Cenos Offshore Windfarm Limited

Cenos EIA

Appendix 5 – UXO Threat and Risk Assessment

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DOCUMENT **CEN001-FLO-CON-ENV-RPT-0040**

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REV	**DATE**	**DESCRIPTION**	**ISSUED**	**CHECKED**	**APPROVED**	**CLIENT**




CENOS Offshore Wind Farm

FLOTATION ENERGY

Unexploded Ordnance Threat and Risk Assessment

Meeting the requirements of the UK's
Construction Industry Research and Information Association's UXO Risk Management Framework:
"Assessment and Management of the UXO Risk in the Marine Environment" (C754)

6 Alpha Associates Ltd

Project No.: 50024
20th July 2023

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This UXO threat and risk assessment is considered a living document. Should the proposed methodologies change, further evidence of UXO sources be found, or if UXO is found during these or other operations, then this assessment for the Study Site is to be reassessed and updated by 6 Alpha Associates Ltd.

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Print Name	**Laurence Gregory**	**Simon Cooke**
Position	Reporting Services Manager	Managing Director

Executive Summary

Project Overview

Flotation Energy has commissioned *6 Alpha Associates Ltd* (6 Alpha) to deliver a desk-based Unexploded Ordnance (UXO) threat and risk assessment to support the development of the *CENOS* floating offshore wind farm (OWF) and associated export cable installation. A risk mitigation strategy has also been commissioned and will be delivered separately and subsequently to this report.

The proposed location of the *CENOS* OWF array, together with the proposed export cable corridor, has been provided in draft format by the Client and is presented at Figure I.

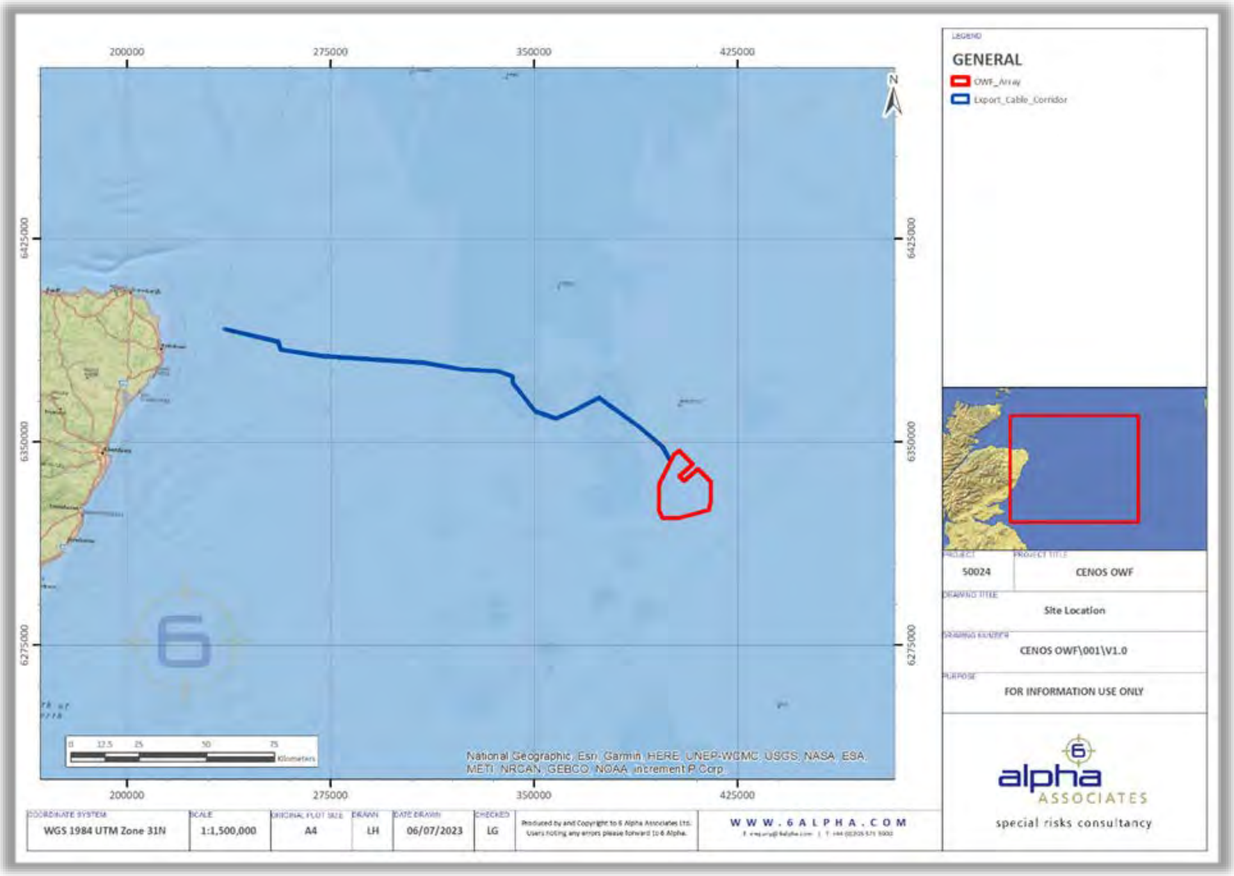

Figure I: Site Location

An analysis of threats and risks associated with the proposed the export cable installation situated within the *UK*'s territorial sea limit (12 nautical miles from the coastline), is outside the scope of this report.

UXO Threat Summary

Significant archive research associated with the Study Site has unearthed evidence of a clear UXO contamination threat; primarily in the western extent of the Study Site driven by the WWII-era defensive minelaying operations undertaken by *British* vessels across the *North Sea*. In addition, background UXO contamination threats might have been generated by WWII-era bombing of land-based and nearshore targets by the *Luftwaffe,* WWI-era naval mine deployment in the general area by the *Imperial German Navy*, and WWI-era *German* submarine activity on or in close proximity to the Study Site.

The prospective UXO threats together with their (worst-case) likelihood of encounter scenarios, generated by the proposed works at the Study Site, are summarised at Table I.

Likelihood of Encounter	UXO Threat Items
HIGHLY LIKELY	N/A
LIKELY	WWII-era *British* Naval Mines
POSSIBLE	N/A
UNLIKELY	WWI-era Naval Projectiles and Torpedoes, WWI-era Naval Mines
HIGHLY UNLIKELY	WWII-era AAA Projectiles and WWII-era *German* aerially delivered ordnance.

Table I: UXO Threat Assessment Summary

UXO Risk Assessment Summary

A strategic level semi-quantitative UXO risk assessment has been undertaken, based upon the likelihood of encountering threat spectrum UXO across the Study Site during the proposed seabed intrusive operations. The assessment of UXO risk is based upon several factors including but not limited to, the nature, scope, and location of UXO threat sources as well as the prospective amelioration of the consequences of their initiation in general (and through-water shock wave effects in particular), in a variety of depths of water.

Considering the proposed operations together with the UXO threats, the outputs of *6 Alpha*'s semi-quantitative risk assessment focussing upon the impact upon vessels and their crews, is presented in chart format, at Figure II and Figure III.

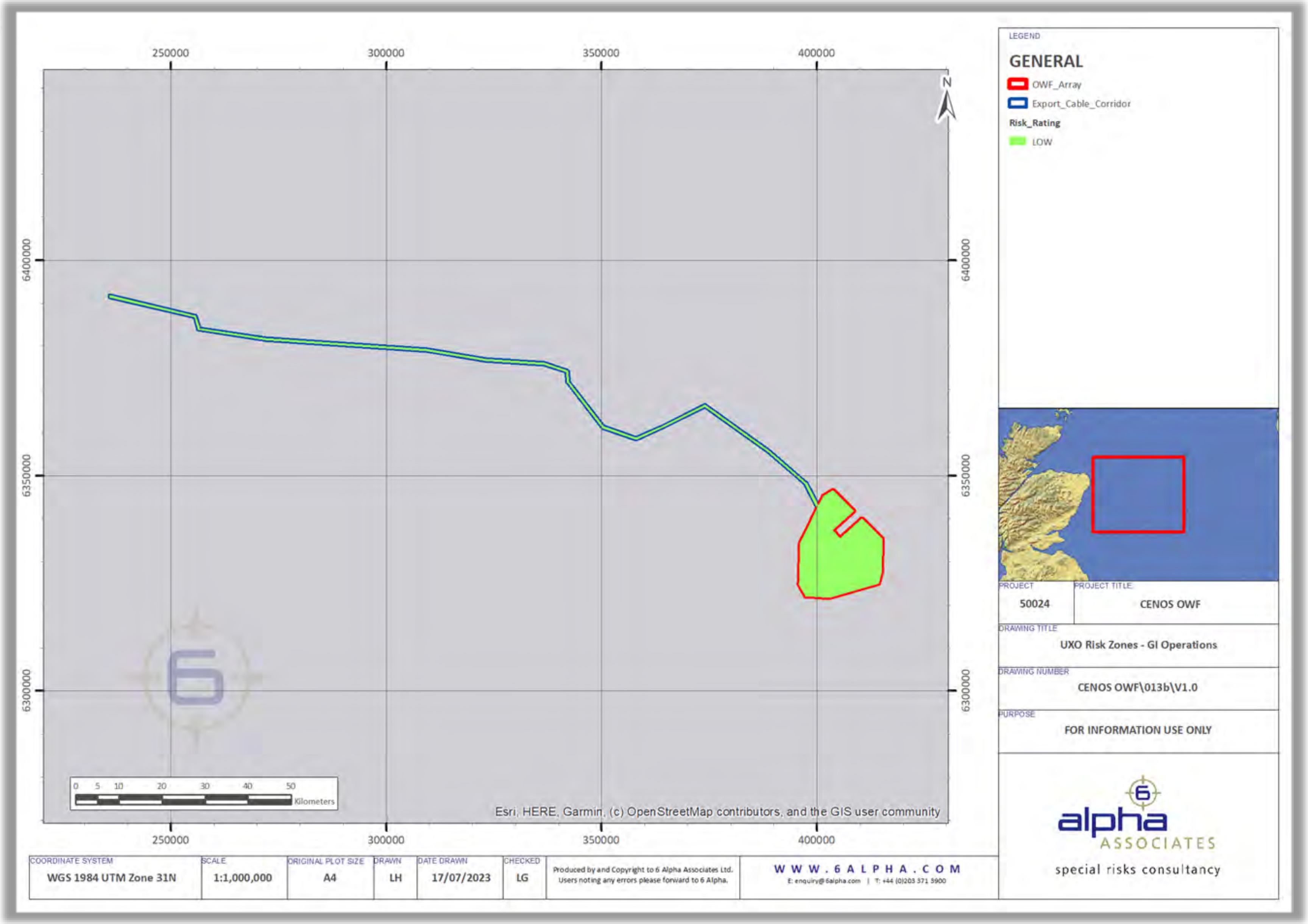

Figure II: UXO Risk Rating for GI Operations (Vessels and Vessel Crews)

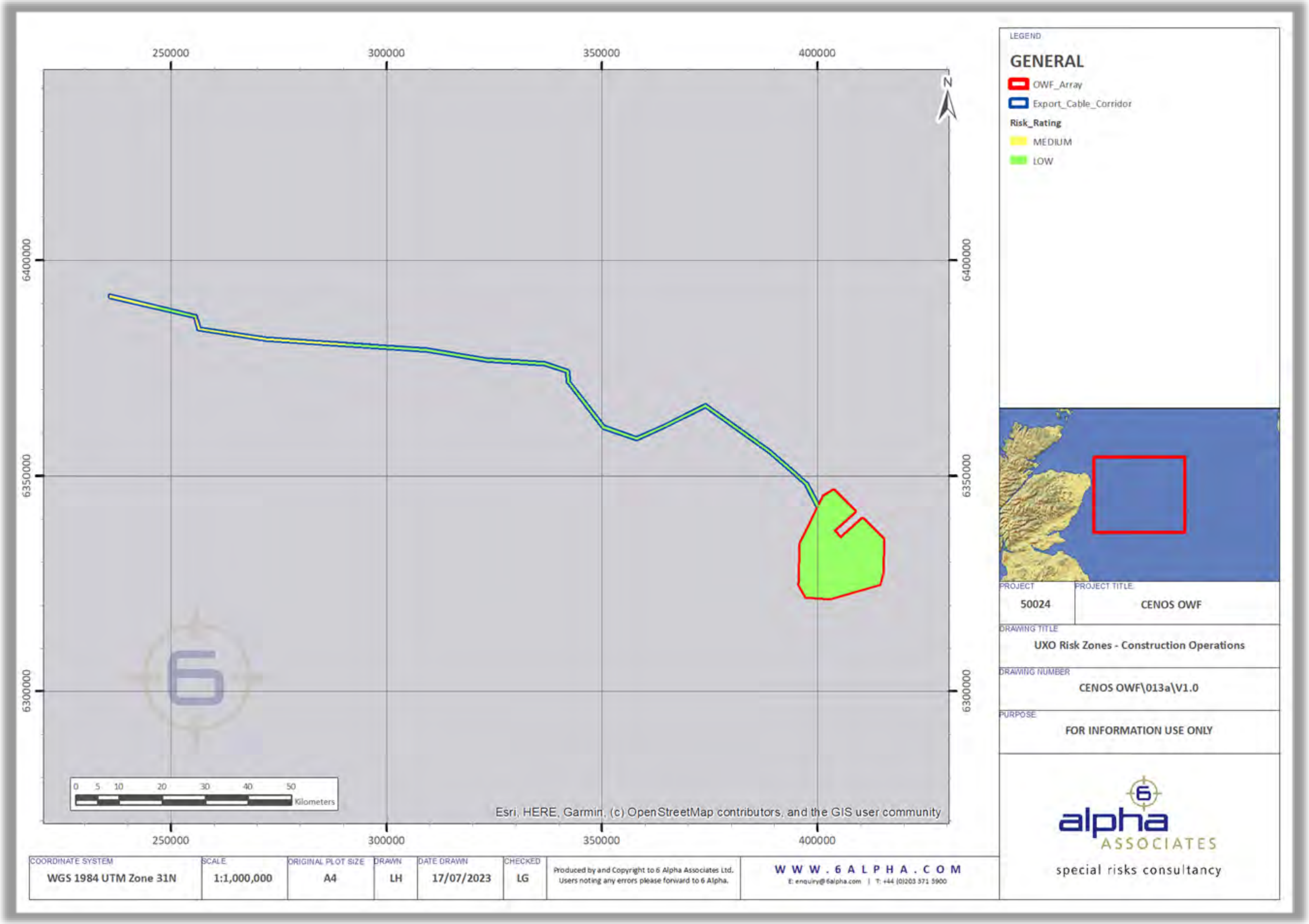

Figure III: UXO Risk Zones for WTG and Cable Installation (Vessels and Vessel Crews)

In accordance with the industry best practice and the UXO risk assessment methodology that *6 Alpha* adhere to, UXO risks to vessels and vessels' crews can be zoned into areas of ***MEDIUM*** or ***LOW***. UXO risks to geotechnical investigation operations, wind turbine generator installation and any enabling works are assessed as ***LOW*** across the entirety of the Study Site due to the low probability of encountering and initiating UXO during such works, or due to the risk mitigation afforded by the significant depths of water present at the Site should threat spectrum UXO be initiated.

UXO risks to export cable installation are classified as ***MEDIUM*** in the western portion of the Study Site. This categorisation of UXO risk is driven primarily by the elevated probability of encountering and initiating WWII-era *British* naval mines in those ***MEDIUM*** risk areas and the potential harm that may be caused to vessels and vessels' crews in water depths up to 100m Lowest Astronomical Tide (LAT). Export cable installation operations outside of the ***MEDIUM*** risk zones is categorised as ***LOW*** risk due to either the low probability of encountering UXO in those areas or the risk mitigative effect of the water depths (in any areas greater than 100m LAT).

Underwater investigative and construction equipment is unlikely to be robust enough to withstand the consequences of a nearby initiation of most large Net Explosive Quantity, threat spectrum UXO (such as naval mines and torpedoes). However, the UXO risk to underwater equipment is likely to be considered tolerable (as compared with the effects associated with vessels and their crews) under the auspices of the As Low As Reasonably Practicable (ALARP) risk reduction, as long as the latter risks do not also pose a hazard to the former.

Recommendations

6 Alpha recommend that the UXO risks posed to the project are mitigated within the bounds of the ALARP risk reduction principle and in accordance with national laws. Specifically, risk reduction can be achieved through the holistic implementation of the subsequent phases of the *Construction Industry and Research Information Association C754* derived risk management framework, including a suitable and cost-effective risk mitigation strategy. This document has already been commissioned and will be delivered separately and subsequently to this report.

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Acronyms and Abbreviations

AAA	Anti-Aircraft Artillery
ALARP	As Low As Reasonably Practicable
CIRIA	Construction Industry Research and Information Association
cm	Centimetre
CPT	Cone Penetration Testing
DP	Dynamically Positioned
GI	Geotechnical Investigation
HE	High Explosive
kg	Kilogram
km	Kilometre
LAT	Lowest Astronomical Tide
MDA	Managed Defence Area
m	Metre
mm	Millimetre
MMBA	Munitions Migration and Burial Assessment
MPa	Mega Pascal(s)
NEQ	Net Explosive Quantity
OSPAR	Oslo-Paris Conventions for the Protection of the North-East Atlantic
OWF	Offshore Wind Farm
PEXA	Practice and Exercise Area
PLGR	Pre-Lay Grapnel Run
pUXO	Potential Unexploded Ordnance
RC	Route Clearance
SQRA	Semi-Quantitative Risk Assessment
TARA	Threat and Risk Assessment
TNT	Trinitrotoluene
UK	United Kingdom
UXO	Unexploded Ordnance
WGS	World Geodetic Survey
WTG	Wind Turbine Generator
WWI	World War One
WWII	World War Two

Part I – Introduction

1 Project Overview

1.1 Scope of Work

Flotation Energy has commissioned *6 Alpha Associates Ltd* (6 Alpha) to deliver a desk-based Unexploded Ordnance (UXO) threat and risk assessment to support the development of the *CENOS* floating Offshore Wind Farm (OWF) array and associated export cable installation. A Risk Mitigation Strategy has also been commissioned and will be delivered separately and subsequently to this report.

1.2 Project Location

The project is located in the *North Sea,* with the *CENOS OWF* array situated approximately 200km to the east of *Aberdeen, Scotland*. The proposed location for the export cable corridor extends approximately 225km from the *OWF* and to near *Peterhead, Aberdeenshire,* where it is expected to make landfall. An analysis of threats and risks associated with the proposed the export cable installation situated within the *UK*'s territorial sea limit (12 nautical miles from the coastline), is outside the scope of this report.

The location of the *CENOS OWF,* together with its proposed export cable corridor, is presented at Figure 1 below, as well as at Appendix 1.

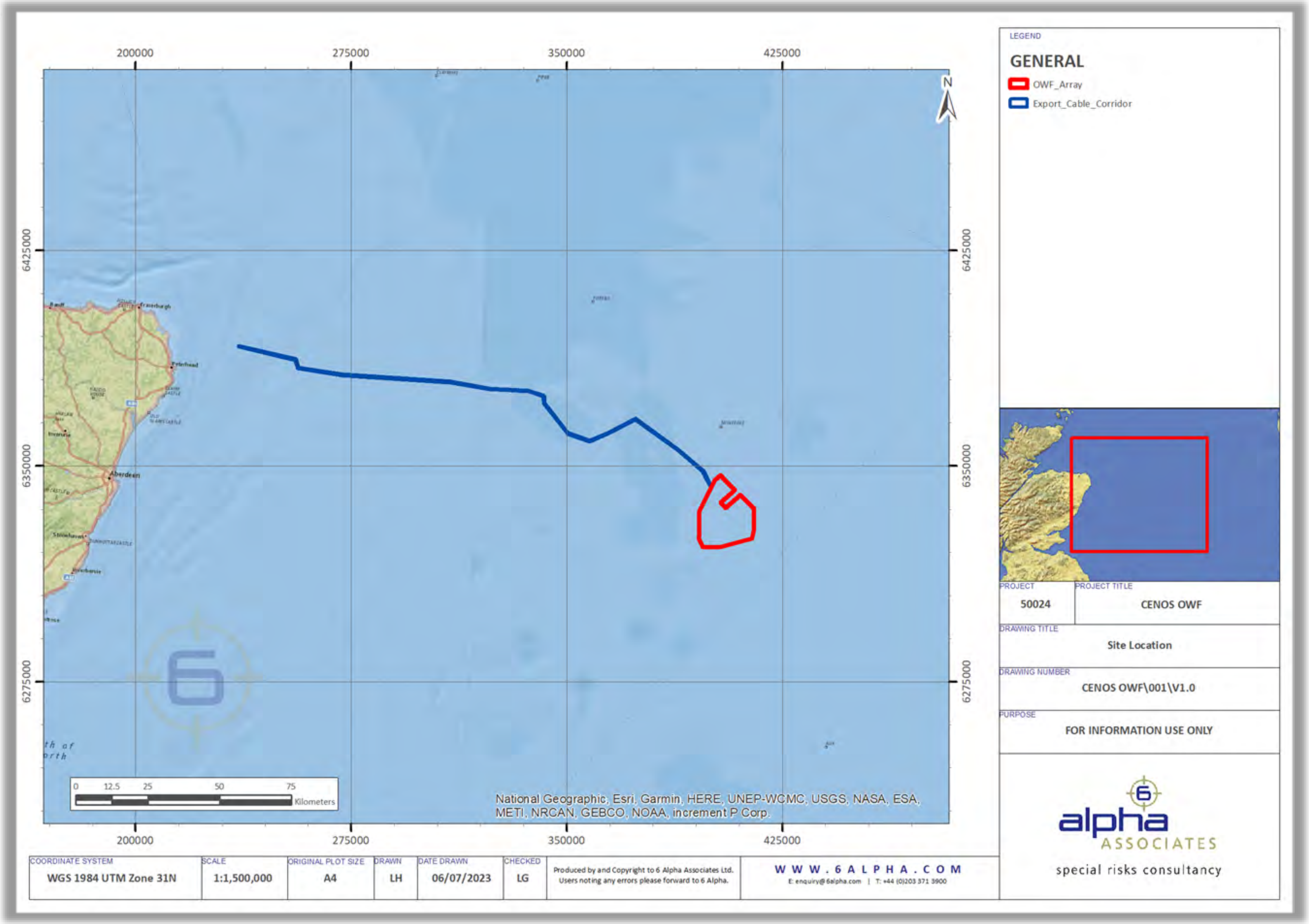


Figure 1: Site Location

2 Introduction to UXO

2.1 UXO in the Marine Environment

All military technology has an inherent base-line failure rate, meaning that not all ordnance functions as the designer intended, during either its training or operational use. Consequently, the military activities and conflicts of the 20th Century have left a legacy of munitions contamination in the marine environment, and it is now a relatively common occurrence to encounter UXO during seabed intrusive activities.

2.1.1 Generic UXO Threats

In the offshore environment, there are multiple factors that may have contributed to the UXO contamination because of the warfighting activity in the region. For example, it is generally accepted that during WWII, approximately 10% of *Axis* aerially delivered bombs failed to explode – *Allied* bomb failure rates are estimated to be slightly higher. Aerial bombing targets were also simply missed, and bombs were sometimes jettisoned from aircraft during evasive manoeuvres and/or when seeking to reduce aircraft weight during a return journey, to deliver a higher safety margin when landing.

During the conflicts of the 20th Century, the naval theatre of war played a crucial role with surface vessels and submarines often involved in naval skirmishes and covert operations. Sea mines were also deployed in significant quantities in both offensive and defensive naval operations and pose a further UXO contamination threat to intrusive sub-seabed activities in the marine environment.

Wartime training exercises also employed live munitions filled with high explosives (or else other substances including toxic chemicals or ignition/burning agents), which may have remained after the training exercises had been completed. Modern military training areas, such as offshore firing ranges, may have also contributed to the background UXO contamination in the offshore environment.

Conventional and chemical munitions dumping was also prevalent, often with little consideration given to future safety implications. Widespread unrecorded dumping of Small Arms Ammunition and Land Service Ammunition was also perceived to be inconsequential, and it was therefore frequently undertaken without regard to munitions dump positional accuracy – resulting in so-called "short dumping". Some dumped munitions may also have migrated from their original locations because of natural seabed sediment transportation and other forces.

Besides the clearance of naval minefields to open sea lanes, minimal effort was made in the immediate post-war periods to clear the unexploded bombs and projectiles that contaminated the seabed. As such, unexploded munitions relating to previous conflicts, but particularly WWII-era munitions, often pose a considerable contamination threat source in the marine environment.

2.1.2 Generic UXO Risks

The explosive or chemical fill within UXO rarely becomes inert or loses its effectiveness with age, but instead the explosive fill may change or crystallise over time – increasing the high explosive's sensitivity to a physical shock or an impact. Trigger mechanisms and fuses, which may have failed, may corrode and deteriorate in the saltwater environment becoming more sensitive to detonation. It is therefore possible that a significant impact on the UXO case, and the resultant effect upon the fuse, may cause its inadvertent detonation.

Prospective UXO incidents that may result in harm are generally considered low probability-high consequence events, which present a challenge when designing project, public and commercial safety policies. Nonetheless, there are clear safety risks associated with UXO encounters for any subsea operation that interacts with the seabed, which must be managed in order to protect offshore personnel from injury or, in the very worst-case scenario, prospective fatalities. Such risks must also be considered, to fulfil Clients' statutory obligations under the auspices of national laws.

2.2 UXO Industry Best Practice

In the absence of specific legislation concerning the management of UXO risks during offshore investigation and construction projects, the *UK's Construction Industry Research and Information Association* (CIRIA) has published a best practice guide for the assessment and management of UXO risk in the marine environment (document reference C754, first published in February 2016). *CIRIA* C754 guidance provides a coherent framework for offshore UXO risk management projects and not only has significant and wide-reaching offshore industry recognition, but also has been formally endorsed by the *UK*'s *Health and Safety Executive* and subsequently, by other regulatory bodies internationally. *6 Alpha* were *CIRIA's* lead technical author for this publication and as such, it guides *6 Alpha's* UXO risk management practices.

Therefore, in undertaking this assessment *6 Alpha* has ensured compliance with industry best practice and As Low As Reasonably Practicable (ALARP) risk reduction criteria – through continued adherence to the framework, the project stakeholder's legal obligations will be fulfilled.

Further information regarding national and international legislation within the *UK*, and the management and reduction of UXO risk to ALARP, is presented at Annex A and is indicative of the safety benchmark to which *6 Alpha* adhere.

2.3 UXO Risk Management Strategic Framework

At Section 5 of *CIRIA's* C754 guide, the risk management framework is divided into five key phases that correspond with those employed by *6 Alpha*, as presented at Table 1. A complete overview of *6 Alpha's* UXO Risk Management Framework is presented for completeness, at Appendix 2.

6 Alpha Risk Management Framework	UXO Risk Management Phase	CIRIA C754 Risk Management Framework	Delivered within Report? (✔/✘)
UXO Threat Assessment	**PHASE ONE**	UXO Threat Assessment	✔
UXO Risk Assessment	**PHASE TWO**	UXO Risk Assessment	✔
Strategic Risk Mitigation Options	**PHASE THREE**	UXO Risk Management Strategy	✘
Risk Mitigation Design and Specification	**PHASE FOUR**	UXO Risk Mitigation (Planning)	✘
Implementation	**PHASE FIVE**	UXO Risk Mitigation (Delivery)	✘

Table 1: 6 Alpha and CIRIA UXO Risk Management Frameworks

The purpose of this report is to address Phases One and Two of the above UXO risk management framework. This framework is applied to provide a holistic solution for managing UXO risks to ALARP, as per Appendix 3.

The potential nature and scope of the UXO threat is addressed initially (Phase One), before the potential UXO risk pathways are identified and analysed to assess the UXO risks associated with the proposed operations (Phase Two).

Once the associated UXO risks have been assessed, recommendations are outlined in order to offer early guidance on fulfilling Phase Three of the UXO Risk Management Framework through the completion of a Risk Mitigation Strategy (which has been commissioned and delivered separately).

In addition, *6 Alpha* recommend that Phase Four, which typically involves the detailed and more specific scope, design and specification of UXO risk mitigation measures for the project, should be undertaken once designs, plans and schedules are finalised, and before intrusive works commence.

3 Assessment Scope and Structure

3.1 Report Structure

This report comprises a desk-based collation and review of readily available documentation and records (which have been summarised separately in Section 3.2), relating to the types of UXO that might be encountered in order to assess the potential UXO risks at the Study Site.

Therefore, the following aspects will be covered in this assessment:

- The sources of prospective UXO contamination that might be encountered at the Study Site will be summarised;
- A variety of options for prospective Geotechnical Investigation (GI), Wind Turbine Generator (WTG) installation, cable installation and burial, construction, and associated enabling operations will be outlined;
- An assessment of the water depths (in terms of Lowest Astronomical Tide (LAT)) across the extent of the site will be considered, in order to assess the prospective UXO detonation consequences;
- The likely UXO risk receptors will be identified;
- A Semi-Quantitative Risk Assessment (SQRA) will be undertaken;
- Conclusions will be drawn, and recommendations made to facilitate reducing UXO risks to ALARP.

3.2 Information Sources

6 Alpha has employed the following generic sources of information (amongst others) to inform and to compile this report:

- British Geological Survey;
- European Marine Observation and Data Network;
- James Martin Centre for Nonproliferation Studies;
- Naval Historical Centre;
- Naval History and Heritage Command;
- Oslo-Paris Conventions for the Protection of the North-East Atlantic (OSPAR) databases;
- Royal Navy (Diving Units);
- UK National Archives;
- UK Hydrographic Office.

3.2.1 Azimuth© UXO Threat Database

6 Alpha's Azimuth© database also contains digitised historic charts, aerial photographs and other extensive analogue records from an exhaustive range of additional national, regional and global archives and/or data sets that have also been digitised. That database has been heavily drawn upon to deliver the UXO threat assessment element of this report.

3.3 Constraints and Limitations

This UXO threat and risk assessment is constrained and limited by that information which is reasonably available to *6 Alpha* at the time of writing, as well as that UXO information that is reasonably accessible in a variety of archives, which *6 Alpha* have digitised and georeferenced or have otherwise summarised in written form.

This document may also require updates and changes, especially wherever and whenever the circumstances and factors associated with assessing UXO risk change. For example, if UXO threats are subsequently discovered and they are different from those that have been anticipated, and/or if proposed subsea operations are significantly changed.

In such circumstances, risks may require re-evaluation and any such changes are to be made by *6 Alpha*, to ensure the continued technical veracity and risk management efficacy of this document.

4 Risk Assessment Methodology

4.1 Source – Pathway – Receptor Model

The source-pathway-receptor model is a conceptual risk model employed by *6 Alpha* across all marine projects (as per *CIRIA* guidance and industry best practice), which informs how UXO risks are assessed for each seabed intrusive activity associated with the project. The model also helps to explain the link between the separate sections of this report and the UXO risk assessment at Section 8. The components of the model are as follows:

4.1.1 UXO Sources

The source element of the source-pathway-receptor model is comprised of the UXO itself. The nature and scope of the UXO contamination threat at the Study Site and its immediate vicinity is summarised in the threat assessment (at Section 5), which details the activities that might have generated a source of UXO contamination and the specific types of munitions that might be present as a result.

4.1.2 UXO Pathways

The UXO pathways are the routes by which the sources can reach the receptors. Marine UXO pathways are likely to be either by direct contact and/or through soil or water energy transfer, through which the resulting shock wave (generated by a UXO source, or sources) may reach potential receptors. Nonetheless, surface events (e.g. if UXO is inadvertently brought back to the vessel and is initiated), may also generate a through-air risk pathway in which blast and fragmentation from the UXO sources might also reach the receptors.

UXO risk pathways may be generated by a variety of operations that interact with the seabed. Therefore, likely operations associated with the project have been assessed and summarised (at Section 6), to demonstrate the potential risk pathway elements of the model.

4.1.3 UXO Receptors

Receptors are defined as anything which might be adversely affected by the consequences of an inadvertent detonation of any UXO source through an identified pathway. The proximity, robustness, and sensitivity of such receptors is essential in determining their capacity to withstand such high explosive effects and defining what degree of UXO risk might be tolerated (if any). For example, risks to underwater equipment might be tolerated by some (or all) stakeholders but risks to personnel, that might generate injuries (in general) and fatalities (in particular), are highly unlikely to be considered tolerable.

Typically, offshore receptors include subsea equipment and infrastructure; as well as underwater (e.g. Work-Class Remotely Operated Vehicle) equipment and surface vessels, and where appropriate, their crews. Divers are also especially vulnerable to underwater high explosive effects, as are marine mammals and fish.

4.2 Semi-Quantitative Risk Assessment Methodology

The SQRA is specifically designed to assess the probability of an unplanned discovery and initiation of UXO, as well as their prospective consequences upon a range of potential sensitive receptors (e.g. surface vessels and any associated underwater equipment), in order to determine the level of UXO risk for each intrusive activity. A full explanation of *6 Alpha's* SQRA process is presented at Annex B, but most importantly, the SQRA embodies the source-pathway-receptor risk model and is achieved by employing the following formula:

Risk **(R)** = Probability **(P)** x Consequence **(C)**.

4.2.1 Probability

Probability is determined by considering the likelihood of both encountering and initiating UXO.

The probability of encountering UXO is a function of the prospective nature, scope, and extent of the potential UXO contamination at the site and the juxtaposition of all seabed intrusive activities with respect to them. Nonetheless, the prospective UXO threats are difficult to accurately quantify due to the nature of historical records associated with depositional events. This can include unrecorded and abandoned ordnance, anti-aircraft artillery gun fire, and/or jettisoned aerial High Explosive (HE) bombs – which cannot be spatially defined with either certainty or accuracy. Such uncertainty is accounted for by employing the (undermentioned) precautionary principle.

4.2.2 Consequence

The consequences of an unplanned UXO initiation are a function of the mass of high explosives in the UXO and their proximity to, and the robustness of, sensitive receptors – including the support vessels, their crews, and any subsea equipment/tools.

The mass of high explosives and their underwater and/or surface effects can generally either be estimated or accurately modelled. Other assessment factors include the prospective position of the UXO on the seabed at the moment of encounter (i.e. on the surface or shallow buried – and in the latter case to what depth), the soil type, the through soil and through water/air separation distances between the UXO and the receptor; and the robustness of such receptors.

The likely through-water and/or through-air effects upon such receptors are dependent upon their juxtaposition with reference to the UXO, as well as their robustness in general and their capacity to withstand such high-explosive events in particular. Generally, personnel are very vulnerable to high explosive fragmentation, as well as underwater shock and to a reduced extent surface-blast. As long as workers are not jeopardised, limited adverse effects upon vessels, barges and subsea equipment might be tolerated.

4.3 The Precautionary Principle

Making predictions about the yet unobserved states of UXO, generates uncertainties within the risk assessment, especially when determining the probability of UXO initiation. The probability of UXO encounter and initiation is therefore steered by the precautionary principle that, for risk assessment and mitigation purposes, informs risk-mitigating actions in such circumstances.

The principle concludes that if there is uncertainty about the nature of the risk (e.g. the condition and viability of UXO), then a proportionate, transparent, and consistent approach must be taken during the decision-making process that aligns with industry best practice. Therefore, for risk assessment and precautionary purposes, it is assumed any direct kinetic energy encounter with UXO is likely to cause its initiation and generate a potential UXO risk pathway.

Part II – UXO Threat and Risk Assessment

5 Sources of UXO Contamination

Significant archive research associated with the Study Site has been undertaken to corroborate and to highlight, any and all potential sources of UXO contamination as well as to assess their likelihood of encounter.

Background information detailing generic military ordnance and UXO classification, as well as their associated high explosive and prospective detonation effects, is presented separately at Annexes C and D, respectively.

5.1 Aerial Bombing

Air dropped bombs may be encountered in areas where conflict and/or air campaigns have occurred, although the precise locations of bombing raids and aerial attacks have not always been accurately documented – especially in the offshore environment. In addition, offshore bombing ranges have also been employed by military air forces, which may also have contributed to the contamination of the marine environment. Nonetheless, extensive desk-based research of historical records did not uncover any evidence to suggest that historic aerial bombing occurred at the Study Site itself or within 5km of the Study Site boundary.

However, a residual threat is posed at the Study Site due to the sustained *Luftwaffe* bombing campaigns directed against the *Aberdeenshire* coastline, particularly around *Peterhead*, throughout WWII. *Luftwaffe* bombing aircraft also deliberately targeted *Allied* shipping during WWII. For example, an analysis of historical records identified that the closest recorded offshore bombing incident was the unsuccessful bombing of a convoy near *Peterhead,* approximately 10.5km to the west-south-west of the Study Site. Furthermore, it is also possible (if largely unquantifiable) that unwanted bombloads might have been jettisoned in the general area across the *North Sea*, due to the bombing raids documented in the wider area and the Site's general position along flight paths for both *Allied* and *Axis* military aircraft.

Nonetheless, as there is no evidence to suggest an elevated UXO threat level is posed by aerial bombing events at this Study Site specifically; such an encounter is considered a background threat only**.**

Likelihood of UXO Contamination	Associated UXO Threat Items
HIGHLY UNLIKELY	*German* WWII-era Aerially Delivered Ordnance

Table 2: Aerial Bombing Threat Summary

5.2 Naval Engagements

The combatant navies of the 20th Century commanded fleets that consisted of armed surface craft such as destroyers and battleships, as well as more covert craft such as submarines and motor torpedo boats – all of which were armed with a variety of weapons systems. As with aerial bombardment in the offshore environment, the specific locations of most naval engagements were neither commonly nor accurately recorded in contemporary records.

Such evidence is readily presented by an analysis of *6 Alpha's* in-house *Azimuth*© database, however. Eight naval encounters are documented within a 5km radius of the Study Site boundary - all occurring during WWI. Most notably, the armed *German U-14* submarine was shelled and subsequently rammed and sunk by the armed trawlers *Oceanic II* and *Hawk* on the 5th June 1915 (approximately 1km to the south-west of the export cable corridor). A further seven vessels were sunk by *German* submarines within 5km of the Study Site boundary during WWI; two, the *British FV Gem* and *Manx Princess,* were scuttled by gunfire from the *German UC-33* submarine on the 29th June 1917 (both approximately 2.4km south-west); the *Dutch* drifter *Geertruida* was scuttled by the *German U-45* submarine on the 5th July 1916 (approximately 3km south-west), a further three vessels – *FV Lillian, FV Crown Prince* and *FV Osprey* – were also scuttled by gunfire from the *German UC-76* submarine on the 12th April 1917 (all approximately 3.3km north); and the final vessel, the *FV Petrel,* was scuttled and sunk by emplaced explosive charges from the *German UC-77* on the 30th March 1917 (approximately 4.2km south-east).

Consequently, it is plausible that naval projectiles – and potentially naval torpedoes associated with the *German U-14* submarine - may have contaminated the seabed resulting from these engagements. The prospective magnitude of these threats is reduced somewhat, however, by the limited operational capacity of most submarines during this period and the relative rarity of WWI ordnance encounters in the marine environment.

The locations of shipwrecks originating from naval engagements during WWI, in relation to the Study Site, have been georeferenced and are presented at Appendix 4.

Likelihood of UXO Contamination	Associated UXO Threat Items
UNLIKELY	20th Century Naval Projectiles and Torpedoes

Table 3: Naval Engagements Threat Summary

5.3 Naval Minefields

A naval sea mine is a self-contained high-explosive weapon that is placed in the water to destroy ships and/or submarines and would have been fused to ensure that detonation under appropriate circumstances, either upon impact or otherwise upon a close encounter with a ship. During the conflicts of the 20th Century, naval mines were generally employed either offensively, to hamper enemy shipping and to blockade harbours; or defensively, to protect shipping and by creating safe movement zones through them.

During WWI and WWII, defensive minefields were typically laid by surface craft, whereas offensive minefields were often laid by aircraft or submarines – the latter therefore delivering an element of secrecy and uncertainty to the positions of the minelaying operations. Minefields that were deployed by aircraft or submarines were also less likely to be accurately recorded than those laid by surface vessels and as such, the exact positions of these types of minelaying operations are difficult to corroborate with any degree of certainty.

5.3.1 WWI Minefields

Detailed desk-based research of historical records and charts indicated that multiple mining operations were undertaken around the *Aberdeenshire* coastline, including one WWI-era *German* minefield which intersected the Study Site in the western sector of the export cable corridor. Documentary sources suggest that this operation comprised of at least 92 mines which were laid by the *Imperial German Navy,* and are therefore, considered likely to have been of the E-variety, as these were the standard *German* contact mines employed during WWI.

One further WWI-era *German* minefield was also located approximately 1.1km to the north-north-east of the proposed export cable route. This minefield comprised of 34 mines employed by the *Imperial German Navy* and are, again, likely to be of the E-variety.

Despite this, WWI-era mines are typically only encountered very rarely within the marine environment and as such, are unlikely to pose a significant UXO threat. The georeferenced location of these minefield are presented at Appendix 5.

Likelihood of UXO Contamination	Associated UXO Threat Items
UNLIKELY	WWI-era *German* naval mines

Table 4: WWI-era Naval Minefields Threat Summary

5.3.2 WWII Minefields

Extensive desk-based research of historical records and charts indicated that the western sector of the proposed export cable corridor is located within a former *British* declared mining area, which spanned a large area of the *North Sea,* from the east of the *Moray Firth* to southern *Aberdeenshire.*

Given the large extent of this declared mining area, it is unlikely that mines would have been deployed across its entire mapped extent, however, further analysis of *British* mining operations revealed that two specific minelaying operations directly intersected the export cable corridor, designated *"SN13"* and *"SN16C".* Collectively, a total of approximately 2,404 mines were deployed across these recorded minelays between 1940-1941, although not all would have been situated within the Study Site boundary. Of these, approximately 2,090 mines were laid within *"SN13"* by an array of *British* minelaying vessels in August 1940 and comprised of Mk XVII and XX mines. The remaining 314 mines were laid in *"SN16C"* and were deployed by the *HMS Manxman* and *HMS Welshman* in October 1941 and similarly comprised of Mk XVII and XX mines. Consequently, it is considered likely that WWII-era mines may present an ongoing UXO contamination threat in certain areas of the Study Site, given their deployment across the area.

The locations of these *Allied* minefields in relation to the Study Site are presented at Appendix 6.

Likelihood of UXO Contamination	Associated UXO Threat Items
LIKLEY	WWII-era Naval Mines

Table 5: WWII-era Naval Minefields Threat Summary

5.4 Military Practice and Exercise Areas (PEXA)

The *North Sea*, as well as the *British* coastline, has been used for much of the 20th and 21st centuries by various national and international military forces to conduct training and weapons' systems testing. These activities may have employed live or practice munitions (the latter being difficult to distinguish from the former once abandoned on the surface of the seabed for many years), which are likely to have remained in the marine environment, once the training activities have ceased.

5.4.1 Historic Military Training Areas

An analysis of pertinent historic mapping and military documents did not reveal any evidence to suggest that military training activities have previously been undertaken on-site nor within 5km of it. Indeed, the closest such military training area was a live bombing range designated *N241 Crimond (Rattray Head)* located 9.6km to the north-west of the Study Site.

Likelihood of UXO Contamination	Associated UXO Threat Items
HIGHLY UNLIKLEY	N/A

Table 6: Historic Military Training Areas Threat Summary

5.4.2 Modern Military PEXA

An analysis of available documentation relating to modern military PEXA in the UK indicated that the central sector of the proposed export cable corridor was situated within a section of the large *Central Managed Defence Area (MDA),* designated *"D613A".* This military PEXA is listed as a "danger area" due to intense aerial activity and is known to be used by the *Royal Air Force* for aerial flight training, including high energy air combat manoeuvres. It is in *6 Alpha's* experience that such manoeuvres are not commonly associated with the discharge of on-board weapon systems, although it is not impossible that air weapons may have been employed and in such circumstances UXO might have been generated.

Nonetheless, it is considered highly unlikely (although not impossible) that an additional UXO contamination threat would have been generated in the marine environment as a result of this designated training area.

The location of this modern military PEXA, in relation to the Study Site, is presented at Appendix 7.

Likelihood of UXO Contamination	Associated UXO Threat Items
HIGHLY UNLIKELY	N/A

Table 7: Modern Military PEXA Threat Summary

5.5 Coastal Armaments

An assessment of local and national archive sources and databases did not identify any artillery installations in the *UK* that would have possessed firing templates sufficient to intersect the Study Site itself. Although, it must be noted that a coastal artillery gun battery at *Burnhaven*, which comprised of two 6" Mark XII/IX guns, did indeed possess a firing range that extended to approximately 4.6km to the south-west of the export cable corridor, however there is no evidence to suggest that such installations would have generated a UXO contamination threat at the Study Site itself.

Likelihood of UXO Contamination	Associated UXO Threat Items
HIGHLY UNLIKLEY	WWII-era AAA Projectiles

Table 8: Coastal Armaments Threat Summary

5.6 Munitions Dumping

Stockpiles of *Allied*, *Central Powers*, and *Axis* munitions of the conventional variety (i.e. HE filled), and chemical munitions that had been earmarked for wartime use, were disposed of at the end of WWI and WWII. As a cost effective and military expedient, conventional and chemical munitions were often dumped offshore or into other suitable bodies of water, such as lakes.

Whilst the centre of mass of such dumpsites were typically recorded, the logistical accuracy of dumping such munitions was then, less than perfect. Such munitions were commonly short-dumped and although some chemical and conventional munitions were dumped in small munitions containers, the effects of their break-up and subsequent munitions migration may well have further spread the theoretical extent of such contamination.

An analysis of pertinent naval and admiralty charts, together with relevant marine environment protection agency databases and specific supplementary research, did not identify any recorded munitions dumps within 10km of the Study Site.

Likelihood of UXO Contamination	Associated UXO Threat Items
HIGHLY UNLIKELY	N/A

Table 9: Munitions Dumping Threat Summary

5.7 Munitions Related Shipwrecks and Aircraft

Merchant and naval vessels that were sunk during 20th Century conflicts may have contained munitions – as armament and/or cargo. The prospective extent of UXO contamination may vary, depending upon nature and integrity of the wrecks. Wreck investigations have found that munitions can spill from ships as they sink and break up, otherwise their ordnance may remain sealed within their holds and remain immobile. Similarly, military aircraft that were shot down or otherwise had to forcibly crash-land into the sea, may have also carried munitions.

It is also unlikely that any ship would have been sunk in the first exchange of fire due to the relative inaccuracy of naval weapons during these conflicts; and it is therefore likely that many bombs, projectiles, and torpedoes would have initially missed their targets and might remain on the seabed as UXO. Regardless of the type of weapons systems employed to attack ships or aircraft, it is entirely feasible that several exchanges of fire would have preceded a successful attack. Generally, the closer the munitions related shipwreck is located to the Study Site, the more likely a UXO contamination threat is to have been generated in its vicinity.

Extensive desk-based research, together with corroborative evidence gathered from *6 Alpha's Azimuth*© UXO database, highlights evidence to suggest that some war fighting has occurred at the Study Site, although some munitions related shipwrecks were recorded. Notably, eight vessels were sunk within 5km of the Study Site, as a result of naval engagements during WWII, seven of which were a result of *German* submarine activity (further details of these incidents are presented in Section 5.2). However, other than the *German* submarine *U-14* - which was sunk by two *British* vessels 1km south-west of the Study Site - these vessels were not documented as being armed themselves and therefore would not present a UXO contamination threat beyond the ordnance expended in their sinking.

Table 10 summarises the quantity of potential munitions related shipwrecks located in the vicinity of the Study Site, which are also depicted at Appendix 8.

Distance from Site	Cause of Sinking				Total
	Air Raid	Naval Skirmish	Mined	Other	
On-Site	0	0	0	0	0
<500m	0	0	0	0	0
500m – 1km	0	1	0	0	1
1km – 2km	0	0	0	0	0
2km – 5km	0	7	0	0	7
Total	0	8	0	0	8

Table 10: Munitions related shipwrecks within 5km of the Study Site

5.8 Previous UXO Encounters

An analysis of the *OSPAR* database, together with extensive desk-based research of national records and news sources did not identify any munitions encounters within 5km of the Study Sites boundary. Indeed, the closest such documented munitions encounter was one WWII-era *German* naval mine approximately 9.6km south-west of the export cable corridor, which was discovered during a routine survey of the *Forties Oil Pipeline.*

Nevertheless, UXO encounters within the marine environment are not always documented in the public domain, though the fact that historic munitions continue to be found highlights the longevity of the threat that might be posed by UXO in the marine environment. Further information concerning *inter alia*, the longevity of the UXO threat in the marine environment is nonetheless included for completeness, at Annex E.

5.9 UXO Threats – Summary

A georeferenced chart depicting the considered range of prospective UXO contamination sources at the study area is presented at Figure 2 below, as well as at Appendix 9.

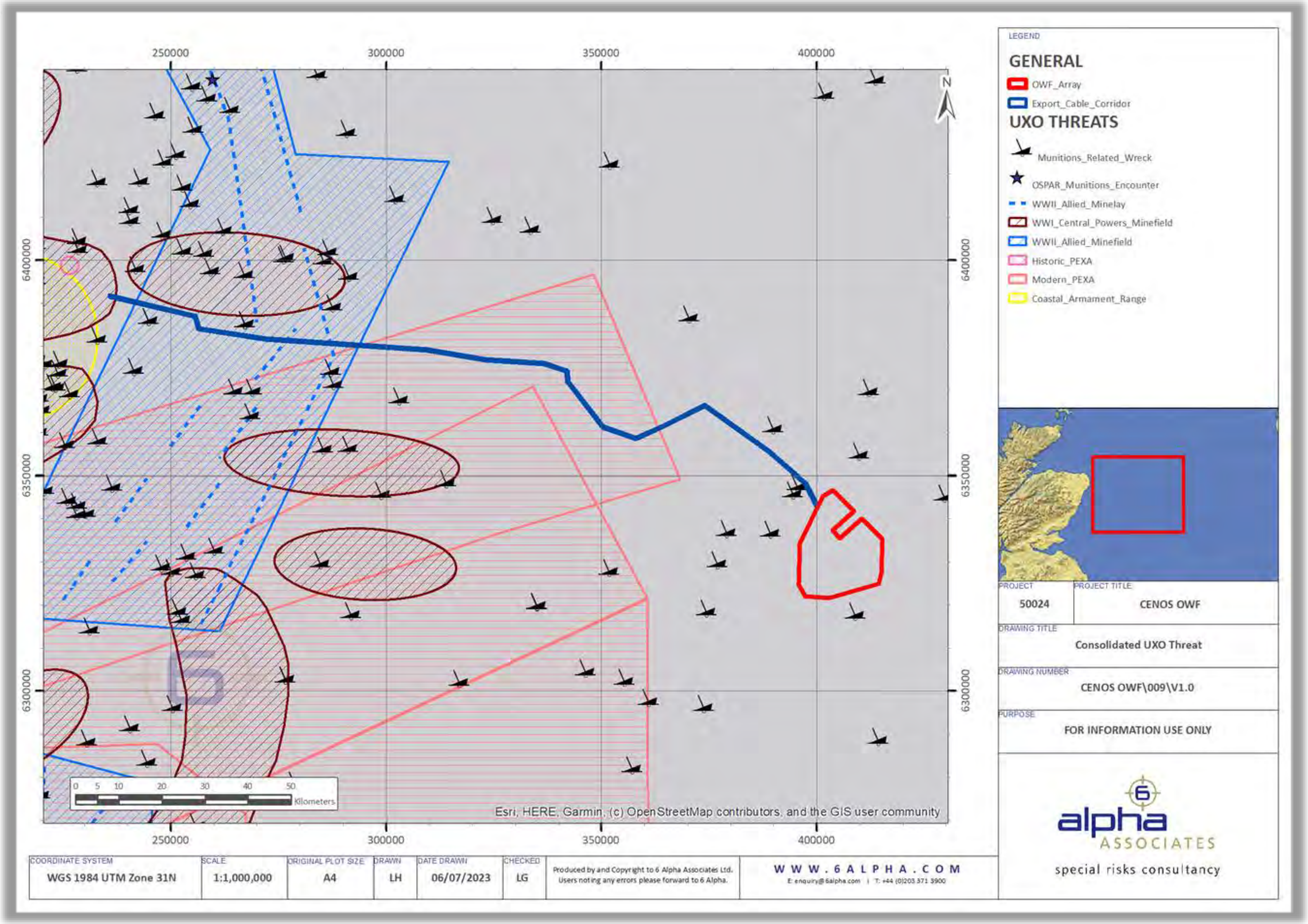


Figure 2: Consolidated UXO Threat

Based upon the threat element of this assessment, the following types of UXO, complete with their measurements, estimated ferrous mass, and expected Net Explosive Quantity (NEQ) (based upon equivalent Trinitrotoluene (TNT) masses), may pose a UXO threat at the Study Site.

5.9.1 Aerially Delivered Ordnance

Designation	Length x Diameter	Estimated Ferrous Mass	NEQ
SC-500 HE Bomb	1,415mm x 457mm	280kg	220kg
SC-250 HE Bomb	1,194mm x 368mm	126kg	130kg
SC-50 HE Bomb	762mm x 200mm	25-30kg	25kg

5.9.2 Torpedoes

Designation	Length x Diameter	Estimated Ferrous Mass	NEQ
45cm C/06 Torpedo	5,650mm x 450mm	750.8kg	122.6kg

5.9.3 Naval Mines

Designation	Length x Diameter	Estimated Ferrous Mass	NEQ
Mark XVII Mine	1,321mm x 1,016mm	313-317kg	227kg
Mark XX Mine	1,321mm x 1,016mm	331kg	227kg
E Mine	1,168mm x 864mm	208kg	165kg

5.9.4 Artillery Gun and Naval Gun Projectiles

Designation	Length x Diameter	Estimated Ferrous Mass	NEQ
6” Artillery Projectile	582mm x 152mm	39.4kg	6kg
8.8cm Naval Projectile	394mm x 88mm	12.4kg	1.42kg
12pdr Naval Projectile	210mm x 78mm	5.259kg	0.0425kg

6 UXO Risk Pathways – Planned Operations

An outline of the expected operations that may be employed is presented in order to evidence the potential UXO risk pathways that may be generated, should such work encounter those threat spectrum UXO that have been identified in Section 5. If the planned methods are changed, then the risk assessment is to be reviewed and updated if necessary.

6.1 Geophysical Survey

Geophysical survey methodologies are likely to include Multi-Beam Echo Sounder, Side Scan Sonar, Sub-Bottom Profiler and magnetometer/gradiometer survey operations. These methodologies employ remote and direct sensing 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 sensitive marine UXO, 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.

However, where equipment is deployed on the seabed to aid in the calibration of the various geophysical survey tools, such as a ferrous target for magnetometer validation, the potential for contact with UXO items on the seabed may be introduced.

6.2 Geotechnical Investigation Operations

A GI campaign will likely then be undertaken in order to gather data on the local seabed's makeup and conditions within the Study Site, in addition to a benthic survey. It is expected that the following GI methodologies may be employed as part of the campaign:

6.2.1 Boreholing

Continuous sampling/coring borehole operations employ kinetic energy to invasively penetrate the seabed. Such techniques are capable of initiating UXO, especially if the leading edge of the borehole equipment comes into contact with it.

6.2.2 Cone Penetration Testing (CPT)

CPT measures the resistance to penetration of the seabed, using a steel rod with a conical tip. Given that this methodology employs kinetic energy to invasively penetrate the seabed, it is possible that if the CPT tool comes into direct contact with UXO, the kinetic energy generated may be sufficient to cause its initiation.

6.2.3 Vibrocoring

Vibrocoring employs the force of gravity, combined with kinetic energy (supplied by a vibrating head), to drive a sampling-core into the seabed, in order to collect sub-seabed samples. Therefore, given the kinetic energy involved in the process, vibrocoring is considered to be capable of initiating UXO, especially if the leading edge of the sampling equipment comes into direct contact with it.

6.2.4 Environmental Grab Sampling

Surface grab sampling can be used as a method of recovering sediments from the seabed during environmental/benthic surveys of the seabed and involves a simple grab bucket being lowered to the seafloor, closing upon impact and securing a sediment sample, before being brought back to the surface – usually through the means of a winch. Grab sampling tends to be an aggressive investigative operation which generates kinetic energy as the bucket falls to the seabed and as the sample is taken. In addition, there is a possibility of inadvertently recovering small UXO to the deck of the vessel along with the grabbed sample; such risks should therefore be mitigated.

6.3 Construction Operations

It is expected that WTGs are to be installed and operated from floating platforms and therefore, it is the mooring points for the WTGs that present a potential UXO risk pathway because they will likely penetrate the seabed. Each floating WTG will likely require mooring points and the installation of each mooring point into the seabed could generate sufficient kinetic energy to detonate threat spectrum UXO in their proximity.

Typical methodologies for such mooring systems can include but are not limited to; drag-embedded anchors, gravity anchors, suction piles, and pin piles. It is likely that similar UXO risk pathways might be generated irrespective of the specific mooring methodology, given the kinetic energy involved in each.

Once the mooring anchors and/or piles have been installed, subsequent works to connect catenary mooring cables should not generate a significant or further UXO risk pathway, as long as initial and subsequent mooring is accounted for.

6.4 Cable Installation and Burial Operations

It is expected that cables could be installed using several different methodologies depending on the geological conditions, although specific methodologies are yet to be defined. Alternatively, the cables may be pre-laid on the seabed and subsequently buried.

An overview of prospective cable installation and burial methodologies is described briefly below, to inform subsequently the risks that UXO might pose to such techniques.

6.4.1 Pre-Lay Operations

Pre-Lay Grapnel Run (PLGR) and Route Clearance (RC) will likely be employed to ensure that the working area is clear of disused communication cables and other seabed debris, which may prove detrimental to the cable lay and post-lay burial equipment.

PLGR operations generally involve towing an array of spear-point grapnels along the surface of the seabed within the designated cable corridor(s). PLGR is not a UXO risk mitigative method and nor should it be considered as such in other than the most extreme circumstances (and only where no other technique is likely to work – in such conditions it needs careful supervision and risk mitigation). RC operations also typically involve the identification and removal of specific and significant impediments to cable lay and/or burial, such as boulders, anchors, chain, steel-wire rope, disused cables, and obstructions generated by wrecks and the like.

It is therefore possible that pre-lay operations could cause a UXO detonation event, should pre-lay equipment come into direct contact with UXO that is very shallow buried or else on the surface of the seabed.

6.4.2 Surface Laid Cable

The cables may be laid on the surface of the seabed and then subsequently buried where necessary. Cables are also surface laid where they cross existing infrastructure (such as existing pipelines and other cables), as they cannot be buried at these locations.

The kinetic energy associated with surface laying the cable might be sufficient to initiate UXO, especially if the cable makes direct contact with it - subject to, amongst other factors, the mass of the cable per linear meter, the water depth and rate of lay. Even if the cable lay energy is considered insufficient to initiate UXO (because e.g. the cable is relatively low mass and it is laid slowly), it is not considered best practice to deliberately overlay UXO with cables and in such circumstances, post-lay inspection and burial is likely to be both compromised and/or jeopardised.

6.4.3 Jetting

Where soft seabed conditions are encountered, jetting seabed sediments can be employed to bury cables either concurrently or in a separate operation once it has been laid on the surface of the seabed. Jetting functions by fluidising the seabed to enable burial of the cable, to its target depth of burial.

Jetting procedures are considered a more benign and less aggressive installation methodology (as compared with e.g. mechanical cutting) and is therefore, less likely to inadvertently initiate UXO when benchmarked with other methods. Despite this, a risk pathway may still be generated if direct contact is initiated between UXO and the jetting tool itself or the direct or indirect effects of its high-pressure water jetting system.

6.4.4 Ploughing

Displacement ploughs create an open V-shaped trench into which the cable can be concurrently laid. This process causes significant disturbance to the seabed as the trench can typically be up to 3m wide and 1.5m deep, whilst the plough can have a skid footprint of up to 10m wide, between its support skids. The open trench can be then backfilled using blades mounted to the rear of the plough, thus burying concurrently the cable behind it. The large footprint, significant mass of the machine and the kinetic energy it generates could collectively, encounter and initiate UXO.

Alternatively, a non-displacement plough could be used to cut through the seabed using a thin blade-like shear, through which the cable runs. This method generates a reduced level of disturbance to the seabed, by comparison with a displacement plough and it creates a narrow trench (usually between 0.3m and 1.0m wide). In such circumstances the trench, is normally backfilled as the cable is laid.

The risk considerations associated with plough methodologies are generated by the mass of the shear (and any supports skids) and their velocity, which in combination may be sufficient to initiate UXO either directly or indirectly.

6.5 Protection and Crossing Operations

WTG moorings may require some form of anti-scour protection. In addition, where offshore cable burial is not possible, and where existing cables or pipelines are crossed, some form of surface cable crossing and protection is likely to be required.

Options that might be considered include, but are not limited to, the following:

6.5.1 Scour Protection

It is expected that the WTG moorings may require some form of anti-scour protection, possibly in the form of either static or dynamic rock armour to be emplaced after installation works are complete. The specific type and overall extent of the scour protection depends on the local seabed conditions (i.e. soil conditions) as well as the type of mooring that is installed. Nonetheless, the emplacement of rock armour around such moorings may present a UXO risk pathway, should any UXO be encountered directly or in close proximity subject to the kinetic energy associated with such emplacement.

6.5.2 Concrete Mattress and/or Rock Placement

To protect any existing (live and in-use) cable(s), concrete mattresses and/or rock placement may be employed to facilitate cable crossing(s), or else split-piping may be applied to protect the cable. A UXO risk pathway may be generated by the emplacement of mattresses, rock (or rock-bags) or split-pipe, alongside and over the cable. The probability of an inadvertent UXO detonation is dependent upon the resultant kinetic energy generated by the emplacement of the protection method and the juxtaposition, sensitivity and NEQ of such UXO.

The potential risks may well be reduced if direct contact with UXO is avoided. Where there is potential UXO (pUXO) located within close proximity, then the cable protection system(s) are not only to be deployed in a controlled fashion, but also as slowly as is reasonably practicable (to reduce the resultant kinetic energy generated). Minimum pUXO safety avoidance distances are also to be adhered to.

6.5.3 Crossing Design

In consideration of third-party cable crossing and/or the removal of out-of-service cables, it is assumed that such cables would not have been (deliberately) installed on top of, or in close proximity to UXO. Nonetheless, this does not mean that UXO will not be encountered anywhere such routes, and therefore, a risk pathway may still be generated depending on the precise methodology employed to work in areas where third-party or out-of-service cables are located.

6.6 Enabling Operations

The following methodologies may be employed to facilitate future works:

6.6.1 Dynamically Positioned (DP) Vessels

DP vessels employ computer-controlled systems to automatically maintain their position and heading by using propellers and thrusters. Position reference sensors and satellite navigation, combined with wind sensors, motion sensors, and gyrocompasses provide information to a computer that maintains vessels' positions, constantly accounting for the magnitude and direction of environmental forces affecting them. DP vessels are commonly used to support a wide variety of sub-seabed operations.

If a DP vessel does not contact the seabed (because it is not anchored and will not ground), then a prospective encounter with UXO from such a work platform does not presents a UXO pathway and thus a risk is not generated. A risk however might be presented in shallow water, if thrusters disturb UXO in close proximity of the influence (of the thruster), especially if the UXO is located on the surface of the seabed or shallow buried beneath it.

6.6.2 Vessel Anchoring

It is possible that other types of vessels will anchor independently or otherwise employ Anchor-Handling Tugboats, to support the proposed works. There is a risk that anchors could initiate UXO if they were to come into direct contact with it, either as they are positioned and especially emplaced. However, the deployment and post-tensioning of anchor catenaries are considered less likely to inadvertently initiate UXO.

In the latter case, this is due to a number of factors, namely: the cable forces are comparatively longer in duration and of lower magnitude; the risk is generally confined to surface UXO only (as the cables may be deployed under tension and may not sweep extensive areas of the seabed). Nonetheless, any cable contact with UXO is likely to be linear (i.e. along the cable/UXO length rather than as a “point” force), which is considered less aggressive when compared with a point induced force.

6.6.3 Diving Operations

There is no indication that divers are currently being considered to assist or undertake works. Nonetheless, divers are especially vulnerable to the types of underwater shock generated by UXO detonations and, subject to UXOs’ NEQ, diver fatalities can easily be generated hundreds of metres from the seat of an underwater high explosive event. Therefore, divers should not be deployed where there is a risk of occurrence of such a detonation event.

If divers are to be used, then the risks associated with diving operations must be reassessed by *6 Alpha*.

7 Study Site Characterisation

7.1 Local Seabed Conditions

The Study Site's local seabed conditions are important influencing factors when assessing the potential for UXO burial and/or migration and the potential consequences of an unplanned encounter and initiation of UXO during the proposed operations.

7.1.1 Bathymetry

A body of water will both absorb and transmit energy, generated by either a bomb entering the water and/or a high explosive event of the sort that might be generated by a UXO detonation. In general, the consequences of a through-water UXO detonation will reduce, as the "stand-off" (or separation distance) increases between prospective receptors and the UXO either buried in or lying upon the seabed.

An analysis of publicly available bathymetric data indicated that water depths across the proposed OWF array boundary are likely to range from between 91m to 100m LAT. In addition, water depths within the export cable corridor are expected to range from 78m up to 105m LAT. Given the significant water depths across the majority of the Study Site, the degree of prospective risk mitigation in general (and consequence mitigation in particular) provided by the depth of water is likely to have a significant impact on the results of the SQRA (at Section 8).

The water depths across the Study Site (in LAT) are presented at Figure 3 and Appendix 10.

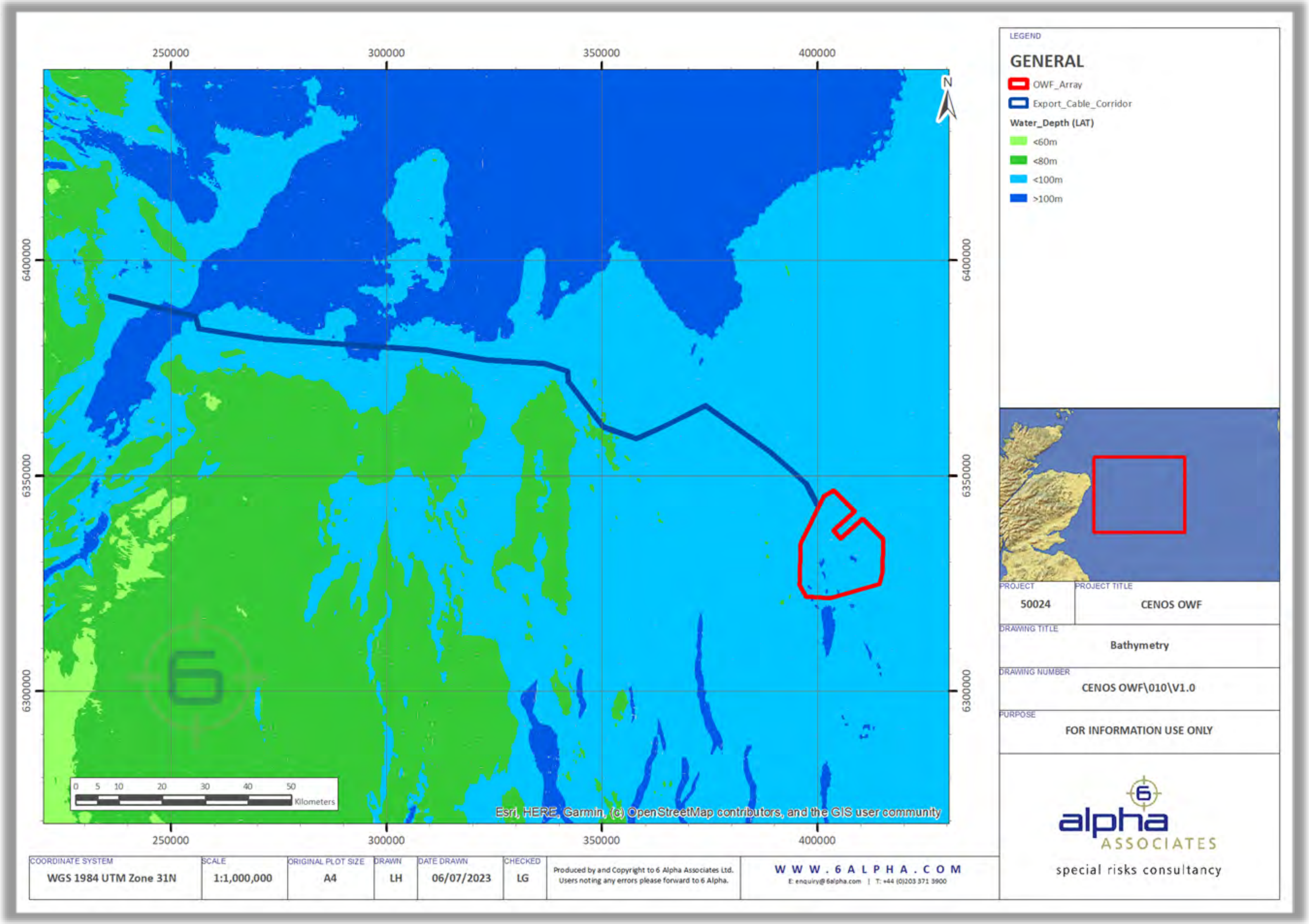


Figure 3: Bathymetry

7.1.2 Seabed Sediments and Shallow Soils

The nature of local seabed sediments and shallow soils also needs to be considered to determine the prospect for UXO burial in general and UXB burial in particular, upon their initial deployment and/or subsequently by seabed sediment movement. UXO scour and/or migration may also be influenced by seabed sediments.

Although detailed shallow soil and seabed sediment information for the Study Site has not yet been collected, an analysis of *BGS* records indicated that the seabed across the Study Site is likely to comprise predominantly of sandy sediments, together with some areas of muddy sand, gravelly sand and slightly gravelly sand.

Coarse sediments such as gravels are generally less likely to form a mobile seabed than one comprising solely of sandy sediments. It is still possible that UXO may have become shallow buried (after their initial deployment, having come to rest upon the surface of the seabed), by mobile seabed sediment, particularly in those areas comprising of predominantly sand sediments.

7.2 UXO Burial and Munitions Migration

In the offshore environment, all items of UXO are potentially subject to a variety of environmental and human factors, which may result in their scour and burial, or else their migration across the seabed. Primarily, this is driven by the localised bathymetric conditions including the composition of the seabed sediments, water depth and tidal currents.

7.2.1 Initial Impact Burial

As with impact burial of UXO on land, only those munitions travelling at a high terminal velocity at the point of impact (typically aerially delivered iron bombs or gun/mortar launched projectiles), have the potential to penetrate the seabed upon their initial deployment. Historically, studies of typical bomb penetration depths have been undertaken for the terrestrial environment based upon *inter alia*, the soil type in general and its shear strength in particular, as well as the UXO type, size and mass and their angle/speed of initial impact.

Such studies are not directly applicable in the offshore environment, given the mitigative effects of water (e.g. in slowing and reducing the impact of munitions on the seabed). Nonetheless and in general, UXO penetration into the seabed beyond 2m below seabed level, is considered highly unlikely in water depths of more than 20m.

7.2.2 Munitions Migration Effects

If geophysical UXO survey data is more than one year old from its date of capture, it may compromise the subsequent longevity of an ALARP safety sign-off certificate in general and the positional accuracy of pUXO (designated for avoidance) in particular, because of the risk of prospective munitions migration effects.

To address this issue and to extend the longevity of ALARP safety sign-off certification, a Munitions Migration and Burial Assessment (MMBA) can be undertaken. An MMBA can be based on appropriate metocean data, which would model the potential for UXO migration based upon seabed geomorphology in general and the Site's seabed characteristics in particular. Such characteristics can typically comprise the seabed sediments, current direction, and strengths.

Further background information regarding UXO scour, burial and migration is presented separately at Annex F.

7.3 Marine Protection Areas

Areas of the offshore marine environment have been designated as requiring protective, conservation, restorative and/or precautionary measures and there is a growing body of regional, national and international legislation supporting offshore environmental conservation. An analysis of national and regional databases indicated that a large portion of the OWF array, and part of the export cable corridor, intersects the *East of Gannet and Montrose Fields* marine protection area.

Whilst it is unlikely that UXO disposal should be required within therefore unlikely that UXO disposal should be required within the bounds of such areas, it is *6 Alpha's* typical recommendation that techniques such as low-order/low-noise or deflagration might be preferred over other high-order disposal methods regardless of location, although it is of particular pertinence within marine protection areas.

The location of this marine protection area is presented at Appendix 11.

8 UXO Risk Assessment

8.1 Risk Assessment Findings

The results of the strategic level risk assessment at summarised and presented below and are supported by an unexpurgated project SQRA, which is presented at Appendix 12. The latter presents the complete risk assessment for each individual seabed intrusive activity for each UXO threat group.

8.1.1 GI Operations

The likely GI operations are categorised as posing ***LOW*** UXO risks to both the vessel and personnel (i.e. vessels' crews) across the entire Study Site – as presented at Table 11. This is as a result of the reduced likelihood of encountering threat spectrum UXO during relatively small point-focal GI operations, together with the risk mitigative effects of the substantial depths of water across the entire Study Site in the event that threat spectrum UXO is encountered and initiated.

UXO Threat	UXO Risk (Vessels and Personnel Only)	
	Water Depth of ~80m LAT	Water Depth of ~100m LAT
Naval Projectiles	**VERY LOW**	
Naval Torpedoes	**VERY LOW**	
Naval Mines	**LOW**	

Table 11: GI Operations SQRA Summary

8.1.2 WTG Construction/Installation Operations

The mooring of WTG platforms, whether by piled or anchored means has also been assessed as either a ***LOW*** or ***VERY LOW*** risk activity at this site. This is primarily driven by the lack of evidenced UXO threat sources within the bounds of the OWF array, or in its immediate vicinity, which suggests an encounter with UXO is unlikely (but not impossible).

UXO Threat	UXO Risk (Vessels and Personnel Only)	
	Water Depth of ~80m LAT	Water Depth of ~100m LAT
Naval Projectiles	VERY LOW	
Naval Torpedoes	VERY LOW	
Naval Mines	LOW	VERY LOW

Table 12: Construction Operations SQRA Summary

8.1.3 Cable Installation and Burial Operations

Inter-array cable installation operations – including pre-lay and protection operations – are also likely to generate either ***LOW*** or ***VERY LOW*** risks due to the lack of evidenced UXO threat sources within the OWF array or nearby.

However, export cable installation and burial operations may generate ***MEDIUM*** UXO risks as a reasonable worst-case scenario within a limited western portion of the proposed route. This is driven by the elevated likelihood of encountering *British* WWII-era naval mines in the west of the proposed export cable corridor – such ordnance poses a risk to vessels and vessels' crews in depths up to 100m due to the high NEQ content that they contain.

Export cable installation and burial in the majority of the Study Site is assessed as posing ***LOW*** category UXO risk due to the reduced likelihood of encountering threat spectrum UXO in most areas.

The risk levels for the cable installation phase of the project are summarised and presented at Table 13.

UXO Threat	UXO Risk (Vessels and Personnel Only)	
	Water Depth of ~80m LAT	Water Depth of ~100m LAT
Naval Projectiles	LOW	
Naval Torpedoes	LOW	

UXO Threat	UXO Risk (Vessels and Personnel Only)	
	Water Depth of ~80m LAT	Water Depth of ~100m LAT
Naval Mines	**MEDIUM**	**LOW**

Table 13: Cable Installation and Burial Operations SQRA Summary

8.1.4 Enabling Operations

The UXO risk associated with the potential enabling operations in support of proposed GI, construction and/or installation is also assessed as either ***LOW*** or ***VERY LOW*** due to the lower likelihood that such operations will encounter and initiate UXO at this Study Site – especially if DP vessels are deployed to enable these operations. Nonetheless, Table 14 articulates the worst-case scenario associated with the prospective enabling operations.

UXO Threat	UXO Risk (Vessels and Personnel Only)	
	Water Depth of ~80m LAT	Water Depth of ~100m LAT
Naval Projectiles	**VERY LOW**	
Naval Torpedoes	**VERY LOW**	
Naval Mines	**LOW**	

Table 14: Enabling Operations SQRA Summary

8.2 UXO Receptors

8.2.1 Surface Vessels and Personnel

Although there is evidence to suggest that encountering and initiating UXO is plausible at the Study Site, such an encounter is generally considered a low probability-high consequence event. The consequences of exposing the vessels' crews to the kind of forces associated with an underwater initiation of an indicative selection of high, medium, and low NEQ threat spectrum UXO has been carefully modelled and the results are summarised separately at Table 15. These consequences are presented as a "worst-case" scenario, in the event that no risk mitigation measures have previously been enacted to reduce the likelihood of encountering and initiating threat spectrum UXO.

UXO	NEQ	Consequence	
		Water Depth of ~80m LAT	Water Depth of ~100m LAT
Mark XVII Mine	227kg	Light Damage	Acceptable
45cm C/06 Torpedo	122.6kg	Acceptable	
8.8cm Naval Projectile	1.42kg	Acceptable	

Table 15: Consequences of UXO Initiation

Table 15 has been compiled using *6 Alpha's* in-house shock wave calculator. This tool employs algorithms based on a variety of open-source academic and military studies concerning military ordnance detonations underwater, the peak pressures generated, and the effects of through water shock waves on the vessels' hulls directly as well as the indirect effects upon their crew.

Although the probability of initiating UXO varies with the types of subsea operations, the consequences of an initiation of each type of UXO is not driven by how such an initiation event might be caused. The calculations presented within Table 15 are also employed to inform *6 Alpha's* SQRA (at Appendix 12) to assess and grade potential UXO detonation consequences based upon the shock wave effects.

8.2.2 Underwater Equipment

If UXO is inadvertently encountered and initiated, it is possible that underwater equipment or tools employed in their close proximity are likely to be damaged. Such risks are presented in the full SQRA (at Appendix 12) but are highly likely to be considered tolerable, under the auspices of the ALARP principle, as long as they are unlikely to also pose a concurrent risk of harm to surface vessels and their crew.

8.2.3 Vessel and Diver Safety Distances

The SQRA assesses the risk of an unplanned initiation of UXO with reference to relevant sensitive receptors (e.g. vessels and their crew and/or underwater equipment), resulting from underwater explosive shock waves and to a reduced extent, localised underwater, high velocity fragmentation effects.

Such underwater detonation effects are determined by the energy that might be generated by detonating high explosive UXO. TNT is employed as a representative baseline high explosive for the likely type of UXO that might be encountered within the Study Site (regardless of the precise nature of their high-explosive fill), as well as estimating the distances separating the source (UXO) and the sensitive receptors (equipment/vessels).

The following formula has been applied to calculate peak pressure with the resultant shock wave output (Reid, 1996):

$$Peak\ Pressure\ (MPa) = 52.4.\left(\frac{M^{\frac{1}{3}}}{R}\right)^{1.18}$$

Using this formula, Table 16 summarises the distances at which point the prospective consequences of an underwater encounter and initiation of a selection of threat spectrum UXO to the vessel(s) and their crew(s) becomes intolerable (e.g. where injuries are sustained from exposure to more than 4MPa of peak pressure). In addition, Table 16 also summarises the minimum safety distance for divers – if they are to be employed (these distances have been calculated by *6 Alpha's* UXO experts).

UXO	NEQ	SQRA Consequence Score Peak Pressure Exposure (MPa) and Vessel Safety Distance		Swimmers and Divers Safety Distance
		1 0 – 2 (MPa)	**2** 2 – 4 (MPa)	Burst on seabed with diver on seabed
Mark XVII Mine	227kg	97m	54m	1,614m
45cm C/06 Torpedo	123kg	80m	44m	1,446m
8.8cm Naval Projectile	1.42kg	18m	10m	648m

Table 16: Underwater Explosion Safety Distances

For the consequences of an initiation of this high NEQ UXO to be completely ameliorated in terms of its effects upon the vessel (<2 MPa and see consequence column 1), the minimum vessel safety stand-off distance must be not less than 97m.

Consequence column 2 articulates the depths of water at which superficial damage to the vessel may be caused and the exposure of the vessel and its crew to intolerable and dangerous high-explosive effects is likely to occur at depths of less than 54m, if this such UXO are initiated. If the vessel(s) and its crew(s) are exposed to greater than 4MPa of pressure, the likely effects include damage to electronics, injuring crew and partial loss of vessel steering and control. Vessel damage becomes more severe as the peak pressure exposure increases, with fatalities highly likely to be caused at 8MPa pressure and greater. These consequences have been calculated without accounting for the vessels' age/condition nor their specific design characteristics in general or their robustness, in particular. Therefore, the precise consequence modelling and minimum safe stand-off distances are subject to change, especially as additional factors such as vessel draught are introduced.

In addition, divers are highly vulnerable if they are exposed to the kind of underwater shock generated by UXO initiation. As Table 16 evidences, swimmers and divers must be located at least 1,614m from the seat of a seabed initiation of threat spectrum UXO, to be considered safe, which further evidences the risks involved with deploying divers during sub-seabed operations, wherever UXO contamination might be expected.

8.3 UXO Risk Zones

It is standard *6 Alpha* practice to divide the Study Site into multiple UXO risk zones based upon one, or a combination of, the following factors:

- The nature and scope of seabed intrusive activities and the distances from pertinent UXO threat sources;
- The varying water depths (in LAT) across the Study Site;
- The project stakeholders' assumed appetite for the carriage of residual UXO risks.

Given the distribution of UXO threat sources (identified in Section 5) and their various NEQ, it is possible to split the Study Site into UXO risk zones at a high-level for the two general phases of the proposed works.

Specifically, the UXO risk to GI and enabling activities has been categorised as ***LOW*** across the entire Study Site due to the low likelihood that such activities will encounter and initiate UXO, combined with the risk mitigative effect of the water depths present at the Site on the consequences of an initiation of threat spectrum UXO in depths greater than 100m LAT.

UXO risks to the construction/installation of the OWF array and the installation of the associated inter-array and export cables have been zoned into areas of ***MEDIUM*** and ***LOW. MEDIUM*** category UXO risks have been defined for export cable installation and/or burial activities in the western sector of the Study Site due to the increased probability of encountering WWII-era *British* naval mines and the risk of harm to vessels/vessels' crews in the event that such UXO is encountered and initiated in depths of less than 100m LAT. Cable installation and burial activities in the remainder of the Study Site are assessed as ***LOW*** due to either the low probability of encountering UXO or the risk mitigation afforded to vessels and vessels' crews by the water depths should threat spectrum UXO be encountered and initiated.

6 Alpha have produced risk zoning charts for the worst-case scenario according to the proposed scope of works, as per Figures 4 and 5 and Appendix 13.

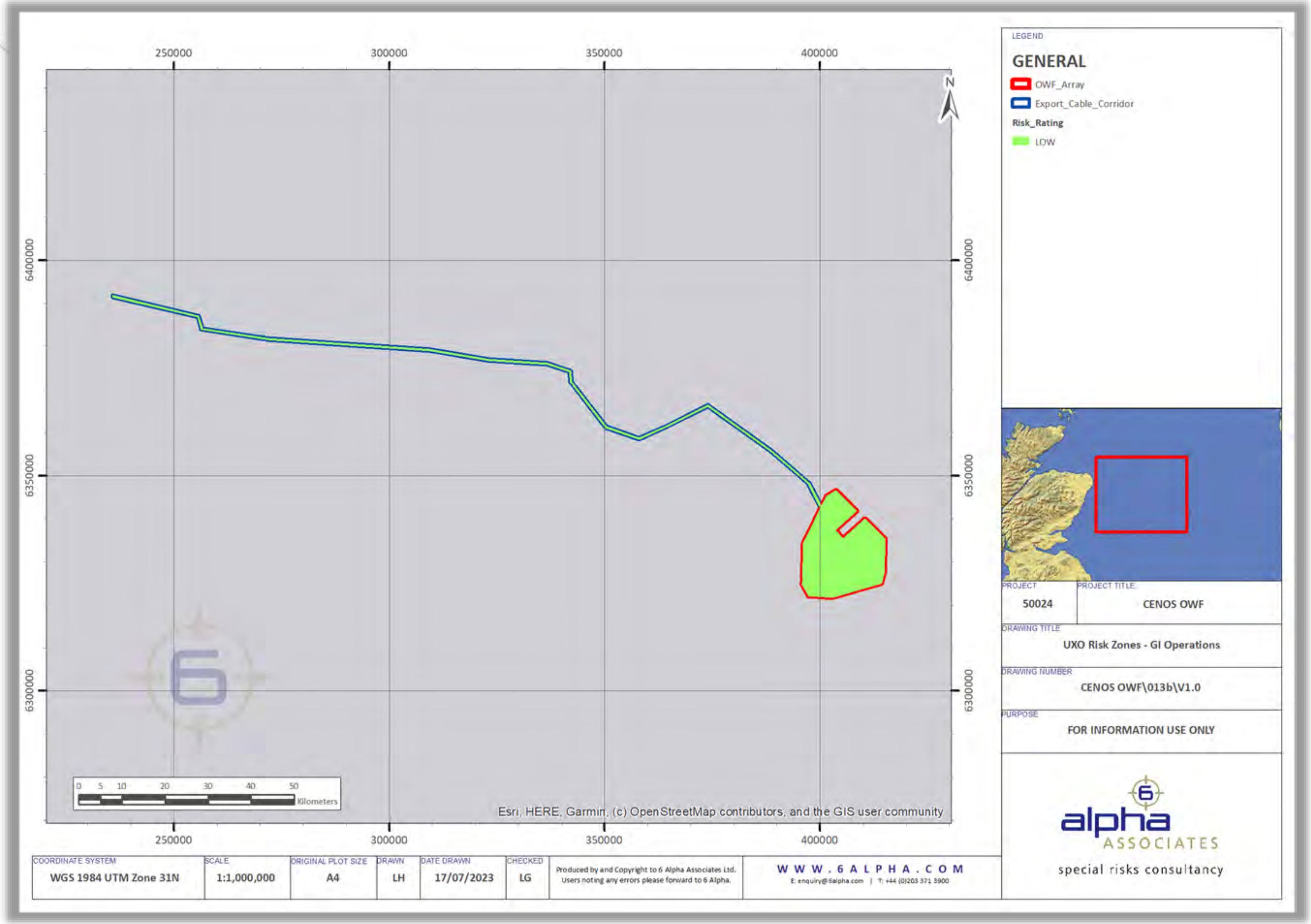


Figure 4: UXO Risk Zones for GI Operations (Vessels and Vessel Crews)

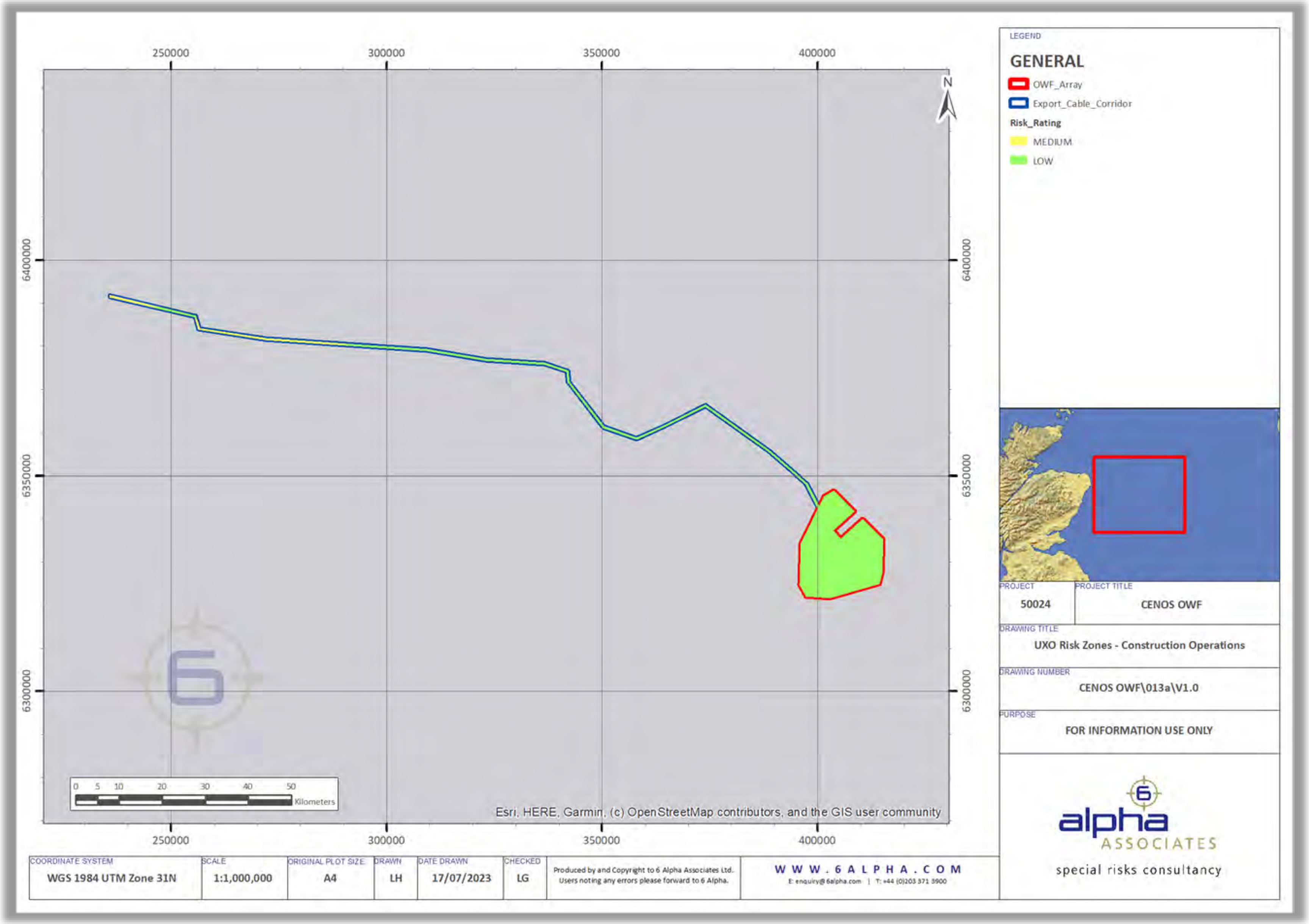


Figure 5: UXO Risk Zones for WTG and Cable Installation (Vessels and Vessel Crews)

9 Conclusions and Recommendations

9.1 Conclusions

The nature and scope of the UXO risks have been categorised based upon a source-pathway-receptor review in general, as well as an analysis of the probability of encountering and of initiating UXO and the prospective consequences of initiating UXO, in particular.

9.1.1 UXO Risks to Surface Vessels and Crews

After an extensive desk-based analysis of historical and military records, UXO risks to vessels and vessels' crews can be zoned into areas of ***MEDIUM*** or ***LOW***. UXO risks to GI operations, WTG turbine installation and any enabling works are assessed as ***LOW*** across the entirety of the Study Site due to the low probability of encountering and initiating UXO during such works, or due to the risk mitigation afforded by the significant depths of water present at the Site should threat spectrum UXO be initiated.

UXO risks to export cable installation are classified as ***MEDIUM*** in the western portion of the Study Site. This categorisation of UXO risk is driven primarily by the elevated probability of encountering and initiating WWII-era *British* naval mines in those ***MEDIUM*** risk areas and the potential harm that may be caused to vessels and vessels' crews in water depths up to 100m LAT. Export cable installation operations outside of the ***MEDIUM*** risk zones is categorised as ***LOW*** risk due to either the low probability of encountering UXO in those areas or the risk mitigative effect of the water depths (in any areas greater than 100m LAT).

9.1.2 UXO Risks to Underwater Equipment

Underwater investigative and construction equipment is unlikely to be robust enough to withstand the consequences of a nearby initiation of most large NEQ, threat spectrum UXO (such as naval mines and torpedoes). Therefore, the prospective UXO risks posed to underwater equipment are classified as ***HIGH*** and/or ***MEDIUM***, in all depths of water.

The UXO risk to underwater equipment is likely to be considered tolerable (as compared with the effects associated with vessels and their crews) under the auspices of the ALARP risk reduction, as long as the latter risks do not also pose a hazard to the former.

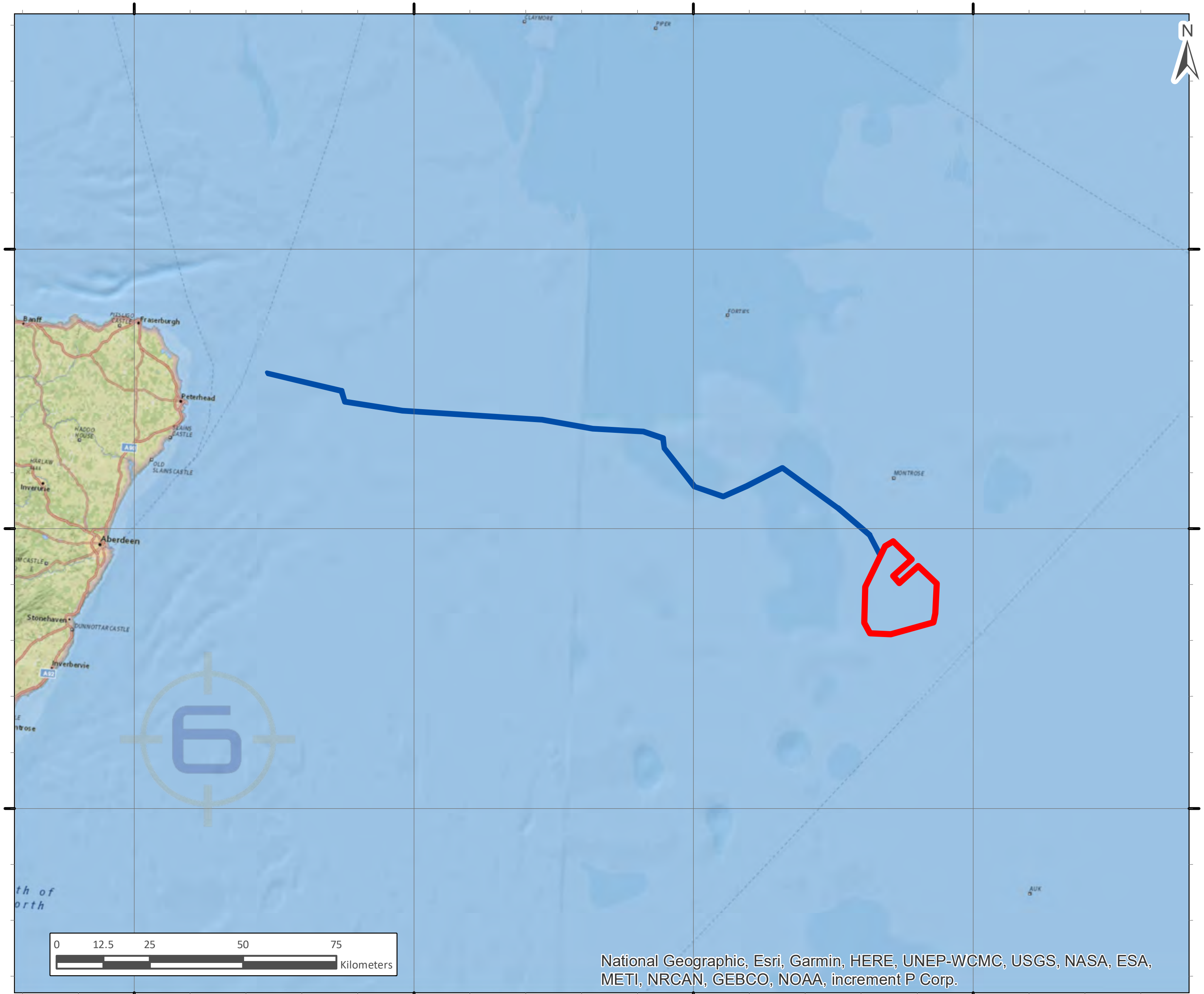
9.2 Recommendations

6 Alpha recommend that the UXO risks posed to the project are mitigated within the bounds of the ALARP risk reduction principle and in accordance with national laws. Specifically, risk reduction can be achieved through the holistic implementation of the subsequent phases of the *CIRIA C754* derived risk management framework, including a suitable and cost-effective risk mitigation strategy. This document has already been commissioned and will be delivered separately to this report to cover the *CENOS* OWF and export cable corridor.

Appendices

Appendix 1

Site Location



LEGEND

GENERAL

- OWF_Array
- Export_Cable_Corridor

PROJECT	PROJECT TITLE
50024	CENOS OWF

DRAWING TITLE

Site Location

DRAWING NUMBER

CENOS OWF\001\V1.0

PURPOSE

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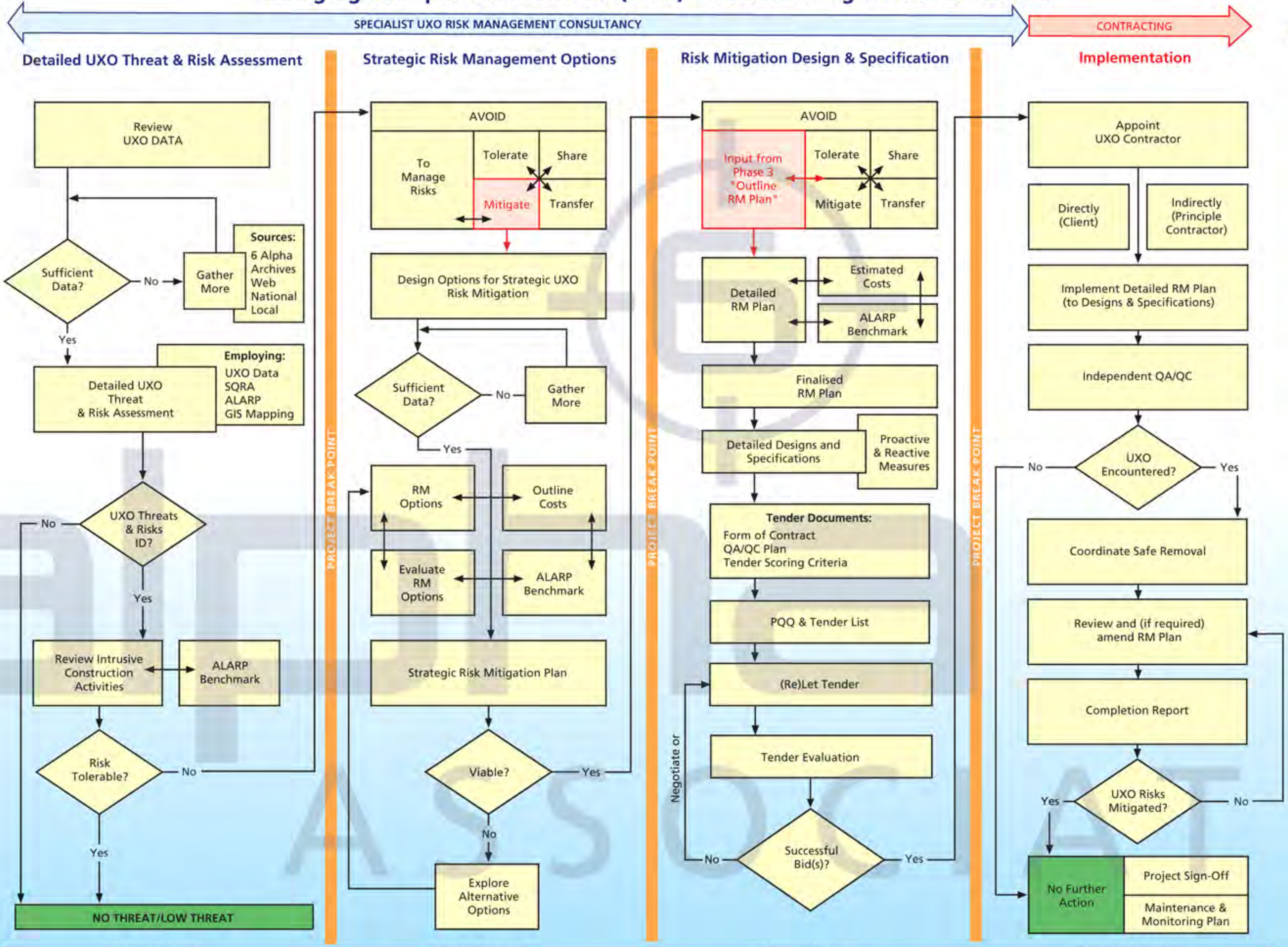
Appendix 2

Marine Risk Management Framework

Managing Unexploded Ordnance (UXO) - A Risk Management Framework



Expected Outputs

Detailed UXO Risk Assessment
Expected Consultancy Outputs:
UXO Threat Assessment employing:
Comprehensive UXO Data Sources
Semi-Quantitative Risk Assessment (SQRA) & ALARP
GIS Mapping
Independent/Robust/Transparent Assessment
Comprehensive & Informative Report

Expected Outputs

Strategic Risk Management Options
Expected Consultancy Outputs:
Strategic Risk Mitigation (RM) options
Criteria for selection of mix of options
Selection of best mix of options
Benchmark with Client's Tolerance of UXO Risk
Strategic Risk Mitigation Plan

Expected Outputs

Risk Mitigation Design & Specification
Expected Consultancy Outputs:
Detailed Risk Mitigation Design
Accompanying Risk Mitigation Specifications
Sufficient for Incorporation into Tender Documents

Expected Outputs

Implementation
Expected Consultancy & Contractor Outputs:
Safe Removal of UXO
Independent QA/QC on Contractor
Completion Reposts
Independent Consultancy Sign-off
Post Construction Maintenance/Monitoring Plan

Appendix 3

Holistic UXO Risk Management Process

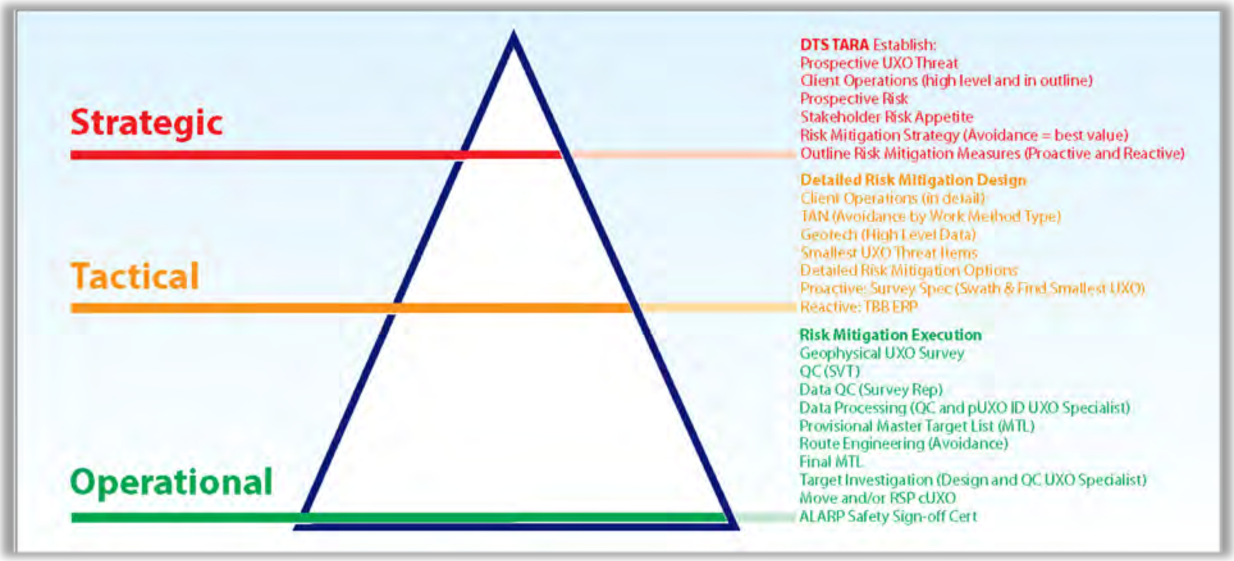
Holistic UXO Risk Management Process

1.1 Concept

There are generally, three sequential strands of Unexploded Ordnance (UXO) risk management work to consider in order to reduce risks ALARP and they have been depicted (at Figure 1) and grouped together, at the Strategic, Tactical and Operational levels.

Figure 1: 6 Alpha UXO Risk Management – Concept

1.2 Strategic Level – A Holistic Perspective of UXO Threat, Risk and Risk Management



A UXO Desk Top Study (DTS) will establish the prospective UXO threat and risk in sequence, as follows:

- **Operations**; it will establish the nature of prospective Client operations (at high level and in outline) for example and typically:
    - Geotechnical Investigation (GI);
    - Cable Installation;
    - OWF Installation;
- **Risk**; establish prospective UXO risk by examining (using Semi Quantitative Risk Assessment), two key factors:
    - **Probability**; of UXO encounter and of its initiation (the former is driven by UXO/civil engineering juxtaposition; the latter by kinetic energy);

- **Consequence**; of UXO initiation, which is driven by the Net (High) Explosive Quantity (NEQ) in each type of UXO. And (critically); the proximity and robustness of sensitive receptors (e.g. people, GI and/or installation equipment);

- **Stakeholder Risk Appetite**; what risks can stakeholders reasonably and legally tolerate? What cannot be tolerated (e.g. risk of injury to personnel)?;
- **Risk Mitigation Strategy**; e.g. UXO avoidance which delivers the best value for money solution;
- **Risk Mitigation Measures**; divided typically into proactive and reactive categories.

1.3 Tactical Level – Detailed Risk Mitigation Design

Following GI and/or installation solution has been designed (or concurrent with it), 6 Alpha then deliver a "Detailed UXO Risk Mitigation Design", considering the following factors, in sequence:

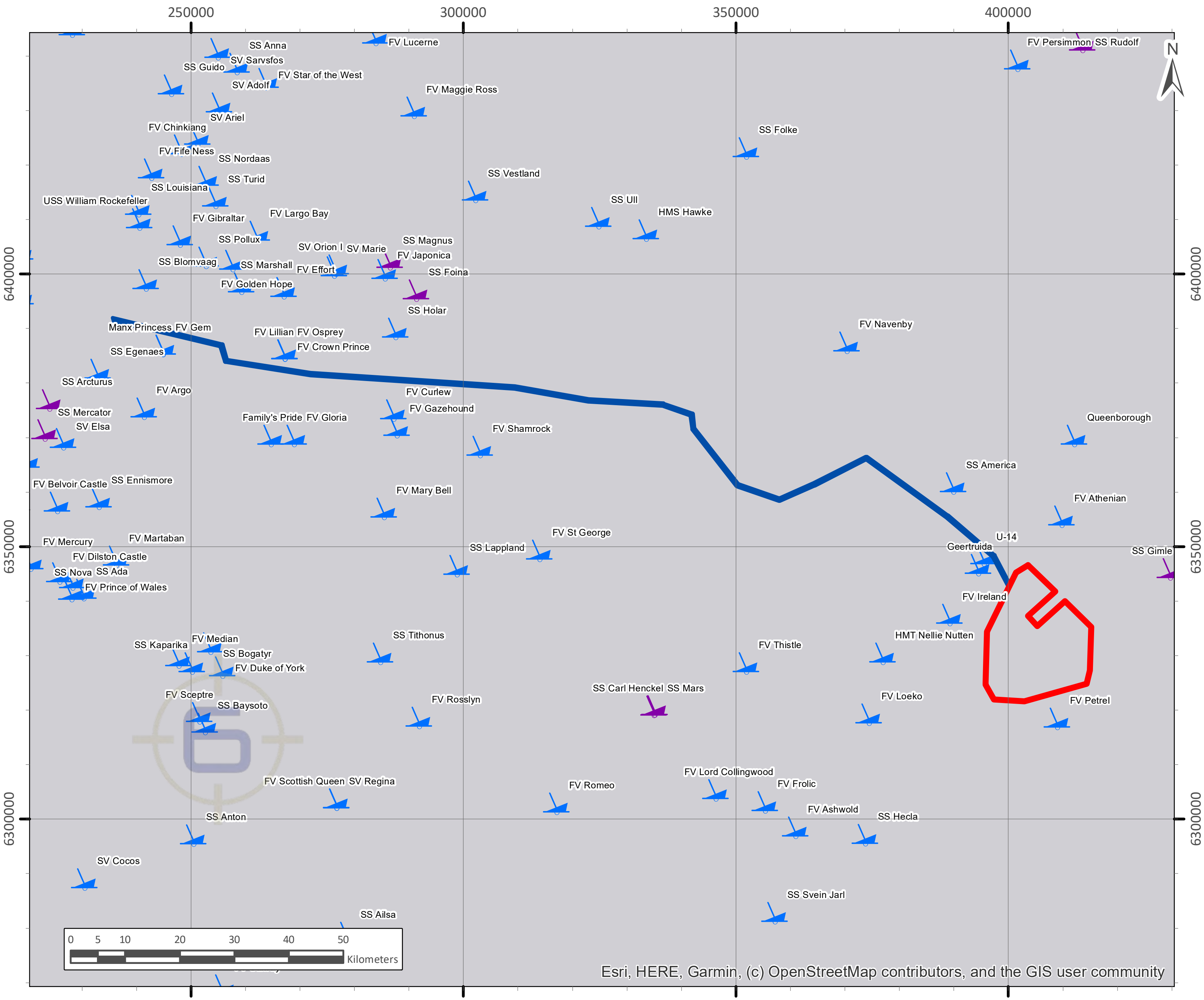
- The Client's and Principal Contractor's installation operations (in detail);
- Technical Advisory Notes (TAN) that deliver potential UXO (pUXO) avoidance by work method type. Benefits: reduced pUXO avoidance (initially 15m radius, but typically ~10m radii, post TAN); therefore, more freedom of manoeuvre, micro-routing and micro siting, in advance of installation; fewer pUXO to be avoided; less investigation; thus save time, reduce schedule and save money;
- Geotech input in the form of high level data on soil types and shear strengths. Detailed geotech will enable more accurate and better focussed TAN;
- Smallest UXO threat items for detection v stakeholder appetite for risk?
- Therefore, outline risk mitigation measures are typically sub-divided into the following categories:
    - **Proactive Measures** e.g.:
        - Geophysical UXO survey (accounting for the smallest UXO threat) and its avoidance
        - If pUXO cannot be avoided, then verify it by investigation;
        - If it is confirmed UXO (cUXO) then move it (if it both safe and practical to do so) and/or destroy it;
    - **Reactive Measures** e.g.:
        - Site Emergency Response Plans (ERP);
        - Tool Box Briefs (TBB) for site workers.

1.4 Operational Level – Delivery of UXO Risk Managements and Mitigation Solutions

UXO risk mitigation execution might typically include, sequentially:

- Geophysical UXO Survey pre-installation;
- Survey Quality Control (QC) via a Survey Verification Test (SVT);
- Data QC;
- Data Processing (QC and pUXO ID - by a UXO Specialist, such as 6 Alpha), concurrent with survey operations;
- Provisional Master Target List (MTL) generated by UXO Specialist consisting of all pUXO;
- Micro-siting and/or route engineering (thus avoidance) is undertaken (benefit - saves time and money);
- Final MTL produced, which ensured that the following activities are reduced to the minimum in order to reduce risk ALARP and to save time and money:
    - Target Investigation (designed, and QC'd by a UXO Specialist such as 6 Alpha);
    - Move and/or Redner Safe Procedure (RSP) on confirmed UXO (cUXO);
    - ALARP Safety Sign-off Certs delivered for all installation methods.

Naval Engagements



LEGEND

GENERAL

OWF_Array

Export_Cable_Corridor

UXO THREATS

WWI_Naval_Wreck

WWII_Naval_Wreck

PROJECT	PROJECT TITLE
50024	CENOS OWF

DRAWING TITLE
Naval Engagements

DRAWING NUMBER
CENOS OWF\004\V1.0

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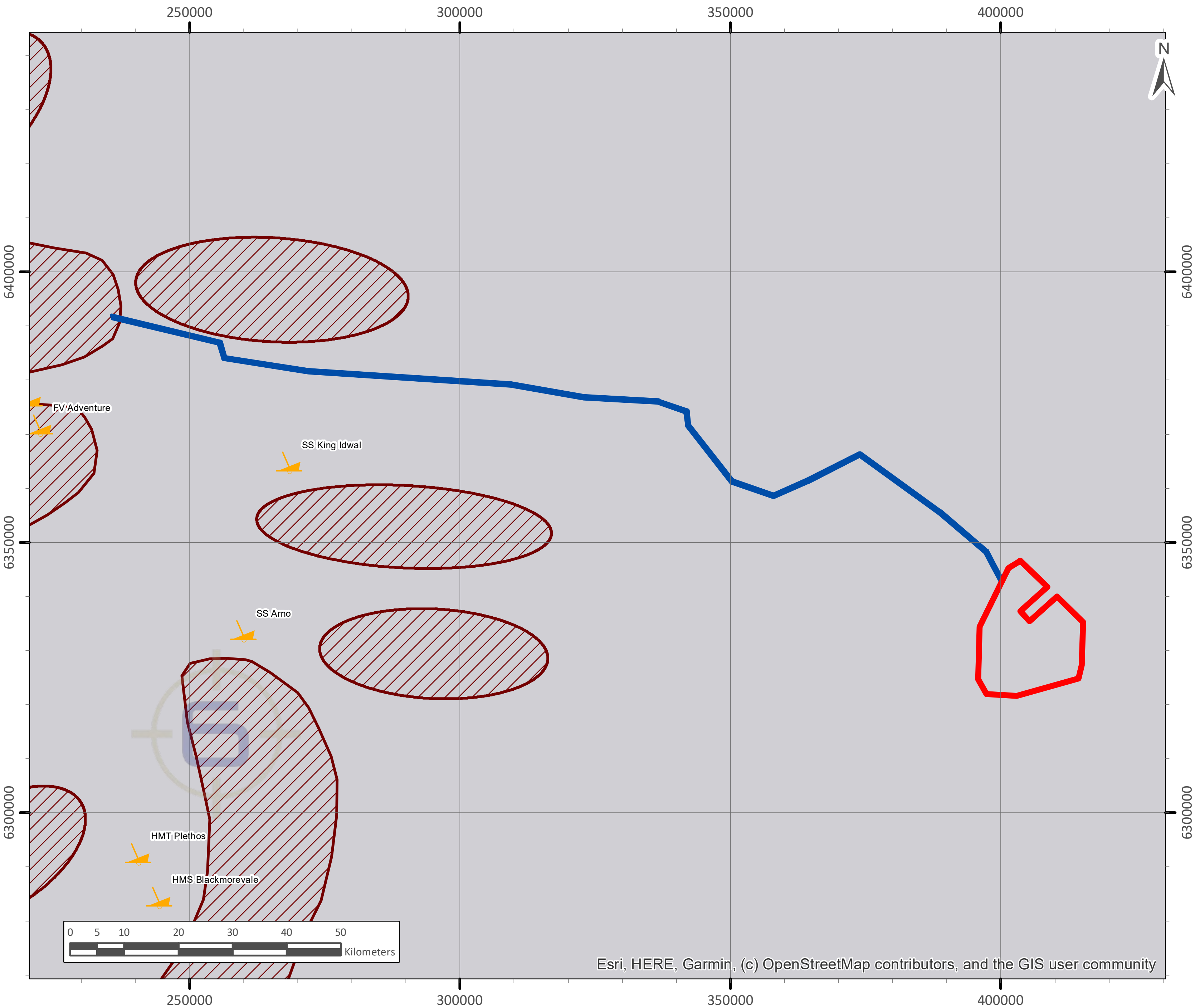
WWI Minefields



LEGEND

GENERAL

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- Export_Cable_Corridor

UXO THREATS

- WWI_Mined_Wreck
- WWI_Central_Powers_Minefield

PROJECT	PROJECT TITLE
50024	CENOS OWF

DRAWING TITLE

WWI Minefields

DRAWING NUMBER

CENOS OWF\005\V1.0

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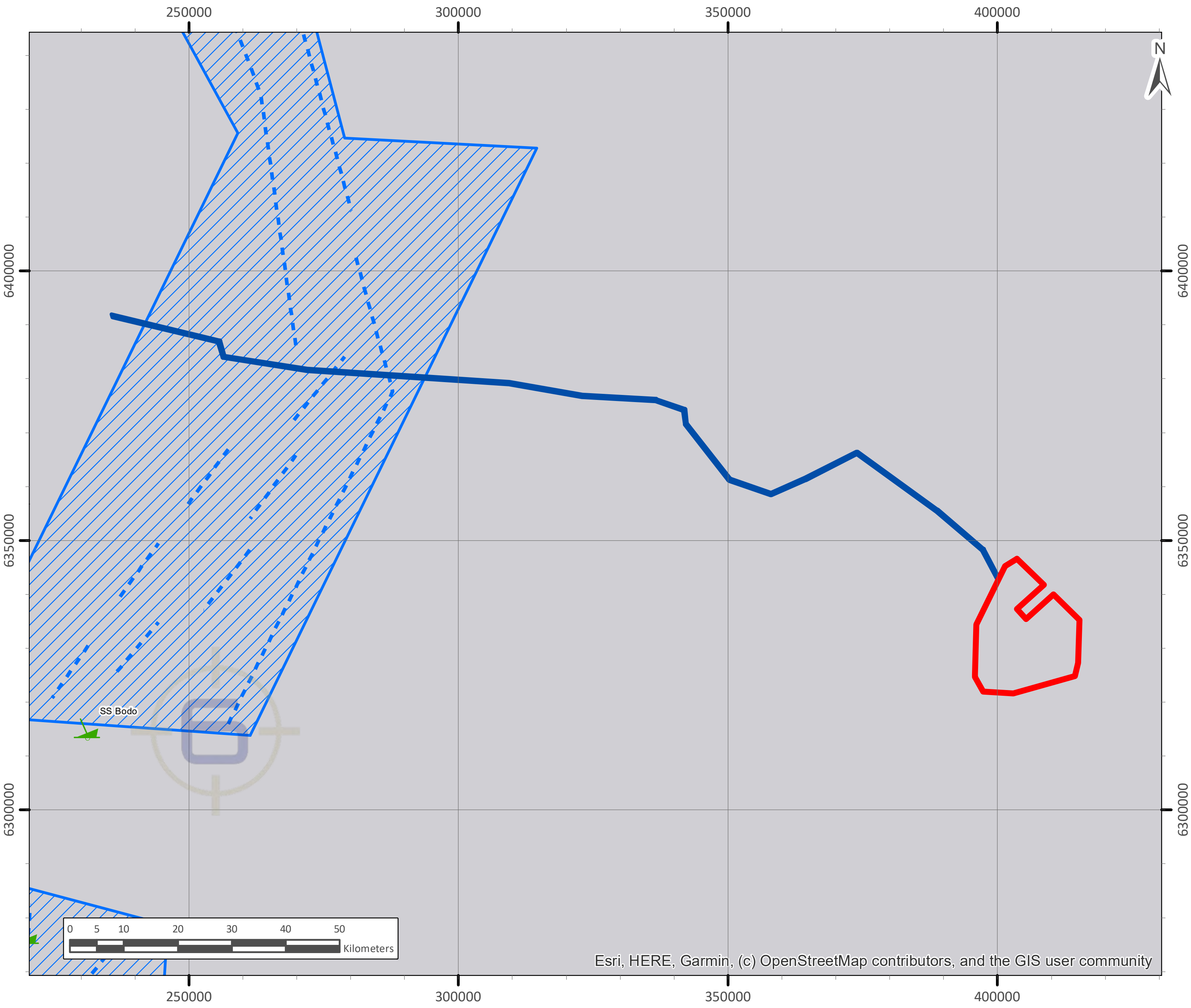
Appendix 6

WWII Minefields



LEGEND

GENERAL

- OWF_Array
- Export_Cable_Corridor

UXO THREATS

- WWII_Mined_Wreck
- WWII_Allied_Minelay
- WWII_Allied_Minefield

PROJECT	PROJECT TITLE
50024	CENOS OWF

DRAWING TITLE
WWII Minefields

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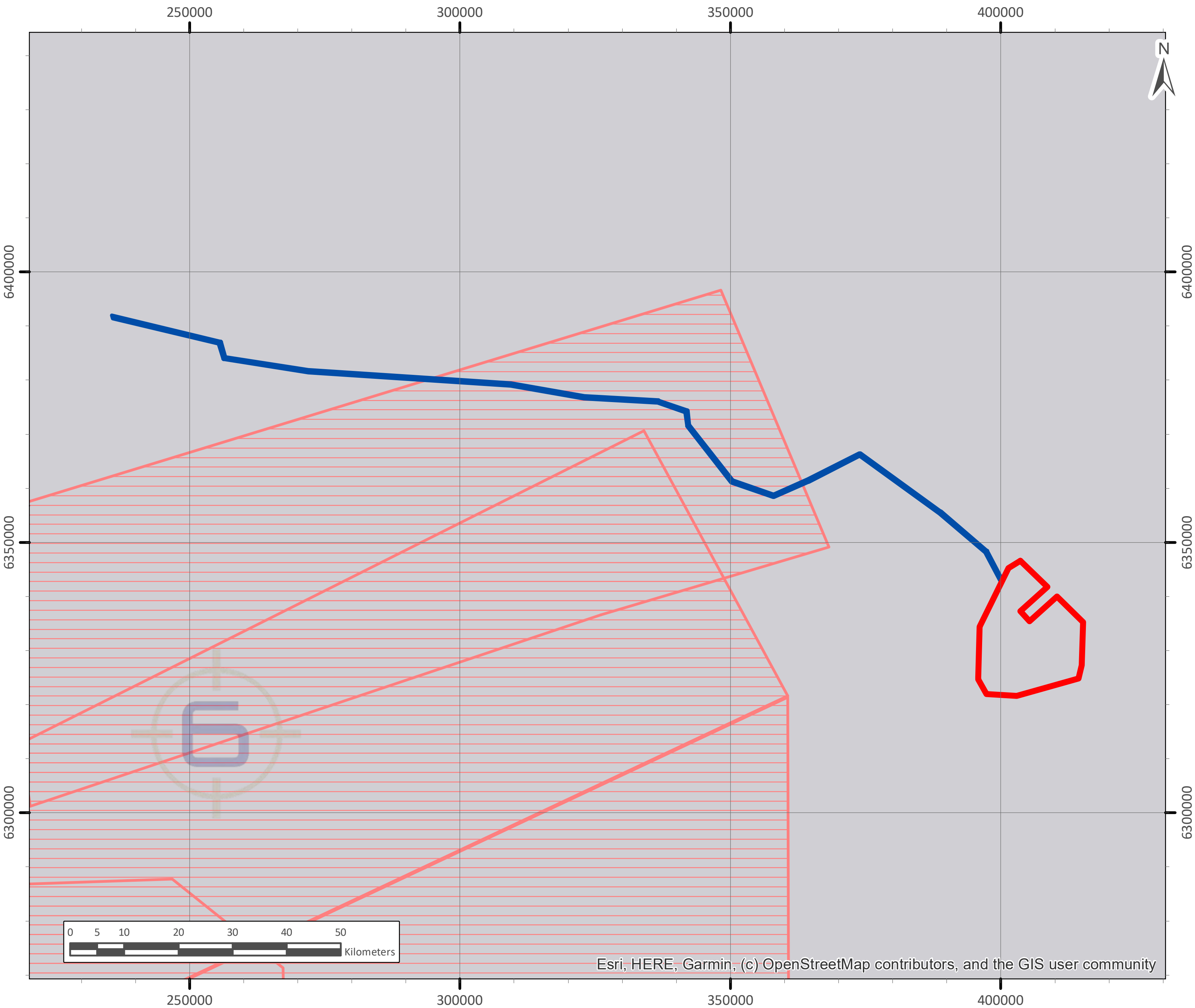
Modern Military PEXA



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- Export_Cable_Corridor

UXO THREATS

- Modern_PEXA

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DRAWING TITLE: Modern PEXA

DRAWING NUMBER: CENOS OWF\007\V1.0

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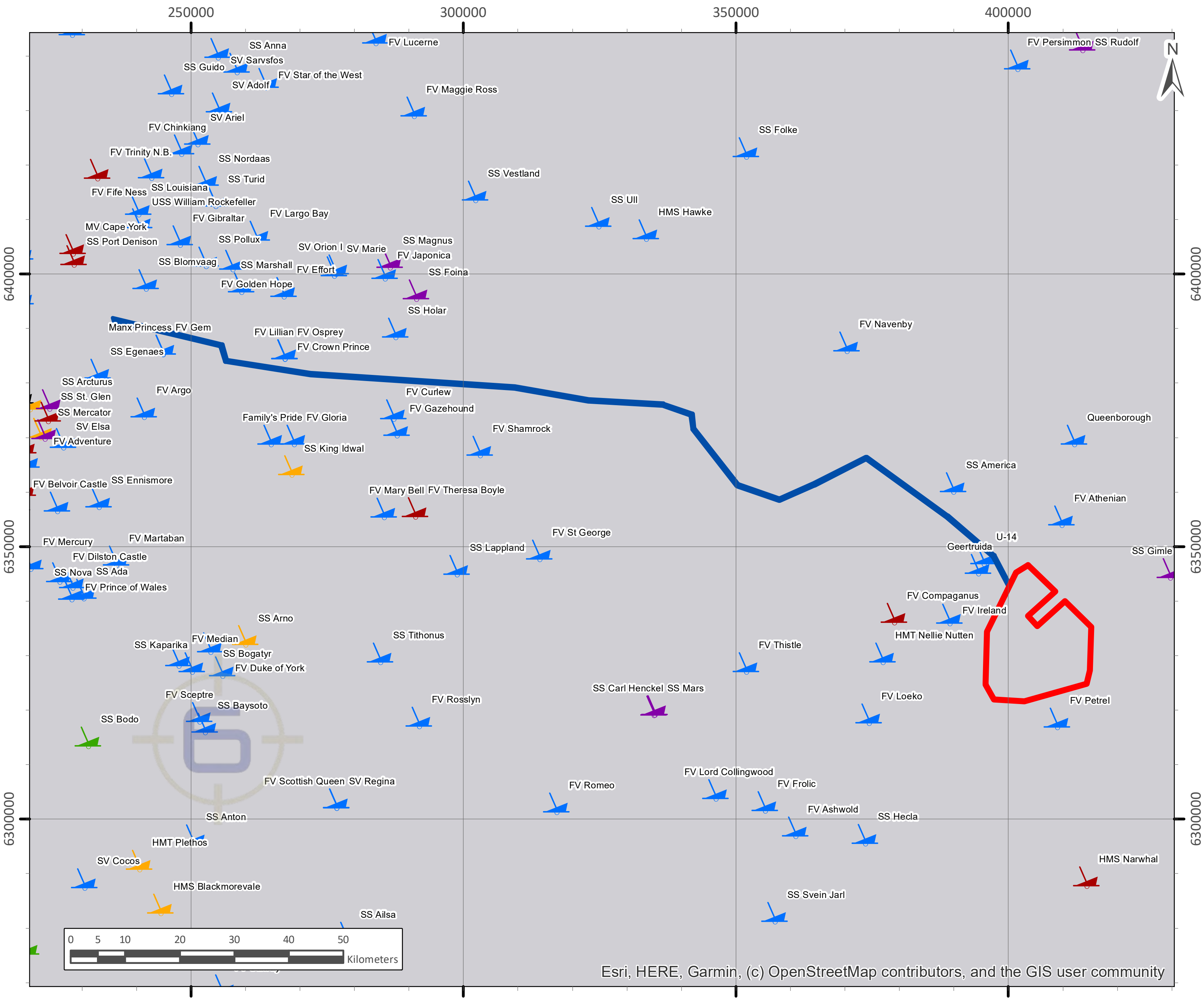
Appendix 8

Munitions Related Shipwrecks



LEGEND

GENERAL

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UXO THREATS

- WWII_Air-Raid_Wreck
- WWI_Naval_Wreck
- WWII_Naval_Wreck
- WWI_Mined_Wreck
- WWII_Mined_Wreck
- Other_Munitions_Wreck

PROJECT	PROJECT TITLE
50024	CENOS OWF

DRAWING TITLE
Munitions Related Shipwrecks

DRAWING NUMBER
CENOS OWF\008\V1.0

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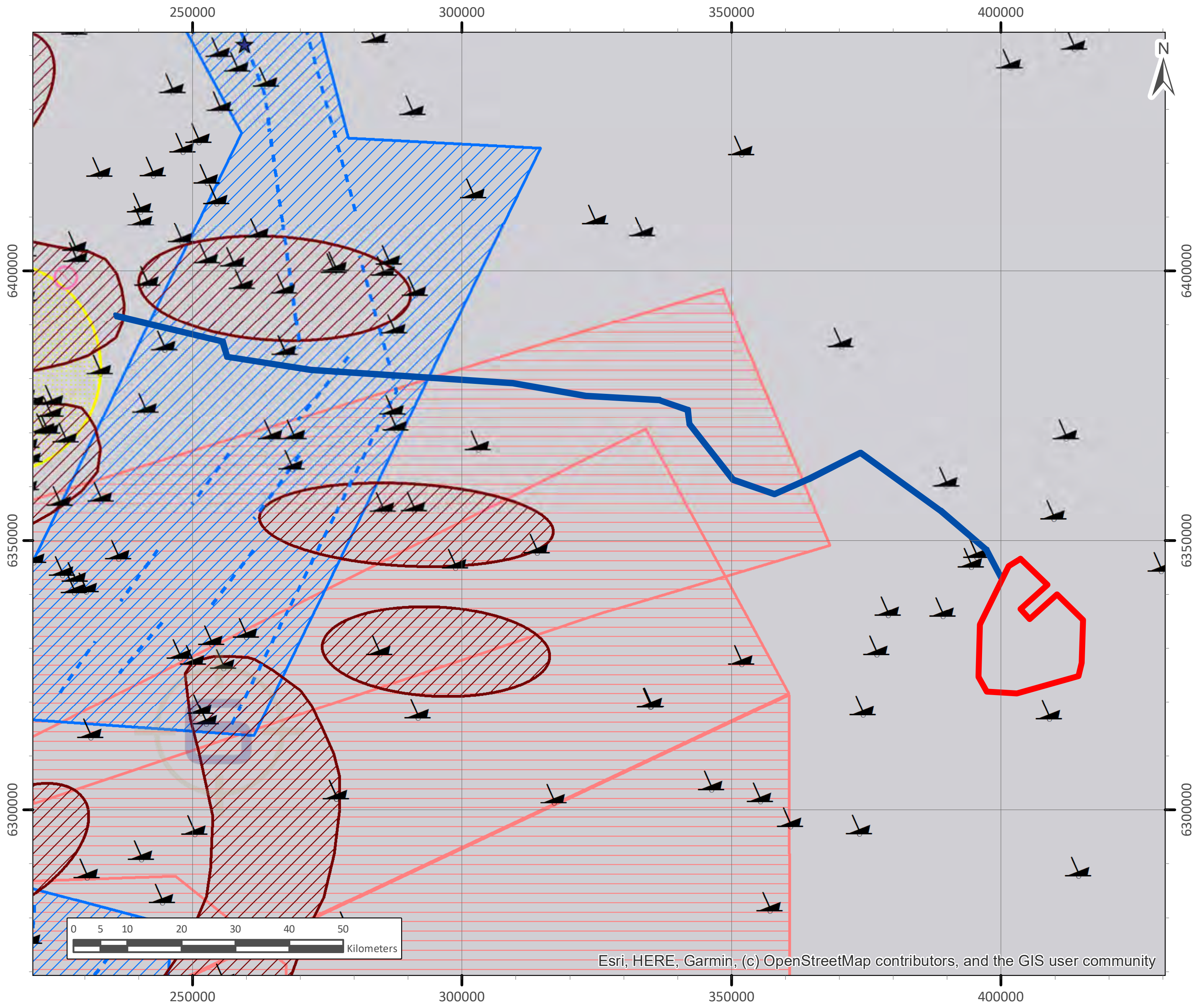
Appendix 9

Consolidated UXO Threats



LEGEND

GENERAL

- OWF_Array
- Export_Cable_Corridor

UXO THREATS

- Munitions_Related_Wreck
- OSPAR_Munitions_Encounter
- WWII_Allied_Minelay
- WWI_Central_Powers_Minefield
- WWII_Allied_Minefield
- Historic_PEXA
- Modern_PEXA
- Coastal_Armament_Range

PROJECT	PROJECT TITLE
50024	CENOS OWF

DRAWING TITLE
Consolidated UXO Threat

DRAWING NUMBER
CENOS OWF\009\V1.0

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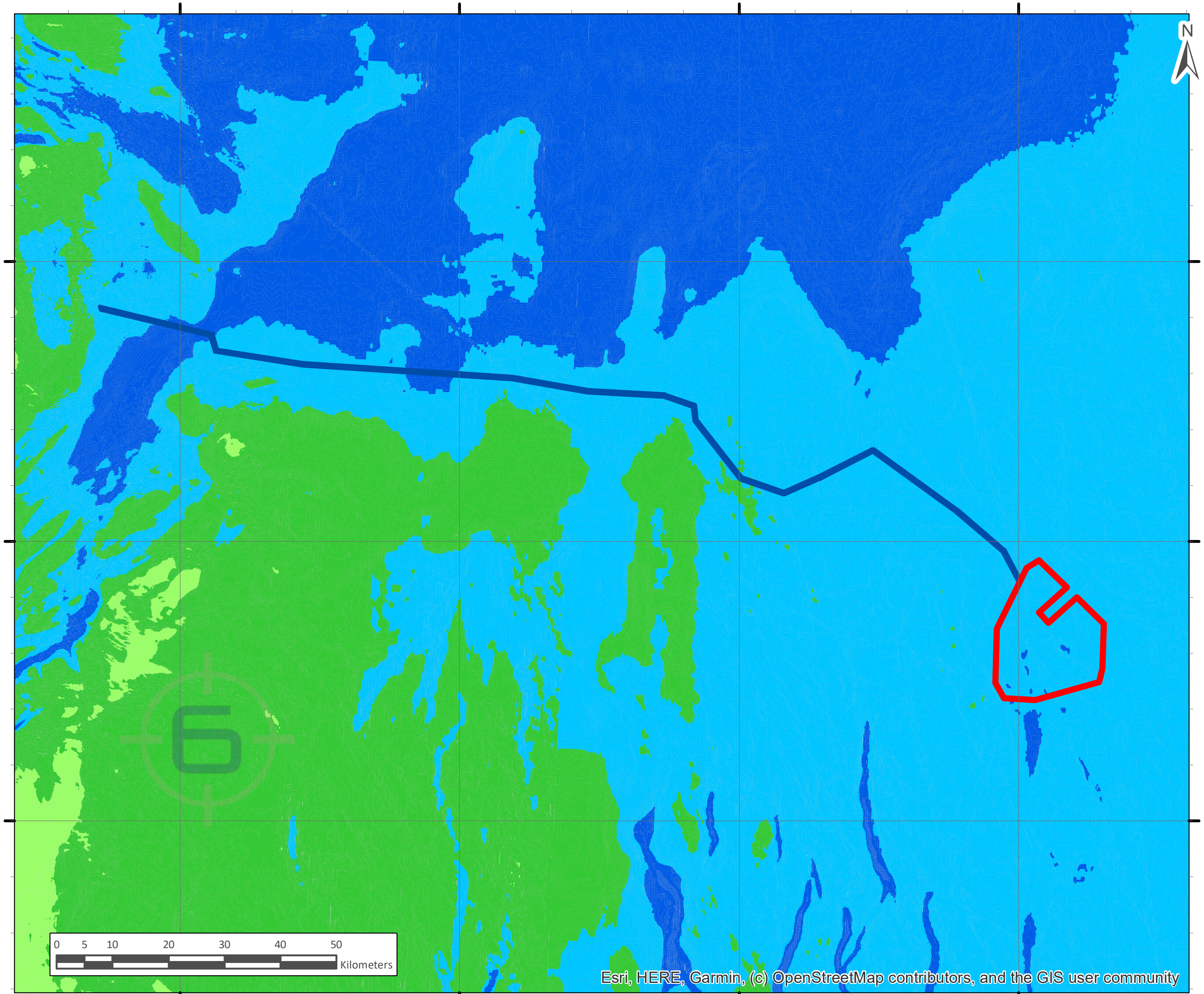
Appendix 10

Bathymetry



LEGEND

GENERAL

OWF_Array

Export_Cable_Corridor

Water_Depth (LAT)

<60m

<80m

<100m

>100m

PROJECT	PROJECT TITLE
50024	CENOS OWF

DRAWING TITLE

Bathymetry

DRAWING NUMBER

CENOS OWF\010\V1.0

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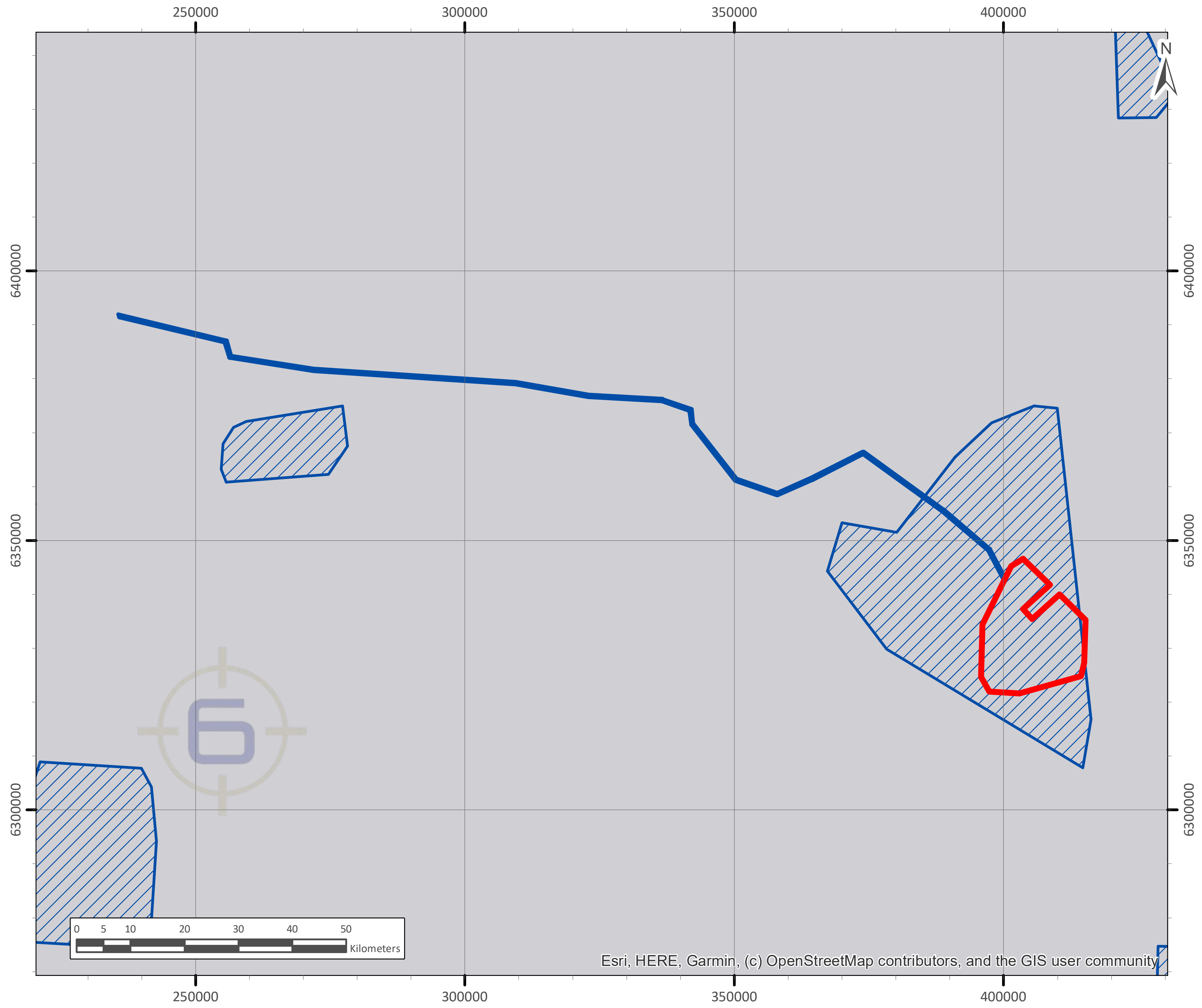
Appendix 11

Marine Protection Areas



LEGEND

GENERAL

- OWF_Array
- Export_Cable_Corridor
- Marine_Protected_Area

PROJECT	PROJECT TITLE
50024	CENOS OWF

DRAWING TITLE
Marine Protection Areas

DRAWING NUMBER
CENOS OWF\011\V1.0

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
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Appendix 12

Semi-Quantitative Risk Assessment Tables

GI Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel			UXO Risk to Underwater Equipment		
			P	C	R	P	C	R
GI Offshore ~80m LAT	WWII Naval Mine	227	2	2	**4**	2	5	**10**
	WWI Naval Mine	165	1	2	**2**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**
GI Deep Offshore ~100m LAT	WWII Naval Mine	227	2	1	**2**	2	5	**10**
	WWI Naval Mine	165	1	1	**1**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**

Construction Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel			UXO Risk to Underwater Equipment		
			P	C	R	P	C	R
Piling Offshore ~80m LAT	WWII Naval Mine	227	1	2	**2**	1	5	**5**
	WWI Naval Mine	165	1	2	**2**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**
Piling Deep Offshore ~100m LAT	WWII Naval Mine	227	1	1	**1**	1	5	**5**
	WWI Naval Mine	165	1	1	**1**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel			UXO Risk to Underwater Equipment		
			P	C	R	P	C	R
Anchoring Offshore ~80m LAT	WWII Naval Mine	227	1	2	**2**	1	5	**5**
	WWI Naval Mine	165	1	2	**2**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**
Anchoring Deep Offshore ~100m LAT	WWII Naval Mine	227	1	1	**1**	1	5	**5**
	WWI Naval Mine	165	1	1	**1**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**

Cable Installation and Burial Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel			UXO Risk to Underwater Equipment		
			P	C	R	P	C	R
PLGR + RC Offshore ~80m LAT	WWII Naval Mine	227	4	2	**8**	4	5	**20**
	WWI Naval Mine	165	2	2	**4**	2	5	**10**
	WWI Naval Torpedo	123	2	1	**2**	2	5	**10**
	WWI Naval Projectile	1.42	2	1	**2**	2	2	**4**
PLGR + RC Deep Offshore ~100m LAT	WWII Naval Mine	227	4	1	**4**	4	5	**20**
	WWI Naval Mine	165	2	1	**2**	2	5	**10**
	WWI Naval Torpedo	123	2	1	**2**	2	5	**10**
	WWI Naval Projectile	1.42	2	1	**2**	2	2	**4**

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel			UXO Risk to Underwater Equipment		
			P	C	R	P	C	R
Surface Lay Offshore ~80m LAT	WWII Naval Mine	227	2	2	**4**	2	5	**10**
	WWI Naval Mine	165	1	2	**2**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**
Surface Lay Deep Offshore ~100m LAT	WWII Naval Mine	227	2	1	**2**	2	5	**10**
	WWI Naval Mine	165	1	1	**1**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel			UXO Risk to Underwater Equipment		
			P	C	R	P	C	R
Jetting Offshore ~80m LAT	WWII Naval Mine	227	3	2	**6**	3	5	**15**
	WWI Naval Mine	165	1	2	**2**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**
Jetting Deep Offshore ~100m LAT	WWII Naval Mine	227	3	1	**3**	3	5	**15**
	WWI Naval Mine	165	1	1	**1**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel			UXO Risk to Underwater Equipment		
			P	C	R	P	C	R
Ploughing Offshore ~80m LAT	WWII Naval Mine	227	4	2	**8**	4	5	**20**
	WWI Naval Mine	165	2	2	**4**	2	5	**10**
	WWI Naval Torpedo	123	2	1	**2**	2	5	**10**
	WWI Naval Projectile	1.42	2	1	**2**	2	2	**4**
Ploughing Deep Offshore ~100m LAT	WWII Naval Mine	227	4	1	**4**	4	5	**20**
	WWI Naval Mine	165	2	1	**2**	2	5	**10**
	WWI Naval Torpedo	123	2	1	**2**	2	5	**10**
	WWI Naval Projectile	1.42	2	1	**2**	2	2	**4**

Protection and Crossing Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel			UXO Risk to Underwater Equipment		
			P	C	R	P	C	R
Rock Emplacement Offshore ~80m LAT	WWII Naval Mine	227	3	2	**6**	3	5	**15**
	WWI Naval Mine	165	1	2	**2**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**
Rock Emplacement Deep Offshore ~100m LAT	WWII Naval Mine	227	3	1	**3**	3	5	**15**
	WWI Naval Mine	165	1	1	**1**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**

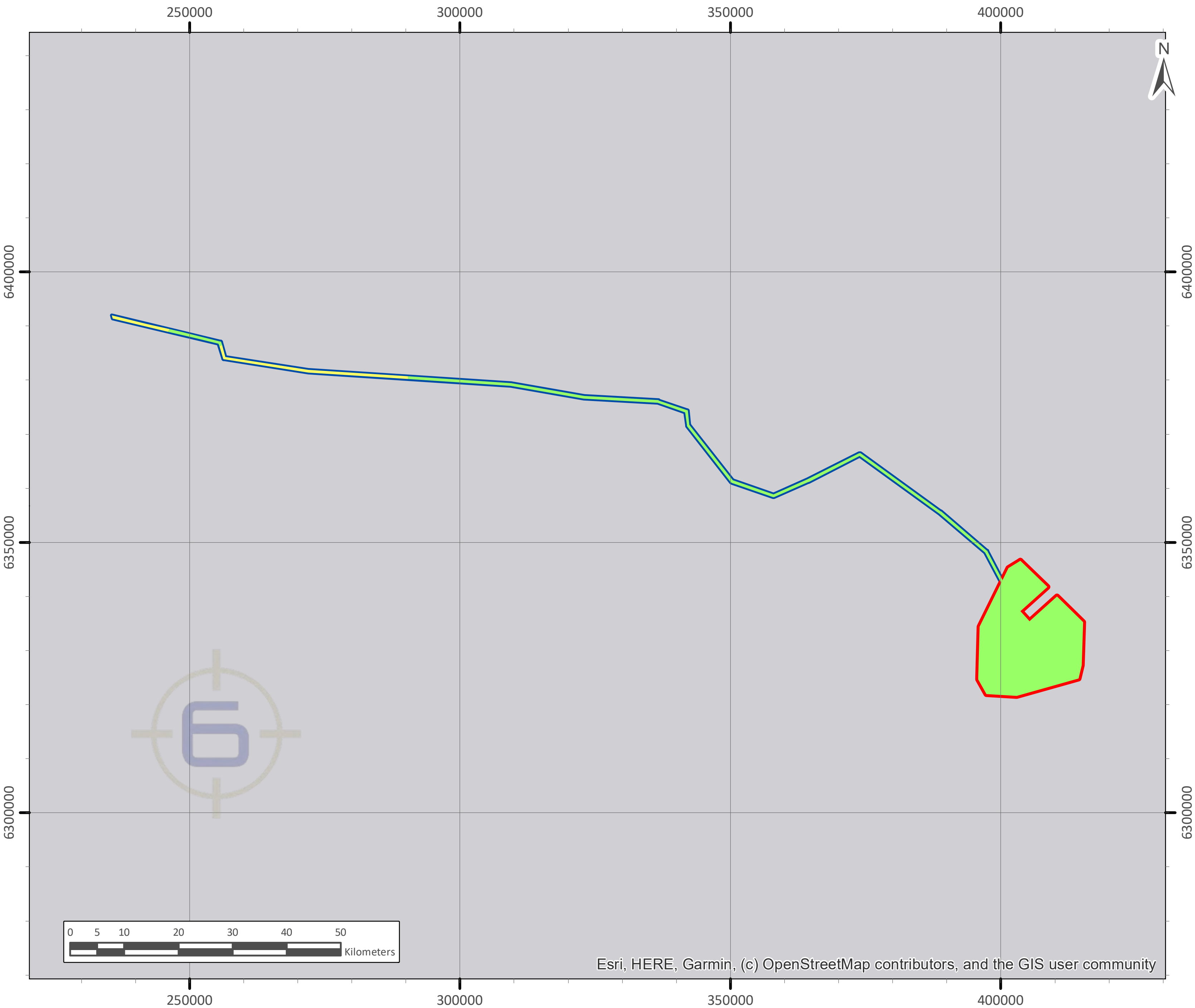
Enabling Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel			UXO Risk to Underwater Equipment		
			P	C	R	P	C	R
DP Vessels Offshore ~80m LAT	WWII Naval Mine	227	1	2	**2**	1	5	**5**
	WWI Naval Mine	165	1	2	**2**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**
DP Vessels Deep Offshore ~100m LAT	WWII Naval Mine	227	1	1	**1**	1	5	**5**
	WWI Naval Mine	165	1	1	**1**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel			UXO Risk to Underwater Equipment		
			P	C	R	P	C	R
Vessel Anchoring Offshore ~80m LAT	WWII Naval Mine	227	2	2	**4**	2	5	**10**
	WWI Naval Mine	165	1	2	**2**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**
Vessel Anchoring Deep Offshore ~100m LAT	WWII Naval Mine	227	2	1	**2**	2	5	**10**
	WWI Naval Mine	165	1	1	**1**	1	5	**5**
	WWI Naval Torpedo	123	1	1	**1**	1	5	**5**
	WWI Naval Projectile	1.42	1	1	**1**	1	2	**2**

Appendix 13

UXO Risk Zones



LEGEND

GENERAL

- OWF_Array
- Export_Cable_Corridor

Risk_Rating

- MEDIUM
- LOW

PROJECT	PROJECT TITLE
50024	CENOS OWF

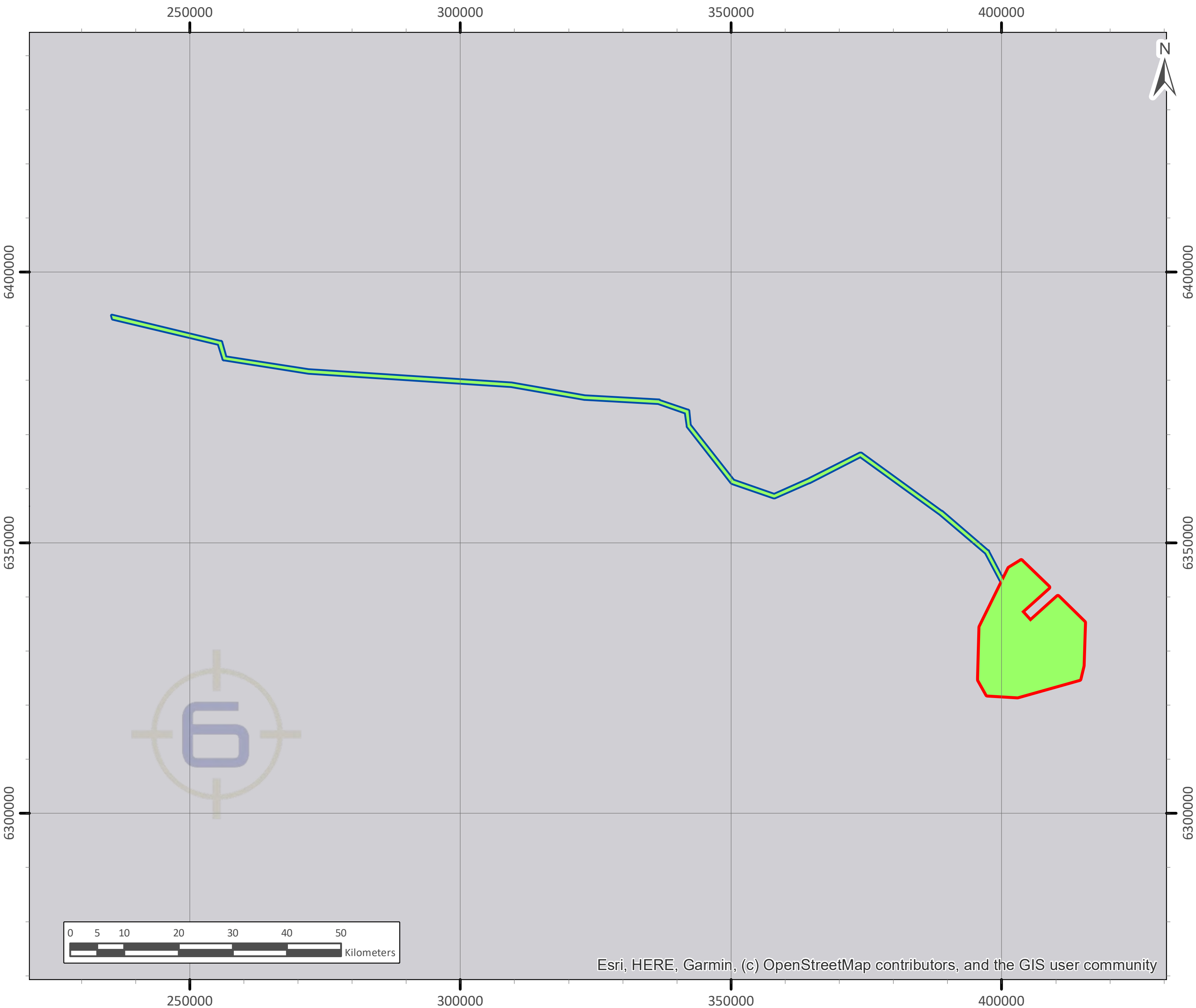
DRAWING TITLE
UXO Risk Zones - Construction Operations

DRAWING NUMBER
CENOS OWF\013a\V1.0

PURPOSE
FOR INFORMATION USE ONLY

alpha ASSOCIATES
special risks consultancy

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED		
WGS 1984 UTM Zone 31N	1:1,000,000	A4	LH	17/07/2023	LG	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please forward to 6 Alpha.	WWW.6ALPHA.COM E: enquiry@6alpha.com | T: +44 (0)203 371 3900



LEGEND

GENERAL

- OWF_Array
- Export_Cable_Corridor

Risk_Rating

- LOW

PROJECT	PROJECT TITLE
50024	CENOS OWF

DRAWING TITLE
UXO Risk Zones - GI Operations

DRAWING NUMBER
CENOS OWF\013b\V1.0

PURPOSE
FOR INFORMATION USE ONLY

alpha ASSOCIATES
special risks consultancy

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
WGS 1984 UTM Zone 31N	1:1,000,000	A4	LH	17/07/2023	LG

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Annexes

Annex A – Legislation and UXO Risk Management

References

A. CIRIA Assessment and Management of Unexploded Ordnance (UXO) risk in the marine environment (*C754*), 2015.
B. Schade, C., Kunreuther, H., & Koellinger, P. (2012). *Protecting Against Low-Probability Disasters: The Role of Worry.* Journal of Behavioral Decision Making.

1.1 Introduction

English (and generally, other national) law requires that Clients fulfil both their statutory and legal duties to protect those that may be exposed to harm. In the event of a UXO incident that causes harm, failure to adequately manage the UXO risk may lead to the prosecution (and prospectively unlimited fines and imprisonment), of those deemed responsible for breaching their duty of care. The following sections outline national legislation, industry best practice, the common law principle of reducing risks to As Low As Reasonably Practicable (ALARP), the assumptions made concerning organisational risk tolerance, as well as the expected behavioural responses of the project stakeholders when confronted with UXO risks.

1.2 National Legislation

In addition to common law (upon which the ALARP risk reduction principle is founded), the primary statutory UK legislation concerning health and safety is delivered by *inter alia*, the following key legislation:

- Health and Safety at Work etc Act 1974;
- Management of Health and Safety at Work Regulations 1999;
- Construction Design and Management Regulations 2015.

By seeking UXO risk management advice, organisations can evidence that their projects have taken advice from a competent UXO organisation, not only by performing UXO threat and risk assessments but also by taking advice implementing measures in order to reduce risks ALARP. In doing so, organisations can evidence that they have discharged their responsibilities associated with common and statutory duties.

1.3 UXO Industry Guidance and Good Practice

The Construction Industry Research and Information Association (CIRIA) has published guidance on the assessment and management of unexploded ordnance risks in the marine environment (Reference A). CIRIA is a neutral, non-governmental, not-for-profit body, linking member organizations with common interests, to setting and/or to improve agreed level of industry standards and good practice.

CIRIA C754 guidance therefore, represents industry agreed standards and good practice for the assessment and management of UXO risks. It has been recognised by the UK's Health and Safety Executive (HSE) as a source of good practice which when implemented, satisfies English law.

6 Alpha not only authored the technical content of the CIRIA C754 guide but also applies it, to ensure compliance with legal requirements as well as industry good practice, and to ensure that UXO risks are reduced to ALARP.

1.4 Reducing Risks to ALARP

Reducing risks to ALARP is the concept of weighing a risk against the resources required (typically measured by finical outlay), to a level that adequately control the risks. The law sets this level of what is reasonably practicable, whilst stakeholders determine what is considered tolerable whilst fulfilling their legal obligations.

Industry best practice offers guidance as to assessing both UXO threat, risk and risk tolerance, so that an agreement amongst stakeholders can be reached as to what not only a reduced risk to ALARP means but also, what resources are required to achieve it. ALARP therefore describes the level to which risks are controlled, as determined by the law through the implementation of good practice.

Confirming that the UXO risks have been reduced to ALARP involves weighing the residual risks against the resources to further reduce them. If it can be demonstrated that the resource requirement is grossly disproportional to the benefits of further risk reduction, then risks have been reduced to ALARP. Consequently, the principle of reducing risks to a reasonably practicable level will usually result in a residual level of risk, as well as de minimis risks that must be either shared, transferred, mitigated, and/or tolerated.

A diagrammatic representation for meeting with ALARP risk reduction is presented at Figure 1.

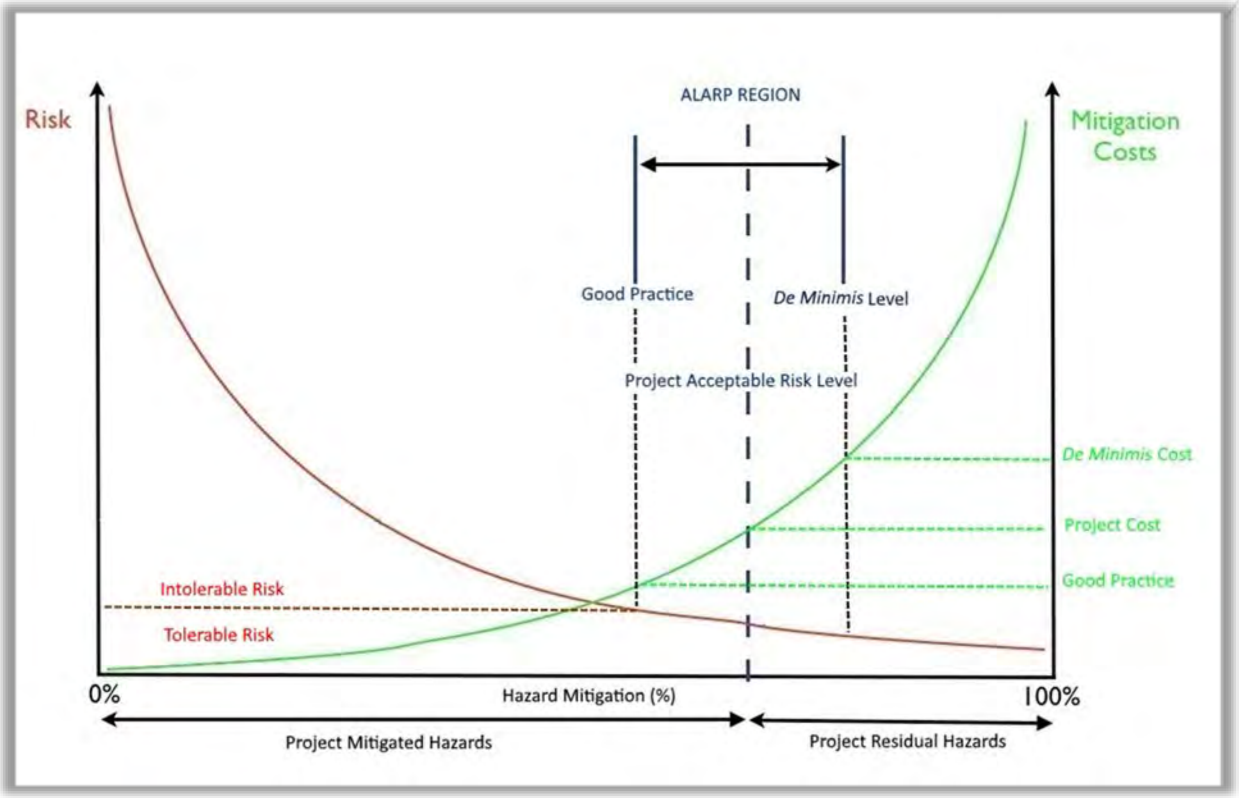

Figure 1: The ALARP Principle of managing risk.

1.5 UXO Risk Tolerance

6 Alpha Associates have made certain assumptions about the reasonable tolerance of UXO risks. Our assumptions include that the following interrelated elements that might be considered when determining UXO risk tolerance:

- **Safety**; personnel safety will assume the highest priority for any project. The protection and preservation of equipment, property, and the environment, although important, will remain a secondary priority to that of the prevention of harm to personnel involved with the project;
- **Corporate Governance**; is a system of rules, practices, and processes by which companies are managed and controlled. It is assumed that any Client will wish to adhere to high standards of corporate governance. Discharge of corporate responsibility is expected to be on risk-based criteria and it is expected that the Clients will have in place a framework for managing risks for good governance. It is anticipated that safety and risk management are integrated in Client business culture and that such measures will be actively applied throughout the execution of any project;
- **Risk Management**; high standards of risk and safety management are expected to be applied to any project and that a risk management system is expected to be in place to deal with business, programme, and project risks. Projects will commonly engage with competent

consultants not only to identify UXO risks, but also to design appropriate UXO risk management solutions in accordance with the law and industry good practice. The latter demands that any risks posed by UXO must be assessed based upon probability and consequence criteria. Potential UXO are best avoided (as this provides a best value-for-money solution) or the risk that they pose ought to be mitigated and reduced ALARP not only in accordance with the law, but also in accordance with CIRIA best practice guidelines. A competent consultant is to be expected to deliver *inter alia* desk studies and to design and oversee any UXO geophysical surveys and subsequently a suite of UXO risk mitigation measures, ensuring they are performed to appropriate quality and good practice standards.

1.6 UXO Risk – Probability, Consequence and Perception

UXO incidents that result in harm are may be classified as Low Probability, High Consequence (LP-HC) events. Given the ambiguity and uncertainty surrounding such events, project stakeholders might respond to such risks in an extreme manner but with good intent, but in doing so demanding a disproportionate level of risk mitigation. Stakeholders should be aware of the following common responses and attitudes to LP-HC risks, in order to manage stakeholder expectations concerning UXO risks, throughout project life cycles. There are a number of common general behavioural patterns for dealing with LP-HC events (see Reference B), namely:

- Individuals do not think probabilistically and seek zero risk when costs do not need to be absorbed. Alternatively, when individuals do need to absorb costs themselves, they are more likely to tolerate very high probability risks;
- Risk is a multidimensional problem which cannot be simply measured quantitively, such as by the number of fatalities generated annually;
- Risk tends to be influenced by attitudes to catastrophic situations, fear, lack of familiarity, or situations they perceive to be beyond their control. By nature, humans are risk averse when exposed to uncertainty and will enhance the level of risk mitigation accordingly;
- Given the lack of knowledge over the probability of UXO events, organizations are more likely to use simple decision-making measures;
- The general perception is, that the probability of LP-HC risks is low and as a result they might not be mitigated appropriately.

Such behaviour patterns typically lead to one or more of the following common responses from project stakeholders:

- A desire to seek zero risks;

- A perception that the situation is under their control and therefore a UXO event might never happen;
- That the hazard is perceived to be benign with the passage of time (especially when a risk has not materialised).

Such perceptions can be overcome through the expert application of risk analysis based upon probability and consequence criteria and then tailoring the delivery of UXO risk mitigation measures in accordance with ALARP risk reduction principles.

Annex B – Semi-Quantitative Risk Assessment Methodology

1.1 Overview

6 Alpha Associates use a Semi-Quantitative Risk Assessment (SQRA) approach to assess the prospective Unexploded Ordnance (UXO) risk for each of the project's intrusive investigation, installation and/or construction operations that interacts with the seabed. The SQRA process relies upon *6 Alpha*'s risk matrix, which is used to provide guidance on the required risk mitigation measures to be implemented, in order to manage the UXO risk to As Low As Reasonably Practicable (ALARP).

The following sections transparently outline *6 Alpha*'s SQRA methodology. The risk assessment tables for each of the project's investigation, installation and/or construction operations are presented separately within the report appendices.

1.2 Risk Matrix

For the purposes of this report, **Risk (R)** is calculated as a function of **Probability (P)** of encounter and initiation of UXO and **Consequence (C)** of initiation:

$$R = P \times C.$$

For each investigation, installation and/or construction activity that interacts with the seabed, the probability and consequence of the identified UXO threats has been assessed on a scale of 1 to 5. (Where 1 = Very Low, & 5 = Very High). These ratings are multiplied together (with a maximum of twenty-five) in order to determine a risk rating based on *6 Alpha*'s UXO risk matrix. Not only does this allow relative weighting and comparison of UXO risk across the project's seabed intrusive operations, but it also ensures that *6 Alpha* assesses UXO risk in a way that is consistent across projects which is a key responsibility of a UXO consultant. *6 Alpha*'s risk matrix is shown below in Table 1.2a.

		Consequence of Initiation				
Probability of Encounter and Initiation		**1** Negligible	**2** Minor	**3** Moderate	**4** Major	**5** Severe
	5 Highly Likely	**5** Low	**10** Medium	**15** High	**20** High	**25** Very High
	4 Likely	**4** Low	**8** Medium	**12** High	**16** High	**20** High
	3 Possible	**3** Low	**6** Medium	**9** Medium	**12** High	**15** High
	2 Unlikely	**2** Low	**4** Low	**6** Medium	**8** Medium	**10** Medium
	1 Highly Unlikely	**1** Very Low	**2** Low	**3** Low	**4** Low	**5** Low

Table 1.2a: *6 Alpha Associates*' UXO Risk Matrix

The numerical values assigned to the UXO risk are compared to Table 1.2b, which shows *6 Alpha*'s risk grading and describes the recommended best practice strategic risk mitigation measures required in order to satisfactorily manage the UXO risk to ALARP.

Whilst this risk matrix is aligned with *6 Alpha*'s standards in providing a UXO risk mitigation strategy, we also recognise that other UXO risk management consultancies may differ in their own assessment of the UXO risk and their recommended UXO risk mitigation measures.

<table>
<tr><th>Risk Rating (P x C)</th><th>Grading</th><th>Risk Tolerance</th><th>Action Required</th></tr>
<tr><td>1</td><td>Very Low Risk</td><td rowspan="2">Tolerable</td><td rowspan="2">The risk is at, or below the de minimis level with no further action required to reduce the UXO risk to ALARP. Operations may proceed without proactive UXO risk mitigation measures in place. Nonetheless, reactive mitigation measures might be recommended in order to mitigate residual UXO risks and to align with industry best practice. Risks will be reviewed periodically to ensure risk mitigation controls remain effective.</td></tr>
<tr><td>2-5</td><td>Low Risk</td></tr>
<tr><td>6-10</td><td>Medium Risk</td><td>Potentially Tolerable</td><td>The UXO risk may be tolerable depending on the specific nature of the UXO risk and the potential consequences of a UXO initiation and the project stakeholder’s risk tolerance. Where vessel crews and/or other personnel may be exposed to harm, then the UXO risk is intolerable.</td></tr>
<tr><td>12-20</td><td>High Risk</td><td rowspan="2">Intolerable</td><td rowspan="2">Operations may not proceed without proactive risk mitigation measures being implemented prior to intrusive investigation, installation and/or construction works. Reactive risk mitigation measures must also be implemented.</td></tr>
<tr><td>25</td><td>Very High Risk</td></tr>
</table>

Table 1.2b: *6 Alpha Associates*’ Risk Tolerability

1.3 Calculating the Project’s Probability of Encounter and Initiation

At the strategic level, and for risk assessment purposes, *6 Alpha* applies the precautionary principle to all prospective UXO encounters within a Study Site. For example, the probability of initiating an item of UXO upon an encounter is considered certain, whereas in practice factors such as the kinetic energy transfer and UXO sensitivity will impact whether direct or indirect contact with UXO will cause an initiation event. Therefore, the probability of encountering and initiating UXO is primarily influenced by the likely level of UXO contamination within the Study Site, but also subsequently through the application of a methodology modifier (the value of which is determined by the spatial extent of the soil intrusion). Further details of 6 Alpha's guidance on the scoring of the probability of UXO contamination can be found in Table 1.3 below.

Probability of UXO Contamination	**Likelihood Score**	**Description** (based on a 5km Assessment Distance)
Highly Unlikely	**1**	There is no indication of historical or modern ordnance activity or discovered ordnance **within 5km of the Study Site**. Potential UXO discoveries are, therefore, likely to be from unquantifiable sources and/or from subsequent UXO migration.
Unlikely	**2**	There is evidence of historical or modern ordnance activity or discovered ordnance **within 2km to 5km** (or 4km to 10km for a munitions dump) of the Study Site's boundary.
Possible	**3**	There is evidence of historical or modern ordnance activity **within 1km to 2km** (or 2km to 4km for a munitions dump) of the Study Site's boundary.
Likely	**4**	There is evidence of historical or modern ordnance activity or discovered ordnance **either on-site or within 1km of it**. If the prospective UXO threat source intersects the Study Site, then the precise nature of the threat source and/or the proximity and concentration of any previous UXO encounters may influence whether the assessment concludes a "Likely" or "Highly Likely" probability of contamination.
Highly Likely	**5**	There is significant evidence of historical or modern ordnance activity, **within the Study Site** that is corroborated with evidence that **UXO has been encountered previously** either on-site or in the immediate vicinity.

Table 1.3: *6 Alpha Associates*' Probability of UXO Contamination Assessment Criteria

The categorisation of UXO threats may not always be straightforward, and multiple additional factors might also be considered that result in a potential threat source being classified as a higher or lower threat than indicated by Table 3. For example, WWI-era ordnance is rarely encountered in the marine environment in the 21st Century and therefore, the likelihood of encountering such ordnance may be reduced.

Additionally, the categorisation of potential threat sources such as Anti-Aircraft Artillery projectiles (or similar) might also be influenced by the total number of artillery batteries in any given area that possess a firing arc template that encompasses a Study Site and/or the likelihood that they were fired for training or operational purposes (amongst other things).

In order to calculate the overall probability of encounter, the probability of UXO contamination at the Site is modified based upon the likely spatial extent of the seabed disturbance, caused by the proposed investigation, installation or construction activity. This provides the final calculation for the probability of encounter and initiation, which is used for the risk assessment.

1.4 Calculating the Project Consequences

The risk assessment performed by *6 Alpha* assesses the risk of an unplanned initiation of UXO to the relevant sensitive receptors (e.g. human life, the vessel(s) and/or underwater equipment), resulting from explosive shockwave and/or fragmentation effects.

This is achieved by calculating the resulting peak pressure for an equivalent mass of trinitrotoluene (TNT) representative of the likely UXO threat items within the Site, as well as estimating the distances separating the source (UXO) and the sensitive receptors.

The following formula is applied to calculate peak pressure in megapascals (MPa), of the resultant shockwave (Reid, 1996):

$$Peak\ Pressure\ (MPa) = 52.4.\left(\frac{M^{\frac{1}{3}}}{R}\right)^{1.18}$$

For SQRA calculations, R is the separation distance in metres between the source and the receptor and M is the mass of TNT explosive equivalent in kilograms.

The resulting peak pressure calculated is compared to Table 1.4, which provides the final consequence calculation for entry into the risk matrix (Szturomski, 2015).

Peak Pressure (MPa)	Consequence Rating	Consequence Score	Description
0 – 2	**Negligible**	**1**	Damage to the vessel is likely to be negligible and vessel crews are highly unlikely to be hurt. Damage to underwater equipment will be influenced by the robustness of such equipment and its internal mechanisms.
2 – 4	**Minor**	**2**	There may be minor damage to brittle materials and to the sensitive electronics. The vessel crews are unlikely to be injured. Damage to underwater equipment will be influenced by the robustness of such equipment and its internal mechanisms.
4 – 6	**Moderate**	**3**	More significant damage to vessel is likely and may impact vessel steering and control and light injuries might be sustained by the crew. There is also the prospect of light damage to underwater equipment.
6 – 8	**Major**	**4**	Serious damage to the vessels electronics, generators and control systems is likely and serious injuries and/or fatalities amongst the vessel crew are possible. Serious damage to underwater equipment is also likely.
More than 8	**Severe**	**5**	Catastrophic structural vessel damage is likely and it is also likely that there will be multiple injuries and fatalities to personnel aboard. Catastrophic damage to underwater equipment is likely.

Table 1.4: Consequence Rating of an unplanned initiation based on shockwave peak pressure.

1.5 References

1. Reid, W.D., 1996, The response of surface ships to underwater explosions;
2. Szturomski, B., 2015, The effect of an underwater explosion on a ship. Scientific Journal of Polish Naval Academy.

Annex C – Classification of UXO

1.1 General

Unexploded Ordnance (UXO) is any munition, weapon delivery system or ordnance item that contains explosives, propellants, or chemical agents, after they are either:

- Armed and prepared for action;
- Launched, placed, fired, thrown, or released in a way that they cause a hazard;
- Remain unexploded either through malfunction or through design.

1.2 Classification of Unexploded Ordnance

UXO items can be classified into 11 broad categories which are detailed below:

1.2.1 Small Arms Ammunitions (SAA)

Small Arms Ammunition (SAA) is a generic catchall term for projectiles that are generally less than 13mm in diameter and less than 100mm in length. SAA is fired from various sizes of weapon, such as pistols, shotguns, rifles, machine guns. Generally, the outer casings comprise either brass or steel. As UXO, they present a minimal risk compared to other high Net Explosive Quantity (NEQ) UXO, although SAA may explode if subjected to extreme heat, or if struck with a sharp object.

1.2.2 Hand Grenades

Hand grenades are small bombs thrown by hand and come in various sizes and shapes. Typical types of hand grenades include fragmentation, smoke, incendiary, chemical, training, and illumination. As UXO, they present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed to extreme heat.

1.2.3 Projectiles

Projectiles are munitions generally ranging in diameter from 20mm to 406mm and can vary in length from 50mm to 1,219mm. All projectiles are fired from some type of launcher or gun barrel and may comprise either an explosive, chemical, smoke, illumination, or inert/training fill. Projectiles may also be fitted with stabilising fins and their fuzes are typically located either in the nose or located at the base. As UXO, they present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed to extreme heat.

1.2.4 Mortar Bombs

Mortar bombs come in a range of shapes, sizes, and types, typically ranging between 25mm to 280mm in diameter and typically fired from a mortar; a short smooth barrelled tube. Mortar bomb types and functions can vary to include fragmentation, smoke, incendiary, chemical, training, and illumination. Mortar bombs may be found with or without stabilising fins and they present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.5 Landmines

Landmines are an explosive device typically shallow buried or concealed on the ground and used to defend vulnerable areas or to deny the area completely for any use. After WWII, the defensive minefields around the coastlines were swept clear and the munitions either buried or dumped at sea. Landmines come in various sizes, shapes and types including fragmentation, incendiary, chemical, training and illumination. The cases of landmines are typically made of metal but can comprise any non-magnetic material such as wood, clay, glass, concrete, or plastic so that they are harder to detect. As UXO, they present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.6 Bombs

Bombs come in a range of size and types, generally weighing from 0.5kg to 10,000kg with typical components of a metal casing, a mechanical or electrical fuze, a main charge, a booster charge, and stabilising fins. The metal casing contains the explosive or chemical fill and may be compartmentalised. Bomb types include high explosive, incendiary, chemical, training, and concrete. As UXO, they present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.7 Sea Mines

Sea mines are self-contained explosive devices either placed on the seabed or moored in the water column to damage or destroy surface ships or submarines. Like land mines, they are typically used to defend vulnerable areas or to deny the area completely for any use. After WWI and WWII, sea minefields were swept, with surface vessels working in tandem to cut the mooring tether so that the sea mine would float to the surface. The sea mine was then shot with SAA so that it either exploded or flooded and sank to the seabed. Some sea mines were also simply lost or were not recovered and remain unaccounted for. Sea mines come in all shapes and sizes and as UXO, they present a risk mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.8 Rockets

Rockets are self-propelled unguided munitions that generally vary in diameter from 37mm to more than 380mm and can vary in length from 300mm to 2,743mm. All rockets comprise a warhead, fuze and motor section, with the warhead typically containing either an explosive or chemical fill. As UXO, they may or may not be present with tail fins and present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.9 Depth Charges

A depth charge is a container, typically barrel or drum shaped, of high explosive fitted with a hydrostatic pistol, designed to trigger at a pre-programmed depth. As UXO, they present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.10 Torpedoes

Torpedoes are guided or unguided, underwater, self-propelled weapons typically fitted with a high explosive warhead. The dimensions of complete torpedoes vary but are generally between 400mm to 600mm in diameter and between 4,500mm to 7,500mm in length. As UXO, torpedoes are they are rarely found completely intact with the warhead and propulsion stages often discovered separated. Both the warhead and propulsion stages of the torpedo present a hazard if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.11 Guided Missiles

Guided missiles are similar in design to rockets, with the exception being that they are guided to their targets by some form of guidance system and can be either self-adjusting or operator controlled. Guided missiles can be found in a variety of size, shape and colour and may be found with or without stabilising fins attached. As UXO, they present a hazard if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

Annex D – Explosives and Detonation Effects

1.1 Introduction

Explosives can be categorised into two broad categories, namely: those designed to be detonating (or high explosives) and those designed to be deflagrating (or low explosives). In the case of Unexploded Ordnance (UXO) risk management in the marine environment, the primary concern is associated with ordnance comprising high explosive content.

Due to the infrequency of UXO initiation events that cause harm, it is a commonly held notion that WWI and WWII ordnance devices may have deteriorated and no longer function as designed, presenting a false sense of tolerable risk to project stakeholders. The precautionary principle of risk management prevents this misplaced assumption from being carried throughout the risk assessment and project life cycle. Ordnance must, for the purposes of risk management, be assumed to be fully functional until determined safe by an Explosive Ordnance Disposal (EOD) operative.

This annex describes the classification of explosives, the generic design of the explosives train and the effects of a detonation in the marine environment.

1.2 Classification of Explosives

Explosives can be classified into two broad categories, which are detailed below:

1.2.1 Detonating or High Explosives

Detonating or High Explosive (HE) compounds are characterised by their very rapid decomposition and development of a high-pressure shock wave. These explosives detonate at velocities ranging from 1,000m/s to 9,000m/s and may be subdivided into two explosives classes, differentiated by their respective sensitivity or ease with which an explosive may be ignited or initiated:

- **Primary Explosives** – are extremely sensitive to impact, friction, sparks, flames or other methods of generating heat to which they will respond by burning rapidly or detonating. Examples include mercury fulminate and lead azide. This high sensitivity to initiation makes them unsuitable to use as a base explosive (i.e. main-fill explosive in military ordnance).
- **Secondary Explosives** – are relatively insensitive to impact, friction, sparks, flame or other methods of producing heat. They may burn when exposed to heat in small-unconfined quantities, although the risk of initiation is always present especially when they are confined and/or burnt in bulk. Dynamite, trinitrotoluene (TNT), RDX and HMX are classed as secondary high explosives, which are commonly used as base explosives in military ordnance. Pentaerythritol tetranitrate (PETN) is the benchmark compound for comparative purposes,

with those explosives that are more sensitive to initiation than PETN classified as primary explosives.

1.2.2 Deflagrating or Low Explosives

A low explosive is usually a mixture of a combustible substance and an oxidant that decomposes rapidly, a process known as deflagration which produces a relatively low pressure, shock wave. Under normal conditions, low explosives undergo deflagration at rates that vary from a few centimetres per second to approximately 400m/s, yet when concentrated and confined may be caused to detonate and produce a relatively high-pressure shock wave.

Deflagration processes of low explosives are easier to control than the detonations of high explosive, that they are typically used as ballistic propellants for rockets, artillery projectiles and bullets. Typical ballistic propellants include the family of smokeless propellants known as cordite which was used extensively during WWII.

1.3 Generic Design of Ordnance

In general, explosive ordnance items, such as bombs or sea mines tend to have the following basic components:

- **Case** – the casing or body of the ordnance item is typically manufactured from a ferrous metal such as steel. The *German Luftmine A* and *B* (LMA and LMB respectively) parachute mines used during WWII, were however manufactured from aluminium. The case shatters during detonation of the high explosive fill, fragmenting at high velocity to increase the potential damage and harm;
- **Main Charge** – the main charge makes up most of the explosive mass of the ordnance item comprising a high explosive fill with a relatively low sensitivity to initiation;
- **Booster** – a secondary high explosive booster charge is used to ignite the main charge component and comprises a more sensitive, albeit smaller quantity of high explosive;
- **Fuze** – a small quantity, high explosive charge is usually incorporated into the device which is sensitive to initiation. The fuze acts as the primary explosive which is used to ignite the booster. The fuze is relatively small when compared to the booster and housed with a fuze pocket within the casing of the ordnance item, located immediately adjacent to the booster charge;
- **Trigger** – a mechanical, electrical, or chemical mechanism is used to initiate the fuze at the appropriate time, such as upon impact, hydrostatic depth, magnetic field distortion or time. The trigger is the most sensitive component to the firing train and the primary method of ignition, that if interfered with may cause an inadvertent detonation.

An explosive chain reaction is therefore started when the sufficient energy (kinetic, electrical, or chemical) is generated to initiate the explosive content of the fuze, which in turn detonates the booster and finally the main charge. These components form the explosive train of the ordnance device.

1.4 Underwater High Explosive Detonations

An explosion underwater differs from that within air due to the formation of a gas bubble within the water in addition to the fragmentation and shockwave effects. Upon detonation, the ordnance case will fragment and cause damage to proximal receptors such as underwater equipment, with the main hazard to the surface vessel, personnel aboard, and underwater equipment being from the resulting gas bubble and shockwave.

An underwater explosion results in the change of solid matter (the main charge) into a gas of high temperature and pressure (the gas bubble) as well as a spherical shockwave. The pressure acting outwards from the gas bubble is opposed by the hydrostatic pressure of the surrounding water, which causes an oscillating effect of expansion and contraction as the gas bubble moves towards the water surface.

Each expansion of the gas bubble causes a shockwave that is propagated outwards throughout the water in all directions. Although these shockwaves gradually become weaker as the gas bubble rises through the water column, it may close with nearby receptors such as surface vessels, situated offset or directly above the gas bubble causing damage. When the gas bubble reaches the surface, a columnar plume is formed from the sudden release of the gas into the atmosphere as well as carrying water. Should a vessel be directly in the path of the gas bubble as it contracts, the vessel may be subjected to bubble jetting loads; a high-energy jet of water capable of rupturing the vessel's hull.

The shockwave from an underwater explosion propagates radially outwards from the source location. Possessing an initial high velocity, the shock wave decelerates over distance from the source location, eventually decreasing to the underwater speed of sound. As the distance from the source location increases, the peak pressure of the shockwave decreases reducing the damage potential of the shockwave.

A surface vessel must therefore be kept a safe distance away from a source of an explosion so that resultant shockwave causes no damage.

If a nearby surface vessel is struck by the shockwave, the vessel can experience significant vibrations resulting in the damage to underwater hull mounted equipment and the dislodgment of loose objects, machinery, and power cables on board the vessel. Both the initial vibrations and secondary effects resulting from the vessel damage, have the capacity to cause disabling injuries to personnel aboard, from being struck by loose objects, trips and falls, and joint damage (ankles, knees, hips, spine, and neck) from a sudden acceleration.

A second damage mechanism may arise from the whipping effect. The whipping effect occurs when the frequency of the expansion and contraction of the gas bubble matches the vessels natural oscillating frequency. The vessel's hull will be driven to vibrate at its natural resonating frequency, vibrating at a greater amplitude than that of the initial pressure wave from the expanding gas bubble.

A badly affected ship usually sinks quickly due to cracking and deformation of the hull, resulting in flooding across the length of the ship and eventual sinking.

Divers, as well as marine mammals, are especially vulnerable to underwater shockwave effects and can be seriously injured or killed by the detonation of relatively small, high explosive charges.

Annex E – UXO Discovery, Detonation and Sympathetic Detonation Risks

1.1 Introduction

A host of theoretical and empirical studies have provided strong evidence that Unexploded Ordnance (UXO) becomes more sensitive to trigger events that transfer kinetic energy (such as a physical impact or shock) and/or chemical energy (such as heat) as they age. Theoretically, a spontaneous detonation of UXO may occur but such instances are exceptionally rare. Therefore, UXO risk management focuses on the avoidance of known trigger events, even those of small magnitude, that may cause UXO to detonate.

Subject to its size and Net Explosive Quantity (NEQ), significant risks may be present by the discovery and accidental detonation of a singular item of UXO. Additionally, it is not uncommon for UXO to be discovered in close proximity to one another, in the offshore environment especially. For example, UXO might be found in very close proximity in munitions dumps, within the body of a shipwreck, or clustered together due to underwater topography. These circumstances are not unusual, with numerous 20th century shipwrecks and munitions dumps having been discovered around the world. Given that UXO becomes more sensitive to trigger events as they age, it is reasonably foreseeable that one detonation may trigger others in close proximity to explode in a chain reaction, a process known as sympathetic detonation.

1.2 Objectives

The objective of this annex is to present open-source examples of UXO discovery in individual and group circumstances that evidences the longevity and severity of UXO threats in the marine environment. Secondly, this annex aims also to highlight the potential hazards associated with a prospective UXO detonation and/or a sympathetic detonation event and the emergency reaction of the authorities to such discoveries.

1.3 Open-Source Examples

The *North Sea* was a significant a naval theatre of war in both WWI and WWII, given its location adjacent to the *United Kingdom* and its proximity to *Luftwaffe* bases in *Norway*. Numerous submarine engagements and offensive and defensive mine campaigns have specifically involved the deployment of munitions across the region. With the advances in aircraft technology and understanding in the mid-20th century, the coastline of *North-Eastern Scotland* was also in range of bomber aircraft during

WWII, which also resulted in deliberate air-to-surface vessel attacks, air mining and bomb jettisoning at sea.

As such, both WWI and WWII have left a legacy of unexploded munitions along the *Scottish* coastline which are still encountered to the present day. Although almost 75 years have passed since the end of the WWII, associated UXO are still located and discovered within the coastline and offshore environments of *Scotland* to this day, as demonstrated by the following publicly accessible news article summarising encounters with historic munitions.

PICTURE UPDATE: Bomb squad blows up ancient device discovered at north-east nature reserve

By Ben Hendry   May 19, 2020, 8:45 pm

Explosives experts were scrambled to a north-east beauty spot this afternoon to detonate a device dating back to the Second World War.

The Royal Navy's bomb disposal team was called to a stretch of the Forvie National Nature Reserve at Collieston in Aberdeenshire.

Police had been called at 10.55am and stood guard over the two-inch mortar until the experts arrived and carried out a controlled explosion.

Inspector Steven McDonald, of Banff Police Station, said: "Police were called to a report of unexploded ordnance found on the beach near Collieston.

"The area has been cordoned off as a precaution. EOD attended and carried out a controlled explosion."

Pictures have now revealed that a two-inch mortar had washed ashore at the beach, along with some other suspected munitions from the Second World War such as a possible floating smoke candle – which were designed to be used to screen amphibious forces.

The two-inch mortar was one of a number of small mortars brought into service by European nations between the two World Wars.

Ben Hendry, *Bomb squad blows up ancient device discovered at north-east nature reserve*, 19th May 2020.

https://www.pressandjournal.co.uk/fp/news/aberdeen-aberdeenshire/2207185/picture-update-bomb-squad-blows-up-ancient-device-discovered-at-north-east-nature-reserve/

BP oil pipeline closed to remove unexploded war mine

Second world war mine off Peterhead coast in Scotland forces five-day closure of BP Forties pipeline for safe removal

BP's Forties oil pipeline has been closed for five days for the safe removal off an unexploded second world war mine off the coast of Peterhead in Scotland. Photograph: Graham Turner for the Guardian

An oil pipeline off the north-east coast of the UK, responsible for delivering around 40% of oil produced in UK waters into the country, has been shut down for five days so that an unexploded mine from the second world war can be removed.

The German-build sea-mine will be transported four kilometres (2.5 miles) away and detonated safely underwater, the operator of the Forties pipeline, BP, said.

The explosive was found in 300ft of water 25 miles off the coast of Peterhead, Scotland, in late March.

"It didn't pose any risks where it was, but we knew pretty quickly we didn't want it there," a BP spokesman said on Monday.

"It's very rare that the whole system is shut down, but we are not taking any chances."

BP has decided to shut down the pipeline now to deal with it because demand is typically lower around this time of year. The downtime will allow BP to carry out essential maintenance on the pipeline.

BP said on Monday: "The Forties pipeline system has started a five-day planned shutdown, to enable the safe removal and disposal of ordnance lying next to the pipeline. BP is also taking the opportunity to conduct some important maintenance while the system is shut down. All users of the Forties pipeline system have been kept regularly informed and are fully aware of the plan. The plans have also received full regulatory approvals and support."

Alex Hawkes, *BP oil pipeline closed to remove unexploded war mine*, 1st August 2011.

https://www.theguardian.com/business/2011/aug/01/bp-oil-pipeline-closed-unexploded-mine

Police shut off harbour following discovery of unexploded bomb

A HARBOUR was closed for six hours today after a fishing boat brought in what was thought to be a torpedo caught in its nets.

A HARBOUR was closed for six hours today after a fishing boat brought in what was thought to be a torpedo caught in its nets.

The crew brought the object into Peterhead harbour, Aberdeenshire, this morning after finding it at sea.

Police were contacted at around 8.30am after a "torpedo-shaped" object was brought ashore.

The harbour was cordoned off until the device was inspected and removed. The area was reopened at 3.20pm.

Explosive experts from the Royal Navy travelled to the harbour and inspected the torpedo-shaped object on a quayside.

A spokeswoman for Grampian Police said: "The explosive ordnancedisposal team have removed the device and will perform a controlled detonation offshore.

"Grampian Police realise that the incident has causedconsiderable disruption to the Peterhead area today and wish to thank the public for their co-operation and patience during this time."

Charlie Gall, *Police shut off harbour following discovery of unexploded bomb*, 30th March 2011.

https://www.dailyrecord.co.uk/news/scottish-news/police-shut-off-harbour-following-discovery-1098916

Annex F – Ordnance Scour, Burial and Migration

1.1 Overview

Unexploded Ordnance (UXO) is typically found washed up on the coastlines, typically during severe weather periods, that strongly suggests movement from their originally deployed position. Consequently, any item of UXO detected during the geophysical UXO survey will be subjected to similar forces and processes and may therefore migrate and change position over time. The following annex provides an overview of the forces and processes to be considered for the assessment of UXO migration, to inform the UXO consultant of the longevity of the UXO risk As Low As Reasonably Practicable (ALARP) sign-off certificate, as well as the expansion size of the avoidance radii.

1.2 Physical Environment

There are several environmental factors that can influence munitions migration and burial on the seabed, namely:

1.2.1 Bathymetry

Both the local bathymetry and the seabed morphology have a significant influence on where munitions are likely to be situated, as well as their prospective mobility. For instance, ordnance located in shallower water depths will be exposed to higher wave generated forces than in deeper water depths. High seabed gradients will also promote migration downslope under the force of gravity.

Whilst it may take relatively little force for an item of UXO to roll or slide downslope into a topographic low, such as a depression or a channel, an increased amount of force will be required to transport the UXO item back upslope. It is widely accepted that any UXO items found in such areas will effectively become trapped and is highly unlikely to move any further.

1.2.2 Tidal Currents

The force generated at the seabed by the tidal current flow will determine the rate and direction of movement of mobile sediments and hence bedform features, but also any debris on the seabed including UXO items.

Tides may be semi-diurnal (generating two low and two high tides within a 24-hour period) or diurnal (generating one high and one low tide during a 24-hour period). Localised tidal variations vary by the alignment of the Sun and Moon, by the pattern of tides in the deep ocean, by the amphidromic systems of the oceans and by the shape of the coastline and near-shore bathymetry. Analysis of metocean data is necessary to fully understand the localised tides and currents which operate within a region to understand the potential for UXO migration.

Depending on the local region, a tidal system will generate either a stronger ebb or flood tide and, dependent on the tidal current vector (magnitude and direction), will influence the predominant direction and rate of movement of an item of UXO.

1.2.3 Wind Generated Surface Waves and Storm Events

Long periods of high wind speeds associated with storm events, which can generate large surface waves, have the highest potential to mobilise items of UXO on the seabed.

The frequency, direction and duration of these storm events is difficult to predict, and therefore there is no proven way to accurately predict the net rate of mobility of UXO on-site without direct observation. Nonetheless, if a 1:50 year storm was to take place on the site after a geophysical UXO survey had already been undertaken, then some form of confirmatory geophysical survey (and investigation) may be required to evidence that the potential UXO targets have not moved, or to scope the magnitude and direction of any such movement.

1.2.4 Seabed Sediments

The nature of the sediments on any site is important for understanding the prospective movement of UXO. The ability of sediments to allow for either full or partial burial of such objects, is key to understanding the potential for scour, burial and the future mobility of the UXO item.

UXO can become buried, either by penetrating the seabed upon its initial deployment (subject to its residual energy upon impact with the seabed) or subsequently, over time, because of scour. UXO items that do become partially or fully buried are unlikely to migrate any further, due to requiring a significantly greater force to mobilise them from their partially buried position. If a UXO item is situated above the mean seabed level and covered by mobile bedforms, such as megaripples or sand waves, they may potentially become uncovered if the bedform position migrates over time.

UXO items are likely to be found on the surface of the seabed of consolidated cohesive sediments as well as bedrock. In comparison, UXO items located on granular soils or unconsolidated cohesive soils may be subjected to greater a potential of scouring and subsequent burial.

The disturbance of the water flow across the UXO item itself causes scouring. Vortices are generated in front of the UXO item, which in turn exerts a shear force at the seabed and mobilise the seabed sediments away from the UXO item. This process is periodic, accelerating with energetic wave and tidal current conditions, and will continue until the UXO item is of a similar roughness to the surrounding seabed. Eventually, the UXO item will be undermined by the scouring action and fall into its own scour pit as shown in Figure 1.2.4.

1. Vortices are produced in the front of the UXO scouring sediment away;
2. The UXO is eventually undermined by the scouring action and rolls/slides into the scour pit;
3. Scour – burial cycle begins again until vortices are too weak to transport the seabed sediments

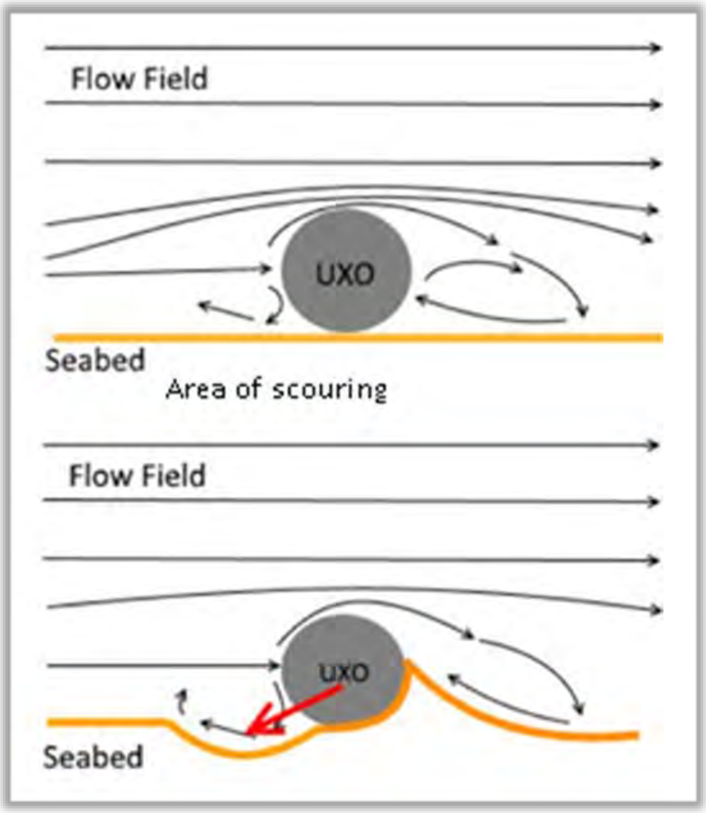

Figure 1.2.4: Vortex scouring and burial mechanism for UXO.

1.3 Human Factors – Fishing

Commercial fishing activities have the capability to inadvertently snag and move items of UXO, particularly in areas where dredging, beam and pair trawling is prevalent and nets are in contact with the seabed. These snagged UXO items may have been transported with the movements of the vessel's nets for considerable distances before they are returned to the seabed or recovered to the vessel.

Fishing boats which accidentally recover items of UXO have also been known to dispose of them/cut them free once they have been brought up to the surface, rather than inform the authorities (which involves considerable delay, but reduced risk).

1.4 Munitions Properties – Size, Shape and Density

The density, which is dependent on the mass and volume of the ordnance item, the cross-sectional area presented to the residual flow direction, and the hydrodynamic shape are primary factors considering an ordnance item's propensity to migrate.

In general, the denser and smaller an item of UXO is, the less likely it is to migrate. A large cross-sectional area will experience a higher hydrodynamic drag force than a smaller cross-sectional area, and a more streamlined body will experience a lower hydrodynamic drag force than a non-streamlined body.

Items of UXO, particularly high explosive bombs, are effectively hollow cases filled with an explosive fill. A large proportion of the bomb's volume is therefore dedicated to this low-density explosive fill. In comparison, a heavy anti-aircraft artillery projectile is significantly smaller and lighter, but is also denser, with a larger proportion of the volume dedicated to the casing to maximise the fragmentation effect. The projectile will also have a much smaller area exposed to the water flow. Given these circumstances, it is likely that the heavy anti-aircraft projectile will have a lower propensity to migrate than the high explosive bomb.