorities, in order to ensure that the highest quality of work is always being delivered at best client value.

12.3 Marine Operations – UXO Probabaility and Risk Mitigastion

12.3.1 UXO Risk - Overview

At first sight, the general level of UXO contamination and potential for its encounter during wind farm construction activities at this site may appear daunting. However, whilst UXO undoubtedly poses a risk across the development, it is not uncommon and it has been encountered on a high proportion of wind farm developments in the North Sea.

Therefore, the presence of UXO should not present a barrier to development although there is requirement to better quantify the risk by reviewing the possible types (including size and mass and density) of UXO contamination and reviewing the available information from previous geophysical, geotechnical and/or clearance surveys to determine the remaining/residual risk. In high risk areas no intrusive works should be undertaken without the location being properly cleared, however, it is usual practice to investigate possible ground investigation and/or structural locations before undertaking work. It is important to ensure this sort of investigation is correctly specified in order to ensure that when the survey instruments are deployed they can identify the anticipated munitions that are expected to be in the threat spectrum. If this investigation identifies munitions then the holistic risk mitigation options can be taken, including:

- Technically assess the nature of the UXO together with the nature of the proposed operations (eg an encounter of most natures of small arms ammunition are unliley to pose a risk to foundation installation or cable jetting/ploughing;
- Wherever possible rerouting should be employed to avoid survey anomalies that might be associated with dangerous items of UXO;
- Relocate to works to areas which appear less risky;
- If rerouting or relocation is neither practical nor possible, then conduct either diver investigation or ROV inspection, which might either discount the item or lead to UXO disposal.

Drawing upon 6 Alpha's considerable experience in this sector, the risks can be managed throughout the construction phase in general (and the foundation, inter-array and export cable installation phases in particular). By employing the proven risk management techniques we have described in general (and in section 12.3.2 in particular), those risks can be managed and reduced to ALARP, at best value.

The potential presence of UXO and the associated hazard it might pose should not be considered a barrier to wind farm development.

12.3.2 UXO Probability Grading - Overview

Red Zones (Rated 5); prior to undertaking any site investigation or positioning of the turbine locations and cable routes, the "*Almost Certain"* threat area as displayed at *Appendix 11* coloured red (and rated 5), should be avoided.

6 Alpha draw specific attention to the "munitions" related shipwreck (HMS Lynx - shown as a "red" spot) is outside of the concession area, it is on its periphery and should be avoided.

Orange Zones (Rated 4); prior to undertaking any site investigation or positioning of the turbine locations and cable routes, the "*Highly Likely* " threat area as displayed at *Appendix 11* coloured orange (and rated 4) should be subject to the following risk mitigation options, in priority order:

- Option 1 - Conduct a UXO Specific Geophysical Survey and avoid targets. This survey should be designed to match the defined UXO threat and provide 100% coverage of specific threat area;
- Option 2 – Relocate works to areas with a grading 2 or 3;
- Option 3 – If target avoidance not possible conduct either diver investigation or ROV inspection, which may discount the item or lead to UXO disposal.

6 Alpha draw specific attention to the semi-circular "orange" zone in the southeastern section of the site. The threat is driven by the presence of historically live bombing ranges i.e. current military range D807 (and see Appendix 04) and WWII Armament Range 127A (and see Appendix 03).

Yellow Zones (Rated 3); prior to undertaking any site investigation or positioning of the turbine locations and cable routes, the "*Likely* " threat area as displayed at *Appendix 11* coloured yellow (and rated 3) should be subject to the following risk mitigation options, in priority order:

- Option 1 - Conduct a UXO Specific Geophysical Survey and avoid targets. This survey should be designed to match the defined UXO threat and provide 100% coverage of specific threat area;
- Option 2 – Relocate works to areas with a grading of 2;
- Option 3 – If target avoidance not possible conduct either diver investigation or ROV inspection, which may discount the item or lead to UXO disposal.

6 Alpha draw specific attention to two "yellow" zones; the first is located to the east the threat is driven by the presence current range activities at "D809 South"; the second is to the west and the threat is driven by a former WWII armament range N228.

Green Zones (Rated 2); prior to undertaking any site investigation or positioning of the turbine locations and cable routes, the "*Possible*" threat area as displayed at *Appendix 11* coloured green (and rated 2), should be subject to the following risk mitigation option: wherever possible, existing geophysical datasets for UXO risk reduction. Define smallest UXO threat items, interpret the datasets for contacts similar to UXO and avoid during future works.

6 Alpha draw specific attention to one central "green" zone; it is considered to have background residual UXO threat of encounter driven the general wartime and subsequent military training activities in the region.

12.3.3 UXO Risk Mitigation Options - Summary

6 Alpha have recommended that the following actions are required to address the UXO risk. This table should be read in conjunction with the "probability of UXO encounter map" at *Appendix 11*.

UXO Probability Encounter Rating	Grading	Action Required ahead of Intrusive Works	Associated Additional Costs (Low → High)
1-2	**Remote - Possible**	Areas defined as "background residual risk". Use, wherever possible, existing geophysical datasets for UXO risk reduction. Define smallest UXO threat items, interpret the datasets for contacts similar to UXO and avoid during future works. **6 Alpha Deliverable** - Client's must accept that this is not a 100% survey coverage for UXO, although if conducted by 6 Alpha the risk will be reduced to ALARP.	Low
3-4	**Likely - Highly Likely**	Areas which display a specific significant threat, there are three options for dealing with the risk in these areas: • **Option 1** - Conduct a UXO Specific Geophysical Survey and avoid targets. This survey should be designed to match the defined UXO threat and provide 100% coverage of specific threat area; • **Option 2** – Relocate works to areas with a grading of 1 or 2; • **Option 3** – If target avoidance not possible conduct either diver investigation or ROV inspection, which may discount the item or lead to UXO disposal. **6 Alpha Deliverable** - Once the UXO risk reduction actions have been successfully implemented and subject to our own QA/QC measures, 6 Alpha will sign-off the UXO risk as ALARP.	
5	**Almost Certain**	6 Alpha would strongly suggest avoiding these areas, and relocation work. As the costs associated reducing the risk to ALARP are likely to be considerable.	High

Table 12.3.2 – Recommended UXO Risk Mitigation

13 Conclusions

13.1 Key Findings

In terms of UXO threat, this report has demonstrate that the UXO threat is primarily the result of munitions and weaponry employed during WWI and WWII; this includes in priority order sea-dumped explosives/munitions, shipwrecks and sea mines.

Military artillery ranges are recorded within the general region however given the nature of these operations and the type of munitions used 6 Alpha does not consider that this source will pose a significant threat to the project. This has been reflected in the SQRA tables presented at *Appendix 11*. It is conceivable that live HE items would have been fired out to sea (from land based weapons platforms) and a proportion of UXO could still be present in the area today. However, 6 Alpha's view is that there is only a remote chance that a grappling iron or cable plough would both strike and then initiate a projectile. Moreover, even if the unlikely but worst case scenario did occur (i.e. the item was struck on the fuze causing its initiation), the Net Explosive Quantity (NEQ) within these relatively small projectiles is highly unlikely to have any direct effect on the vessel itself or crew, especially as the grappling irons or plough would be towed at a significant distance from the vessel in sufficiently deep water to contain any HE blast or associated fragmentation.

The maximum penetration of a 500kg bomb along this route is not likely to exceed 1.0m below seabed level. It is conceivable that, if present, any bombs, mines, torpedoes and parachute mines would be on or just below the seabed.

Due to the relatively slow tidal movement within the North Sea, tides are likely to have a minimal short-term effect on seabed munitions movement. In the coastal areas, however, there may be sufficient tidal flow to move threat items either into, or out of, the proposed project area. Therefore it would be prudent to assume that items are still in the process of migration, although the magnitude is likely to negligible. Importantly, targets identified (potentially as UXO) may have moved since the time of the geophysical survey, in addition to new items being introduced via migration along the route of the cables.

Where detonation occurs underwater, potential damage may result from direct fragmentation as well as the pulsing gas bubble and its resultant shock wave. The main consequence depending upon water depth is likely to include injury to personnel and damage to installation vessels, and associated support vessels and equipment. Given typical water depths seen in the area, assumed to be between <10 to >55m, a reasonable and practical working assumption is that any UXO which has a charge weight of 40kg or greater, is capable of causing significant damage.

As many of the sea mines and bombs that may be encountered have a NEQ of around 100kg or greater, the effect of them detonating (even on the seabed), is likely to be catastrophic, and remain extremely serious in the deeper waters.

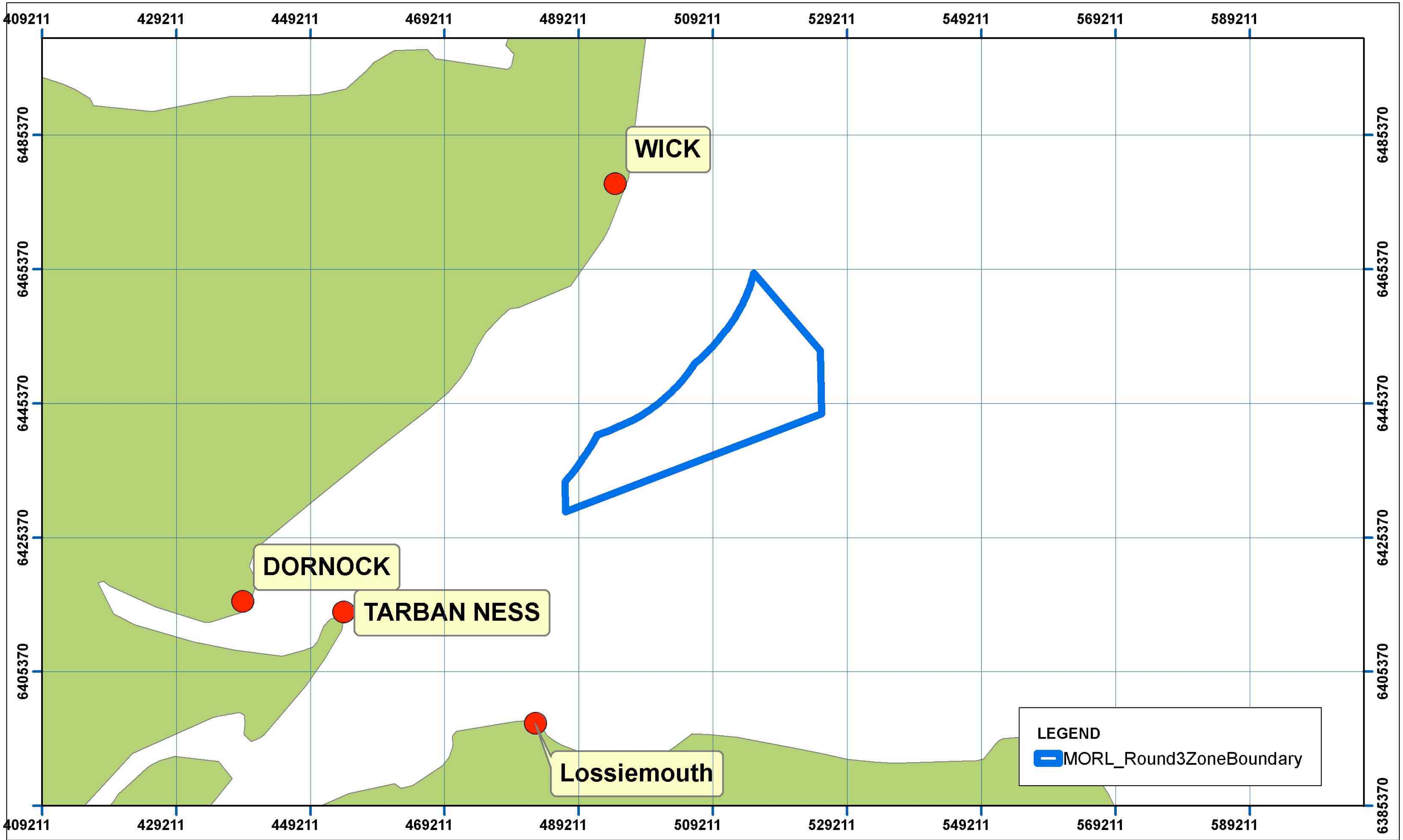
Appendices

Appendix 01

Moray Firth Offshore Wind Farm – Project Location

Offshore Wind Farm - Moray Firth
Project Location

Appendix 01



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		Scale @ A4: 1:750,000 Revision: 002		Projection System: UTM Zone 30N Datum: WGS84 Spheriod: WGS84	Checked by: Lee Gooderham Date: 9th November 2010

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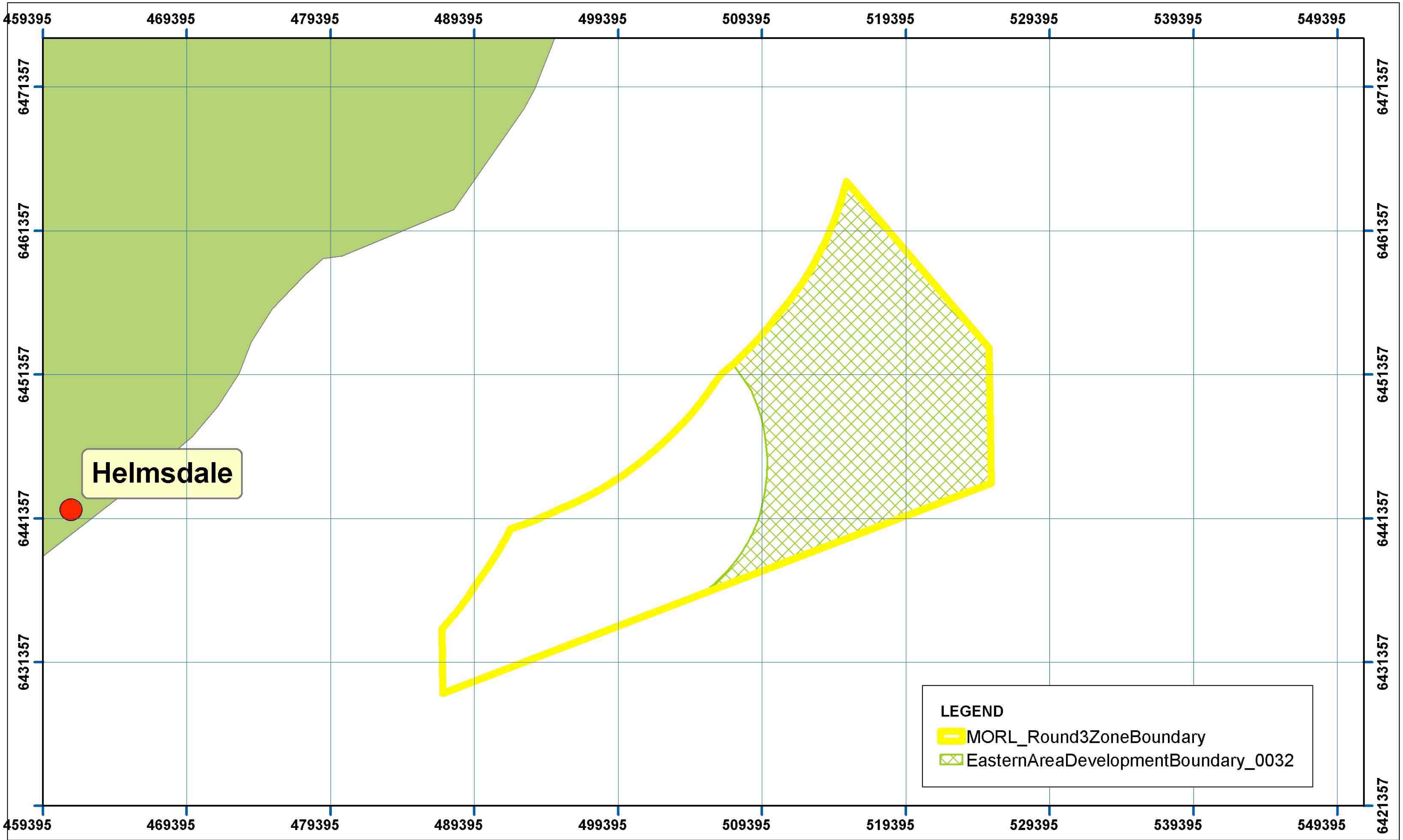
Appendix 02

Project Study Areas

Offshore Wind Farm - Moray Firth
Eastern Development Area - Round 3 Zone

Appendix 02



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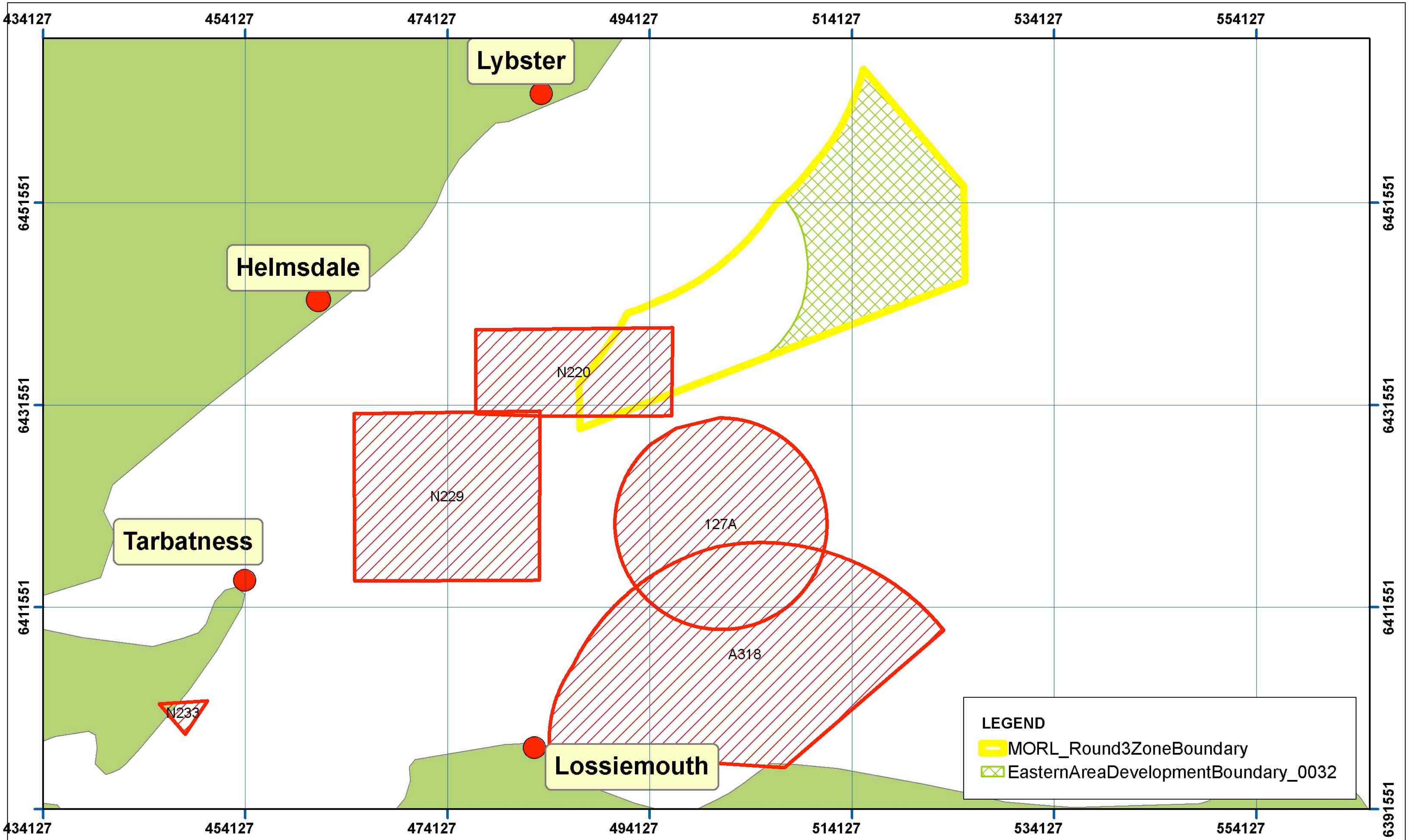
Appendix 03

WWII Armament Areas

Offshore Wind Farm - Moray Firth
WWII Armament Ranges

Appendix 03



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Date: 23rd November 2010

Appendix 04

Current Armament & Training Areas

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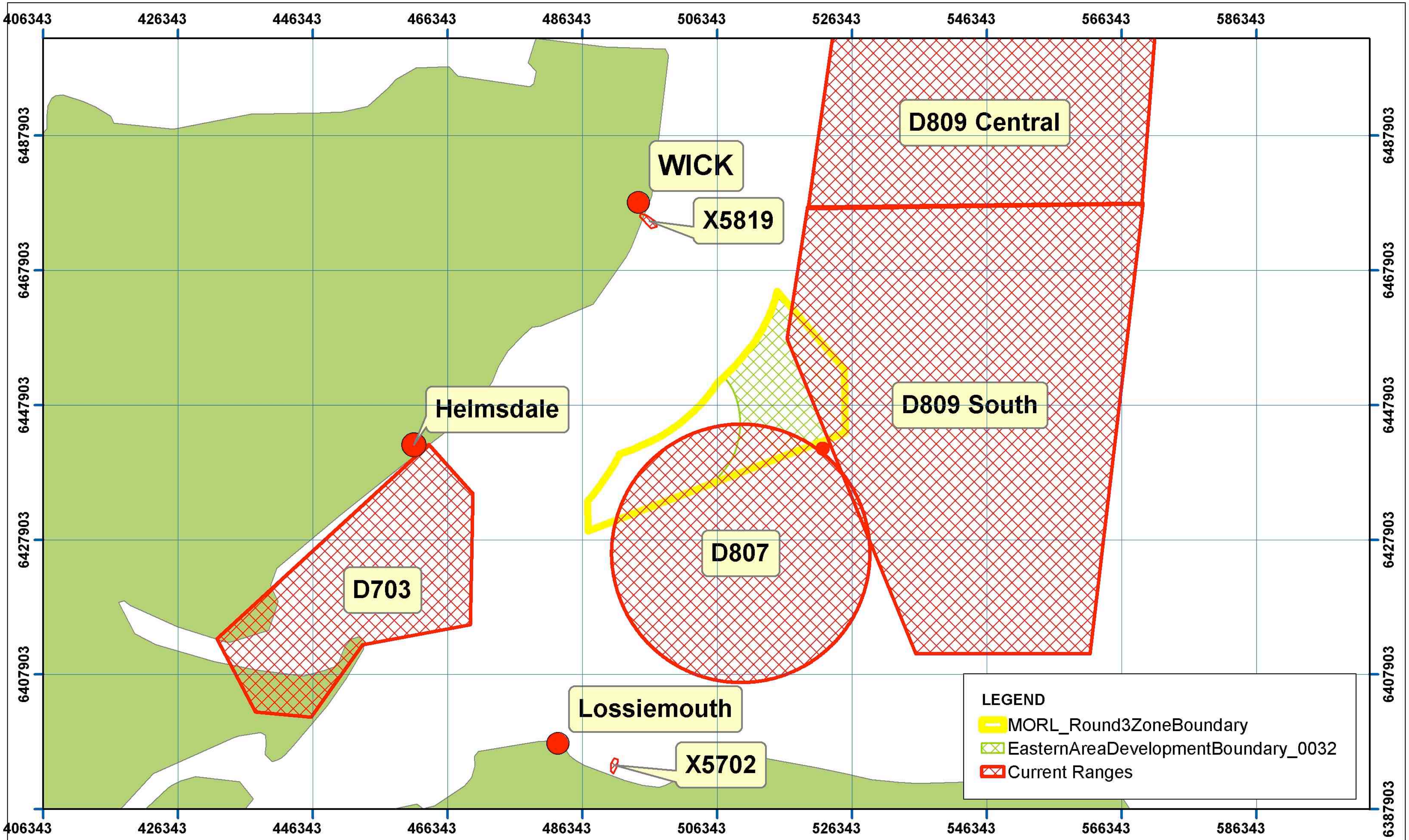
Offshore Wind Farm - Moray Firth
Current Military Activity

Appendix 04



alpha ASSOCIATES special risks consultancy	6 Alpha Associates Ltd. Quatro House Frimley Road Camberley Surrey GU16 7ER United Kingdom www.6alpha.com 0203 371 3900	0 2 4 8 12 Nautical Miles Scale @ A4: 1:750,000 Revision: 000	N	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please forward to 6 Alpha. Development zone (in GIS format) obtained from Crown Estates Website. Projection System: UTM Zone 30N Datum: WGS84 Spheriod: WGS84	Project Number: P2295 Drawn By: Gary Hubbard Checked by: Lee Gooderham Date: 23rd November 2010

Appendix 05

Marine UXO Threats

Unexploded Ordnance (UXO) in the Marine Environment

Cable Plough

Picture courtesy of Global Marine Systems Ltd

Turbine Installation

Legend

German Bomb	
Torpedo	
German Air Delivered Mines	
British Sea Mine	
General Munitions	
Artillery Projectiles	

Round 3 Wind Farms

Dumped Munitions

Artillery Ranges

Minefields

User Notes

1. This map should not be used as a substitute for UXO risk assessment. Should a perceived risk be identified then professional advice should be sought.
2. Map is for illustration purposes only and should not be used for navigation or scaling purposes.
3. Data has been extracted from third party historical sources and 6 Alpha will not be held responsible for the accuracy.
4. Only key UXO threat sources have been shown, further locations may be present but not shown due to scale and clarity of imagery.
5. Some UXO threat areas may be the sum total of numerous threat boundaries.

Jack Up Barge

Picture courtesy of Fugro

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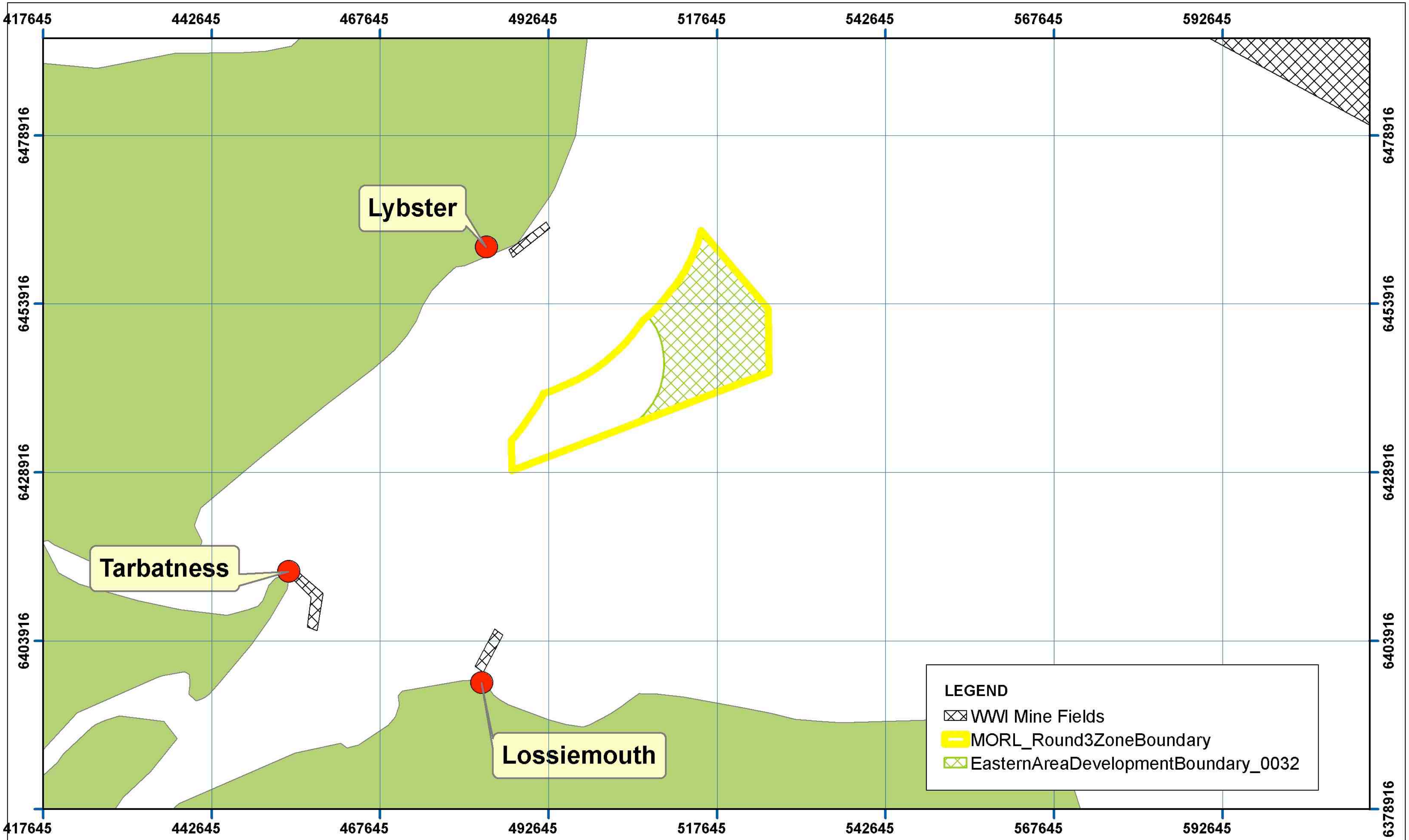
Appendix 06

WWI Allied Minefields

Offshore Wind Farm - Moray Firth
WWI Mine Fields

Appendix 6



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Date: 19th November 2010

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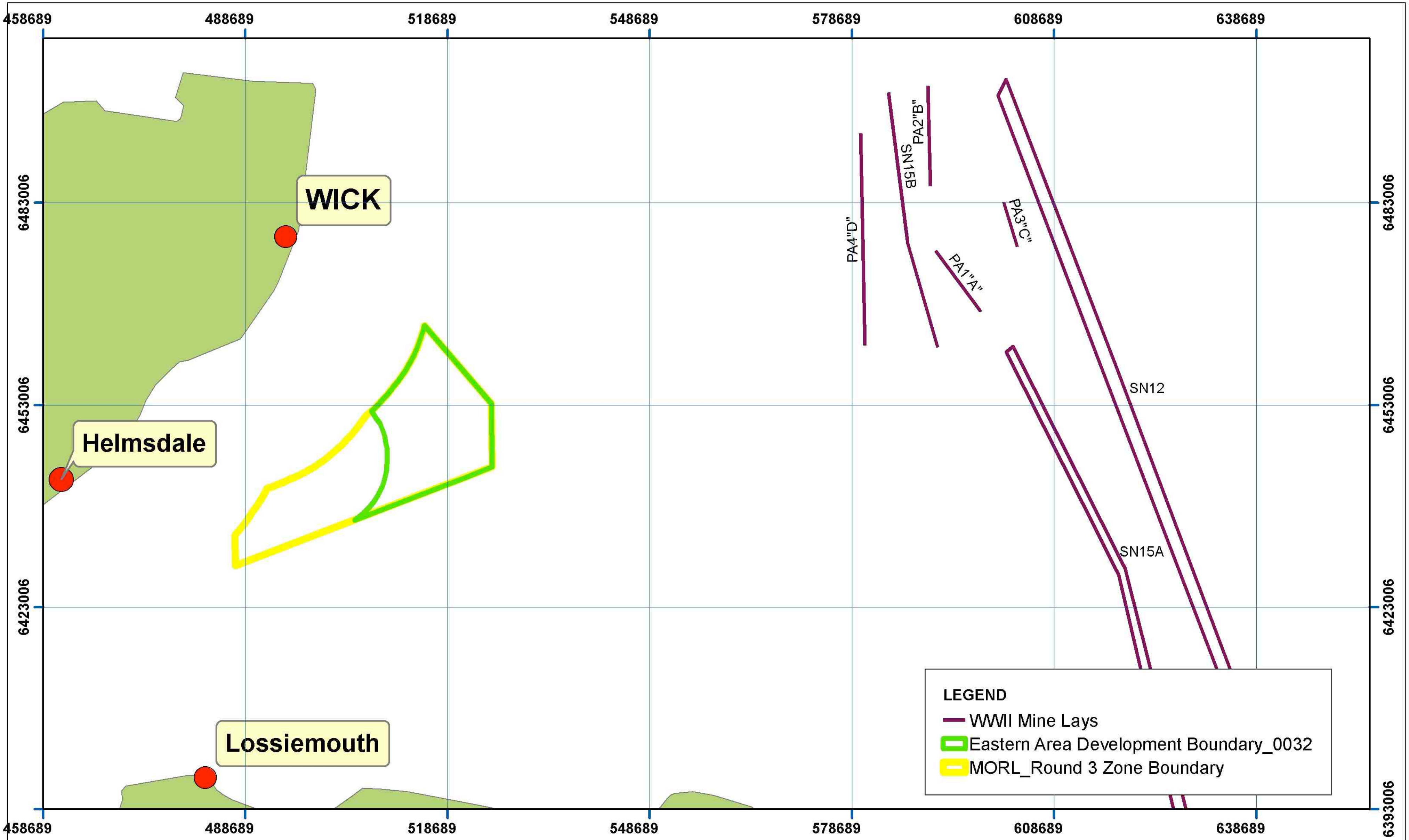
Appendix 07

WWII Allied Minefields

Offshore Wind Farm - Moray Firth
WWII Mine Lays

Appendix 6



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Spheriod: WGS84

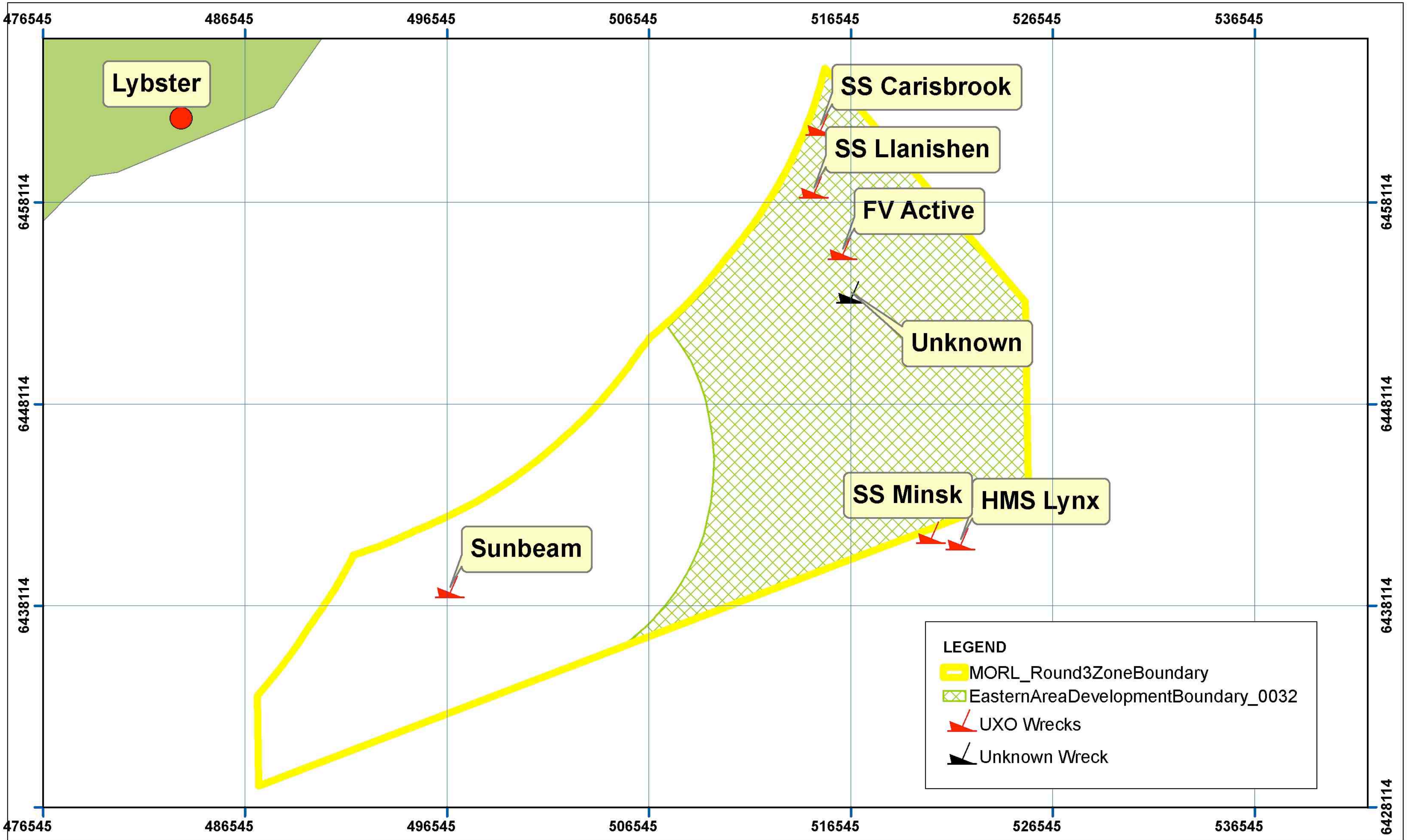
Project Number: P2295
Drawn By: Gary Hubbard
Checked by: Lee Gooderham
Date: 19th November 2010

Appendix 08

All Shipwrecks

Offshore Wind Farm - Moray Firth
UXO Wrecks

Appendix 08



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Scale @ A4: 1:250,000
Revision: 002

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Datum: WGS84
Spheriod: WGS84

Project Number: P2295
Drawn By: Gary Hubbard
Checked by: Lee Gooderham
Date: 24th November 2010

Appendix 09

Ordnance Characteristics

WWII Sea Mines				
Ordnance Variant	**Shape**	**Width**	**Length**	**Charge Weight**
German Contact Mine. Code EMA/EMB British Designation: GU	Ovoid	EMA: 1600mm EMB: ~1400mm	EMA: 800mm EMB: 900mm	EMA: 220kg EMB: 150kg
German Contact Mine. Code BMC British Designation: GM	Cylindrical with hemispherical top and bottom	660mm	1000mm	50kg
German Contact Mine. Code EMC British Designation: GY	Spherical	1120m diameter	1120mm diameter	300kg
German Contact Mine. Code KMA British Designation: GJ	Spherical	380mm diameter	380mm diameter	12kg
German Influence Mine. Code KMA British Designation: GA/GD	Cylindrical with hemispherical nose and rear parachute housing	660mm diameter	1800mm	300kg
German Influence Mine. Code LMF British Designation: GT	Cylindrical, finned	530mm diameter	2700mm	230kg
German Influence Mine. Type LMB British Designation: GB/GC	Cylindrical with hemispherical nose and rear parachute housing	660mm diameter	Up to 3200mm	700kg
German Influence Mine. Type GMB British Designation: GN & GS	Cylindrical with hemispherical ends	GN: 530mm diameter GS: 530mm diameter	GN: 3100mm GS: 2300mm	GN: 900kg GS: 420 to 560kg
German "Mine-bomb". Type BM1000 British Designation: GG	Cylindrical	660mm diameter	~2000mm long depending on tail unit	725kg
British Contact Mine Mk XIV & XV	Ovoid	1016mm diameter	1016mm diameter	145kg or 295kg
British Contact Mine. Mk XVII	Ovoid	1016mm diameter	1016mm diameter	145kg
British Contact Mine. Mk XIX & XIXS	Spherical	790mm diameter	790mm diameter	45kg

WWII High Explosive Bombs				
Ordnance Variant	**Bomb Shape**	**Dimensions**	**Body Diameter**	**Charge Weight**
German SC 50	Cylindrical	1090 x 280mm	200mm	25kg
German SC 250	Cylindrical	1640 x 512mm	368mm	125-130kg
German SC 500	Cylindrical	1957 x 640mm	470mm	250-260kg
German SC 1000	Cylindrical	2580 x 654mm	654mm	530-590kg
German SC 1800	Cylindrical	3500 x 670mm	670mm	1000kg
German SC 2500	Cylindrical	3895 x 829mm	829mm	1700kg

Appendix 10

Project Risk Assessment Tables

Risk Assessment Table notes (applicable to all segments):

1. Risk level is prior to risk mitigation actions for that specific operation but in operational order i.e. previous action may have reduced cumulative risk level;
2. Values for both probability and consequence to be found in main report;
3. Risk mitigation measures are cumulative and assumes that previous stage has been undertaken;

APPENDIX 5.8 A

Moray Firth Offshore Wind Farm – UXO Risk Assessment

Orange Zone – Highly Likely

Phase	Activity	Ordnance Variant	Probability of Encounter	Consequence of Initiation	Risk Level (Note 1)	Risk Mitigation … lower risk to … o
Site Investigation	Geophysical Survey	Sea Mines/Torpedoes	1	2	2	Ensure survey … not encounter …
		Air-delivered Bombs	1	2	2	
		AAA Projectiles	1	1	1	
		Practice Bombs	1	2	2	
	Geotechnical Investigation	Sea Mines/Torpedoes	2	4	8	Geophysical survey and target avoidance – employing either camera survey and/or focused SSS (for BH/CPS - not jack-up legs)
		Air-delivered Bombs	2	4	8	
		AAA Projectiles	1	1	1	
		Practice Bombs	2	1	2	
Cable Installation	PLGR seabed operations	Sea Mines/Torpedoes	3	3	9	UXO focussed survey and target avoidance
		Air-delivered Bombs	4	3	12	
		AAA Projectiles	2	1	2	
		Practice Bombs	3	3	9	
	PLGR equipment recovery to vessel	Sea Mines/Torpedoes	2	5	10	Safety procedures to be followed in the event of item recovery
		Air-delivered Bombs	1	5	5	
		AAA Projectiles	1	3	3	
		Practice Bombs	2	5	10	
	Barge Anchor Deployment	Sea Mines/Torpedoes	2	3	6	Existing Geophysical survey and target avoidance
		Air-delivered Bombs	2	3	6	
		AAA Projectiles	1	1	2	
		Practice Bombs	2	3	6	
	Cable Installation (Array Seabed Operations)	Sea Mines/Torpedoes	1	4	4	No further action - subject to the previous cable installation ameliorative measures having been taken
		Air-delivered Bombs	1	4	4	
		AAA Projectiles	2	1	2	
		Practice Bombs	1	4	4	
Turbine Installation	Foundation Installation	Sea Mines/Torpedoes	3	4	12	UXO Focussed Survey & Target Investigation (latter if required)
		Air Delivered Bombs	4	4	16	
		Artillery Projectiles	2	1	2	
		Practice Bombs	3	4	12	

Moray Firth Offshore Wind Farm – UXO Risk Assessment
Yellow Zone – Likely

Phase	Activity	Ordnance Variant	Probability of Encounter	Consequence of Initiation	Risk Level (Note 1)	Risk Mitigation Actions to lower risk to ALARP
Site Investigation	Geophysical Survey	Sea Mines/Torpedoes	1	2	2	Ensure survey array does not encounter seabed
		Air-delivered Bombs	1	2	2	
		AAA Projectiles	1	1	1	
		Practice Bombs	1	2	2	
	Geotechnical Investigation	Sea Mines/Torpedoes	3	4	12	**Western Zone** Geophysical survey and target avoidance –employing either camera survey and/or focused SSS (for BH/CPS - not jack-up legs) **Eastern Zone** Existing Geophysical survey and target avoidance
		Air-delivered Bombs	2	4	8	
		AAA Projectiles	1	1	1	
		Practice Bombs	2	1	2	
Cable Installation	PLGR seabed operations	Sea Mines/Torpedoes	3	3	9	**Western Zone** UXO focussed survey and target avoidance **Eastern Zone** Existing Geophysical survey and target avoidance
		Air-delivered Bombs	3	3	9	
		AAA Projectiles	2	1	2	
		Practice Bombs	2	3	6	
	PLGR equipment recovery to vessel	Sea Mines/Torpedoes	2	5	10	Safety procedures to be followed in the event of item recovery
		Air-delivered Bombs	1	5	5	
		AAA Projectiles	1	3	3	
		Practice Bombs	2	5	10	
	Barge Anchor Deployment	Sea Mines/Torpedoes	3	3	9	Existing Geophysical survey and target avoidance
		Air-delivered Bombs	2	3	6	
		AAA Projectiles	1	1	2	
		Practice Bombs	2	3	6	
	Cable Installation (Array Seabed Operations)	Sea Mines/Torpedoes	1	4	4	No further action - subject to the previous cable installation ameliorative measures having been taken
		Air-delivered Bombs	1	4	4	
		AAA Projectiles	2	1	2	
		Practice Bombs	1	4	4	
Turbine Installation	Foundation Installation	Sea Mines/Torpedoes	4	4	16	**Western Zone** UXO focussed survey and target investigation **Eastern Zone** Existing Geophysical survey and target avoidance
		Air Delivered Bombs	3	4	16	
		Artillery Projectiles	2	1	2	
		Practice Bombs	2	4	8	

APPENDIX 5.8 A

Moray Firth Offshore Wind Farm – UXO Risk Assessment
Green Zone – Possible

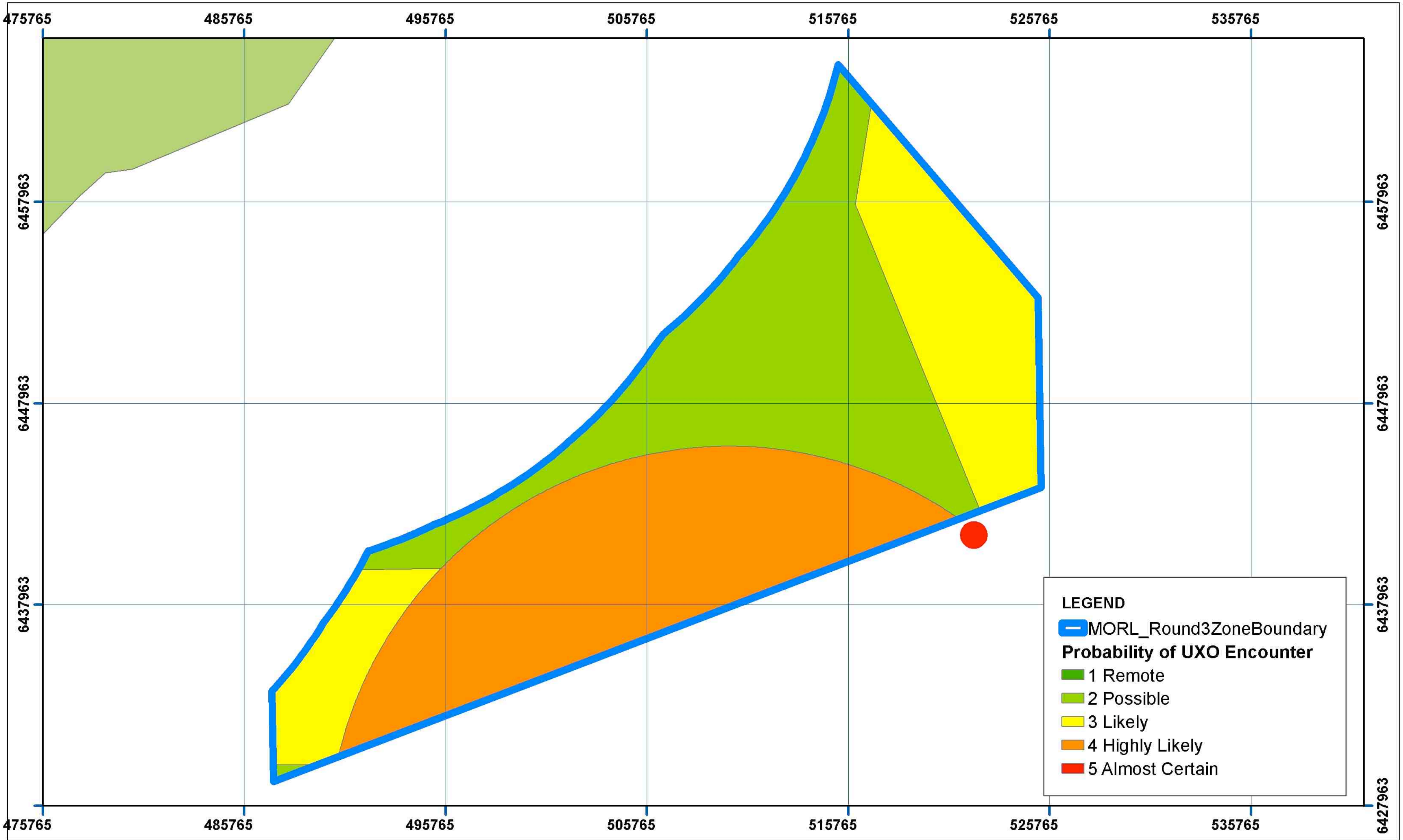
Phase	Activity	Ordnance Variant	Probability of Encounter	Consequence of Initiation	Risk Level (Note 1)	Risk Mitigati[illegible]s to lower risk [illegible]
Site Investigation	Geophysical Survey	Sea Mines/Torpedoes	1	2	2	Ensure surv[illegible] does not e[illegible] seabed
		Air-delivered Bombs	1	2	2	
		AAA Projectiles	1	1	1	
		Practice Bombs	1	2	2	
	Geotechnical Investigation	Sea Mines/Torpedoes	2	4	8	Existing Geophysical survey and target avoidance
		Air-delivered Bombs	2	4	8	
		AAA Projectiles	1	1	1	
		Practice Bombs	2	1	2	
Cable Installation	PLGR seabed operations	Sea Mines/Torpedoes	2	3	6	Existing Geophysical survey and target avoidance
		Air-delivered Bombs	2	3	6	
		AAA Projectiles	2	1	2	
		Practice Bombs	2	3	6	
	PLGR equipment recovery to vessel	Sea Mines/Torpedoes	2	5	10	Safety procedures to be followed in the event of item recovery
		Air-delivered Bombs	1	5	5	
		AAA Projectiles	1	3	3	
		Practice Bombs	2	5	10	
	Barge Anchor Deployment	Sea Mines/Torpedoes	2	3	6	Existing Geophysical survey and target avoidance
		Air-delivered Bombs	2	3	6	
		AAA Projectiles	1	1	2	
		Practice Bombs	2	3	6	
	Cable Installation (Array Seabed Operations)	Sea Mines/Torpedoes	1	4	4	No further action - subject to the previous cable installation ameliorative measures having been taken
		Air-delivered Bombs	1	4	4	
		AAA Projectiles	2	1	2	
		Practice Bombs	1	4	4	
Turbine Installation	Foundation Installation	Sea Mines/Torpedoes	2	4	8	Existing Geophysical survey and target investigation
		Air Delivered Bombs	2	4	8	
		Artillery Projectiles	2	1	2	
		Practice Bombs	2	4	8	

Appendix 11

UXO Probability Map

Offshore Wind Farm - Moray Firth
Probability of UXO Encounter

Appendix 11



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Scale @ A4: 1:250,000
Revision: 000

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Projection System: UTM Zone 30N
Datum: WGS84
Spheriod: WGS84

Project Number: P2295

Drawn By: Gary Hubbard

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ber 2010

APPENDIX 5.8 A

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