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Unexploded Ordnance Threat and Risk Assessment and Risk Mitigation Strategy for Geotechnical Investigation Operations

DNV

Project: *AO7 Oleron Offshore Wind Farm*

Meeting the requirements of the UK's Construction Industry Research and Information Association's

UXO Risk Management Framework:

"Assessment and Management of the Unexploded Ordnance Risk in the Marine Environment (C754)"

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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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Executive Summary

Project Overview

DNV has commissioned *6 Alpha Associates* to deliver a desk-based Unexploded Ordnance (UXO) threat and risk assessment for the installation of the *AO7 Oleron* Offshore Wind Farm (OWF). A Risk Mitigation Strategy has also been commissioned concerning the forthcoming Geotechnical Investigation (GI) operations associated with OWF development.

The proposed location of the *AO7 Oleron OWF* and its export cable corridors, together with the additional *Parc 1* and *Parc 2* zones, has been provided by the Client and is presented at Figure 1.

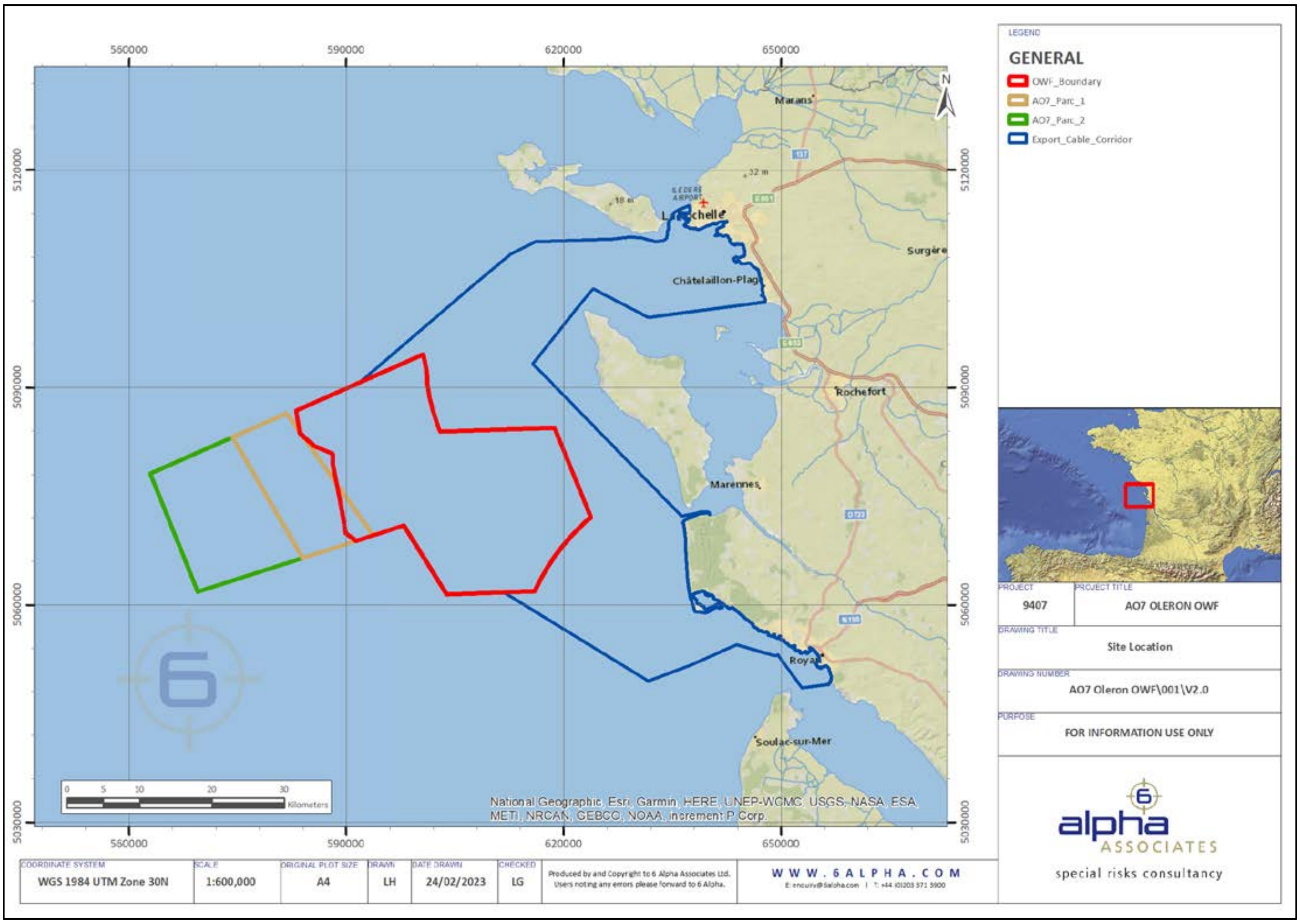

Figure 1 – Site Location

UXO Threat and Risk Assessment Summary

A tabulated summary of the findings of the threat and risk assessment is presented in Figure 2:

Intrusive Operation	UXO Threat	UXO Risk (Vessels and Personnel Only)			
		Ultra-Nearshore ~10m WD	Nearshore ~26m WD	Offshore ~40m WD	Offshore >60m WD
GI Operations	Aerial Bombs	MEDIUM	MEDIUM	MEDIUM	LOW
	Naval Torpedoes	LOW	LOW	LOW	LOW
	Naval Mines	MEDIUM	MEDIUM	MEDIUM	LOW
	Artillery Projectiles	MEDIUM	LOW	LOW	VERY LOW
Pre-Lay Operations	Aerial Bombs	HIGH	HIGH	HIGH	LOW
	Naval Torpedoes	MEDIUM	MEDIUM	MEDIUM	LOW
	Naval Mines	HIGH	MEDIUM	MEDIUM	LOW
	Artillery Projectiles	HIGH	HIGH	HIGH	VERY LOW
Cable Installation Operations	Aerial Bombs	HIGH	HIGH	HIGH	LOW
	Naval Torpedoes	MEDIUM	MEDIUM	MEDIUM	LOW
	Naval Mines	HIGH	MEDIUM	MEDIUM	LOW
	Artillery Projectiles	HIGH	HIGH	HIGH	VERY LOW
WTG Foundation Installation Operations	Aerial Bombs	N/A WTG Installation Operations will not occur at this depth.	HIGH	HIGH	LOW
	Naval Torpedoes		LOW	LOW	LOW
	Naval Mines		HIGH	HIGH	LOW
	Artillery Projectiles		MEDIUM	MEDIUM	VERY LOW
	Aerial Bombs	HIGH	HIGH	HIGH	LOW

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Intrusive Operation	UXO Threat	UXO Risk (Vessels and Personnel Only)			
		Ultra-Nearshore ~10m WD	Nearshore ~26m WD	Offshore ~40m WD	Offshore >60m WD
Protection Operations	Naval Torpedoes	LOW	LOW	LOW	LOW
	Naval Mines	HIGH	HIGH	HIGH	LOW
	Artillery Projectiles	HIGH	MEDIUM	MEDIUM	VERY LOW
Enabling Operations	Aerial Bombs	HIGH	HIGH	HIGH	LOW
	Naval Torpedoes	LOW	LOW	LOW	LOW
	Naval Mines	HIGH	HIGH	HIGH	LOW
	Artillery Projectiles	HIGH	MEDIUM	MEDIUM	VERY LOW

Figure 2 – Representative UXO Risk Assessment Summary

UXO Risk Zones

The categorisation of UXO risk is not universal throughout the Study Site and the zoning of UXO risk is based on several factors, including the nature, scope and location of UXO threat sources within the *AO7 Oleron OWF* and within the export cable corridors, taking into account the expected water depths. As a result, there are areas of HIGH, MEDIUM and LOW UXO risk categories throughout the Site.

It is possible that the UXO risk zones, and any prospective risk mitigation measures that may subsequently be recommended, could be refined further through the delivery of a tactical level UXO risk mitigation examination and through additional and more detailed risk analysis. However, the precise types and extents of any intrusive operations (beyond GI) would need to be considered, together with the water depths and more precise shallow sub-seabed conditions, in order to further refine the UXO risk zoning, across the Study Site.

The high-level UXO Risk Zones for all operations are depicted at Figure 3.

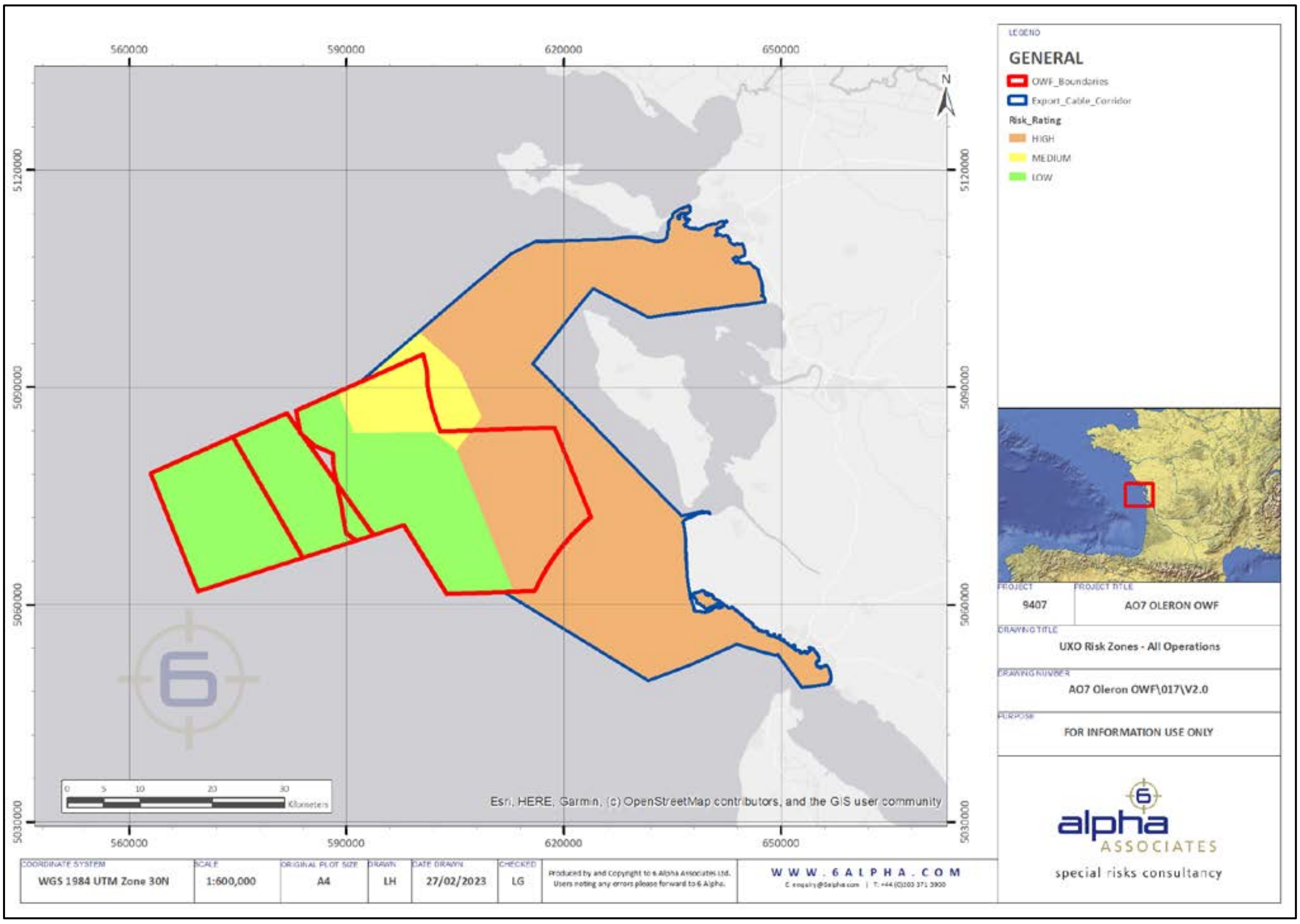

Figure 3 – UXO Risk Zones

Conclusions

The nature and scope of the UXO risks vary across the Study Site, based upon a source-pathway-receptor review in general, as well as the prospective consequences of initiating UXO and an analysis of the probability of encountering and of initiating UXO, in particular. Some UXO risks posed by the proposed operations have been categorised as HIGH and MEDIUM because they are generally associated with the unplanned initiation of threat spectrum UXO - including High Explosive (HE) bombs, naval mines and large Anti-Aircraft Artillery (AAA) projectiles. Such risks are considered intolerable.

Nonetheless, LOW category UXO risks have been identified in the western sector of the *AO7 Oleron OWF*, and the *Parc 1* and *Parc 2* zones, in the areas that correspond with the deepest water depths at the Site. For GI operations, this area of LOW UXO risk extends into portions of the export cable corridors, due to the smaller footprint of such works, together with the juxtaposition of evidenced historical activities and the increased water depths offshore. This is because the effects of the depth of water upon threat spectrum UXO initiation consequences (and *inter alia* the resultant through-seabed and through-water shock), will likely be partly risk mitigative and in such circumstances, where the risk is appropriately mitigated, the residual risks might well be tolerated.

UXO Risks to Surface Vessels and their Crew

Those UXO risks that are posed to vessels and their crews in depths shallower than 40m Lowest Astronomical Tide (LAT), are potentially and theoretically, the most intolerable. HIGH and MEDIUM category UXO risks have been evidenced within the export cable corridors and parts of the *AO7 Oleron OWF* due to the historic aerial bombing, minelaying and prospective AAA engagements that have occurred across much of the area.

The prospective consequences for surface vessels generally reduce, as the depth of water between the vessel and the point of a UXO initiation increases and as such, the western sector of the proposed OWF array has been categorised as a LOW category UXO risk for all operations.

UXO Risks to Underwater Equipment

Underwater investigative and installation equipment are unlikely to be sufficiently robust to withstand the consequences of an initiation of most high Net Explosive Quantity (NEQ), threat spectrum UXO (such as HE bombs and naval mines). The prospective UXO risks posed to underwater equipment are therefore classified as HIGH and/or MEDIUM, in all depths of water where a UXO threat is expected to be present.

Nevertheless, the UXO risk to underwater equipment is likely to be deemed tolerable under the auspices of the As Low As Reasonably Practicable (ALARP) risk reduction principle, as long as such risks do not also pose a hazard to support vessels and their crews.

Recommendations

Those UXO risks classified as HIGH and MEDIUM are to be mitigated within the bounds of the ALARP risk reduction principal through the implementation of an appropriate UXO risk mitigation strategy, which has been developed by *6 Alpha* for the Client in accordance with *EU* laws.

ALARP safety sign-off certificates should then be delivered once the risk mitigation measures have been implemented.

Risk Mitigation Strategy

There are three main options to consider in order to reduce UXO risks ALARP. In priority order they are:

- **Avoidance**; a strategy of potential UXO (pUXO) detection and avoidance is proposed as the most cost effective and efficient method of reducing UXO risks to ALARP. By surveying for and avoiding direct or indirect contact with any pUXO (the source of the risk) and by moving the GI locations where necessary away from such prospective hazards, such risks are appropriately and effectively reduced;
- **Removal of UXO Risk Receptors**; a second option is to remove the receptor element (of the source-pathway-receptor model), by moving certain sensitive and vulnerable receptors (typically the crews of offshore vessels), to a safe distance from the point of the intrusive activity and thus the pUXO hazard, so that it will diminish sufficiently the prospective shock wave consequences (an underwater effect) as well as blast and fragmentation consequences (the former and latter are through air, surface effects), in order to reduce UXO risks to ALARP. Clearly, this is not always achievable and such a course of action is commonly impractical;
- **Removal of Threat Sources**; where pUXO cannot be avoided, an alternative (but commonly, time consuming and costlier) option, is to verify pUXO by investigation and where it is confirmed UXO (cUXO), to remove it (effectively removing the source element of the source-pathway-receptor model), either by moving it to a position where it can do no harm (but only when it is safe to do so and wherever permit licencing and consent condition allow such actions), and/or by destroying it or otherwise rendering it safe.

Risk Mitigation Measures

6 Alpha have designed and recommend, a UXO risk mitigation strategy that has been tailored to the specific marine environment and proposed works, which should be implemented through the employment of proactive and reactive risk mitigation measures, as summarised at Table 1:

UXO Risk Mitigation Measures Overview		
Intrusive Operations	**Recommended Risk Mitigation**	**Final UXO Risk Rating**
GI and enabling Operations	**HIGH Risk Zones**	ALARP
	• **Bespoke geophysical UXO Survey;** • **Surface and Subsurface pUXO detection;** • **pUXO avoidance or target investigation and cUXO removal;** • **Emergency Response Plans (ERP) and Tool Box Briefs (TBBs);** • **On-Call Explosive Ordnance Disposal (EOD) Engineer.**	
	MEDIUM Risk Zones	
	• **Bespoke geophysical UXO Survey;** • **Surface pUXO detection;** • **pUXO avoidance or target investigation;** • **ERP and TBBs;** • **On-Call EOD Engineer.**	
	LOW Risk Zones	
	• **Existing geophysical survey data analysis;** • **Surface pUXO detection;** • **pUXO avoidance or target investigation;** • **ERP and TBBs;** • **On-Call EOD Engineer.**	
The Risk Mitigation Measures are detailed within Sections 10.3 and 10.4 of this document.		

Table 1: UXO Risk Mitigation Measures Overview

Minimum UXO Threat Items

The minimum size of UXO to be detected by geophysical UXO survey across the Study Site varies, depending on a number of factors including but not limited to; water depth, likely GI and their enabling methodologies, the type(s) of the UXO, prospective vessel slant-range to UXO and vessels' robustness. It should also be noted that the minimum size UXO for magnetometer survey purposes especially is based on a UXO threat item's ferrous metal content rather than its physical dimensions or any other factor. Table 2 illustrates the minimum UXO threat items for detection and thus ALARP safety provision, at different water depths.

Water Depths	Minimum UXO Threat	Dimensions (L x W)	Total Mass (Kg)	Ferrous Mass (Kg)	Explosive Fill
Intertidal Zone	***German* 8cm Heavy Mortar**	325mm x 81mm	3.5kg	3kg	0.51kg
Up to 10m LAT	***German* 10.5cm Artillery Projectile**	391/489mm x 105mm	14.8kg	13kg	1.8kg TNT
Up to 26m LAT	***American* AN-M30 100lb HE Bomb**	737mm x 208mm	52kg	26kg	26kg TNT
Up to 40m LAT	***British* 500lb MC Bomb**	1,041mm x 328mm	236kg	111-121kg	105kg Torpex or 95kg Amatol
More than 40m LAT	***American* AN-M65 1,000lb HE Bomb**	1,349mm x 478mm	449kg	196kg	253kg TNT

Table 2: Minimum UXO Threat Items by Water Depth

Residual Risk Tolerance

Following the implementation of the risk mitigation strategy, UXO risks will not usually be reduced to "zero", nor need they be under the auspices of ALARP principle. Residual UXO risks may likely remain in the offshore environment due to *inter alia*, the limits of geophysical UXO survey technology, data interpretation limitations and the fact that small scale low NEQ UXO threats might be tolerated - which is acceptable under the principles of ALARP risk reduction.

Project stakeholders are therefore requested to consider and to formally endorse the assumed risk tolerance recommendations for offshore residual UXO risks, as presented and labelled as Option 2, in Table 3.

UXO Risk Tolerance	Prospective Residual UXO Risk	Project Implications
Option 1 - Very Conservative	Damage to subsea equipment or installed assets, of any kind, will not be tolerated.	Most expensive and time-consuming option but the risk of damaging the GI equipment is significantly reduced.
Option 2 - Recommended (within ALARP threshold)	Damage/destruction of subsea equipment and installed assets may be considered tolerable - if undesirable. Significant damage to vessels that may injure or endanger personnel (either directly or indirectly), is intolerable and will require proactive and reactive risk mitigation.	Time and cost efficient, although carries the risk of repair and/or replacement of equipment in the event of unplanned low NEQ UXO encounter and detonation.

Table 3: Recommended Residual UXO Risk Tolerance

ALARP Safety Sign-Off Certification

ALARP safety sign-off certification provides an independent source of evidence that a Client has followed industry best practice and has successfully managed and reduced UXO risks to ALARP. Following the execution of UXO risk mitigation measures, ALARP safety sign-off certification should be obtained and distributed in advance of GI operations.

In such circumstances the Client will be able to certify for the benefit of all project stakeholders, that all reasonably practicable measures have been taken to protect offshore contractors (including their own workers and third parties), from UXO hazards and that the commissioning client will have acted in compliance with industry best practice as well as the national safety legislation.

In accordance with best practice, *6 Alpha* ALARP safety sign-off certificates do not imply that the Site is free from UXO, rather, that the necessary and appropriate UXO risk mitigation measures have been appropriately applied to evidence that UXO risks have been reduced ALARP.

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Acronyms and Abbreviations

AAA	Anti-Aircraft Artillery
AHT	Anchor Handling Tugboat
ALARP	As Low As Reasonably Practicable
CIRIA	Construction Industry Research and Information Association
cm	Centimetre
CPT	Cone Penetration Testing
cUXO	Confirmed Unexploded Ordnance
DP	Dynamically Positioned
EOD	Explosive Ordnance Disposal
ERP	Emergency Response Plan
EU	European Union
GI	Geotechnical Investigation
GP	General Purpose
HE	High Explosive
JuB	Jack-up Barge
km	Kilometre
kg	Kilogram
kHz	Kilohertz
LAT	Lowest Astronomical Tide
LMA/B	Luft Mine A/B
LSA	Land Service Ammunition
m	Metre
MBES	Multi-Beam Echo Sounder
MC	Medium Capacity
mm	Millimetre
MMBA	Munition Migration and Burial Assessment
MPa	Mega Pascal(s)
NEQ	Net Explosive Quantity
OSPAR	Oslo-Paris Convention 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
QC	Quality Control
RAF	Royal Air Force
RC	Route Clearance
SAA	Small Arms Ammunition
SQRA	Semi-Quantitative Risk Assessment
SSS	Side Scan Sonar
SVT	Survey Verification Test
TAN	Technical Advisory Note
TBB	Tool Box Brief
TI	Target Investigation
TNT	Trinitrotoluene
USAAF	United States Army Air Force
UTM	Universal Transverse Mercator
UK	United Kingdom
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
WD	Water Depth
WGS	World Geodetic Survey
WROV	Work-Class Remotely Operated Vehicle
WTG	Wind Turbine Generator
WWI	World War One
WWII	World War Two

Key Definitions

There are several terms that are used within this UXO threat and risk assessment report, namely:

<u>**Key Industry Definitions**</u>

- **As Low As Reasonably Practicable (ALARP)** – a term used in the management of safety-critical and safety-involved systems. The ALARP principle is that risks shall be reduced as low as reasonably practicable, which is effectively a (UK) legal minimum requirement;
- **Best Practice –** those standards for controlling risk which have been judged and recognised by a regulatory body as satisfying the law, when those standards are applied in an appropriate manner;
- **Competency –** a person or organisation with sufficient training, experience, and knowledge;
- ***De Minimis*** – an abbreviated form of the Latin maxim *de minimis non curat lex*, "the law cares not for small things". In terms of risk management, risks that are defined as too small to be of concern and exempt from further consideration; the purpose being, to avoid a disproportionate use of finite resources by mitigating a virtually inexhaustible supply of insignificant or low-level risks;
- **Hazard –** anything that has the potential to cause harm or damage;
- **Precautionary Principle –** an action with the potential risk to cause harm or damage without certainty or scientific consensus that the action is not harmful or damaging. The burden of proof that the action is not harmful or damaging falls upon those undertaking risk assessment and taking risk mitigation action;
- **Risk –** the intentional interaction of something of value with the potential for danger, harm, or loss;
- **Risk Assessment** – a systematic process of identifying and evaluating the potential risks of an action or undertaking;
- **Threat –** anything that has the potential to cause harm or damage, but especially UXO;
- **Uncertainty –** an unknown element that is not fully understood to properly inform the decision-making process;
- **Unexploded Ordnance (UXO)** – any unexploded munition with an explosive or chemical fill that failed to initiate and poses a risk of causing harm or damage.

Key Historical Definitions

- **Allies (WWI)** – the alliance between the *British Empire*, *France*, *Russia,* and the *USA*, though many other "associated powers" are sometimes labelled collectively as the "Allies";
- **Allies (WWII)** – the alliance between the *British Empire*, *France*, the *Soviet Union,* and the *USA*, though many other "associated powers" are also sometimes labelled collectively as the "Allies";
- **Atlantikwall** – an extensive system of coastal armaments and defensive fortifications built by *Germany* along the Atlantic coastlines of continental *Europe* and *Scandinavia* during WWII;
- **Axis** – the alliance between *Germany*, *Italy*, and *Japan* during WWII;
- **Central Powers** – the alliance between the *German Empire*, *Austria-Hungary*, the *Ottoman Empire* and *Bulgaria* during WWI;
- **Grand Fleet** – the main *British Royal Navy* fleet of ships during WWI;
- **High Seas Fleet –** The name of the battle fleet of the *German Imperial Navy* that was created in 1907 and saw action in WWI;
- **Luftwaffe** – the official name of the *German* air force between 1933 and 1946;
- **Kriegsmarine** – the name given to the *German* navy between 1935 and 1945.

Part I – Introduction

1 Project Overview

1.1 Scope of Work

DNV has commissioned *6 Alpha Associates* to deliver a desk-based Unexploded Ordnance (UXO) threat and risk assessment for the installation of the *AO7 Oleron* Offshore Wind Farm (OWF). A Risk Mitigation Strategy has also been commissioned concerning the forthcoming Geotechnical Investigation (GI) operations associated with OWF development.

1.2 Project Location

The *AO7 Oleron OWF* is located in the *Bay of Biscay*, approximately 15km to the west of *France*, with its prospective export cables making landfall near *La Rochelle* and *Royan* in *Charente-Maritime*. Two additional areas have been defined by the Client as *Parc 1* and *Parc 2* and are located to the west of the initial OWF boundary. The location of the *AO7 Oleron* site and its export cable corridors is presented at Figure 4 below, as well as in Appendix 1.

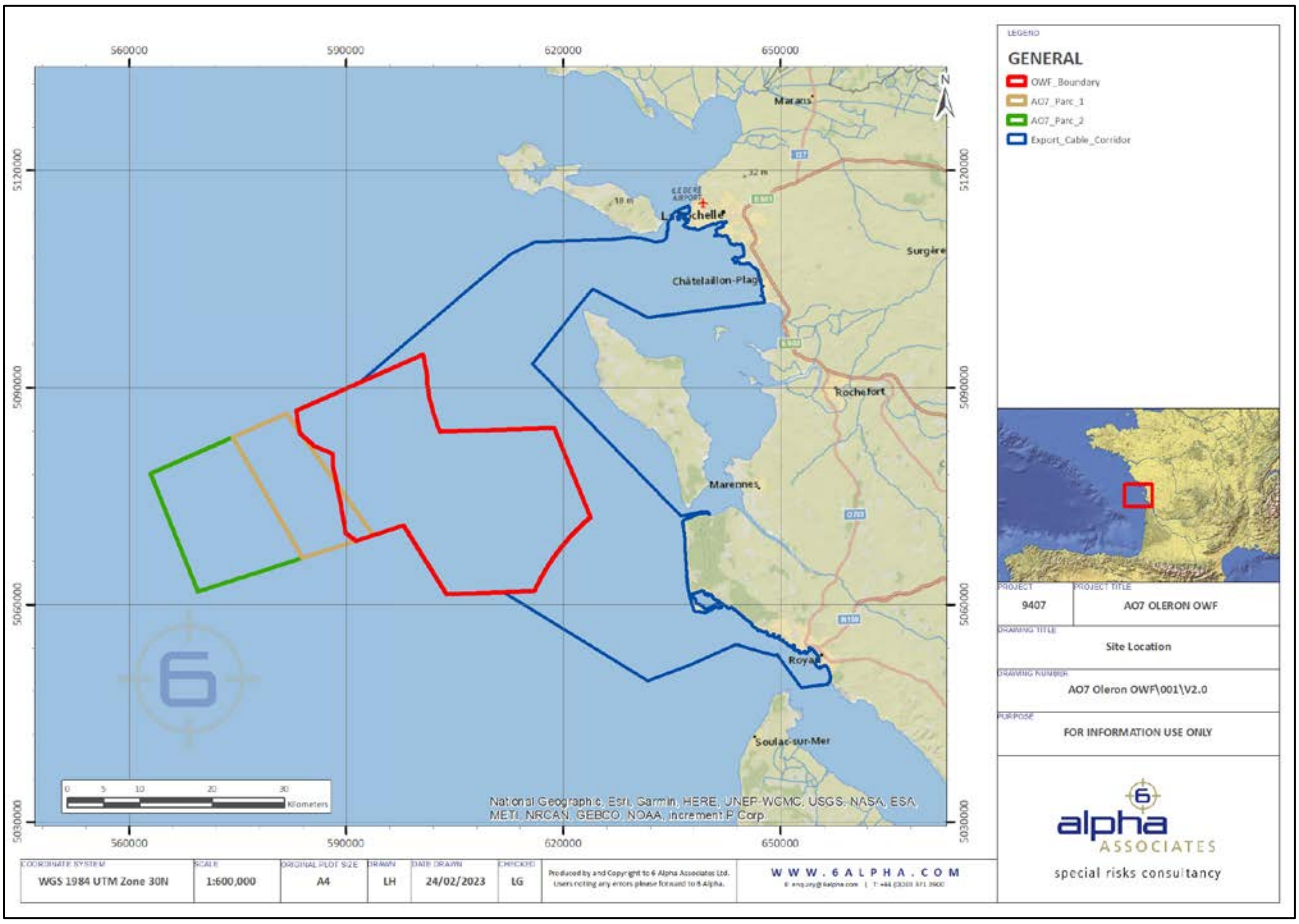

Figure 4 – Site Location

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 which may have contributed to the UXO contamination as a result 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. Offshore and onshore bombing targets were also simply missed, and bombs were sometimes jettisoned from aircraft when evading an adversaries' attacks and/or when seeking to reduce aircraft weight during a return journey to deliver a higher safety margin when landing.

Wartime training and operations also employed live munitions filled with high explosives (as well as other substances and materials including toxic chemicals or ignition/burning agents in incendiary bombs), which may have remained after the training exercises and operations had been completed. During the conflicts of the 20th century, sea mines were deployed in significant quantities in both offensive and defensive naval operations and their residue poses a further UXO contamination threat to intrusive sub-seabed activities in the marine environment. Conventional and chemical munitions dumping was also prevalent in these periods with little consideration given to future safety implications. There was also widespread unrecorded dumping of Small Arms Ammunition (SAA) and Land Service Ammunition (LSA) that was not only perceived to be inconsequential, but also 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. Modern military training areas, such as offshore firing ranges, may have also contributed to the background UXO contamination in the offshore environment.

Besides the clearance of naval minefields in order 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 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. UXO risks must be considered and managed in order to protect offshore personnel from injury or, in the very worst-case scenario, prospective fatalities. Such risks must also be considered, in order to fulfil Clients' statutory obligations under the auspices of national laws.

Further information regarding national and international legislation, and the management and reduction of UXO risk to As Low As Reasonably Practicable (ALARP), is presented at Annex A and is indicative of the safety benchmark to which *6 Alpha* adhere.

2.2 UXO Industry Best Practice

The *United Kingdom's (UK) 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). This guide 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. *CIRIA* C754 guidance has been successfully employed on similar projects in *France* and throughout the *EU*.

Therefore, in undertaking this assessment *6 Alpha* has not only brought to bear our offshore UXO risk management expertise and technical experience, but we have also benchmarked our delivery of offshore service provision with the *CIRIA* C754 guide, in order to ensure compliance with industry best practice and to manage UXO risks in accordance with ALARP risk reduction criteria.

Nonetheless, whilst the *CIRIA* guide outlines "what" steps are to be taken to manage the UXO risk, it lacks detail concerning "how" these steps are to be executed, in order to reduce such risks to ALARP. Where such finer detail is lacking in the *CIRIA* guidance, *6 Alpha* has filled those gaps through the careful and appropriate application of our UXO risk management strategic framework.

2.3 UXO Risk Management Strategic Framework

To manage and to ameliorate prospective UXO risks, *6 Alpha* has developed a detailed UXO risk management strategic framework that is not only in line with *CIRIA* guidance but also, is in accordance with ALARP risk reduction principles. 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 2.3. 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)	✘

* For GI Only

Table 2.3: *6 Alpha* and *CIRIA* UXO Risk Management Frameworks.

Notwithstanding *CIRIA's* guidance, purpose of this report is to address Phases One, Two and aspects of Phase Three of the UXO risk management framework. This framework is applied in order 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 in order to assess the UXO risks associated with the proposed operations (Phase Two). Once the associated UXO risks have been assessed, recommendations for site-specific UXO risk mitigation measures associated with GI works are outlined, to present a coherent risk mitigation strategy (Phase Three) - which if implemented fully, will ensure and evidence that a suitable and appropriate UXO risk management strategy has been undertaken in order to reduce UXO risks to ALARP. The risk mitigation strategy has been commissioned for GI works only at this time and not for the subsequent construction phase of the project.

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 GI designs, plans and schedules are finalised and before intrusive works commence.

2.4 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), that 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:

2.4.1 UXO Sources

The nature and scope of the UXO threat is summarised in the UXO threat assessment (at Section 5) and it forms the source element of the source-pathway-receptor model.

2.4.2 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 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 may also reach the receptors.

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

2.4.3 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, but are not limited to, subsea equipment and infrastructure; as well as underwater (e.g. Work-Class Remotely Operated Vehicle (WROV)) and surface vessels, and where appropriate, their crews. Divers are also especially vulnerable to underwater high explosive effects, as are marine mammals.

3 Scope and Structure of the UXO Risk Assessment

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 and in light of that, to design a suitable and appropriate risk mitigation strategy to reduce such risks to ALARP. The threat and risk assessment element of the report is presented in Part II, with a coherent risk mitigation strategy containing appropriate risk mitigation measures for GI operations detailed in Part III.

Therefore, the report has been structured to summarise the relevant data and to present the UXO threats. The following aspects will be covered in the assessment:

- The sources of prospective UXO contamination that might be encountered at the *AO7 Oleron* OWF site and along its export cable corridors will be summarised;
- A variety of options for prospective GI, cable installation and Wind Turbine Generator (WTG) installation, along with 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, in order to present a viable and cost-efficient risk mitigation strategy for GI works, benchmarked with reducing UXO risks to ALARP.

3.2 Information Sources

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

- *European Marine Observation and Data Network*;
- *James Martin Centre for Nonproliferation Studies*;
- *Naval Historical Centre* at *Portsmouth*;
- *National Geospatial-Intelligence Agency*;

- *Oslo-Paris Convention for the Protection of the North-East Atlantic (OSPAR) databases*;
- *Royal Navy* (Diving Units);
- *Service Hydrographique et Océanographique de la Marine;*
- *Service historique de la défense;*
- *Theatre History of Operations;*
- *UK National Archives* at *Kew*;
- *UK Hydrographic Office* at *Taunton*.

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.

Furthermore, the Client has also provided the below document in support of this updated Threat and Risk Assessment:

- Actimar, Reference: RTE_AO7_Oleron, *Analyses hydro-sédimentaires et morphodynamiques*, Report Version 1.1.

3.3 Constraints and Limitations

The risk mitigation strategy element of the report is focused upon GI only. Otherwise, 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*, in order to ensure the continued technical veracity and risk management efficacy, of this document.

4 Risk Assessment Methodology

4.1 Overarching 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. vessels and any associated underwater equipment), in order to determine the level of UXO risk for each intrusive activity. The SQRA assessment achieved by employing the following formula, which is further described at Section 4.3:

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

The risk assessment has been conducted for all types of operations, irrespective of the prospective risk mitigative effect of any prior operations which by then, may have preceded them.

However, the assessment not only evaluates the level of UXO risks generated, but also highlights the effect of subsequent risk mitigation measures, which are benchmarked with reducing risks ALARP. A full explanation of *6 Alpha's* SQRA process is presented at Annex B.

4.2 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 of its 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. but not limited to, 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.

4.3 Risk Assessment Variables

The UXO risk level at the Study Site has been determined by considering the following factors:

4.3.1 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 prospective UXO contamination at the *AO7 Oleron OWF* and its associated export cable corridors (which have been evidenced separately at Section 5) and the juxtaposition of any and all sub-seabed intrusive activities with respect to them. Nonetheless, the numbers, extent, and locations of all prospective UXO threats are difficult to accurately quantify due to the nature of historical records associated with depositional events (such as, and especially; unrecorded and abandoned ordnance; and/or Anti-Aircraft Artillery (AAA) gun fire; and/or jettisoned aerial High Explosive (HE) bombs that cannot be spatially defined with either certainty or accuracy). Such uncertainty is accounted for by employing the precautionary principle (see Section 4.2).

The likelihood of initiating underwater UXO is generally, but not exclusively, dependent upon kinetic energy; therefore, the likely operations that might generate it have been considered within Section 6, in order to determine if the kinetic energy associated with such activities might create a viable UXO risk pathway.

4.3.2 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 robustness of, sensitive receptors - including the support vessels, their crews as well as subsea equipment/tools.

The mass of high explosives and their underwater and/or surface effects can generally be either estimated or accurately modelled. Other assessment factors include but are not limited to; the prospective position of the UXO on the seabed at the moment of its encounter (i.e. on the surface or partially/completely 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 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 a 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.

Part II – UXO Threat and Risk Assessment

5 Sources of Unexploded Ordnance Contamination

5.1 UXO Hazard Assessment

Significant archive research associated with the Study Site has been undertaken in order to corroborate and to highlight, any and all potential sources of UXO contamination as well as to assess their likelihood of encounter. This assessment is therefore, based upon defined UXO geospatial threat source positions and the anticipated level of contamination from background UXO threats situated upon and within 5km of the Study Site. Where it is deemed appropriate, potential UXO threats that are located further than 5km from it have also been considered for analysis. Such potential sources of UXO are summarised in Table 5.1.

Potential Sources of UXO (within 5km)	Likelihood of UXO Contamination	Associated UXO Threat Items
Aerial Bombing	**Likely:** Significant WWII aerial bombing was documented at the export cable landfall points.	HE Bombs
Naval Engagements	**Unlikely:** Although WWI-era submarine activity was documented across the Study Site.	Torpedoes and Naval Projectiles
Naval Minefields	**Likely:** Naval and aerial mining was recorded within the Study Site.	Naval Mines
Military Practice and Exercise Areas	**Unlikely:** The nearest recorded Firing Practice Area is situated 4.5km to the south-west.	N/A
Coastal Armaments	**Likely:** Numerous coastal armaments and AAA batteries were situated in the vicinity of the Study Site.	AAA Projectiles
Munitions Related Shipwrecks and Aircraft	**Likely:** 41 munitions related shipwrecks were documented within the Study Site.	Shipwreck Related Munitions
Munitions Dumping (within 10km)	**Likely:** One conventional munitions dump is recorded on-site, with a further three located within 5km.	Conventional Dumped Munitions

Table 5.1: Summary of Potential UXO Sources within 5km of the Study Site

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The core types of UXO threats that have been summarised in Table 5.1 are discussed in detail subsequently and they will be subjected to a risk assessment, based upon the proposed operations outlined at Section 6. 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.

It is also important to note that the summary provided in Table 5.1 illustrates the highest level of threat generated by each prospective UXO contamination source. Not all contamination threats are generated across the entire Study Site and nor is there a universal likelihood of encountering each specific UXO threat within the *AO7 Oleron* site or within its export cable corridors. Table 5.1 is intended as a summary of the key findings, which are subsequently detailed and refined throughout this section.

5.2 Aerial Bombing

Air dropped bombs may be encountered in areas where conflict and/or an air campaign has occurred, although the precise locations of bombing raids and aerial attacks have not always been accurately documented - especially in the offshore environment. Nonetheless, there is evidence to suggest that WWII-era aerially delivered HE iron bombs may pose a UXO contamination threat at the Study Site, in particular at the nearshore sector of the export cable corridors.

For example, the landfall points associated with the northern export cable corridor are situated near *La Rochelle*, which was a major naval base during WWII. Along with other cities along the *Atlantic* coast of *France*, the *German* "*Organisation Todt*" undertook construction of reinforced submarine pens in the harbour of *La Rochelle* in 1941, which were situated 850m to the east of the Site. These submarine pens were documented as having been the target of multiple *Allied* bombing raids throughout WWII. In addition, the *United States Army Air Force (USAAF)* and *British Royal Air Force (RAF)* also carried out bombing raids against the city in general, as well as various harbour installations, oil storage depots and coastal artillery batteries – some of which are likely to have been in close proximity to the northern export cable corridor. Furthermore, *La Rochelle Airfield* (situated 1.7km to the north of the Site) was also recorded as being subject to aerial bombing during WWII.

The southern landfall points of the export cable corridor were similarly subject to intensive aerial bombing during WWII, along select areas of the coastline. This is particularly apparent at the town of *Royan* (situated immediately to the north of the Site), which was largely destroyed by *Allied* aerial bombing and naval bombardment in 1945. Significant aerial bombing raids were also noted at the coastal fortifications on either side of the *Gironde Estuary*; at *Point de la Coubre* (situated immediately to the east of the Site) and *Point de Grave* (situated 2.1km to the south-west). Although these bombing campaigns were largely limited to land-based targets, it is highly likely that other targets of opportunity in harbours or on the coast (such as AAA batteries or vessels), in closer proximity of the export cable corridors, would also have been targeted. As a result, it is plausible that some Unexploded Bombs (UXBs) might have been dropped in the sea near to the export cable landfall points, as a result of "overspill" bombing against targets along the coastline.

In addition to aerial bombing at the export cable landfall points, an analysis of historic shipwreck data indicated that several vessels were sunk by aerial bombing during WWII within and near to the export cable corridors. This included the *SS Foucauld* (85m to the west of the Site) and the *SS Adamantios* (330m to the west), which were sunk by the *German Luftwaffe* during the initial invasion and occupation of *La Rochelle* in 1940. In addition, the *SS Mecanicien Principal Carvin* was also sunk as a result of *German* aerial bombing in 1940, within the southern export cable corridor near *Point de la Coubre*. Three *German* vessels were also documented as having been sunk within the southern export cable corridor as a result of *Allied* aerial bombing during WWII, along with the destroyer *Z-24*, which was situated 2.8km to the south of the Site in the *Gironde Estuary*. Consequently, it is likely that a UXB contamination threat might have been generated offshore as a result of the targeting of vessels in the *Bay of Biscay*. Nonetheless, an analysis of shipwreck data did not identify any such incidents further offshore within the OWF itself, nor the additional *Parc 1* and *2* zones, with all shipwrecks resulting from aerial bombing instead being located in the nearshore sectors of the export cable corridor.

There may also be a residual, but largely unquantifiable, UXO contamination threat posed by prospective bomb-jettisoning activities associated with the military airfields situated in *Charente-Maritime*, including *La Rochelle – Laleu* (situated 2.2km to the east of the Site), *La Rochelle – Lagord* (3.1km to the north), *Royan* (3.5km to the north-east) and *Corme-Écluse* (10km to the east). HE bombs were sometimes jettisoned at sea by military aircraft to ensure that for safety purposes, aircraft did not attempt to land with live bomb loads onboard that might also potentially take the aircraft beyond their weight limits designed to ensure a safe landing. HE bombs may also have been jettisoned at sea by aircraft before or after air raids in the vicinity, in order to lighten aircraft for the purposes of either evading their adversaries' attacks or, to reduce their aircrafts' weight for their return journeys. Nonetheless, such a threat remains almost impossible to quantify without such instances being recorded (and often, such events were either inaccurately recorded or, more commonly, were not recorded at all).

A georeferenced overview of the aerial bombing threat at the Study Site is presented at Appendix 4.

5.3 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. Thus, the nature and the scope of naval engagements that were fought throughout the 20th century varied significantly from encounter-to-encounter and were dependant on the types of vessels involved. As with aerial bombardment in the offshore environment, the specific locations of the majority of 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, which indicates that there are 22 such shipwrecks within 5km of the Study Site that are indicative of historic naval engagements, all originating from WWI. Five of these shipwrecks were identified within the OWF boundary itself, with a further 12 located within the export cable corridors. Of these WWI-era wrecks, all were either scuttled by gunfire and/or explosive charges, or else sunk by torpedoes, resulting from *German* submarine activity along the western seaboard of *France*.

Based on the dates of these engagements and the class of submarines involved, the torpedoes used are likely to be of the 50cm G7 variant. In addition, a further UXO contamination threat is presented by the diverse types of naval guns that may have been employed during such engagements, in addition to the armaments and munitions carried by vessels that were sunk within the area. The prospective magnitude of these threats is reduced somewhat, however, by the limited operational capacity of most WWI-era submarines and the relative rarity of WWI ordnance encounters in the marine environment.

In contrast, there is significantly less evidence for large-scale naval engagements across the Study Site during WWII, based on the shipwreck evidence. The closest recorded WWII-era shipwreck was the *Sperrbrecher-7*, a *German* minesweeper that was struck by a torpedo fired by the *HMS Diadem* in 1944, 5.4km to the north-west of the Site. Nonetheless, given that the harbour of *La Rochelle* was active during WWII and maintained a submarine fleet, it is almost certain that military vessels and materiel would have traversed the Study Site. Furthermore in April 1945, the *French* cruiser *Duquesne* was involved in the naval bombardment of *German* fortifications on *Oléron* (situated approximately 2.5km to the east), as part of the *Allied* attempt to retake several *Atlantic* ports – codenamed *Operation Jupiter*. Additional naval bombardment was also documented at *Royan* (situated adjacent to the southern export cable corridor) by *American* naval vessels during the same campaign.

The geospatial extent of the contamination threat relating to naval engagements is presented at Appendix 5. Further corroborating evidence of the nature and scope of the naval engagements and the shipwrecks that were generated as a result, are presented at Section 5.7.

5.4 Naval Minefields

A naval sea mine is a self-contained high-explosive weapon that is placed in the water in order to destroy ships and/or submarines. All mines were fused so that they detonated, 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, in order to hamper enemy shipping and to blockade harbours; or defensively, in order to protect shipping and by creating safe movement zones through them.

During WWI and WWII, defensive minefields were often laid by surface craft, whereas offensive minefields were often laid by aircraft or submarines - the latter therefore delivering an element of secrecy to the positions of the mine-laying 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 mine lays are difficult to corroborate with any degree of certainty.

Nonetheless, there is evidence to suggest that naval mining poses a UXO contamination threat at the Study Site.

5.4.1 WWI Minefields

Neither *Allied* nor *Central Powers* minefields were recorded within the vicinity of the proposed OWF. Nevertheless, an analysis of shipwreck data in the area indicated that five vessels were sunk by *German* submarine-deployed mines in 1917-18, within the bounds of the export cable corridors whilst the *French* liner *SS Quebec* was sunk under similar circumstances only 300m to the south of the .

In addition, the *French* fishing vessel *FV Duplex* was sunk after hauling in a buoyant mine further offshore in February 1916, within the boundary of the *Parc 2* area. Consequently, it is likely that covert mine-deployment was undertaken along the *French* coastline near *La Rochelle* and the *Gironde Estuary* by *German* submarines – specifically; *UC-21*, *UC-70* and *UC-71*. All three of these submarines were equipped with *UC*-variety naval mines (*British* designation Type II), which therefore might pose a UXO contamination threat in select areas of the export cable corridors. The georeferenced location of the recorded shipwrecks resulting from WWI mines, is presented at Appendix 6.

5.4.2 WWII Minefields

Detailed desk-based research of historical records and charts identified one mapped WWII minefield that intersected the proposed OWF array. The *British* vessel *Rorqual* laid 21 Mark XVI mines during November 1941 in this minefield, whilst the *Cachalot* also laid 50 Mark XVI mines in a separate minefield in March 1941, 1.5km to the south-west of the Study Site. Furthermore, an analysis of historical records also indicated that an air-laid minefield, designated *Mine Garden Cinnamon*, was situated between *La Rochelle* and the island of *Oléron*, although its precise extent was not documented. Although the type of mine(s) deployed could not be established, it is highly likely that they comprised A Mark I-IV mines, given that these were commonly employed during the period when this mine garden would have been laid. This supposition is supported by the discovery of an A Mark I mine in the *Pertuis d'Antioche* (situated within the northern export cable corridor), as detailed in Section 5.9 of the report.

In addition, a detailed analysis of related shipwreck data has also identified six mine-related shipwrecks within the bounds of the export cable corridors originating from WWII, with another four shipwrecks within 5km of the Site's boundaries. This data corroborates the evidence associated with mines having been deployed in large quantities across the Study Site, particularly near to *La Rochelle* and it further suggests that WWII mines may pose a direct and substantial UXO contamination threat at the Study Site. Significantly, the *SS Champlain* (situated on-site near *La Rochelle*), the *SS Flandre* (on-site near *Royan*) and the *SS Mexique* (1.2km to the south near *Verdon*) were all reported as being sunk by aerially delivered aluminium-skinned parachute mines in 1940. It is therefore quite possible that non-ferrous (aluminium skinned) *Luft Mines* (of the LMA variety especially, given that the larger LMB mine was first introduced in 1943 and would not have been in use at the time of these vessels' sinking), could present a specific and unique threat in each nearshore sector.

An assessment of the positions of the minefields and mine-related shipwrecks suggests that WWII mines of different varieties are collectively, likely to pose a significant contamination threat across much of the Study Site. It is considered much more likely that WWII naval mines will be encountered (by comparison with WWI mines), as they are estimated to be encountered in the marine environment at a rate of approximately, once a month. Given this comparative encounter ratio, and the nature and scope of the evidenced minelaying operations that intersected the proposed OWF and export cable corridors in multiple areas, the probability that WWII-era naval mines have contaminated the area is assessed as "Likely".

The georeferenced location of the recorded WWII minefields and shipwrecks resulting from WWII mines in relation to the Study Site is presented at Appendix 7.

5.5 Military Practice and Exercise Areas (PEXA)

The *Bay of Biscay* has been used for much of the 20th and 21st Century 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 in most cases are likely to have remained in the marine environment, once the training activities have ceased.

5.5.1 Historic Military Training Areas

Historic military training areas have not been recorded either within the bounds of the Study Site, nor within 5km of its boundaries. Nonetheless, the *French* battlecruiser *Condé* was captured by *Axis* forces during the occupation of *France* and subsequently used for target practice by *Luftwaffe* aircraft in 1944, sinking in the *Gironde Estuary* 725m to the south-east of the export cable corridor. However, this is likely to have been an isolated event, used to dispose of an outdated warship, given the lack of evidence for other vessels having been used for target practice in the same manner.

Furthermore, it is quite possible that naval vessels - across the entire area - and/or coastal artillery batteries at either landfall area, may have fired their weapons systems for validation and/or range finding purposes, and that such events are unlikely to have been recorded. Nonetheless, the likelihood of contamination from this source is considered to be remote and it constitutes a background threat.

5.5.2 Modern Military PEXA

An analysis of available documentation relating to modern military PEXA in *France* indicated that three such areas directly intersected the Study Site. The first, designated as *LFD18A*, is a large general submarine exercise area located across the northern portion of the *Bay of Biscay*. Two smaller danger areas also intersect the site and are designated *LFD124* and *LFD236*, although their usage is unclear from the available information. One further unspecified restricted area was also marked immediately to the south of the export cable corridors, designated as *LFR61*. Nonetheless, it is not documented as to whether live ordnance has been used within any of these danger areas and so, modern naval and artillery projectiles might be considered as part of the background UXO contamination threat.

One confirmed "Firing Practice Area" was recorded nearby however, designated *LFD31D Cazaux*. It is likely that live munitions might have been employed during naval training exercises within this PEXA, although they are unlikely to have contaminated the Study Site directly, given it is located 4.5km to the south-west of the export cable corridor at its nearest point. Furthermore, it is unlikely that live firing exercises would be undertaken within the large marine protection area situated across much of the Study Site (as presented in Section 7.3).

The georeferenced location of modern PEXA, in relation to the Study Site, is presented at Appendix 8.

5.6 Coastal Armaments

Along the *North Sea* and *North Atlantic* coastline of occupied *Europe*, the *German Organisation Todt*, undertook the construction of thousands of permanent defensive positions facing the sea, that collectively formed the *"Atlantikwall"* – which consisted of concrete bunkers, machine gun positions, military fortifications, and AAA positions (amongst other things). Though the *Atlantikwall* was unfinished by the time of the *Allied* invasion of *Europe,* many of these defensive positions were armed and were fully operational. A total of 543 defensive installations related to the *Atlantikwall* were located within 5km of the export cable corridor landfall areas (mostly infantry bunkers and gun emplacements), although it is likely that some of the features identified were constructed by the *French* military and simply repurposed by the occupying *German* forces.

Overall, it is difficult to accurately quantify the prospective contamination threat that might be posed by the proximity of such defensive features that lie in proximity of the export cable's landfall points, because the quantity, frequency, purpose and activities associated with wartime military personnel and their weapons systems stationed there, are not now known. Nonetheless, the very presence of infantry in wartime defensive positions is likely to present a residual background threat of LSA and SAA nearshore, as well as close to the export cable landfall points, especially.

By comparison it is relatively easier to establish that a prospective AAA threat that may have been generated at the Study Site as a result of AAA gun battery training, testing and operations. A total of 181 emplacements were recorded as likely possessing firing ranges overlapping at least part of the Study Site. Although the calibre of guns employed by the artillery batteries around the *Atlantikwall* varied greatly, supplementary research indicated that the majority of the AAA guns in this area were of either 3.7cm, 4.7cm, 7.5cm or 10.5cm calibre, whilst some larger calibre guns may also have been deployed alongside smaller calibre AAA and machine guns – notably and in particular the 24cm calibre coastal artillery battery that was located at *Point de la Coubre*.

The likelihood of AAA contamination from these guns is also considered and classified as "Likely", up to approximately 37km from the landfall areas (based on the maximum firing ranges of the coastal armaments then in the area). As a result, the *Parc 1* and *Parc 2* zones would have been beyond the operational ranges of the recorded gun batteries, although an AAA projectile threat might have been generated within the eastern sector of the initial OWF array. Given that the *RAF* and *USAAF* were then active over what is now the Study Site, it is almost certain that these guns would have been active operationally.

A geo-referenced summary of all recorded coastal armaments at the *Atlantikwall* that had a firing range encompassing the Site, is presented at Appendix 9.

5.7 Munitions Related Shipwrecks and Aircraft

Merchant and naval vessels that were sunk during 20th century conflicts may have contained munitions - either 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 unlikely that any ship would have been sunk in the first exchange of fire due to the relative inaccuracy of early 20th century and WWII era weapons and it is likely that many bombs, projectiles, and torpedoes missed their targets initially. 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. There may, therefore, also be UXO (in the form of iron bombs and/or gun projectiles), situated in the regions of those wrecks that may have been sunk by such exchanges of fire.

Table 5.7 summarises the quantity of potential munitions related shipwrecks located within 5km of the Study Site.

Distance from Site	Cause of Sinking				Total
	Air Raid	Naval Skirmish	Mined	Other	
On-Site	4	25	12	1	42
<500m	2	1	2	0	5
500m - 1km	1	0	0	1	2
1km – 2km	0	0	2	1	3
2km – 5km	1	4	1	0	6

Table 5.7: Munitions related shipwrecks within 5km of the Site, together with their causes of sinking.

An analysis of the data presented in Table 5.7, together with corroborative evidence gathered from *6 Alpha's Azimuth* UXO database, highlights the scale of historical warfighting activities within the OWF and its export cable corridors, which may have led to a UXO contamination threat, evidenced by not less than 42 munitions related shipwrecks having been documented within it. A further 16 munitions related shipwrecks were also recorded within 5km of its boundaries. Generally, the closer the munitions related shipwreck to the Study Site, the more likely a UXO contamination threat, is to have been generated within it.

The majority of the munitions related shipwrecks within the Study Site can be traced to naval engagements occurring within WWI, particularly the actions of *German* submarines in torpedoing and scuttling *Allied* merchant vessels off the coast of *France*. Nonetheless, a reasonable number of shipwrecks in the wider area date from WWII, including those sunk by aerial bombing and significantly, to the effects of naval mines. Any shipwrecks or aircraft identified within the Study Site or else in its close proximity, regardless of their munitions related history, are to be treated with caution and may anyway be the subject of routine avoidance.

A georeferenced summary of all recorded munitions-related shipwrecks in the area, combined with their high-level cause of sinking, is presented at Appendix 10.

5.8 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 suitable bodies of water inland, such as lakes.

Whilst the centre of mass of such dumpsites were 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 and relevant marine environment protection agency databases, together with specific supplementary research, identified one conventional munitions dump located in the northern export cable corridor near *La Rochelle*. Three further conventional munitions dumps were also recorded near to the Study Site, either side of the *Phare de*

Cordouan (situated 825m to the south-west and 3.9km to the south-east of the Site), as well as near *Ile d'Aix* (3.4k to the south).

The exact types of conventional munitions dumped at these locations has not been documented however and therefore, it is not possible to assess the specific type of UXO that may be encountered. Nonetheless, the likelihood of encountering dumped conventional munitions is categorised as "Likely", in the vicinity of the recorded munitions dumps.

The georeferenced locations of munitions dumps recorded near to the Site are presented at Appendix 11.

5.9 Previous UXO Encounters

An analysis of the *OSPAR* database together with supplementary research has indicated that at least two conventional munitions encounters have been recorded within the export cable corridors previously, both of which were subsequently destroyed. In addition, a further 13 conventional munitions encounters were reported within 5km of the export cable corridors, particularly along the south-western coast of *Oléron*. There have been no documented munitions encounters within the proposed OWF array itself, however.

In addition, the following munitions encounters were also reported in public news sources in recent years, within the vicinity of the export cable corridors:

- A *British* A Mark I naval mine was discovered by the *French* minesweeping vessel *Pégase* in the *Pertuis d'Antioche* (situated within the northern export cable corridor) on the 23rd March 2017;
- A 500lb *British* HE bomb was discovered during excavations in *Royan* (situated immediately to the north-east of the southern export cable corridor) in November 2010 and again in December 2013;
- An unexploded incendiary bomb was discovered on the beach at *Grande Conche, Royan* (situated immediately to the north of the southern export cable corridor) on the 27th August 2013;
- An unexploded shell was encountered by a dredging vessel near *l'ile de Ré* (situated approximately 2km to the north of the northern export cable corridor) in November 2010;
- Two unexploded shells were discovered on the beach near *Grand-Village, Oléron* (situated approximately 4.5km to the north-east of the southern export cable corridor) in April 2009;

- An unexploded *British* HE bomb was discovered on the beach near *Grand-Village, Oléron* (situated approximately 4.5km to the north-east of the southern export cable corridor) in February 2011;
- An unexploded 500lb *American* HE bomb was discovered during infrastructure works at *La Tremblade* (situated approximately 4.6km to the south-east of the northern export cable corridor) in January 2013;
- 13 7.5cm *German* artillery shells were discovered on the beach near *Vert-Bois, Oléron* (situated approximately 5.5km to the north-east of the southern export cable corridor) in August 2010.

The georeferenced locations of nearby munitions encounters are presented at Appendix 12. Such encounters serve to highlight the longevity of the threat that might be posed by UXO in the marine environment in general, and the nearshore sector of the export cable corridors in particular. Further information concerning *inter alia*, the longevity of the UXO threat in the marine environment is included at Annex E.

5.10 UXO Threats – Summary

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.

A georeferenced chart depicting the considered range of prospective UXO contamination sources at the study area is presented at Appendix 13.

5.10.1 Aerial Bombs

Designation	Length x Diameter	Ferrous Mass	NEQ
1,000lb MC Bomb	1,334mm x 451mm	202-225kg	309.4kg
AN-M65 1,000lb HE Bomb	1,349mm x 478mm	196kg	253kg
SC-500 HE Bomb	1,415mm x 457mm	280kg	220kg
1,000lb GP Bomb	1,334mm x 411mm	325.4kg	161.9kg

Designation	Length x Diameter	Ferrous Mass	NEQ
500lb MC Bomb	1,041mm x 328mm	111-121kg	136.5kg
SC-250 HE Bomb	1,194mm x 368mm	126kg	130kg
AN-M64 500lb HE Bomb	1,143mm x 361mm	127kg	121kg
250lb MC Bomb	699mm x 254mm	51kg	67.8kg
500lb GP Bomb	925mm x 328mm	147.5kg	65.5kg
AN-M57 250lb HE Bomb	914mm x 277m	59kg	59kg
250lb GP Bomb	711mm x 262mm	82kg	30kg
AN-M30 100lb HE Bomb	737mm x 208mm	26kg	26kg
SC-50 HE Bomb	762mm x 200mm	25-30kg	25kg

5.10.2 Naval Torpedoes

Designation	Body Length x Diameter	Ferrous Mass	NEQ
50cm G7 Torpedo	7,000mm x 500mm	1,170kg	253.5kg

5.10.3 Naval Projectiles

Designation	Body Length x Diameter	Ferrous Mass	NEQ
203mm Naval Projectile	970mm x 203mm	125.9kg	9.4kg

Designation	Body Length x Diameter	Ferrous Mass	NEQ
8.8cm Naval Projectile	394mm x 88mm	12.4kg	1.4kg

5.10.4 Naval Mines

Designation	Body Length x Diameter	Ferrous Mass	NEQ
LMA Mine	1,730mm x 660mm	>10kg	390kg
A Mark I-IV Mine	2,280mm x 470mm	340kg	340kg
Mark XVI Mine	1,219mm x 1,020mm	150kg	145kg
UC 200 Mine	800mm x 800mm	191kg	141.1kg

5.10.5 Artillery Projectiles and LSA

Designation	Body Length x Diameter	Ferrous Mass	NEQ
24cm Artillery Projectile	980mm x 240mm	133.7kg	16.3kg
20cm Artillery Projectile	953mm x 203mm	111.1kg	8.9kg
17cm Artillery Projectile	806mm x 170mm	54.4kg	6.4kg
15.5cm Artillery Projectile	775mm x 155mm	40.8kg	3.9kg
12.8cm Artillery Projectile	958mm x 128mm	22.6kg	3.1kg
10.5cm Artillery Projectile	391/489mm x 105mm	13kg	1.8kg

Designation	Body Length x Diameter	Ferrous Mass	NEQ
8.8cm Artillery Projectile	386mm x 88mm	8.2kg	0.71kg
8cm Granatwerfer 34 Heavy Mortar	325mm x 81mm	3kg	0.53kg
7.5cm Artillery Projectile	358mm x 75mm	6kg	0.51kg
4.7cm Artillery Projectile	187mm x 47mm	1.3kg	0.18kg
5cm Artillery Projectile	165/208mm x 50mm	2.1kg	0.17kg
4cm Artillery Projectile	184mm x 40mm	0.83kg	0.07kg
3.7cm Artillery Projectile	162mm x 37mm	0.72kg	0.03kg
2cm Artillery Projectile	78mm x 20mm	0.12kg	0.006kg

6 UXO Risk Pathways - Planned Operations

6 Alpha have been provided with a high-level outline of the possible scope of work at the *AO7 Oleron* OWF, which will comprise GI works ahead of cable and WTG foundation installation, although the precise scope of works has yet to be confirmed.

An outline of the expected GI, WTG and cable installation, as well as supporting 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 Geotechnical Investigation Operations

A GI campaign will be undertaken in order to gather data on the local seabed's makeup and conditions within the *AO7 Oleron* boundary and along the export cable corridors. It is expected that the following GI methodologies might be employed as part of the campaign:

6.1.1 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.

6.1.2 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.

6.1.3 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 Pre-Lay Operations

Pre-Lay Grapnel Run (PLGR) and Route Clearance (RC) will likely be employed to ensure that the cable route is clear of *inter alia*, 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 along the designated cable Route Position List. Such operations may encounter and initiate UXO that is either very shallow buried or, that is located on the surface of the seabed. 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 possible that pre-lay operations could cause a UXO detonation event, if pre-lay equipment comes into direct contact with it.

6.3 Cable Installation and Burial Operations

An overview of potential cable installation methodologies is described briefly below, in order to inform subsequently the risks that UXO might pose to such techniques. The methodologies described below are not exhaustive, nor are they specific to this project however, they serve to illustrate the risks associated with a variety of commonly employed cable installation and burial methodologies.

6.3.1 Surface Laid Cable

Inter-array and/or export cables may be laid on the surface of the seabed and then subsequently buried. 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, subject to amongst other factors the mass of the cable per linear meter, the water depth and rate of lay, might be sufficient to initiate UXO - especially if the cable makes direct contact with it. 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.

6.3.2 Jetting

Where soft seabed conditions are encountered, jetting seabed sediments can be employed to bury cables either concurrently or in a sperate operation once it has been laid on the surface of the seabed. Jetting fluidises 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 it 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.

6.3.3 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 be up to 3m wide, 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.

6.3.4 Open Cut Trenching

Open cut trenching is typically utilised to bury and thus protect the cable, at the cable landing point onshore. Trenching can be undertaken by a terrestrial-based excavator during low tide and during these operations, a transition or joint-pit(s) may also be excavated.

There are several risk factors to consider for trenching and excavation operations; firstly, the mass of the excavator bucket and its operating velocity may be sufficient to initiate any UXO that might be encountered directly and/or indirectly, if it is in very close proximity. Second, the excavated material is expected to be used to back-fill the trench once the cable has been emplaced within it. If the excavated material is contaminated with UXO, the back-filling operation may also present an inadvertent risk pathway in that UXO might then be initiated.

Nonetheless, the risks that might be presented on “land” (defined for the purposes of this report, as above the high-water mark), are beyond the scope of this document. *6 Alpha* can consider separately the risks associated with trenching and excavation operations, together with those that might otherwise be presented at the cable landing point, in line with CIRIA guidance for managing UXO risks in the onshore environment – which differs from the UXO risk management guidance for offshore cable installation projects.

6.4 Wind Turbine Installation Operations

The following techniques might be considered for WTG foundation and offshore platform installation:

6.4.1 Monopile Support Structures

A monopile support structure is employed where the tower of the wind turbine is supported by a single structure rooted in the seabed and is the most commonly employed foundation type when installing WTG foundations in shallow water (typically, not exceeding 60m deep). A typical method of WTG foundation installation involves driving the piles into the seabed using high energy impact-hammers powered by either steam or hydraulics, often from by a jack-up barge platform. As this method delivers significant kinetic energy as the piles are driven into the seabed, any UXO encountered directly is almost certain to be initiated, with any UXO in the immediate vicinity of such operations being placed at risk of being initiated indirectly by the through seabed shock, generated by such activities.

Drilling may be considered as an alternative methodology, which is most suitable in areas where the seabed is composed of hard sub seabed strata, that has sufficient strength to make the installed structure self-supporting. The probability of UXO encounter remains largely the same as with the employment a high-energy impact hammer due to the intense, invasive force exerted upon and through the seabed.

6.4.2 Jacket Support Structures

Alternatively, the use of jacket support structures is commonly considered for offshore converter platform installation. The potential for UXO encounter and initiation is similar to that associated with WTG monopile installation although the piles used are of a much smaller diameter and are generally expected to be emplaced with less energy. Nonetheless, given that the same holistic installation methodologies are usually used for jacket support structures as with monopiles, the likelihood of UXO initiation remains similar.

6.5 Protection and Crossing Operations

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

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

6.5.1 Scour Protection Systems

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

6.5.2 Concrete Mattress and/or Rock Placement

To protect the inter-array and export cables, either a combination of rock, mattressing, split-piping or similar non-burial cable shielding techniques might be applied to protect the cables. A UXO risk pathway may be generated by the emplacement of such protection - along and over the cable - although 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 pUXO is avoided. And where there is potential UXO (pUXO) in their close proximity, then the cable protection system(s) are not only to be deployed in a controlled fashion but also and as slowly as is reasonably practicable (because the resultant kinetic energy generated is reduced) and that minimum pUXO safety avoidance distances are adhered to.

6.5.3 Third Party and Out-of-Service Cables

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 very close proximity to UXO. Nonetheless, this does not mean that UXO will not be encountered anywhere within the export cable corridors (nor the associated OWF array), and therefore, a risk pathway may still be generated

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depending on the precise methodology employed to install the cable in areas where third-party or out-of-service cables are located.

6.6 Enabling Operations

The following methodologies may be employed to facilitate the proposed investigative and/or installation operations:

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 make contact with 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 Anchoring

It is possible that other types of vessels (than DP), will anchor independently or otherwise employ Anchor-Handling Tugboats (AHT), to support the proposed operations. 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 anchors and their 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 generally 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 Jack-up Barges (JuB)

A JuB is a type of mobile platform that consists of a buoyant hull fitted with a number of movable legs, capable of lifting it over the surface of the sea, thus affording a stable work platform for operations such as piling and boreholing. The buoyant hull facilitates relatively easy transportation of the barge between operations and once it is at the desired location, the hull is raised (jacked-up on legs), to the required elevation above the sea and its legs are supported by the seabed.

From a UXO risk perspective, the legs of such barges may be designed to penetrate the seabed, and/or may be fitted with enlarged sections or footings. Commonly, JuBs are not self-propelled and rely on AHT for positioning and upon its anchors for stability and movement. Nonetheless, if the JuB leg or its anchor (deployed by an AHT) encounters UXO, then a risk pathway might be generated.

6.6.4 Diving Operations

There is no indication that divers are currently being considered to assist or undertake any subsea operations. 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 many 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*.

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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.

Data collected from previous bathymetric surveys across the Study Site indicated that water depths within the two export cable corridors range from landfall (i.e., 0m LAT) up to approximately 40m LAT. Within the proposed OWF array itself, the water depths are expected to range from 20m to 60m LAT. These figures were broadly corroborated by an analysis of publicly available data, which indicated that at their deepest, the export cable corridors might include water depths up to and including 48m LAT. Further offshore, the water depths in *Parc 1* are likely to range between 53 and 69m LAT, whilst those in *Parc 2* are likely to range between 63m and 82m LAT – these are based solely on publicly available data however, as the previous site-specific report did not extend to the two additional areas.

In areas of relatively shallow water (that are likely to be present across the Study Site, particularly along the export cable corridors), the consequences of potential UXO initiation are unlikely to be very significantly mitigated by such a body of water. In the areas of deeper water, notably in the western sector of the *AO7 Oleron* site and both *Parc* areas, the degree of prospective risk mitigation in general and consequence mitigation in particular of the depth of water, is likely to be more effective.

The water depths across the Study Site (in LAT) are presented at Appendix 14.

7.1.2 Seabed Sediments and Shallow Soils

The nature of local seabed sediments and shallow soils also need to be considered to determine the prospect for UXO burial in general and unexploded bomb 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.

Existing studies of the shallow soil and seabed sediment coverage within the Study Site indicated that seabed sediments are likely to vary across the proposed OWF array including "*sand / sand and gravel / gravel*" in its north-western sector and "*mud / sandy mud / muddy sand*" in its south-eastern sector. In addition, the southern export cable corridor is noted as comprising "*muddy / sandy-muddy to sandy (fine sands)*" sediments, whilst the northern corridor comprises a wide range of different sedimentary formations ranging from sands and gravels to muddy sand, with an area of exposed rock near to *La Rochelle*.

This documentation was corroborated by an analysis of *European Marine Observation and Data Network* records, which indicated that the seabed sediments across the Study Site are likely to primarily comprise sandy sediments. Nonetheless, coarse substrate, muddy sand, fine mud and rock are collectively likely to be encountered at varying points within the Study Site.

Muddy sediments are generally less likely to form a mobile seabed than one comprising solely of sandy sediments but, 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. Hydro-sedimentary data associated with the Site suggests at a high level that high sedimentary mobility is expected at the Site, particularly at the *Gironde Estuary*.

7.2 UXO Burial and Munitions Migration

In the offshore environment, all items are UXO are potentially subject to a variety of environmental and human factors, which may result in their scour and burial, or else 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 (e.g. and typically aerially delivered iron bombs and/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, with initial impact burial in deeper waters considered highly unlikely.

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 potential UXO (designated for avoidance) in particular, because of the risk of prospective munitions migration effects.

In order 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, that models the potential for UXO migration based upon *inter alia* seabed geomorphology in general and the Site's seabed characteristics in particular (e.g. 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 has been designated as areas requiring protective, conservation, restorative or precautionary measures and there is a growing body of regional, national and international legislation supporting environmental conservation in the marine environment. An analysis of national and *EU* databases has identified one such marine protection area located within the Study Site, designated as the *Parc naturel marin de 'Estuaire de la Gironde et de la Mer des Pertuis*. This area is further sub-divided into three areas, which collectively cover the entire *AO7 Oleron OWF*, *Parc 1 and 2*, and most of its export cable corridors, except for a small area near *Royan*.

As a result, should UXO disposal be required within the bounds of such areas, then specific techniques such as low noise sympathetic detonation might be preferred other disposal methods.

The recorded marine protection areas in the *Bay of Biscay*, in relation to the Study Site, are presented at Appendix 15.

8 UXO Risk Assessment

8.1 Risk Assessment Findings

The results of the strategic level risk assessment are presented at Table 8.1:

Intrusive Operation	UXO Threat	UXO Risk (Vessels and Personnel Only)			
		~10m WD	~26m WD	~40m WD	>60m WD
GI Operations	Aerial Bombs	MEDIUM	MEDIUM	MEDIUM	LOW
	Naval Torpedoes	LOW	LOW	LOW	LOW
	Naval Mines	MEDIUM	MEDIUM	MEDIUM	LOW
	Artillery Projectiles	MEDIUM	LOW	LOW	VERY LOW
Pre-Lay Operations	Aerial Bombs	HIGH	HIGH	HIGH	LOW
	Naval Torpedoes	MEDIUM	MEDIUM	MEDIUM	LOW
	Naval Mines	HIGH	MEDIUM	MEDIUM	LOW
	Artillery Projectiles	HIGH	HIGH	HIGH	VERY LOW
Cable Installation Operations	Aerial Bombs	HIGH	HIGH	HIGH	LOW
	Naval Torpedoes	MEDIUM	MEDIUM	MEDIUM	LOW
	Naval Mines	HIGH	MEDIUM	MEDIUM	LOW
	Artillery Projectiles	HIGH	HIGH	HIGH	VERY LOW
WTG foundation Installation Operations	Aerial Bombs	N/A WTG Installation Operations will not occur at this depth.	HIGH	HIGH	LOW
	Naval Torpedoes		LOW	LOW	LOW
	Naval Mines		HIGH	HIGH	LOW
	Artillery Projectiles		MEDIUM	MEDIUM	VERY LOW
	Aerial Bombs	HIGH	HIGH	HIGH	LOW

Intrusive Operation	UXO Threat	UXO Risk (Vessels and Personnel Only)			
		~10m WD	~26m WD	~40m WD	>60m WD
Protection Operations	Naval Torpedoes	LOW	LOW	LOW	LOW
	Naval Mines	HIGH	HIGH	HIGH	LOW
	Artillery Projectiles	HIGH	MEDIUM	MEDIUM	VERY LOW
Enabling Operations	Aerial Bombs	HIGH	HIGH	HIGH	LOW
	Naval Torpedoes	LOW	LOW	LOW	LOW
	Naval Mines	HIGH	HIGH	HIGH	LOW
	Artillery Projectiles	HIGH	MEDIUM	MEDIUM	VERY LOW

Table 8.1: Representative UXO Risk Assessment Summary

Table 8.1 is intended as an indicative summary, which is supported by an unexpurgated project SQRA that is presented at Appendix 16. The latter presents the complete risk assessment for each individual sub-seabed intrusive activity for each UXO threat group.

8.1.1 Geotechnical Investigation Operations

The likely GI operations are categorised as posing MEDIUM UXO risks to both the vessel and personnel (i.e. vessels' crews) in the nearshore sectors of the export cable corridors, in addition to a recorded area of WWII-era minelaying further offshore. All other areas generate only LOW category UXO risks. These risks are comparatively lower than the risk associated with other types of installation operations, as GI operations are likely to comprise relatively small, point-focal activities which generate a significantly lower probability of encountering and initiating UXO at the *AO7 Oleron* site when compared with, for example, cable lay operations.

8.1.2 Pre-Lay Operations

Any PLGR and RC that is undertaken in advance of the installation of export and inter-array cables are likely to generate more significant UXO risks than the GI works – depending on the exact location of such works. This is because the former is considered more likely to encounter any UXO contamination as it covers a larger spatial extent and will comprise more contact with the seabed than the GI works.

Consequently, pre-cable lay operations may generate HIGH UXO risks across the entire nearshore sector of the export cable corridors, based on the likelihood of encountering HE bombs, naval mines and AAA projectiles. MEDIUM UXO risks may also be posed to these operations offshore in areas of former naval mining activity, in addition to areas of LOW category UXO risk within the proposed OWF array itself.

8.1.3 Cable Installation and Burial Operations

Surface lay and subsequent burial of cables are likely to generate distinct categories of UXO risks owing to the amount of seabed interaction involved with the various installation and burial methodologies that may be considered.

Where cables are laid on the surface of the seabed and are not subsequently buried, then UXO risks are categorised MEDIUM in the nearshore sector, as well as in areas of former naval mining activity offshore. In much of the offshore sector of the export cable corridors and the OWF array however, UXO risks are assessed to be LOW for all UXO threat sources – assuming that the cable will be installed upon the surface of the seabed in a controlled fashion.

Where cable burial is likely to be undertaken using jetting techniques, then HIGH UXO risks might be generated in the nearshore sector of the export cable corridors, in addition to MEDIUM and LOW category UXO risks across the remainder of the Study Site.

Where ploughing cable burial techniques are to be employed, then such UXO risks are also categorised as HIGH in all nearshore sectors due to the comparatively larger footprint of such installation tools (especially a subsea cable plough) and the significant forces exerted into the seabed by such cable burial tools. In limited areas offshore, MEDIUM and LOW UXO risks may be generated, particularly in the western sector of the proposed OWF array.

8.1.4 WTG Installation Operations

The installation of WTG foundation piles is assessed to pose HIGH levels of UXO risks, only in the far eastern extent of the proposed OWF array. This is driven by the likelihood of encountering large AAA projectiles, whilst further offshore MEDIUM and LOW category UXO risks are generated given the risk mitigative effects of the relatively deep water on the consequences of an unplanned UXO initiation on the seabed.

8.1.5 Protection Operations

The emplacement of rock to protect unburied cables and/or to prevent scour at WTG foundations may generate HIGH category UXO risks nearshore, although the risk is reduced to MEDIUM and/or LOW in areas of deeper water. Dumping rock either over the side of a rock dumping support vessel or through a pipe-fall system, may result in significant kinetic energy being transferred (in comparison with other cable protection methods), which might cause an initiation event should the rock come into direct contact with UXO or if rocks impact the seabed in close proximity of it.

8.1.6 Enabling Operations

Given the possible extent of UXO contamination across the Study Site, HIGH category UXO risks may be generated by JuB leg deployment or of other similar platforms on the seabed, in support of proposed investigative and/or installation operations. This is reduced to MEDIUM and LOW further offshore, where there are fewer large NEQ UXO threat sources, together with the relatively deep body of water.

Vessel anchoring might similarly pose MEDIUM UXO risks nearshore and in areas of recorded naval mining offshore. In addition, LOW category UXO risks might be generated by the use of DP vessels, as these types of operations are considered less likely to encounter and to initiate UXO, given the relatively small spatial extent and point-focal kinetic energy, of such operations.

8.1.7 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 (whilst the probability of encountering certain types of UXO has been evidenced as being elevated in some areas). The consequences of exposing the vessels’ crews to the kind of forces associated with an underwater initiation of a (project indicative) selection of high, medium, and low NEQ threat spectrum UXO has been carefully modelled and the results are summarised separately at Table 8.1.7.

UXO	Estimated Ferrous Mass	NEQ	Consequence at ~10m WD	Consequence at ~26m WD	Consequence at ~40m WD	Consequence at ~60m WD
A Mark I-IV Mine	340kg	340kg	Vessel Sinking / Fatalities	Vessel Sinking / Fatalities	Serious Structural Damage / Fatalities	Mechanism Damage / Minor Injuries
AN-M30 100lb HE Bomb	26kg	26kg	Vessel Sinking / Fatalities	Mechanism Damage / Minor Injuries	Minor Damage	Acceptable
7.5cm Artillery Projectile	6kg	0.51kg	Minor Damage	Acceptable	Acceptable	Acceptable

Table 8.1.7: Consequences of UXO Initiation

Table 8.1.7 has been compiled using *6 Alpha's* in-house through-water, shock wave calculator, which algorithms are based on a variety of open-source academic and military studies concerning military ordnance detonations underwater, the peak pressures generated, and the effects of though 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 8.1.7 are also employed to inform *6 Alpha's* SQRA (at Appendix 16) in order to assess and grade potential UXO detonation consequences based upon the shock wave effects.

8.1.8 Underwater Equipment

If any size of UXO is inadvertently encountered and initiated, it is likely that underwater equipment or tools employed in their close proximity are likely to be significantly damaged and/or completely destroyed. Such risks are presented in the full SQRA (at Appendix 16) 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 to surface vessels and their crew.

8.1.9 Vessel and Diver Safety Distances

The SQRA assesses the risk of an unplanned initiation of UXO with reference to relevant sensitive receptors (e.g. including but not limited to, 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 8.1.9 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 8.1.9 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 Type	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
A Mark I-IV Mine	340kg	112m	62m	1,736m
AN-M 30 100lb HE Bomb	26kg	48m	27m	1,093m
7.5cm Artillery Projectile	0.51kg	13m	8m	539m

Table 8.1.9: **Underwater Explosion Consequences**

For the consequences of an initiation of 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 112m (this may be reduced to 48m and 13m for medium and low NEQ UXO, respectively).

Consequence column 2 articulates the depths of water at which light 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 62m, if a large NEQ UXO is initiated (this may be reduced to 27m and 8m for medium and low NEQ UXO, respectively). If the vessel(s) and its crew(s) are exposed to greater than 4MPa of pressure, the likely effects are *inter alia* 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 deign 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 8.1.9 evidences, swimmers and divers are required to be located at between 539m and 1,736m from the seat of a seabed initiation of threat spectrum UXO (smallest to largest respectively), to be considered safe, which further evidences the risks involved with deploying divers during sub-seabed operations, wherever UXO contamination might be expected.

8.2 UXO Risk Zones

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

- The nature and scope of sub-seabed activities and the distances from pertinent UXO threat sources;
- The varying water depths (in LAT) across the proposed *AO7 Oleron OWF* and the export cable corridors;
- 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 key proposed works, as presented at Figures 5 through 7, as well as at Appendix 17.

HIGH UXO risks have been evidenced within the nearshore sectors of the export cable corridors, where it has been assessed that there is an elevated probability of the proposed works encountering UXO - largely driven by aerial bombing, mining and AAA projectile firing. Additional areas of MEDIUM category UXO risk are also present further offshore in areas of historic naval mining and where the increased water depth serves to mitigate the most severe prospective consequences posed by large AAA projectiles. Finally, an area of LOW category UXO risk was also defined in the western sector of the *AO7 Oleron OWF* and the entire *Parc 1* and *2* zones during all operations, due to a combination of deep waters and the assessed lower probability of encountering large NEQ UXO threats.

These risks may be lessened for some proposed operations, notably GI, with the HIGH category risk zone reducing in its extent. Nonetheless, MEDIUM category UXO risk zones remain present at the Study Site.

It is possible that the UXO risk zones, and any prospective risk mitigation measures that may subsequently be recommended, could be refined further through the delivery of a tactical level UXO risk mitigation examination and through additional and more detailed risk analysis. However, the precise types and extents of any intrusive operations would need to be considered, together with the water depths and more precise shallow sub-seabed conditions, in order to further refine the UXO risk zoning, across the Study Site.

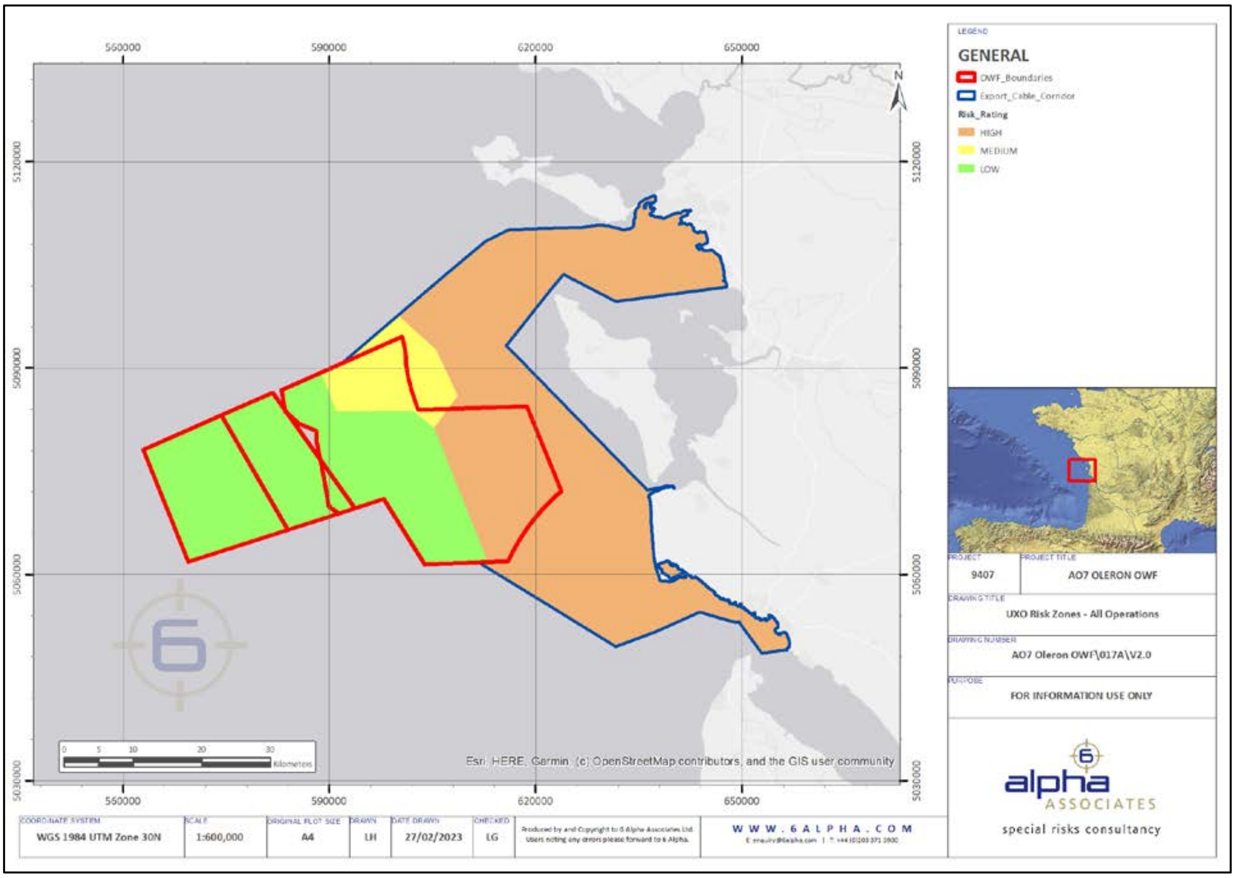


Figure 5 – UXO Risk Zones for All Operations

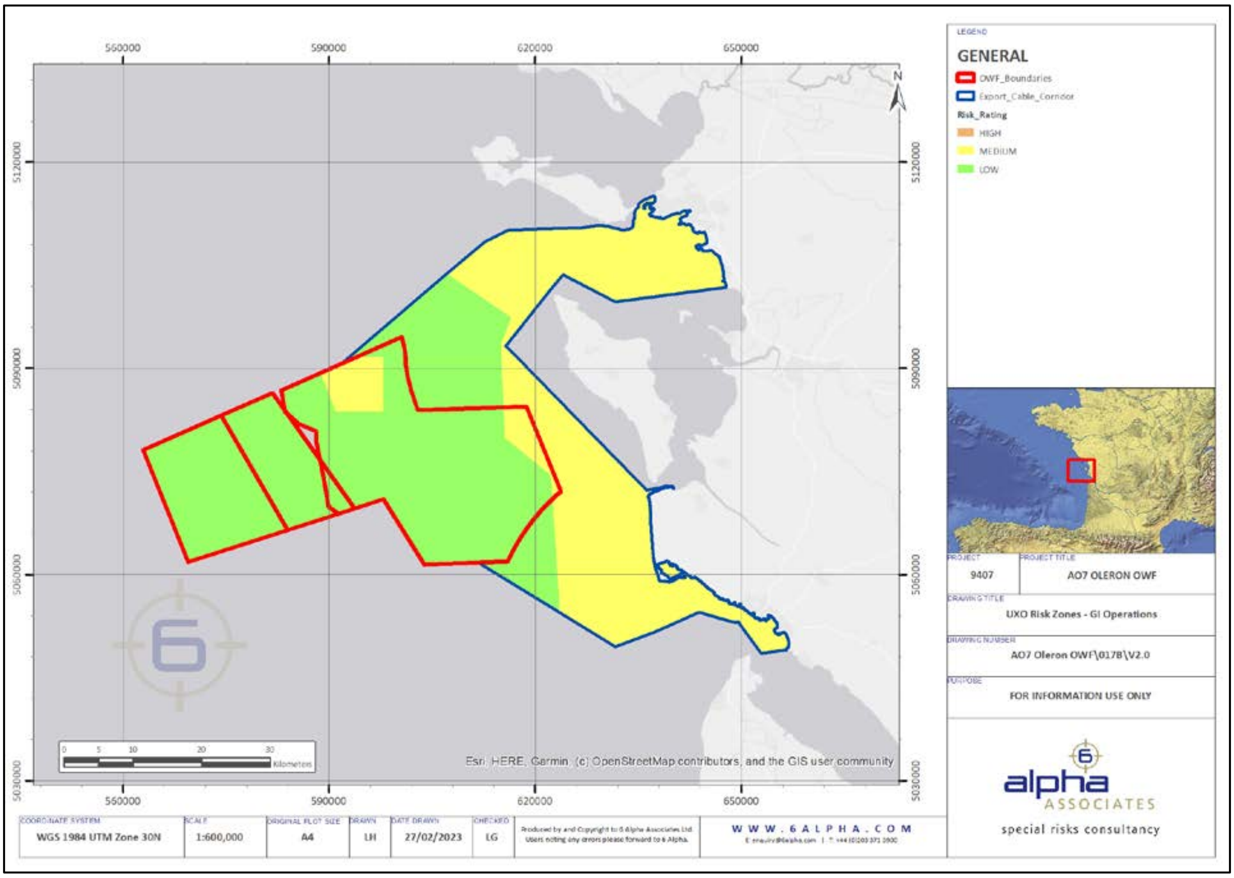


Figure 6 – UXO Risk Zones for GI Operations

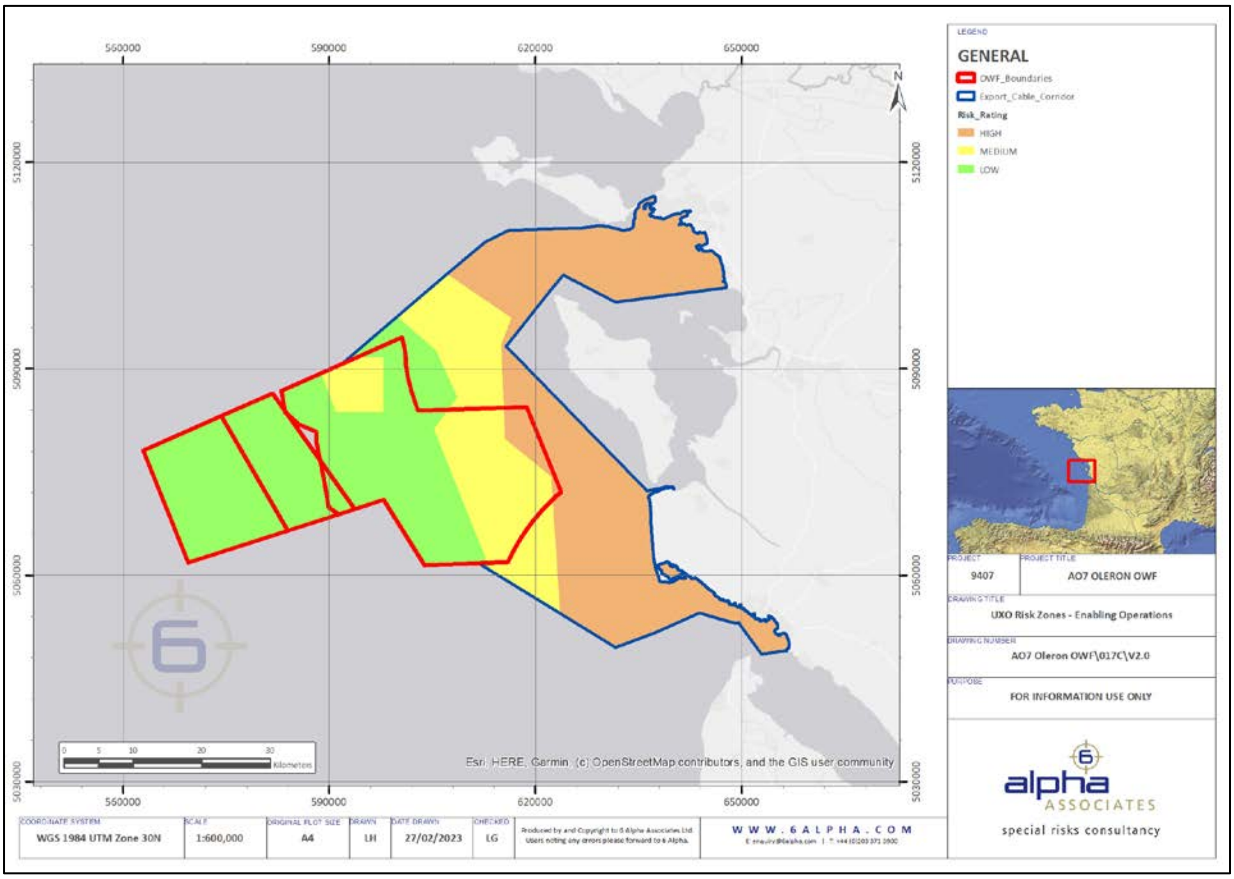


Figure 7 – UXO Risk Zones for Enabling Operations

9 Conclusions and Recommendations

9.1 Conclusions

The nature and scope of the UXO risks vary across the Study Site, based upon a source-pathway-receptor review in general, as well as the prospective consequences of initiating UXO and an analysis of the probability of encountering and of initiating UXO, in particular. Some UXO risks posed by the proposed operations have been categorised as HIGH and MEDIUM because they are generally associated with the unplanned initiation of threat spectrum UXO - including HE bombs, naval mines and large AAA projectiles. Such risks are considered intolerable.

Nonetheless, LOW category UXO risks have been identified in the western sector of the *AO7 Oleron OWF* in the area that corresponds with the deepest water depths at the Site, together with both *Parc 1* and *Parc 2*. For GI operations, this area of LOW UXO risk extends into portions of the export cable corridors, due to the smaller footprint of such works, together with the juxtaposition of evidenced historical activities and the increased water depths offshore. This is because the effects of the depth of water upon threat spectrum UXO initiation consequences (and *inter alia* the resultant through-seabed and through-water shock), will likely be partly risk mitigative and in such circumstances, where the risk is appropriately mitigated, the residual risks might well be tolerated.

9.1.1 UXO Risks to Surface Vessels and their Crew

UXO risks that are posed to vessels and their crews in depths shallower than 40m LAT, are potentially and theoretically the most intolerable. HIGH and MEDIUM category UXO risks have been evidenced within the export cable corridors and parts of the *AO7 Oleron OWF*; due to the historic aerial bombing, minelaying and prospective AAA firings that have occurred across much of the area.

The prospective consequences for surface vessels generally reduce, as the depth of water between the vessel and the point of a UXO initiation increases, and as such, the western sector of the proposed OWF array, *Parc 1* and *Parc 2* have been categorised as LOW category UXO risk for all operations.

If divers are deployed to facilitate subsea operations, then they may be exposed to significant UXO risks because they are especially vulnerable to the effects of UXO if UXO is initiated underwater. In such circumstances, fatalities can be generated hundreds of meters from the seat of such explosions (subject to the NEQ of the UXO).

9.1.2 UXO Risks to Underwater Equipment

Underwater investigative and installation equipment are unlikely to be sufficiently robust to withstand the consequences of an initiation of most high NEQ, threat spectrum UXO (such as HE bombs and naval mines). The prospective UXO risks posed to underwater equipment are therefore classified as HIGH and/or MEDIUM, in all depths of water where an evidenced UXO threat is present.

Nevertheless, the UXO risk to underwater equipment is likely to be deemed tolerable under the auspices of the ALARP risk reduction principle, as long as such risks do not also pose a hazard to support vessels and their crews.

9.2 Recommendations

Those UXO risks classified as HIGH and MEDIUM are to be mitigated within the bounds of the ALARP risk reduction principal through the implementation of an appropriate UXO risk mitigation strategy, which has been developed by *6 Alpha* for the Client in accordance with *French* and *EU* laws.

ALARP safety sign-off certificates should then be delivered once the risk mitigation measures have been implemented.

Part III – UXO Risk Mitigation Strategy for Geotechnical Investigation Operations

10 UXO Risk Mitigation Strategy

10.1 Risk Mitigation Strategy - Options

6 Alpha has been commissioned to deliver a UXO Risk Mitigation Strategy for GI and their enabling works at the *AO7 Oleron OWF*.

6 Alpha's approach is that UXO risk can effectively be reduced to ALARP, by removing one (or more) element(s) of the source-pathway-receptor risk model or otherwise, mitigating the risks associated with a single element of the model. There are three main strategic risk mitigation options based upon source-pathway-receptor modelling that are, in priority order:

10.1.1 Avoidance

A strategy of pUXO detection and avoidance is proposed as the most cost effective and efficient method of reducing UXO risks to ALARP. By surveying for and avoiding direct or indirect contact with any pUXO (the source of the risk) and by moving the GI locations where necessary away from such prospective hazards, such risks are appropriately and effectively reduced.

10.1.2 Removal of Risk Receptors

A second option is to remove the receptor element (of the source-pathway-receptor model), by moving certain sensitive and vulnerable receptors (typically the crews of offshore vessels), to a safe distance from the point of the intrusive activity and thus the pUXO hazard, so that it will diminish sufficiently the prospective blast, fragmentation (the former and latter are through air effects) and/or shock wave (a through water effect) consequences, in order to reduce UXO risks to ALARP. Clearly, this is not always achievable and such a course of action is commonly impractical.

10.1.3 Removal of Threat Sources

Where pUXO cannot be avoided, an alternative (but commonly, time consuming and costlier) option, is to verify pUXO by investigation and where it is confirmed UXO (cUXO), to remove it (effectively removing the source element of the source-pathway-receptor model), either by moving it to a position where it can do no harm (but only when it is safe to do so and wherever permit licencing and consent condition allow such actions), and/or by destroying it or otherwise rendering it safe.

10.2 Risk Mitigation Measures Overview

The UXO Risk Mitigation Strategy ought to be enacted through the implementation of pertinent proactive and/or reactive UXO Risk Mitigation Measures. A summary of the recommended offshore UXO risk mitigation measures for GI and enabling operations is presented at Table 10.2, and the residual UXO risk level (ALARP) is also shown.

<table>
<tr><th colspan="3">UXO Risk Mitigation Measures Overview</th></tr>
<tr><th>Intrusive Operations</th><th>Recommended Risk Mitigation</th><th>Final UXO Risk Rating</th></tr>
<tr><td rowspan="6">GI and Enabling Operations</td><td>HIGH Risk Zones</td><td rowspan="6">ALARP</td></tr>
<tr><td>Bespoke geophysical UXO Survey;
Surface & Subsurface pUXO detection;
pUXO avoidance or target investigation and cUXO removal;
ERP and TBBs;
On-Call EOD Engineer.</td></tr>
<tr><td>MEDIUM Risk Zones</td></tr>
<tr><td>Bespoke geophysical UXO Survey;
Surface pUXO detection;
pUXO avoidance or target investigation;
ERP and TBBs;
On-Call EOD Engineer.</td></tr>
<tr><td>LOW Risk Zones</td></tr>
<tr><td>Existing geophysical survey data analysis;
Surface pUXO detection;
pUXO avoidance or target investigation;
ERP and TBBs;
On-Call EOD Engineer.</td></tr>
<tr><td colspan="3">The Risk Mitigation Measures are detailed within Sections 10.3 and 10.4 of this document.</td></tr>
</table>

Table 10.2: UXO Risk Mitigation Measures Overview

The recommended risk mitigation measures outlined above can be categorised as either 'Proactive' or 'Reactive', based upon whether they are to be implemented before, or concurrently with the recommended GI and enabling operations.

10.3 Proactive Risk Mitigation Measures

The following risk mitigation measures are categorised as 'proactive' and are recommended in advance of investigative and intrusive works associated with GI and their enabling operations at the *AO7 Oleron OWF* and along the export cable corridors:

10.3.1 Geophysical UXO Survey – HIGH and MEDIUM Risk Zones

A geophysical UXO survey, appropriately designed to detect threat spectrum UXO, is recommended prior to the commencement of the GI operations that are planned within the boundaries of the Study Site, in order to provide the basis for a strategy of pUXO avoidance, or for its identification and removal. An overview of geophysical UXO survey methods that might be employed is presented at Annex G.

The geophysical UXO survey should be designed as follows:

10.3.1.1 Surface UXO Detection

Surface detection for threat spectrum UXO should be undertaken in the HIGH and MEDIUM risk zones and should consist of either Side Scan Sonar (SSS), Multi Beam Echo Sounder (MBES) and/or WROV camera search (subject to visibility and resolution, especially in areas where shallow water operations are planned), over the area of proposed GI operations and prior to their commencement. *6 Alpha* recommend that SSS data should be collected at a frequency of at least 600kHz in order to ensure that it is fit for the purpose of identifying and avoiding pUXO. Sufficient working space to provide a margin for safety should be incorporated in the survey area (with pUXO avoidance initially set at 15m), in order to ensure that proposed activities will not initiate pUXO that might be at the very periphery of the surveyed area.

10.3.1.2 Sub-Surface UXO Detection

Sub-surface detection for threat spectrum UXO should also be undertaken but in the **HIGH risk zones only** and should consist of magnetometer/gradiometer survey over the area of the proposed operations, specifically where JuB are to be deployed. *6 Alpha* do not consider the level of risk associated with GI activities to be severe enough to warrant sub-surface UXO detection elsewhere (that is, in the form of magnetometer or gradiometer survey).

Sufficient working space to provide a margin for safety is to be incorporated in the survey area (with pUXO avoidance initially set at 15m), in order to ensure that proposed activities will not initiate pUXO that might be at their periphery.

10.3.2 Geophysical UXO Survey - LOW Risk Zones

In the LOW category risk zones, the prospective level of UXO risk does not warrant undertaking bespoke geophysical UXO survey. However, it is highly likely that some form of general engineering geophysical survey data will be collected in the LOW risk zone for other (non-UXO related) purposes. Therefore, any existing surface data that is appropriate for the identification of threat spectrum UXO in the LOW risk category zone, is to be employed for the purposes of surface pUXO identification and avoidance and/or further investigation.

10.4 Reactive Risk Mitigation Measures

Reactive risk mitigation measures are recommended in all risk zones, not only to reduce intolerable risks to ALARP but also, to help mitigate any residual risks that may remain once the proactive risk mitigation measures have been implemented. They are:

10.4.1 Operational UXO Emergency Response Plan (ERP)

Any vessels involved in intrusive works should be equipped with UXO specific ERPs, so that in the event of an unplanned UXO discovery the vessel Master and/or the offshore superintendent/party chief (or similar) are informed in advance about what safety actions must be taken.

10.4.2 UXO Safety and Awareness Briefings

Safety briefings (also known as Tool Box Briefs (TBB)) are essential whenever there is a possibility of explosive ordnance encounter and as such, they are considered a vital part of the general UXO safety requirement. All GI and operational support staff working on GI/support vessels are to receive a TBB concerning the identification of relevant UXO, what actions are to be taken to keep people and equipment away from such a hazard or otherwise safe and to alert site management.

Safety and awareness mini-posters concerning the nature of the UXO threat and key actions to be taken should also be displayed on GI/support vessels (e.g. for general information and on notice boards, both for reference and as a UXO safety reminder for offshore crew).

10.4.3 On-Call EOD Engineers

Following the implementation of proactive UXO risk mitigation measures, shore-side and office-based Explosive Ordnance Disposal (EOD) Engineers may be engaged to provide remote, rapid UXO recognition advice and to provide immediate safety management guidance in the event that UXO is discovered. Such a service provides UXO risk management expertise as and when it is required on a just-in-time basis and not only affords safety but also avoids prospective project delays, which might otherwise be caused by the discovery of inert or non-UXO debris.

11 Risk Mitigation Measures – Design, Specification and Guidance

The specific designs and specifications of the recommended UXO risk mitigation measures are part of the next stage of the UXO risk management framework. Nonetheless, it is important to evidence that the risk mitigation measures are consistent with an overarching risk mitigation strategy and therefore, the following strategic level guidance ought to underpin any subsequent detailed designs and specifications for risk mitigation.

11.1 Survey Specifications

In accordance with the risk management recommendations contained within *CIRIA*'s C754 guide, the survey contractor will need to provide evidence that their proposed survey methodology and equipment is fit for the purpose of identifying threat spectrum UXO. Accordingly, geophysical survey specifications should be drafted for each type of survey methodology, outlining the required survey parameters, equipment and calibrations to ensure that the survey is fit for the purpose of threat spectrum, UXO detection. In addition, a Survey Verification Test (SVT) is to precede the main survey acquisition work itself, in order to validate and prove the efficacy of the survey equipment in being able to detect the minimum sized UXO threats.

11.2 Minimum UXO Threats

The minimum size of UXO to be detected by geophysical UXO survey across the Study Site varies, depending on a number of factors including but not limited to; water depth, likely GI and their enabling methodologies, the type(s) of the UXO, prospective vessel slant range to UXO and vessels' robustness. It should also be noted that the minimum size UXO for magnetometer survey purposes especially is based on a UXO threat item's ferrous metal content rather than its physical dimensions or any other factor. Figure 8 illustrates the general categorisation of minimum UXO threat items for detection and thus ALARP safety provision, at different water depths.

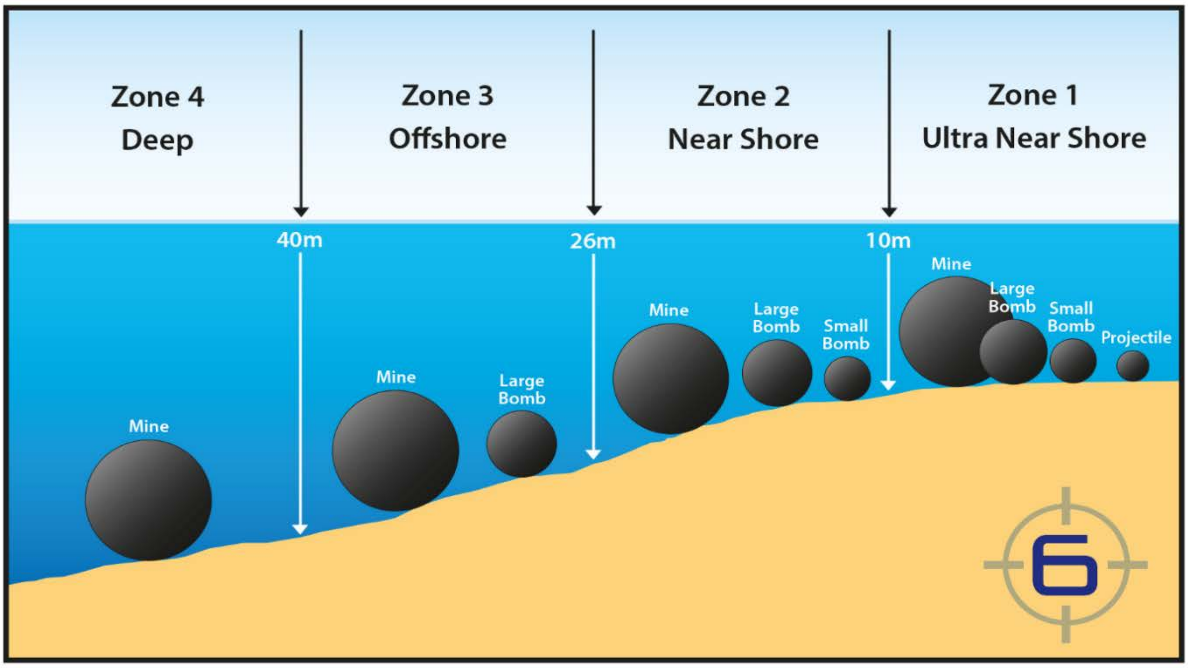


Figure 8: UXO Detection Requirement with Respect to Water Depths (in LAT)

The UXO detection requirement diagram (presented at Figure 8) is intended as a general guide to minimum threat detection at those specified water depths, which is generally correct across all types of offshore projects. At the strategic level it is possible to broadly refine the minimum UXO threats that require detection - according to the water depth mitigation criteria, as presented in Table 11.2.

Water Depths	Minimum UXO Threat	Dimensions (L x W)	Total Mass (Kg)	Ferrous Mass (Kg)	Explosive Fill
Intertidal Zone	***German* 8cm Heavy Mortar**	325mm x 81mm	3.5kg	3kg	0.51kg
Up to 10m LAT	***German* 10.5cm Artillery Projectile**	391/489mm x 105mm	14.8kg	13kg	1.8kg TNT
Up to 26m LAT	***American* AN-M30 100lb HE Bomb**	737mm x 208mm	52kg	26kg	26kg TNT
Up to 40m LAT	***British* 500lb MC Bomb**	1,041mm x 328mm	236kg	111-121kg	105kg Torpex or 95kg Amatol
More than 40m LAT	***American* AN-M65 1,000lb HE Bomb**	1,349mm x 478mm	449kg	196kg	253kg TNT

Table 11.2: Minimum UXO Threat Items by Water Depth

11.3 Geophysical Survey Data QC and Processing

The geophysical UXO survey data is to undergo professional Quality Control (QC) and it is to be properly processed in order to identify those anomalies that represent pUXO within specified survey swath boundaries, as well as to provide interpretational comments as to the nature (length, width, and height) of SSS contacts and to highlight occurrences where an SSS contact correlates with (and where such data has been otherwise gathered, corroborates a magnetic anomaly). The client-side UXO consultant with the responsibility for the provision of ALARP safety sign-off certification should remain responsible for the classification of SSS contacts and/or magnetic anomalies that model as pUXO and they should to ascribe an appropriate safety avoidance distance in order to ensure that GI risks remain reduced ALARP.

11.4 Geophysical Survey Data Longevity and MMBA

Geophysical survey data that is employed for the purposes of UXO risk management, is generally employed for up to 12 months (from the time of its final capture), for UXO risk mitigation purposes. Once the survey data is more than 12 months old and subject to *inter alia* environmental conditions on-site, additional risk mitigation measures may need to account for the potential changes in position of the pUXO, especially in conditions of highly mobile seabed. In such circumstances, an MMBA can be undertaken in order to gain a better understanding of the type of UXO that might move as well as the magnitude and direction of its likely migration path.

12 Risk Mitigation Strategy - Implementation

Once the geophysical UXO survey has been undertaken and the resultant data QC'd and processed in accordance with best practice guidance, it will then afford the implementation of all other elements of this risk mitigation strategy, namely:

12.1 pUXO Avoidance

Any geophysical UXO survey anomaly that is classified as pUXO is to be avoided, wherever possible by not less than 15m from the leading edge of any underwater equipment or GI platform, which might be deployed at the seabed and/or measured from any form of other sub-seabed intrusive activity. Such safety avoidance is designed to ensure that if non-verified pUXO is in fact UXO, it will not be encountered nor initiated (either directly or indirectly).

If such a safety avoidance distance proves problematic to implement (for example, because there is a profusion of pUXO anomalies), such avoidance might be safely reduced through the medium of a Technical Advisory Note (TAN). A TAN would consider *inter alia*: the kinetic energy generated by the type and nature of the intrusive activity; high-level and shallow sub-seabed geotechnical considerations; and the prospective detonation sensitivity of those type of UXO that might be encountered. Such (*6 Alpha* produced) TAN can reduce safety avoidance distances, typically by about a third.

Nonetheless, any sub-seabed intrusive activity (such as GI) within such prescribed avoidance radii should be repositioned if they are too close, so that the operations can be conducted at a suitably safe distance that will not initiate UXO. If GI is to be undertaken within specified avoidance boundaries and the position of the GI cannot be moved (which is considered unlikely and - in *6 Alpha's* experience - highly unusual), then such pUXO will need to be investigated for the purposes of their verification, in advance of the GI commencing.

12.2 pUXO Verification by Investigation

If in the unlikely event that (surface or sub-surface) pUXO cannot be avoided, they might be verified by a campaign of so-called Target Investigation (TI), in order classify them as either cUXO or as benign debris.

Typically, such TI is undertaken by contractors equipped with WROV(s), or in shallow water (which might preclude WROV operations) by suitably equipped and appropriately controlled divers. Such TI operations require professional QC and independent oversight to ensure that its outputs can properly inform and support the subsequent production of ALARP safety sign off certification. For the purposes of continuity of UXO risk management due diligence, the same client-side consultant is usually charged with the responsibility for TI QC and oversight, in order to inform and support subsequently, the production of ALARP safety sign-off certification.

12.3 cUXO Disposal

Where pUXO is investigated and classified as cUXO, it will generally require safe disposal either *in situ* or, if it is considered safe to do so, cUXO might be moved and subsequently rendered safe. For safety reporting and third-party avoidance purposes, the relevant local and national *Coast Guard* authorities - amongst a variety of other stakeholders - will also require notification upon discovery of cUXO.

Necessary cUXO render safe (typically by UXO destruction) may subsequently be undertaken by a suitable and appropriate specialist, although permitting, licensing and consent will need to be sought in advance - which can typically take a number of weeks to acquire. Details of the planned disposal methodology and accompanying risk assessments will usually be required prior to consent being given and the award of a permit/licence.

An exclusion/safety zone prior to explosive ordnance disposal action will need to be established, based upon an assessment of, amongst other factors, the type of UXO and its NEQ. During the disposal operations, guard vessels are usually deployed to ensure mariners are kept at a safe distance, whilst marine mammal mitigation measures are also commonly required.

For the purposes of continuity of UXO risk management due diligence, the same client-side consultant is usually charged with the responsibility for QC and oversight during disposal activities, in order to inform and support ALARP safety sign-off activities.

12.4 Residual Risk Tolerance

Following the implementation of the risk mitigation strategy, UXO risks will not usually be reduced to "zero", nor need they be under the auspices of ALARP principle. Residual UXO risks may likely remain in the offshore environment due to *inter alia*, the limits of geophysical UXO survey technology, data interpretation limitations and the fact that small scale low NEQ UXO threats might be tolerated - which is acceptable under the principles of ALARP risk reduction.

Such residual risks have been tolerated on many other projects, in similar circumstances. Such an approach, therefore, is likely to be deemed acceptable by a wide variety of project stakeholders as well as regulators and such practise is consistent with UXO risk management standards, practices, and frameworks. Therefore, the recommended levels of UXO risk tolerance are outlined at Table 12.4:

UXO Risk Tolerance	Prospective Residual UXO Risk	Project Implications
Option 1 - Very Conservative	Damage to subsea equipment or installed assets, of any kind, will not be tolerated.	Most expensive and time-consuming option but the risk of damaging the GI equipment is significantly reduced.
Option 2 - Recommended (within ALARP threshold)	Damage/destruction of subsea equipment and installed assets may be considered tolerable - if undesirable. Significant damage to vessels that may injure or endanger personnel (either directly or indirectly), is intolerable and will require proactive and reactive risk mitigation.	Time and cost efficient, although carries the risk of repair and/or replacement of equipment in the event of unplanned low NEQ UXO encounter and detonation.

Table 12.4: Recommended Residual UXO Risk Tolerance

12.5 ALARP Safety Sign-Off Certification

ALARP safety sign-off certification provides an independent source of evidence that a Client has followed industry best practice and has successfully managed and reduced UXO risks to ALARP. Following the execution of UXO risk mitigation measures, ALARP safety sign-off certification should be obtained and distributed in advance of GI operations.

In such circumstances the Client will be able to certify for the benefit of all project stakeholders, that all reasonably practicable measures have been taken to protect offshore contractors (including their own workers and third parties), from UXO hazards and that the commissioning client will have acted in compliance with industry best practice as well as the national safety legislation.

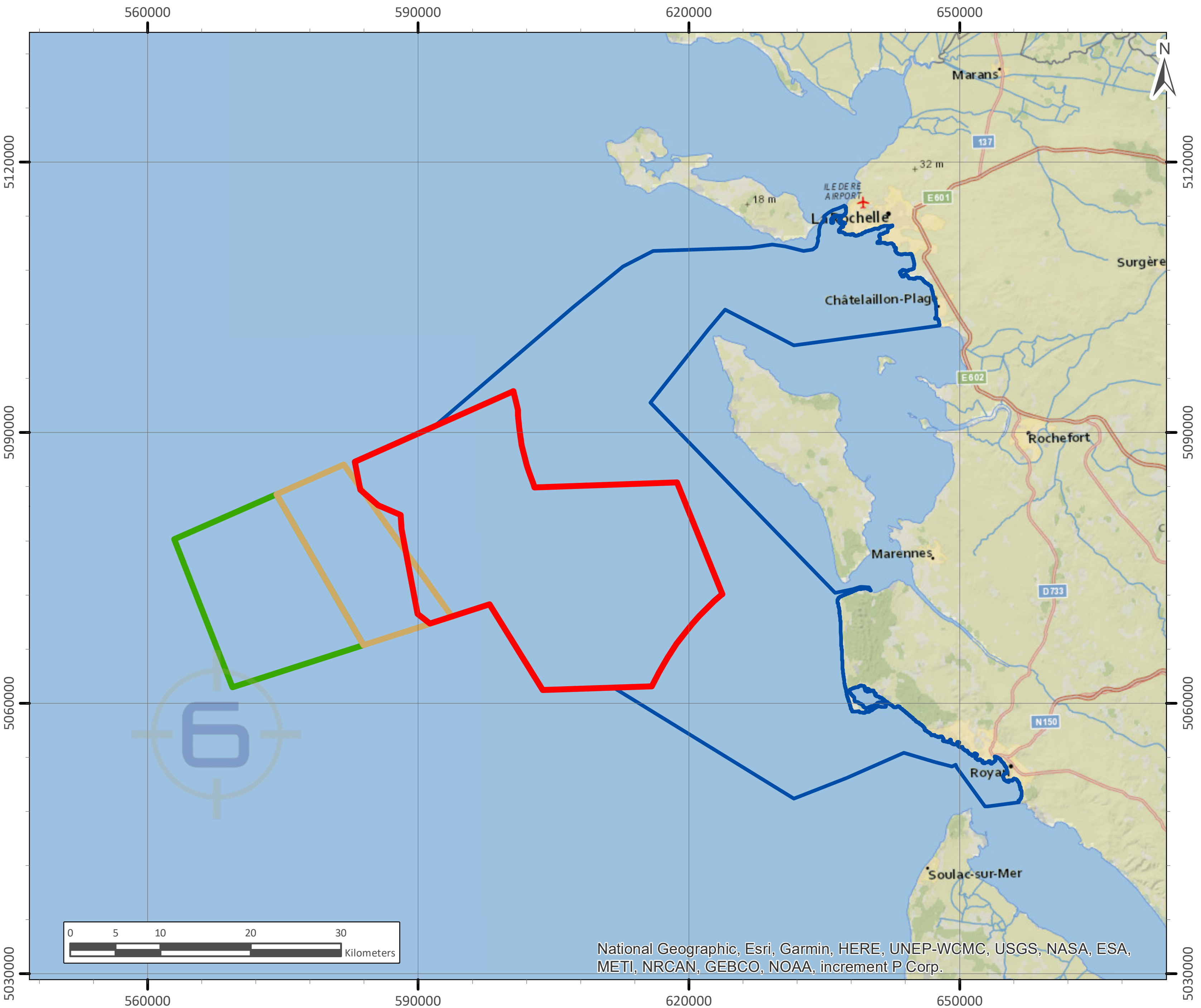
In accordance with best practice, *6 Alpha* ALARP safety sign-off certificates do not imply that the Site is free from UXO, rather, that the necessary and appropriate UXO risk mitigation measures have been appropriately applied to evidence that UXO risks have been reduced ALARP.

Nonetheless, and notwithstanding the delivery of such certification, if significant or dangerous UXO is unexpectedly discovered during the intrusive operations, project ERP should be implemented, and on-call EOD Engineers engaged. In such circumstances, the UXO threat and risk assessment and the risk mitigation measures is to be reviewed by *6 Alpha*, in order to ensure (and to formally endorse) that the risk mitigation measures remain appropriate and relevant.

Appendices

Appendix 1

Site Location



LEGEND

GENERAL

- OWF_Boundary
- AO7_Parc_1
- AO7_Parc_2
- Export_Cable_Corridor

PROJECT	PROJECT TITLE
9407	AO7 OLERON OWF

DRAWING TITLE
Site Location

DRAWING NUMBER
AO7 Oleron OWF\001\V2.0

PURPOSE
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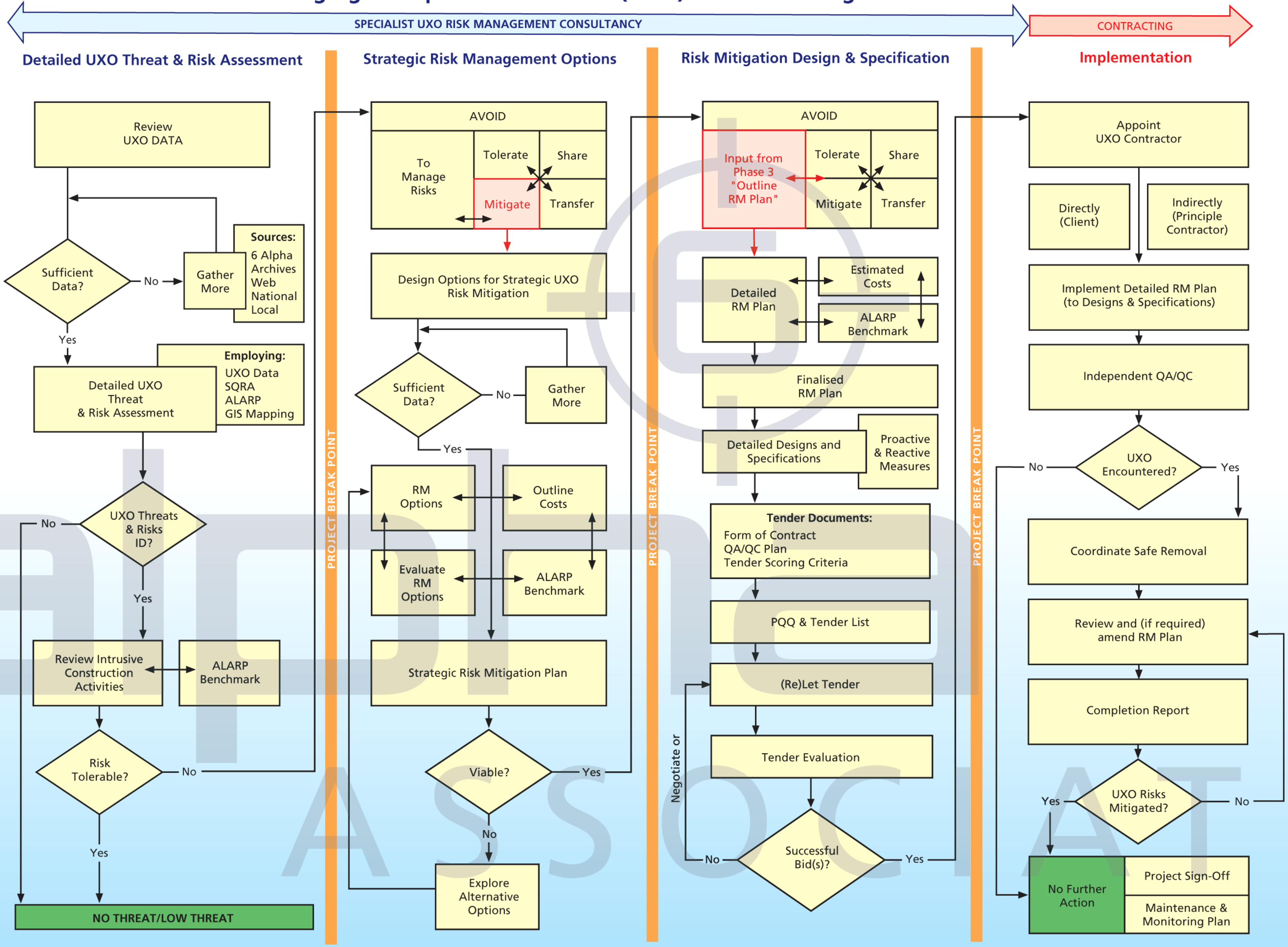
WGS 1984 UTM Zone 30N	1:600,000	A4	LH	24/02/2023	LG	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please forward to 6 Alpha.	WWW.6ALPHA.COM E: enquiry@6alpha.com | T: +44 (0)203 371 3900

Appendix 2

Marine Risk Management Framework

Managing Unexploded Ordnance (UXO) - A Risk Management Framework



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

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.

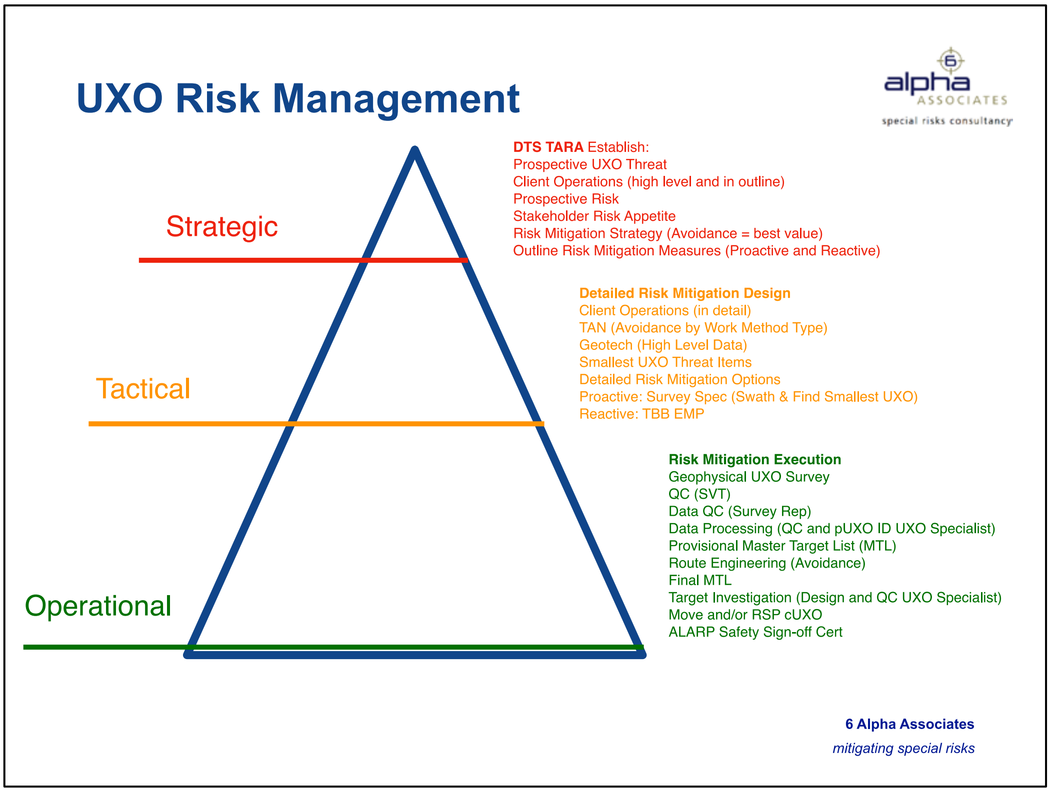


Figure 1: 6 Alpha UXO Risk Management - Concept

DETAIL

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.

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 pipeline 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** eg:
        - Site Emergency Management Plans (EMP);
        - Tool Box Briefs (TBB) for site workers.

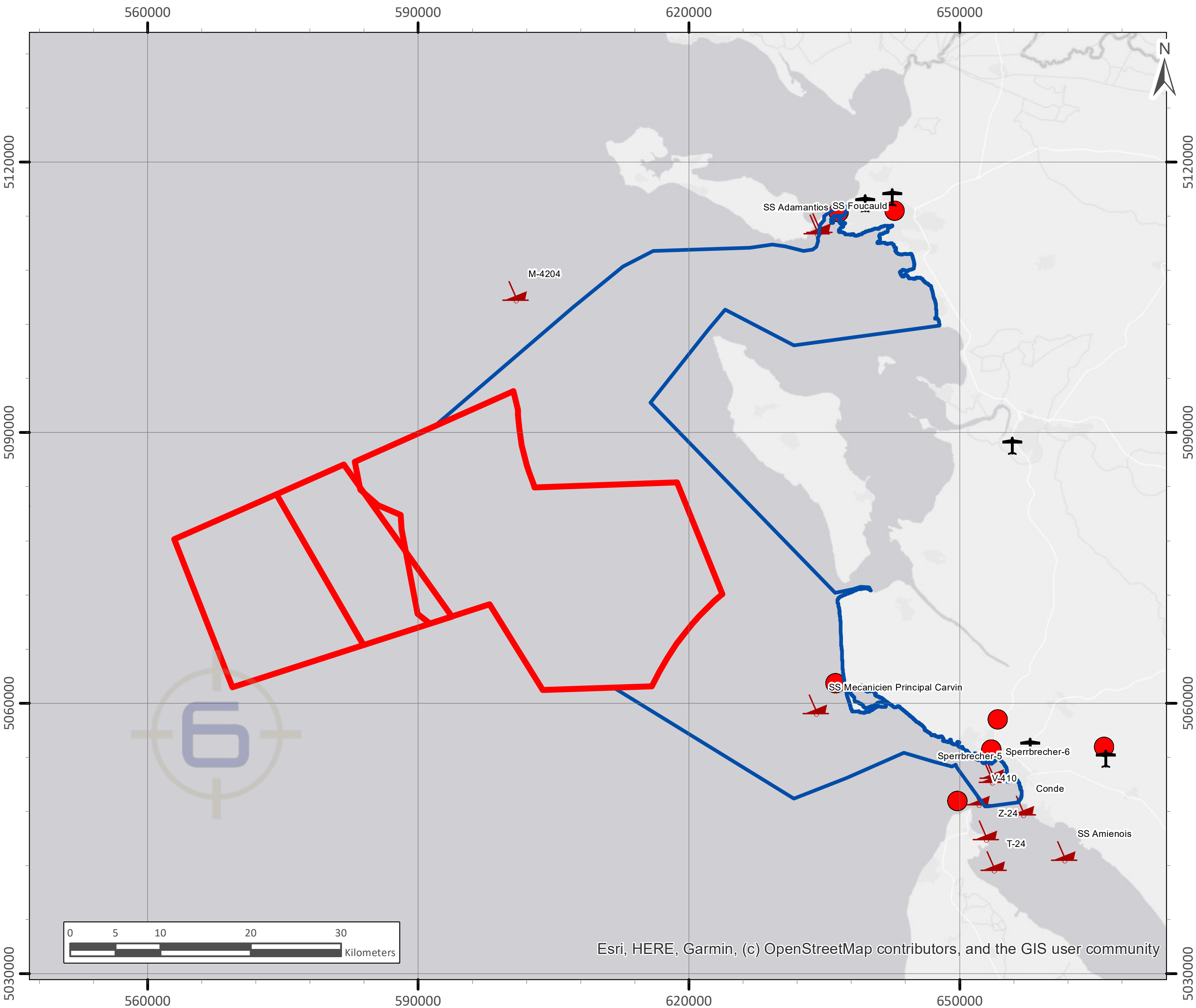
Operational Level - Delivery of UXO Risk Management and Mitigation Solutions

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.

Appendix 4

Aerial Bombing



LEGEND

GENERAL

OWF_Boundaries

Export_Cable_Corridor

UXO THREATS

Luftwaffe_Airfield

Allied_Bombing_Raid

WWII_Air-Raid_Wreck

PROJECT	PROJECT TITLE
9407	AO7 OLERON OWF

DRAWING TITLE

Aerial Bombing

DRAWING NUMBER

AO7 Oleron OWF\004\V2.0

PURPOSE

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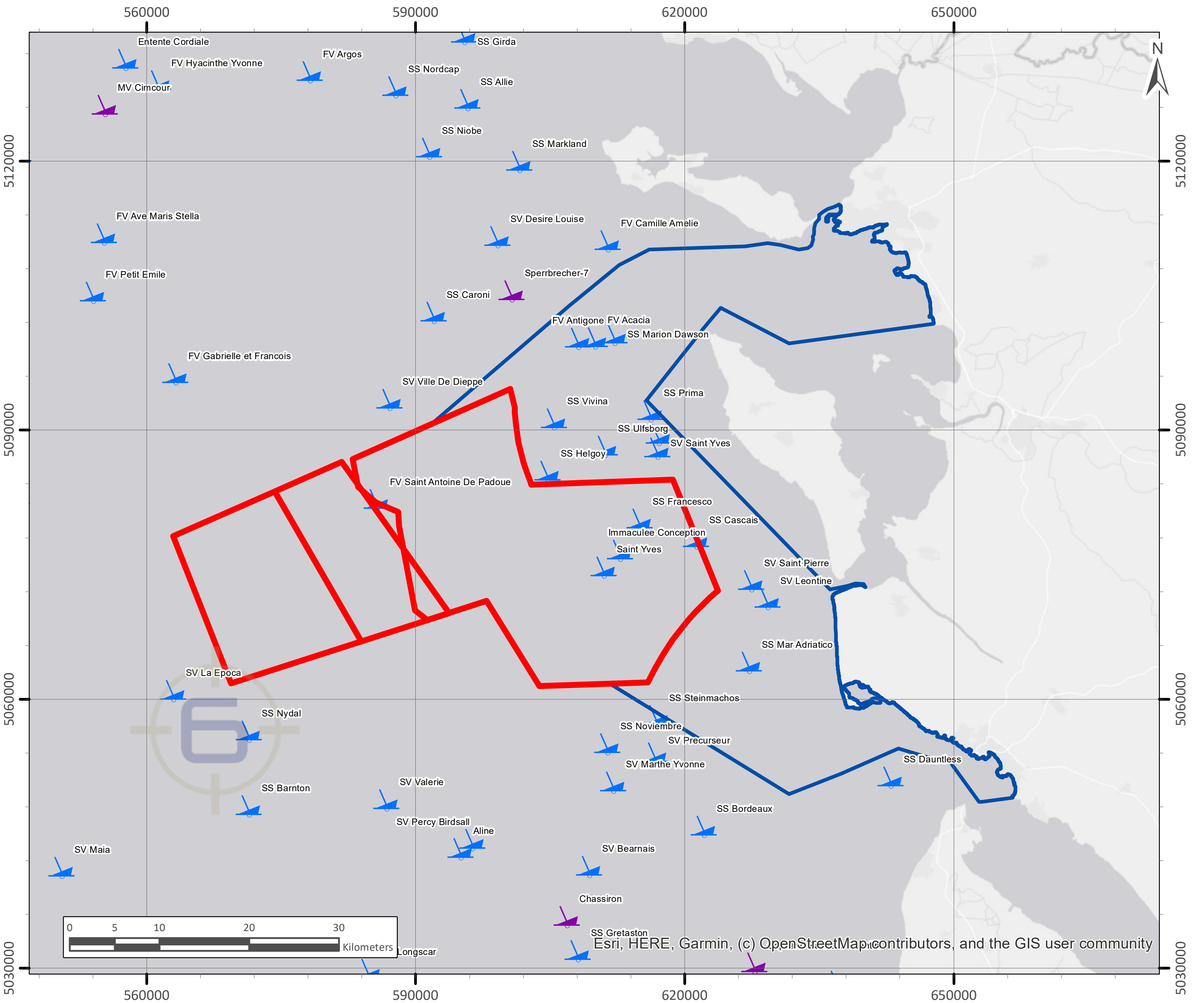
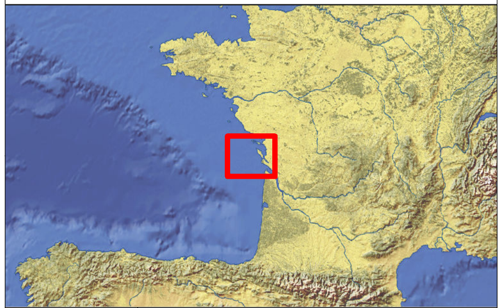
Appendix 5

Naval Engagements





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DRAWING TITLE
Naval Engagements

DRAWING NUMBER
AO7 Oleron OWF\005\V2.0

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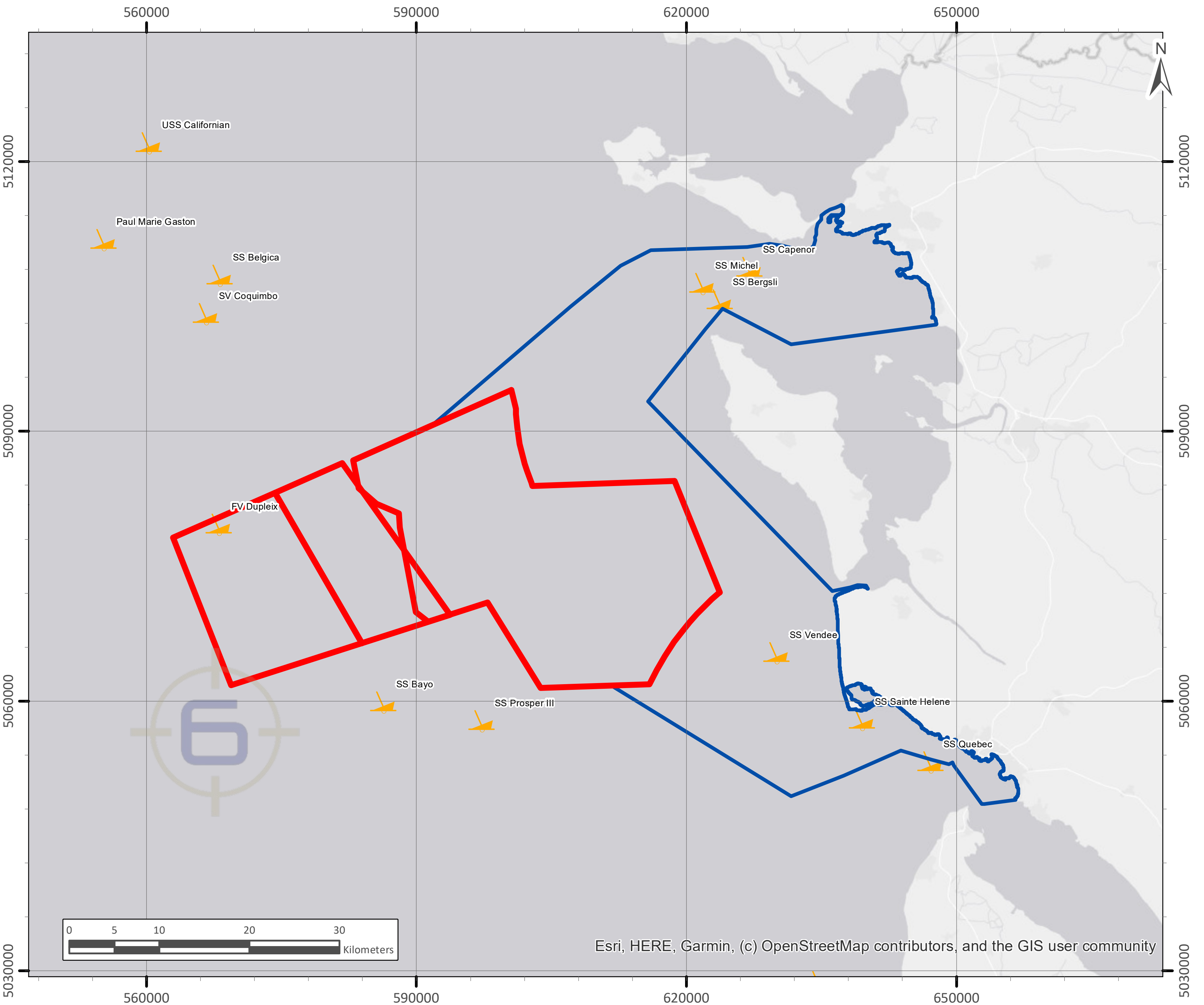
Appendix 6

WWI Minefields



LEGEND

GENERAL

- OWF_Boundaries
- Export_Cable_Corridor

UXO THREATS

- WWI_Mined_Wreck

PROJECT	PROJECT TITLE
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DRAWING TITLE

WWI Minefields

DRAWING NUMBER

AO7 Oleron OWF\006\V2.0

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Appendix 7

WWII Minefields

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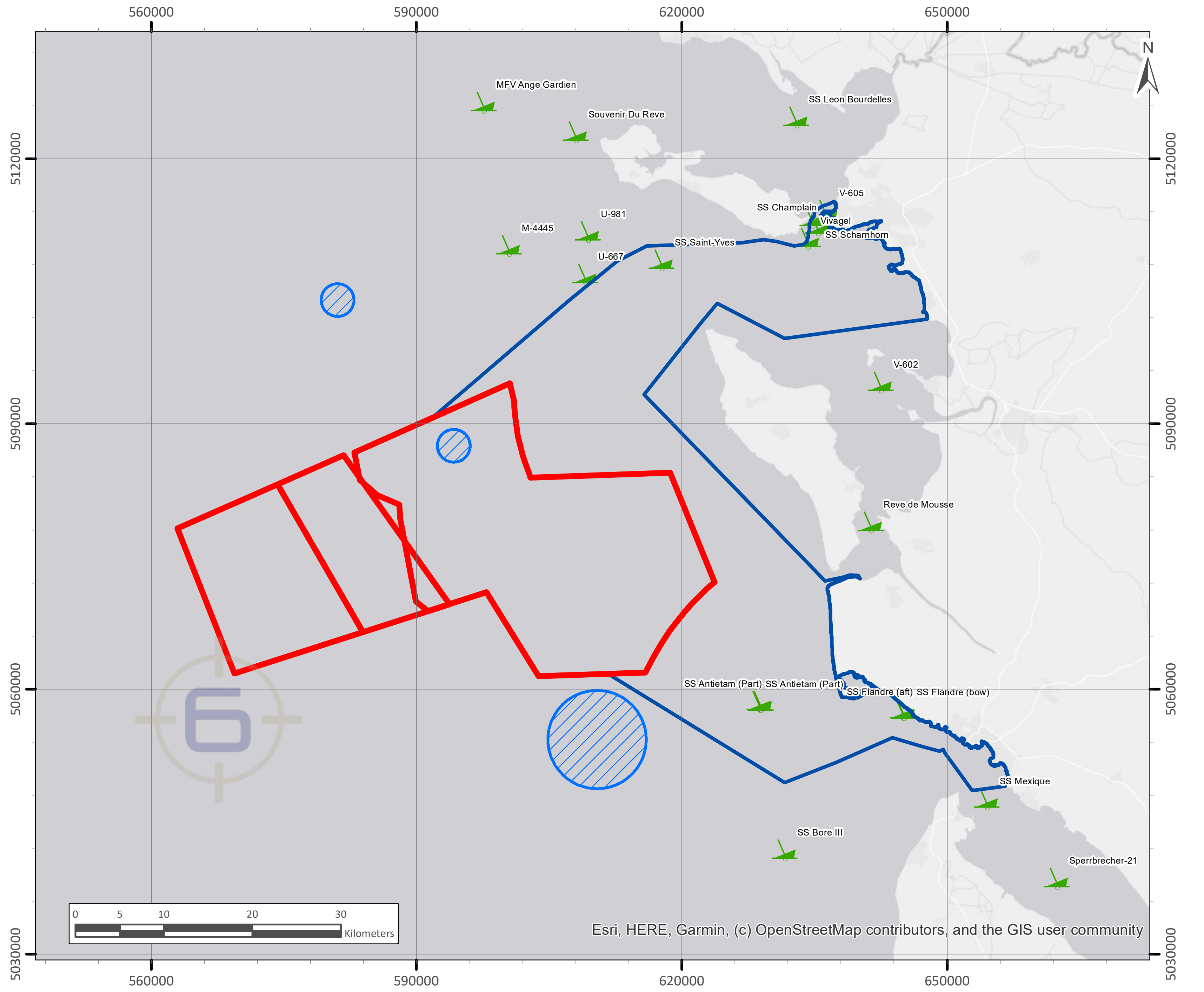

LEGEND

GENERAL

OWF_Boundaries

Export_Cable_Corridor

UXO THREATS

WWII_Mined_Wreck

WWII_British_Minefield

PROJECT	PROJECT TITLE
9407	AO7 OLERON OWF

DRAWING TITLE

WWII Minefields

DRAWING NUMBER

AO7 Oleron OWF\007\V2.0

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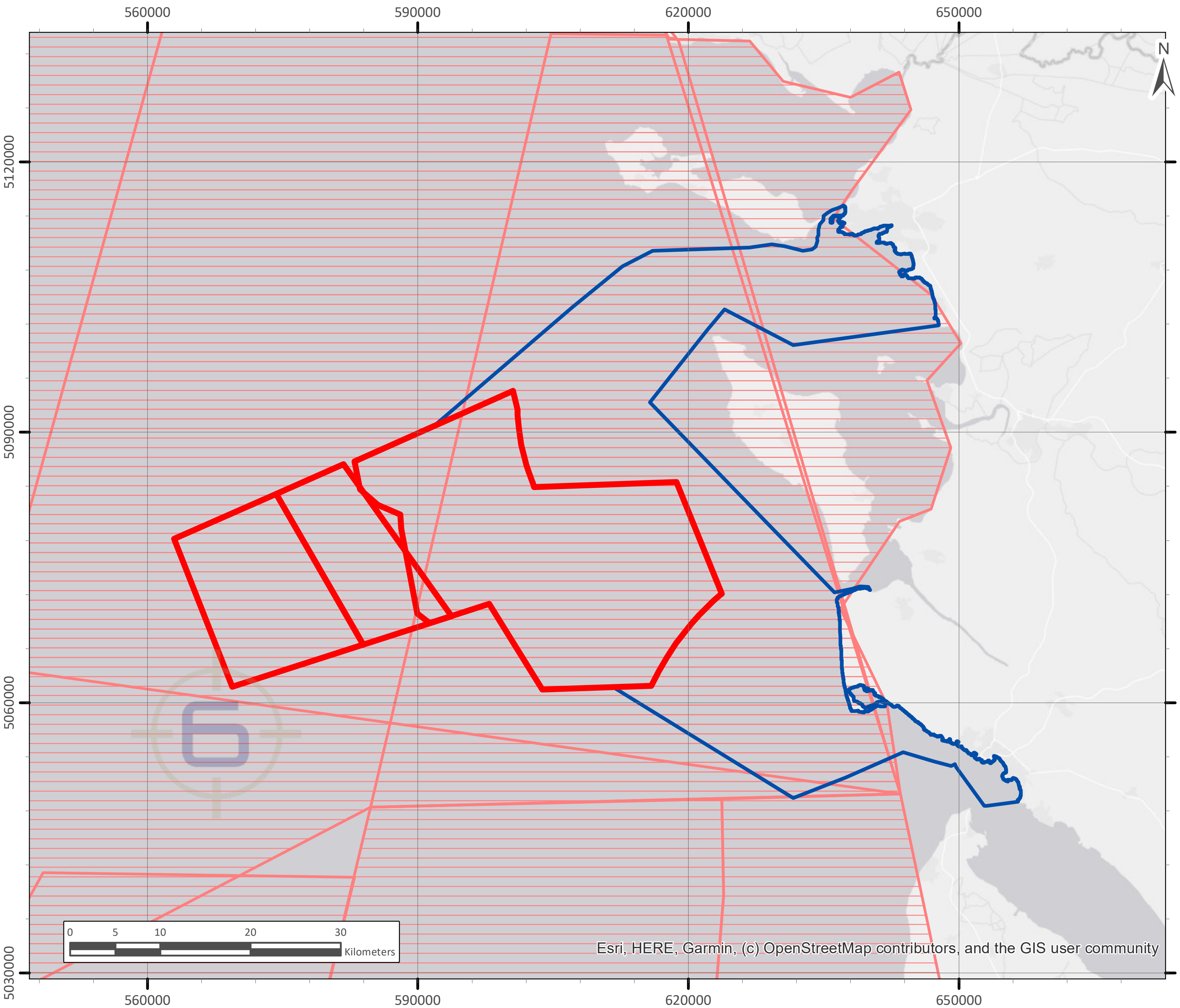
Appendix 8

Modern Military PEXA



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GENERAL

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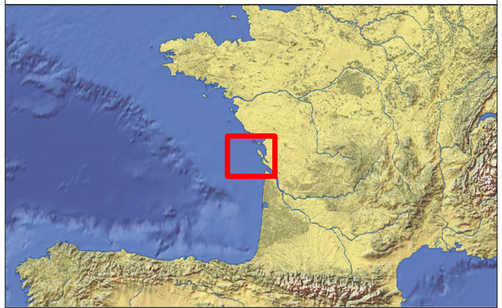
UXO THREATS

Modern_PEXA



PROJECT	PROJECT TITLE
9407	AO7 OLERON OWF

DRAWING TITLE
Modern Military PEXA

DRAWING NUMBER
AO7 Oleron OWF\008\V2.0

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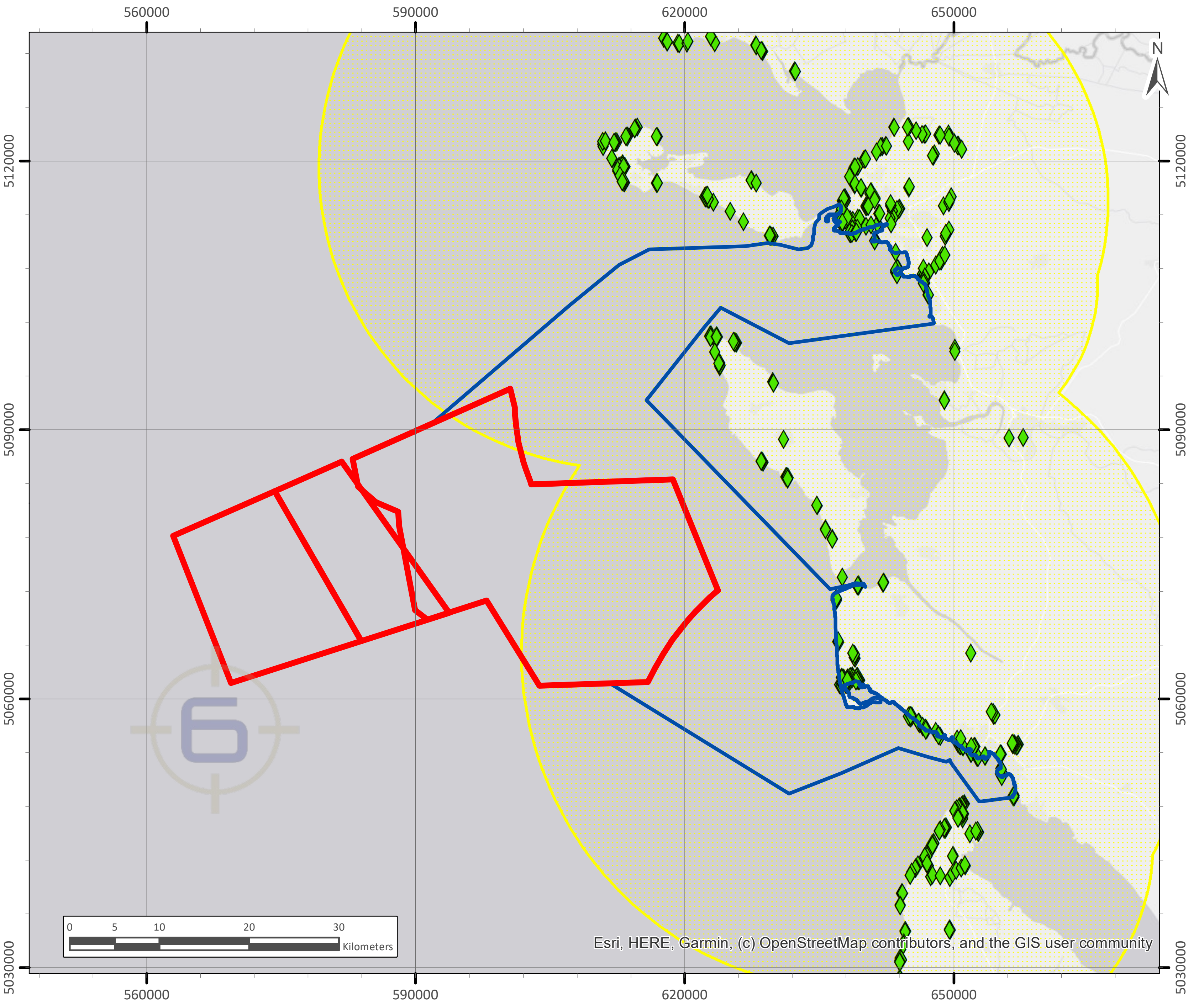
Appendix 9

Coastal Armaments



LEGEND

GENERAL

- OWF_Boundaries
- Export_Cable_Corridor

UXO THREATS

- Atlantikwall_Installation
- Atlantikwall_Range

PROJECT	PROJECT TITLE
9407	AO7 OLERON OWF

DRAWING TITLE
Coastal Armaments

DRAWING NUMBER
AO7 Oleron OWF\009\V2.0

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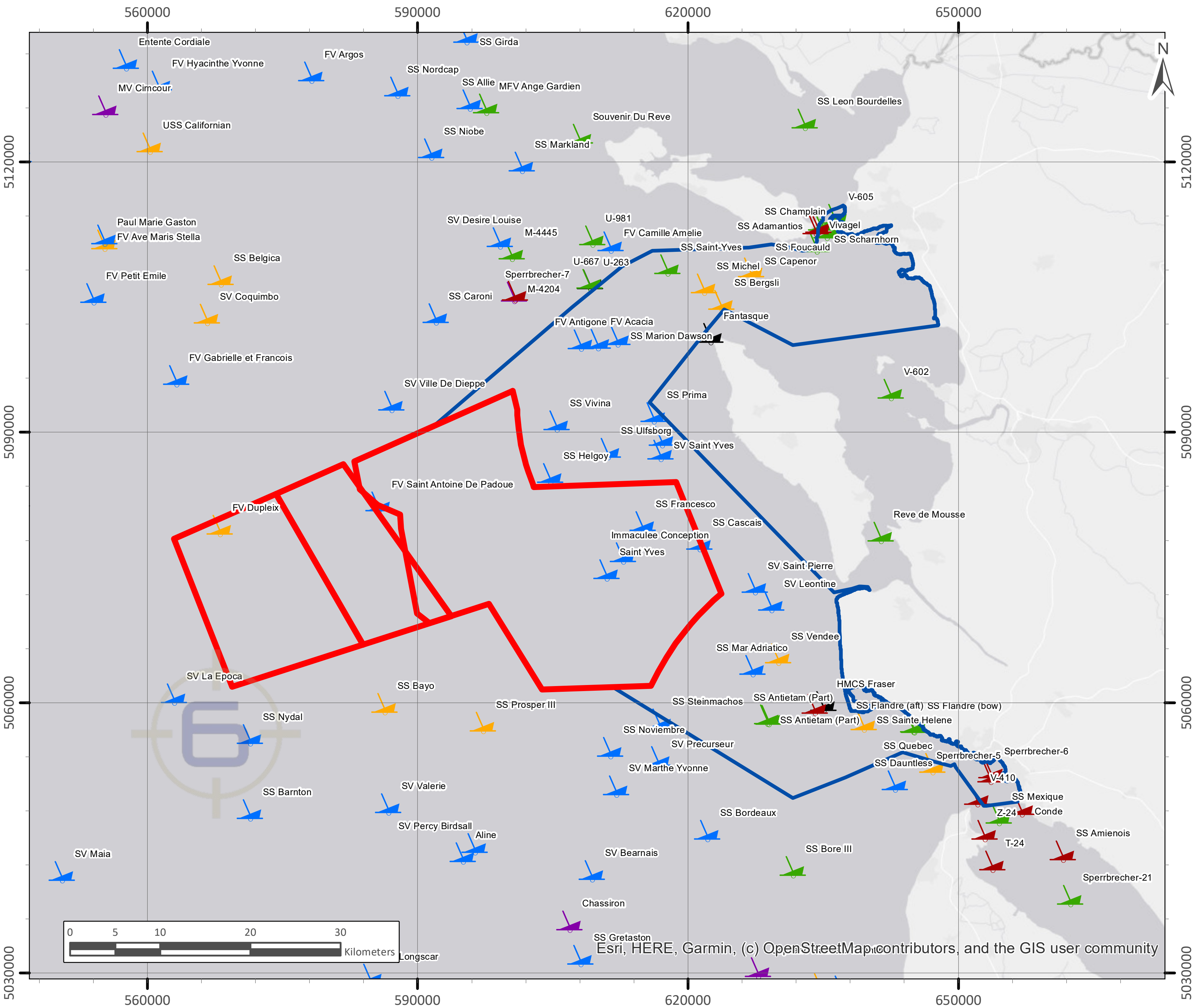
Appendix 10

Munitions Related Shipwrecks



LEGEND

GENERAL

- OWF_Boundaries
- Export_Cable_Corridor

UXO THREATS

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

PROJECT	PROJECT TITLE
9407	AO7 OLERON OWF

DRAWING TITLE	Munitions Related Encounters
DRAWING NUMBER	AO7 Oleron OWF\010\V2.0
PURPOSE	FOR INFORMATION USE ONLY

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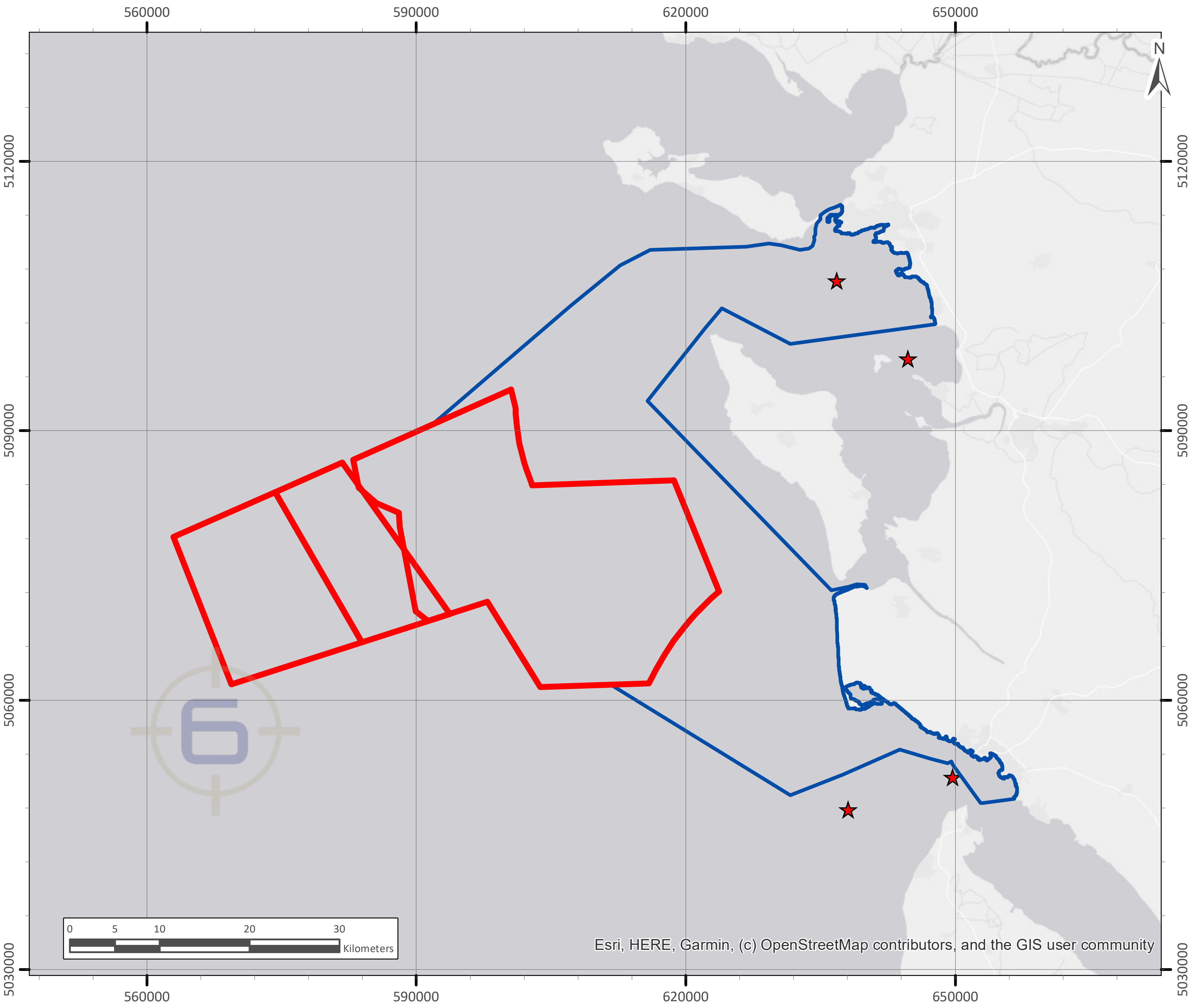
Appendix 11

Munitions Dumping



LEGEND

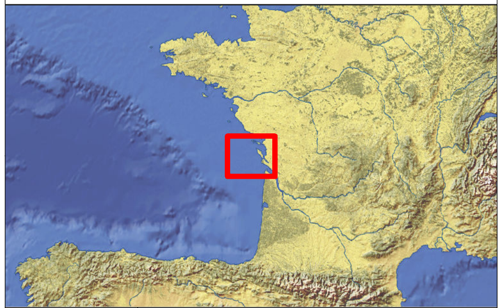
GENERAL

OWF_Boundaries

Export_Cable_Corridor

UXO THREATS

Munitions_Dump



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DRAWING TITLE
Munitions Dumping

DRAWING NUMBER
AO7 Oleron OWF\011\V2.0

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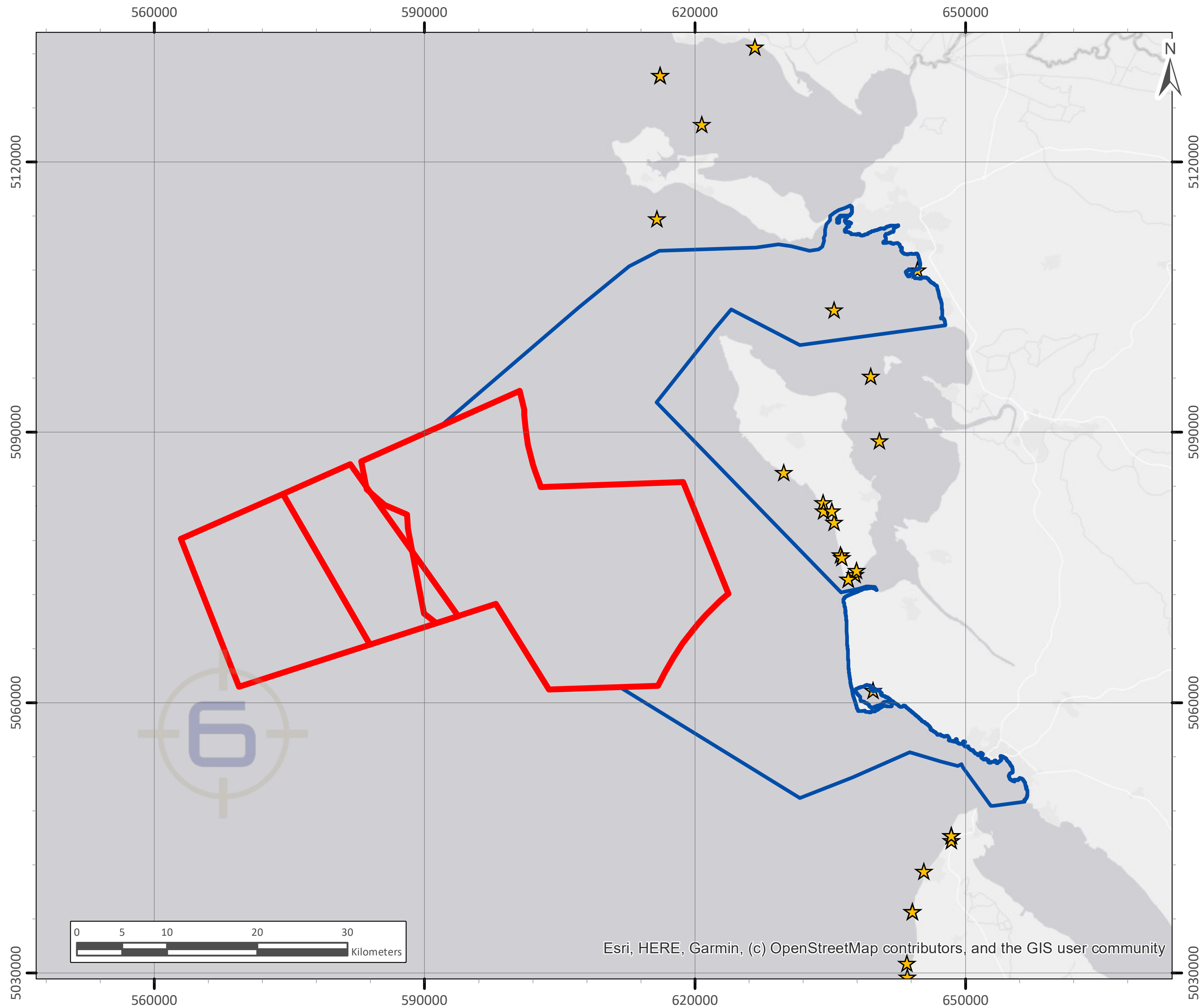
Appendix 12

Munitions Encounters



LEGEND

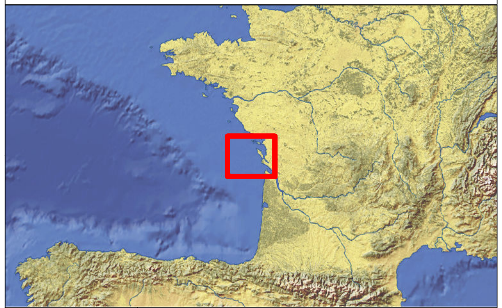
GENERAL

OWF_Boundaries

Export_Cable_Corridor

UXO THREATS

OSPAR_Munitions_Encounter



PROJECT	PROJECT TITLE
9407	AO7 OLERON OWF

DRAWING TITLE
Munitions Encounters

DRAWING NUMBER
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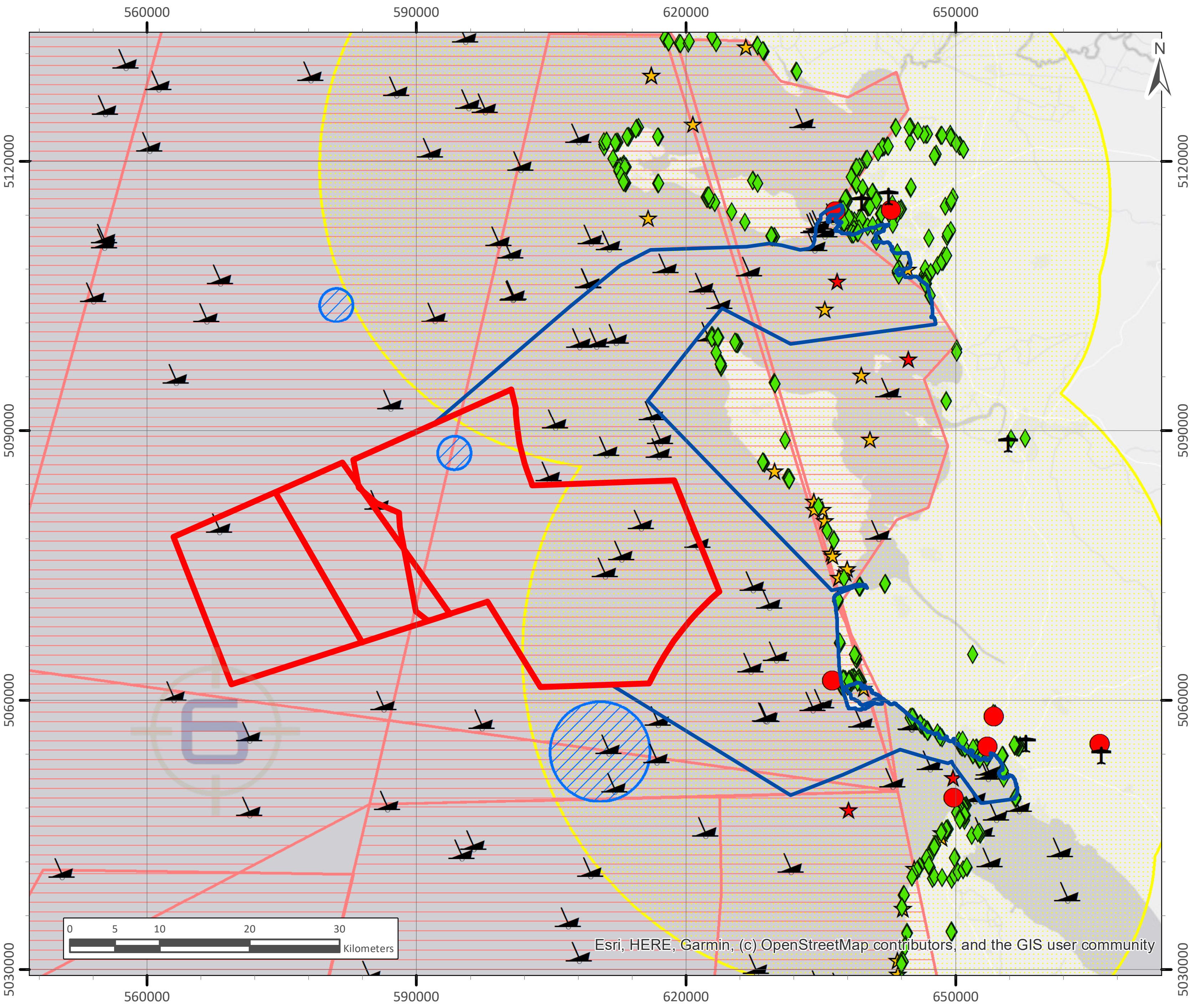
Appendix 13

Consolidated UXO Threat



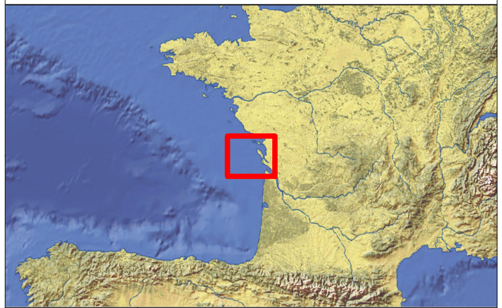
LEGEND

GENERAL

- OWF_Boundaries
- Export_Cable_Corridor

UXO THREATS

- Luftwaffe_Airfield
- Allied_Bombing_Raid
- Atlantikwall_Installation
- Munitions_Related_Wreck
- Munitions_Dump
- OSPAR_Munitions_Encounter
- WWII_British_Minefield
- Modern_PEXA
- Atlantikwall_Range



PROJECT	PROJECT TITLE
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DRAWING TITLE
Consolidated UXO Threat

DRAWING NUMBER
AO7 Oleron OWF\013\V2.0

PURPOSE
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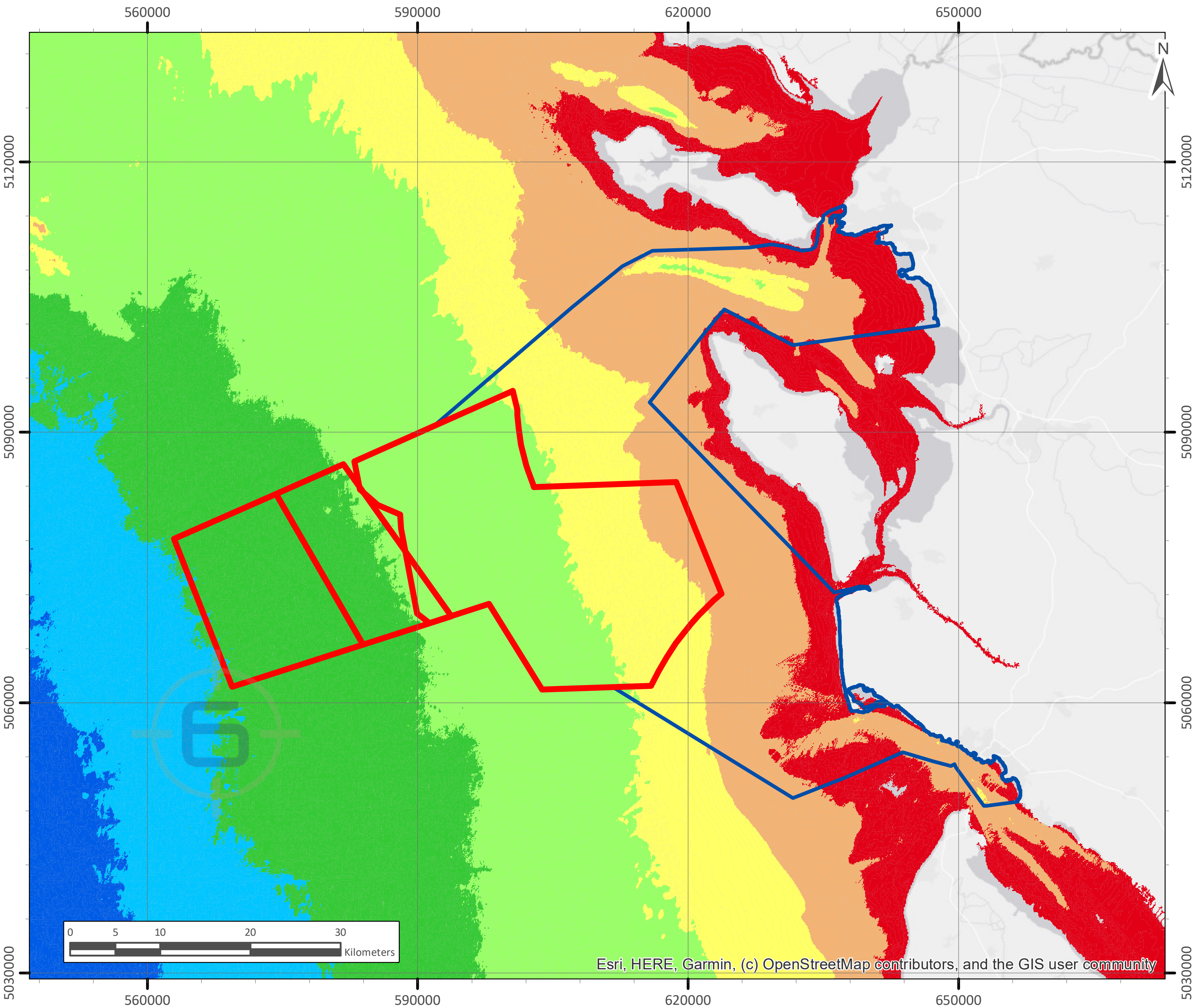
Appendix 14

Bathymetry



LEGEND

GENERAL

- OWF_Boundaries
- Export_Cable_Corridor

Water Depth (LAT)

- <10m
- <26m
- <40m
- <60m
- <80m
- <100m
- >100m

PROJECT	PROJECT TITLE
9407	AO7 OLERON OWF

DRAWING TITLE
Bathymetry

DRAWING NUMBER
AO7 Oleron OWF\014\V2.0

PURPOSE
FOR INFORMATION USE ONLY

alpha ASSOCIATES
special risks consultancy

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED		
WGS 1984 UTM Zone 30N	1:600,000	A4	LH	24/02/2023	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

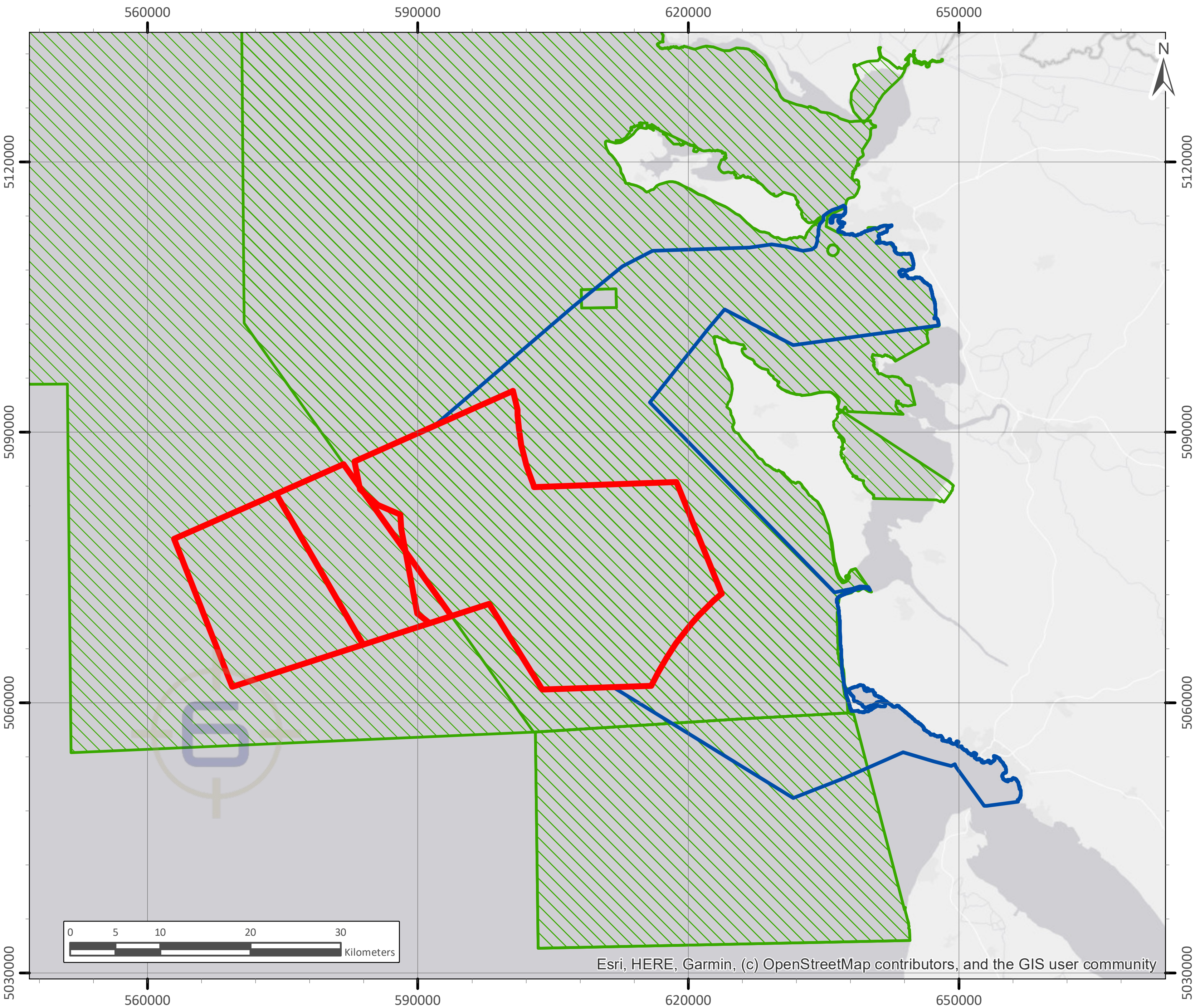
Appendix 15

Marine Protections Areas

LEGEND

GENERAL

- OWF_Boundaries
- Export_Cable_Corridor
- OSPAR_Marine_Protected_Area



PROJECT	PROJECT TITLE
9407	AO7 OLERON OWF

DRAWING TITLE
Marine Protection Areas

DRAWING NUMBER
AO7 Oleron OWF\015\V2.0

PURPOSE
FOR INFORMATION USE ONLY

alpha ASSOCIATES
special risks consultancy

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
WGS 1984 UTM Zone 30N	1:600,000	A4	LH	24/02/2023	LG

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Appendix 16

Semi-Quantitative Risk Assessment Tables

The tables produced on the following pages outline and display the numeric scored assessment for the project as well as the initial and residual UXO risk to each specific operation after mitigation measures have been appropriately applied. It is also important to note that the risk assessment for the various operations is conducted for each individual activity, irrespective of prior operations which may have taken place.

An explanation of the SQRA process and Azimuth risk matrix used by 6 Alpha Associates is presented at Annex B.

Risk (R) is calculated as a function of probability of encounter and initiation (P) and consequence of initiation (C), where R = P x C.

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Geotechnical Investigation Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
GI ~10m WD	Large Naval Mine	340	2	5	10	1	5	5	2	5	10	1	5	5
	Large HE Bomb	309.4	2	5	10	1	5	5	2	5	10	1	5	5
	Medium Naval Mine	145	2	5	10	1	5	5	2	5	10	1	5	5
	Medium HE Bomb	136.5	2	5	10	1	5	5	2	5	10	1	5	5
	Small HE Bomb	26	2	5	10	1	5	5	2	5	10	1	5	5
	Large Artillery Projectile	16.3	2	5	10	1	5	5	2	5	10	1	5	5
	Medium Artillery Projectile	3.91	2	3	6	1	3	3	2	3	6	1	3	3
	Small Artillery Projectile	0.006	2	1	2	1	1	1	2	1	2	1	1	1
	LMA Mine	390	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	5	5	1	5	5	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
GI ~26m WD	Large Naval Mine	340	2	5	10	1	5	5	2	5	10	1	5	5
	Large HE Bomb	309.4	2	5	10	1	5	5	2	5	10	1	5	5
	Medium Naval Mine	145	2	4	8	1	4	4	2	5	10	1	5	5
	Medium HE Bomb	136.5	2	4	8	1	4	4	2	5	10	1	5	5
	Small HE Bomb	26	2	3	6	1	3	3	2	5	10	1	5	5
	Large Artillery Projectile	16.3	2	2	4	1	2	2	2	5	10	1	5	5
	Medium Artillery Projectile	3.91	2	1	2	1	1	1	2	3	6	1	3	3
	Small Artillery Projectile	0.006	2	1	2	1	1	1	2	1	2	1	1	1
	LMA Mine	390	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	4	4	1	4	4	1	5	5	1	5	5

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
GI ~40m WD	Large Naval Mine	340	2	4	8	1	4	4	2	5	10	1	5	5
	Large HE Bomb	309.4	2	4	8	1	4	4	2	5	10	1	5	5
	Medium Naval Mine	145	2	3	6	1	3	3	2	5	10	1	5	5
	Medium HE Bomb	136.5	2	3	6	1	3	3	2	5	10	1	5	5
	Small HE Bomb	26	2	2	4	1	2	2	2	5	10	1	5	5
	Large Artillery Projectile	16.3	2	2	4	1	2	2	2	5	10	1	5	5
	Medium Artillery Projectile	3.91	2	1	1	1	1	1	2	3	6	1	3	3
	Small Artillery Projectile	0.006	2	1	1	1	1	1	2	1	2	1	1	1
	LMA Mine	390	1	4	4	1	4	4	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	3	3	1	3	3	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
GI ~60m WD	Large Naval Mine	340	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	309.4	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Naval Mine	145	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	136.5	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	26	1	1	1	1	1	1	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	1	1	1	1	1	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	2	2	1	2	2	1	5	5	1	5	5

Pre-Lay Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
PLGR + RC ~10m WD	Large Naval Mine	340	4	5	20	1	5	5	4	5	20	1	5	5
	Large HE Bomb	309.4	4	5	20	1	5	5	4	5	20	1	5	5
	Medium Naval Mine	145	4	5	20	1	5	5	4	5	20	1	5	5
	Medium HE Bomb	136.5	4	5	20	1	5	5	4	5	20	1	5	5
	Small HE Bomb	26	4	5	20	1	5	5	4	5	20	1	5	5
	Large Artillery Projectile	16.3	4	5	20	1	5	5	4	5	20	1	5	5
	Medium Artillery Projectile	3.91	4	3	12	1	3	3	4	3	12	1	3	3
	Small Artillery Projectile	0.006	4	1	4	1	1	1	4	1	4	1	1	1
	LMA Mine	390	3	5	15	1	5	5	3	5	15	1	5	5
	WWI Naval Torpedo	253.5	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Mine	141.1	2	5	10	1	5	5	2	5	10	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
PLGR + RC ~26m WD	Large Naval Mine	340	4	5	20	1	5	5	4	5	20	1	5	5
	Large HE Bomb	309.4	4	5	20	1	5	5	4	5	20	1	5	5
	Medium Naval Mine	145	4	4	16	1	4	4	4	5	20	1	5	5
	Medium HE Bomb	136.5	4	4	16	1	4	4	4	5	20	1	5	5
	Small HE Bomb	26	4	3	12	1	3	3	4	5	20	1	5	5
	Large Artillery Projectile	16.3	4	2	8	1	2	2	4	5	20	1	5	5
	Medium Artillery Projectile	3.91	4	1	4	1	1	1	4	3	12	1	3	3
	Small Artillery Projectile	0.006	4	1	4	1	1	1	4	1	4	1	1	1
	LMA Mine	390	3	5	15	1	5	5	3	5	15	1	5	5
	WWI Naval Torpedo	253.5	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Mine	141.1	2	4	8	1	4	4	2	5	10	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
PLGR + RC ~40m WD	Large Naval Mine	340	4	4	16	1	4	4	4	5	20	1	5	5
	Large HE Bomb	309.4	4	4	16	1	4	4	4	5	20	1	5	5
	Medium Naval Mine	145	4	3	12	1	3	3	4	5	20	1	5	5
	Medium HE Bomb	136.5	4	3	12	1	3	3	4	5	20	1	5	5
	Small HE Bomb	26	4	2	8	1	2	2	4	5	20	1	5	5
	Large Artillery Projectile	16.3	4	2	8	1	2	2	4	5	20	1	5	5
	Medium Artillery Projectile	3.91	4	1	4	1	1	1	4	3	12	1	3	3
	Small Artillery Projectile	0.006	4	1	4	1	1	1	4	1	4	1	1	1
	LMA Mine	390	3	4	12	1	4	4	3	5	15	1	5	5
	WWI Naval Torpedo	253.5	2	3	6	1	3	3	2	5	10	1	5	5
	WWI Naval Mine	141.1	2	3	6	1	3	3	2	5	10	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
PLGR + RC ~60m WD	Large Naval Mine	340	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	309.4	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Naval Mine	145	2	2	4	1	2	2	2	5	10	1	5	5
	Medium HE Bomb	136.5	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	26	1	1	1	1	1	1	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	1	1	1	1	1	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	2	2	1	2	2	1	5	5	1	5	5

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Cable Installation Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Surface Lay ~10m WD	Large Naval Mine	340	2	5	10	1	5	5	2	5	10	1	5	5
	Large HE Bomb	309.4	2	5	10	1	5	5	2	5	10	1	5	5
	Medium Naval Mine	145	2	5	10	1	5	5	2	5	10	1	5	5
	Medium HE Bomb	136.5	2	5	10	1	5	5	2	5	10	1	5	5
	Small HE Bomb	26	2	5	10	1	5	5	2	5	10	1	5	5
	Large Artillery Projectile	16.3	2	5	10	1	5	5	2	5	10	1	5	5
	Medium Artillery Projectile	3.91	2	3	6	1	3	3	2	3	6	1	3	3
	Small Artillery Projectile	0.006	2	1	2	1	1	1	2	1	2	1	1	1
	LMA Mine	390	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	5	5	1	5	5	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Surface Lay ~26m WD	Large Naval Mine	340	2	5	10	1	5	5	2	5	10	1	5	5
	Large HE Bomb	309.4	2	5	10	1	5	5	2	5	10	1	5	5
	Medium Naval Mine	145	2	4	8	1	4	4	2	5	10	1	5	5
	Medium HE Bomb	136.5	2	4	8	1	4	4	2	5	10	1	5	5
	Small HE Bomb	26	2	3	6	1	3	3	2	5	10	1	5	5
	Large Artillery Projectile	16.3	2	2	4	1	2	2	2	5	10	1	5	5
	Medium Artillery Projectile	3.91	2	1	2	1	1	1	2	3	6	1	3	3
	Small Artillery Projectile	0.006	2	1	2	1	1	1	2	1	2	1	1	1
	LMA Mine	390	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	4	4	1	4	4	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Surface Lay ~40m WD	Large Naval Mine	340	2	4	8	1	4	4	2	5	10	1	5	5
	Large HE Bomb	309.4	2	4	8	1	4	4	2	5	10	1	5	5
	Medium Naval Mine	145	2	3	6	1	3	3	2	5	10	1	5	5
	Medium HE Bomb	136.5	2	3	6	1	3	3	2	5	10	1	5	5
	Small HE Bomb	26	2	2	4	1	2	2	2	5	10	1	5	5
	Large Artillery Projectile	16.3	2	2	4	1	2	2	2	5	10	1	5	5
	Medium Artillery Projectile	3.91	2	1	1	1	1	1	2	3	6	1	3	3
	Small Artillery Projectile	0.006	2	1	1	1	1	1	2	1	2	1	1	1
	LMA Mine	390	1	4	4	1	4	4	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	3	3	1	3	3	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Surface Lay ~60m WD	Large Naval Mine	340	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	309.4	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Naval Mine	145	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	136.5	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	26	1	1	1	1	1	1	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	1	1	1	1	1	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	2	2	1	2	2	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jetting ~10m WD	Large Naval Mine	340	3	5	15	1	5	5	3	5	15	1	5	5
	Large HE Bomb	309.4	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Naval Mine	145	3	5	15	1	5	5	3	5	15	1	5	5
	Medium HE Bomb	136.5	3	5	15	1	5	5	3	5	15	1	5	5
	Small HE Bomb	26	3	5	15	1	5	5	3	5	15	1	5	5
	Large Artillery Projectile	16.3	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Artillery Projectile	3.91	3	3	9	1	3	3	3	3	9	1	3	3
	Small Artillery Projectile	0.006	3	1	3	1	1	1	3	1	3	1	1	1
	LMA Mine	390	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	5	5	1	5	5	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jetting ~26m WD	Large Naval Mine	340	3	5	15	1	5	5	3	5	15	1	5	5
	Large HE Bomb	309.4	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Naval Mine	145	3	4	12	1	4	4	3	5	15	1	5	5
	Medium HE Bomb	136.5	3	4	12	1	4	4	3	5	15	1	5	5
	Small HE Bomb	26	3	3	9	1	3	3	3	5	15	1	5	5
	Large Artillery Projectile	16.3	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	3.91	3	1	3	1	1	1	3	3	9	1	3	3
	Small Artillery Projectile	0.006	3	1	3	1	1	1	3	1	3	1	1	1
	LMA Mine	390	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	4	4	1	4	4	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jetting ~40m WD	Large Naval Mine	340	3	4	12	1	4	4	3	5	15	1	5	5
	Large HE Bomb	309.4	3	4	12	1	4	4	3	5	15	1	5	5
	Medium Naval Mine	145	3	3	9	1	3	3	3	5	15	1	5	5
	Medium HE Bomb	136.5	3	3	9	1	3	3	3	5	15	1	5	5
	Small HE Bomb	26	3	2	6	1	2	2	3	5	15	1	5	5
	Large Artillery Projectile	16.3	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	3.91	3	1	3	1	1	1	3	3	9	1	3	3
	Small Artillery Projectile	0.006	3	1	3	1	1	1	3	1	3	1	1	1
	LMA Mine	390	2	4	8	1	4	4	2	5	10	1	5	5
	WWI Naval Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	3	3	1	3	3	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jetting ~60m WD	Large Naval Mine	340	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	309.4	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Naval Mine	145	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	136.5	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	26	1	1	1	1	1	1	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	1	1	1	1	1	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	2	2	1	2	2	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Ploughing ~10m WD	Large Naval Mine	340	4	5	20	1	5	5	4	5	20	1	5	5
	Large HE Bomb	309.4	4	5	20	1	5	5	4	5	20	1	5	5
	Medium Naval Mine	145	4	5	20	1	5	5	4	5	20	1	5	5
	Medium HE Bomb	136.5	4	5	20	1	5	5	4	5	20	1	5	5
	Small HE Bomb	26	4	5	20	1	5	5	4	5	20	1	5	5
	Large Artillery Projectile	16.3	4	5	20	1	5	5	4	5	20	1	5	5
	Medium Artillery Projectile	3.91	4	3	12	1	3	3	4	3	12	1	3	3
	Small Artillery Projectile	0.006	4	1	4	1	1	1	4	1	4	1	1	1
	LMA Mine	390	3	5	15	1	5	5	3	5	15	1	5	5
	WWI Naval Torpedo	253.5	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Mine	141.1	2	5	10	1	5	5	2	5	10	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Ploughing ~26m WD	Large Naval Mine	340	4	5	20	1	5	5	4	5	20	1	5	5
	Large HE Bomb	309.4	4	5	20	1	5	5	4	5	20	1	5	5
	Medium Naval Mine	145	4	4	16	1	4	4	4	5	20	1	5	5
	Medium HE Bomb	136.5	4	4	16	1	4	4	4	5	20	1	5	5
	Small HE Bomb	26	4	3	12	1	3	3	4	5	20	1	5	5
	Large Artillery Projectile	16.3	4	2	8	1	2	2	4	5	20	1	5	5
	Medium Artillery Projectile	3.91	4	1	4	1	1	1	4	3	12	1	3	3
	Small Artillery Projectile	0.006	4	1	4	1	1	1	4	1	4	1	1	1
	LMA Mine	390	3	5	15	1	5	5	3	5	15	1	5	5
	WWI Naval Torpedo	253.5	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Mine	141.1	2	4	8	1	4	4	2	5	10	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Ploughing ~40m WD	Large Naval Mine	340	4	4	16	1	4	4	4	5	20	1	5	5
	Large HE Bomb	309.4	4	4	16	1	4	4	4	5	20	1	5	5
	Medium Naval Mine	145	4	3	12	1	3	3	4	5	20	1	5	5
	Medium HE Bomb	136.5	4	3	12	1	3	3	4	5	20	1	5	5
	Small HE Bomb	26	4	2	8	1	2	2	4	5	20	1	5	5
	Large Artillery Projectile	16.3	4	2	8	1	2	2	4	5	20	1	5	5
	Medium Artillery Projectile	3.91	4	1	4	1	1	1	4	3	12	1	3	3
	Small Artillery Projectile	0.006	4	1	4	1	1	1	4	1	4	1	1	1
	LMA Mine	390	3	4	12	1	4	4	3	5	15	1	5	5
	WWI Naval Torpedo	253.5	2	3	6	1	3	3	2	5	10	1	5	5
	WWI Naval Mine	141.1	2	3	6	1	3	3	2	5	10	1	5	5

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Ploughing ~60m WD	Large Naval Mine	340	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	309.4	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Naval Mine	145	2	2	4	1	2	2	2	5	10	1	5	5
	Medium HE Bomb	136.5	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	26	1	1	1	1	1	1	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	1	1	1	1	1	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	2	2	1	2	2	1	5	5	1	5	5

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Wind Turbine Generator Installation Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Piling ~26m WD	Large Naval Mine	340	3	5	15	1	5	5	3	5	15	1	5	5
	Large HE Bomb	309.4	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Naval Mine	145	3	4	12	1	4	4	3	5	15	1	5	5
	Medium HE Bomb	136.5	3	4	12	1	4	4	3	5	15	1	5	5
	Small HE Bomb	26	3	3	9	1	3	3	3	5	15	1	5	5
	Large Artillery Projectile	16.3	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	3.91	3	1	3	1	1	1	3	3	9	1	3	3
	Small Artillery Projectile	0.006	3	1	3	1	1	1	3	1	3	1	1	1
	LMA Mine	390	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	4	4	1	4	4	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Piling ~40m WD	Large Naval Mine	340	3	4	12	1	4	4	3	5	15	1	5	5
	Large HE Bomb	309.4	3	4	12	1	4	4	3	5	15	1	5	5
	Medium Naval Mine	145	3	3	9	1	3	3	3	5	15	1	5	5
	Medium HE Bomb	136.5	3	3	9	1	3	3	3	5	15	1	5	5
	Small HE Bomb	26	3	2	6	1	2	2	3	5	15	1	5	5
	Large Artillery Projectile	16.3	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	3.91	3	1	3	1	1	1	3	3	9	1	3	3
	Small Artillery Projectile	0.006	3	1	3	1	1	1	3	1	3	1	1	1
	LMA Mine	390	2	4	8	1	4	4	2	5	10	1	5	5
	WWI Naval Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	3	3	1	3	3	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Piling ~60m WD	Large Naval Mine	340	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	309.4	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Naval Mine	145	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	136.5	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	26	1	1	1	1	1	1	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	1	1	1	1	1	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	2	2	1	2	2	1	5	5	1	5	5

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Scour and Cable Protection Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Rock Emplacement ~10m WD	Large Naval Mine	340	3	5	15	1	5	5	3	5	15	1	5	5
	Large HE Bomb	309.4	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Naval Mine	145	3	5	15	1	5	5	3	5	15	1	5	5
	Medium HE Bomb	136.5	3	5	15	1	5	5	3	5	15	1	5	5
	Small HE Bomb	26	3	5	15	1	5	5	3	5	15	1	5	5
	Large Artillery Projectile	16.3	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Artillery Projectile	3.91	3	3	9	1	3	3	3	3	9	1	3	3
	Small Artillery Projectile	0.006	3	1	3	1	1	1	3	1	3	1	1	1
	LMA Mine	390	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	5	5	1	5	5	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Rock Emplacement ~26m WD	Large Naval Mine	340	3	5	15	1	5	5	3	5	15	1	5	5
	Large HE Bomb	309.4	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Naval Mine	145	3	4	12	1	4	4	3	5	15	1	5	5
	Medium HE Bomb	136.5	3	4	12	1	4	4	3	5	15	1	5	5
	Small HE Bomb	26	3	3	9	1	3	3	3	5	15	1	5	5
	Large Artillery Projectile	16.3	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	3.91	3	1	3	1	1	1	3	3	9	1	3	3
	Small Artillery Projectile	0.006	3	1	3	1	1	1	3	1	3	1	1	1
	LMA Mine	390	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	4	4	1	4	4	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Rock Emplacement ~40m WD	Large Naval Mine	340	3	4	12	1	4	4	3	5	15	1	5	5
	Large HE Bomb	309.4	3	4	12	1	4	4	3	5	15	1	5	5
	Medium Naval Mine	145	3	3	9	1	3	3	3	5	15	1	5	5
	Medium HE Bomb	136.5	3	3	9	1	3	3	3	5	15	1	5	5
	Small HE Bomb	26	3	2	6	1	2	2	3	5	15	1	5	5
	Large Artillery Projectile	16.3	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	3.91	3	1	3	1	1	1	3	3	9	1	3	3
	Small Artillery Projectile	0.006	3	1	3	1	1	1	3	1	3	1	1	1
	LMA Mine	390	2	4	8	1	4	4	2	5	10	1	5	5
	WWI Naval Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	3	3	1	3	3	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Rock Emplacement ~60m WD	Large Naval Mine	340	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	309.4	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Naval Mine	145	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	136.5	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	26	1	1	1	1	1	1	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	1	1	1	1	1	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	2	2	1	2	2	1	5	5	1	5	5

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Enabling Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
DP Vessels ~10m WD	Large Naval Mine	340	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	309.4	1	5	5	1	5	5	1	5	5	1	5	5
	Medium Naval Mine	145	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	136.5	1	5	5	1	5	5	1	5	5	1	5	5
	Small HE Bomb	26	1	5	5	1	5	5	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	5	5	1	5	5	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	3	3	1	3	3	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	5	5	1	5	5	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
DP Vessels ~26m WD	Large Naval Mine	340	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	309.4	1	5	5	1	5	5	1	5	5	1	5	5
	Medium Naval Mine	145	1	4	4	1	4	4	1	5	5	1	5	5
	Medium HE Bomb	136.5	1	4	4	1	4	4	1	5	5	1	5	5
	Small HE Bomb	26	1	3	3	1	3	3	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	1	1	1	1	1	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	4	4	1	4	4	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
DP Vessels ~40m WD	Large Naval Mine	340	1	4	4	1	4	4	1	5	5	1	5	5
	Large HE Bomb	309.4	1	4	4	1	4	4	1	5	5	1	5	5
	Medium Naval Mine	145	1	3	3	1	3	3	1	5	5	1	5	5
	Medium HE Bomb	136.5	1	3	3	1	3	3	1	5	5	1	5	5
	Small HE Bomb	26	1	2	2	1	2	2	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	1	1	1	1	1	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	4	4	1	4	4	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	3	3	1	3	3	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
DP Vessels ~60m WD	Large Naval Mine	340	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	309.4	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Naval Mine	145	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	136.5	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	26	1	1	1	1	1	1	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	1	1	1	1	1	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	2	2	1	2	2	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Vessel Anchoring ~10m WD	Large Naval Mine	340	2	5	10	1	5	5	2	5	10	1	5	5
	Large HE Bomb	309.4	2	5	10	1	5	5	2	5	10	1	5	5
	Medium Naval Mine	145	2	5	10	1	5	5	2	5	10	1	5	5
	Medium HE Bomb	136.5	2	5	10	1	5	5	2	5	10	1	5	5
	Small HE Bomb	26	2	5	10	1	5	5	2	5	10	1	5	5
	Large Artillery Projectile	16.3	2	5	10	1	5	5	2	5	10	1	5	5
	Medium Artillery Projectile	3.91	2	3	6	1	3	3	2	3	6	1	3	3
	Small Artillery Projectile	0.006	2	1	2	1	1	1	2	1	2	1	1	1
	LMA Mine	390	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	5	5	1	5	5	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Vessel Anchoring ~26m WD	Large Naval Mine	340	2	5	10	1	5	5	2	5	10	1	5	5
	Large HE Bomb	309.4	2	5	10	1	5	5	2	5	10	1	5	5
	Medium Naval Mine	145	2	4	8	1	4	4	2	5	10	1	5	5
	Medium HE Bomb	136.5	2	4	8	1	4	4	2	5	10	1	5	5
	Small HE Bomb	26	2	3	6	1	3	3	2	5	10	1	5	5
	Large Artillery Projectile	16.3	2	2	4	1	2	2	2	5	10	1	5	5
	Medium Artillery Projectile	3.91	2	1	2	1	1	1	2	3	6	1	3	3
	Small Artillery Projectile	0.006	2	1	2	1	1	1	2	1	2	1	1	1
	LMA Mine	390	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	4	4	1	4	4	1	5	5	1	5	5

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Vessel Anchoring ~40m WD	Large Naval Mine	340	2	4	8	1	4	4	2	5	10	1	5	5
	Large HE Bomb	309.4	2	4	8	1	4	4	2	5	10	1	5	5
	Medium Naval Mine	145	2	3	6	1	3	3	2	5	10	1	5	5
	Medium HE Bomb	136.5	2	3	6	1	3	3	2	5	10	1	5	5
	Small HE Bomb	26	2	2	4	1	2	2	2	5	10	1	5	5
	Large Artillery Projectile	16.3	2	2	4	1	2	2	2	5	10	1	5	5
	Medium Artillery Projectile	3.91	2	1	1	1	1	1	2	3	6	1	3	3
	Small Artillery Projectile	0.006	2	1	1	1	1	1	2	1	2	1	1	1
	LMA Mine	390	1	4	4	1	4	4	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	3	3	1	3	3	1	5	5	1	5	5

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Vessel Anchoring ~60m WD	Large Naval Mine	340	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	309.4	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Naval Mine	145	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	136.5	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	26	1	1	1	1	1	1	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	1	1	1	1	1	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	2	2	1	2	2	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jack-Up Barge ~10m WD	Large Naval Mine	340	3	5	15	1	5	5	3	5	15	1	5	5
	Large HE Bomb	309.4	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Naval Mine	145	3	5	15	1	5	5	3	5	15	1	5	5
	Medium HE Bomb	136.5	3	5	15	1	5	5	3	5	15	1	5	5
	Small HE Bomb	26	3	5	15	1	5	5	3	5	15	1	5	5
	Large Artillery Projectile	16.3	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Artillery Projectile	3.91	3	3	9	1	3	3	3	3	9	1	3	3
	Small Artillery Projectile	0.006	3	1	3	1	1	1	3	1	3	1	1	1
	LMA Mine	390	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	5	5	1	5	5	1	5	5	1	5	5

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jack-Up Barge ~26m WD	Large Naval Mine	340	3	5	15	1	5	5	3	5	15	1	5	5
	Large HE Bomb	309.4	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Naval Mine	145	3	4	12	1	4	4	3	5	15	1	5	5
	Medium HE Bomb	136.5	3	4	12	1	4	4	3	5	15	1	5	5
	Small HE Bomb	26	3	3	9	1	3	3	3	5	15	1	5	5
	Large Artillery Projectile	16.3	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	3.91	3	1	3	1	1	1	3	3	9	1	3	3
	Small Artillery Projectile	0.006	3	1	3	1	1	1	3	1	3	1	1	1
	LMA Mine	390	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	4	4	1	4	4	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jack-Up Barge ~40m WD	Large Naval Mine	340	3	4	12	1	4	4	3	5	15	1	5	5
	Large HE Bomb	309.4	3	4	12	1	4	4	3	5	15	1	5	5
	Medium Naval Mine	145	3	3	9	1	3	3	3	5	15	1	5	5
	Medium HE Bomb	136.5	3	3	9	1	3	3	3	5	15	1	5	5
	Small HE Bomb	26	3	2	6	1	2	2	3	5	15	1	5	5
	Large Artillery Projectile	16.3	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	3.91	3	1	3	1	1	1	3	3	9	1	3	3
	Small Artillery Projectile	0.006	3	1	3	1	1	1	3	1	3	1	1	1
	LMA Mine	390	2	4	8	1	4	4	2	5	10	1	5	5
	WWI Naval Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	3	3	1	3	3	1	5	5	1	5	5

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jack-Up Barge ~60m WD	Large Naval Mine	340	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	309.4	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Naval Mine	145	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	136.5	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	26	1	1	1	1	1	1	1	5	5	1	5	5
	Large Artillery Projectile	16.3	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	3.91	1	1	1	1	1	1	1	3	3	1	3	3
	Small Artillery Projectile	0.006	1	1	1	1	1	1	1	1	1	1	1	1
	LMA Mine	390	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	141.1	1	2	2	1	2	2	1	5	5	1	5	5

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Appendix 17

UXO Risk Zones

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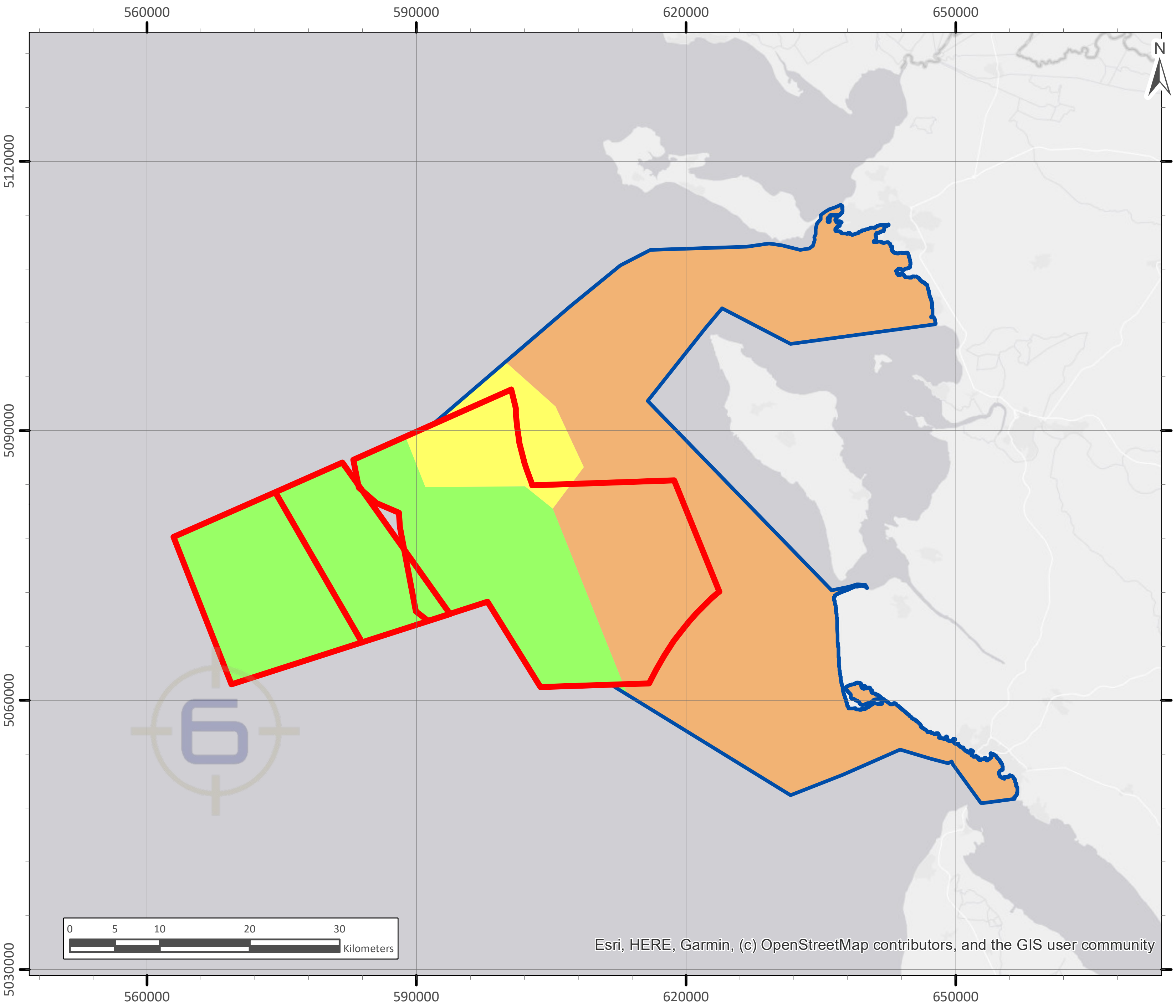

LEGEND

GENERAL

- OWF_Boundaries
- Export_Cable_Corridor

Risk_Rating

- HIGH
- MEDIUM
- LOW

PROJECT	PROJECT TITLE
9407	AO7 OLERON OWF

DRAWING TITLE

UXO Risk Zones - All Operations

DRAWING NUMBER

AO7 Oleron OWF\017A\V2.0

PURPOSE

FOR INFORMATION USE ONLY

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED	
WGS 1984 UTM Zone 30N	1:600,000	A4	LH	27/02/2023	LG	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please forward to 6 Alpha.

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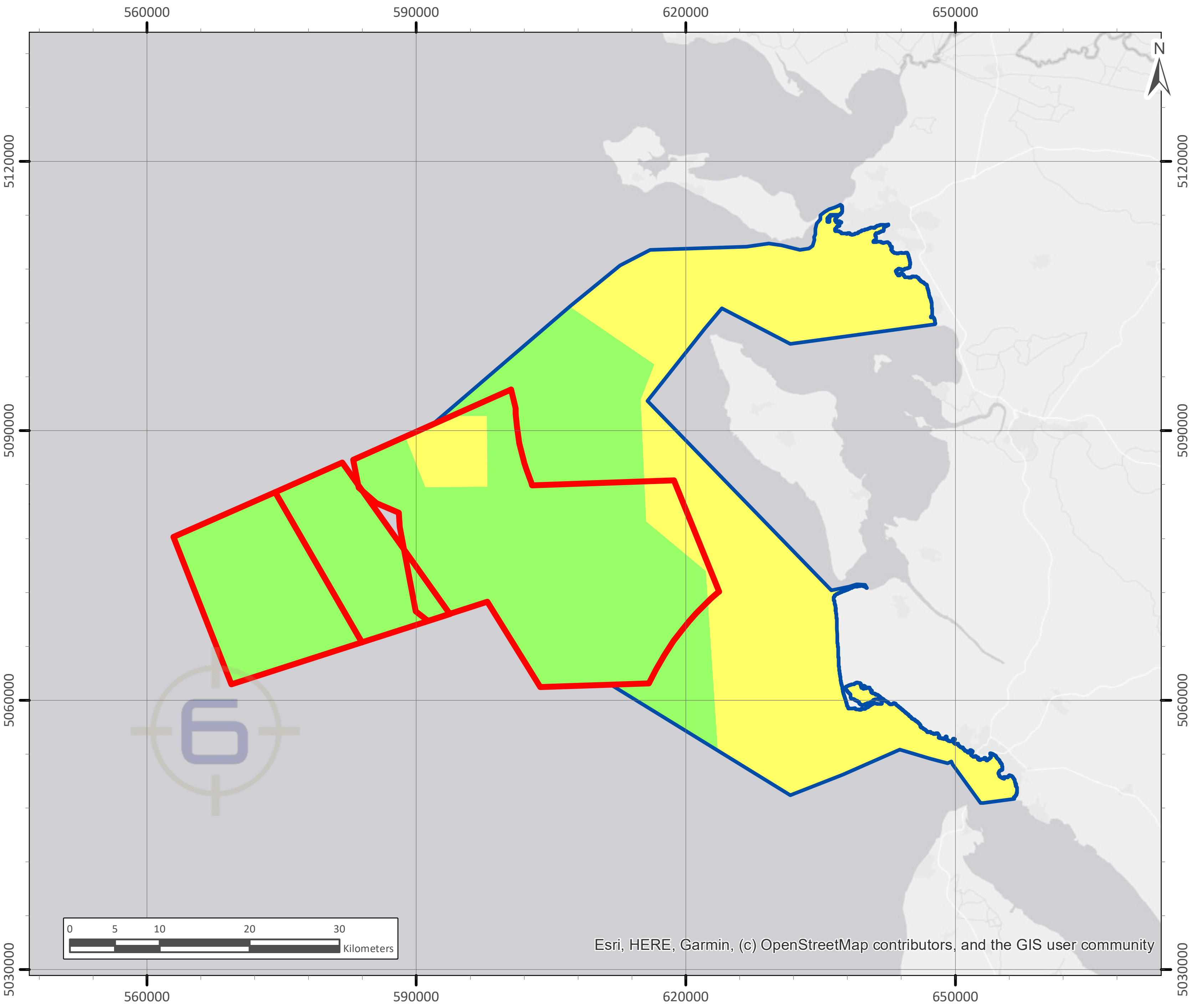


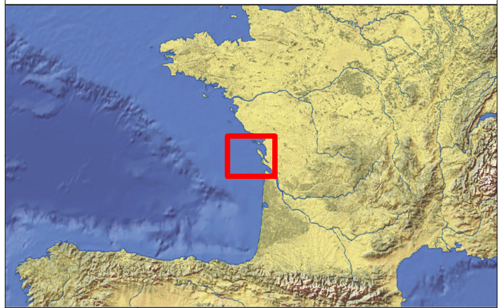
LEGEND

GENERAL

- OWF_Boundaries
- Export_Cable_Corridor

Risk_Rating

- HIGH
- MEDIUM
- LOW



PROJECT	PROJECT TITLE
9407	AO7 OLERON OWF

DRAWING TITLE

UXO Risk Zones - GI Operations

DRAWING NUMBER

AO7 Oleron OWF\017B\V2.0

PURPOSE

FOR INFORMATION USE ONLY

alpha ASSOCIATES

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
WGS 1984 UTM Zone 30N	1:600,000	A4	LH	27/02/2023	LG

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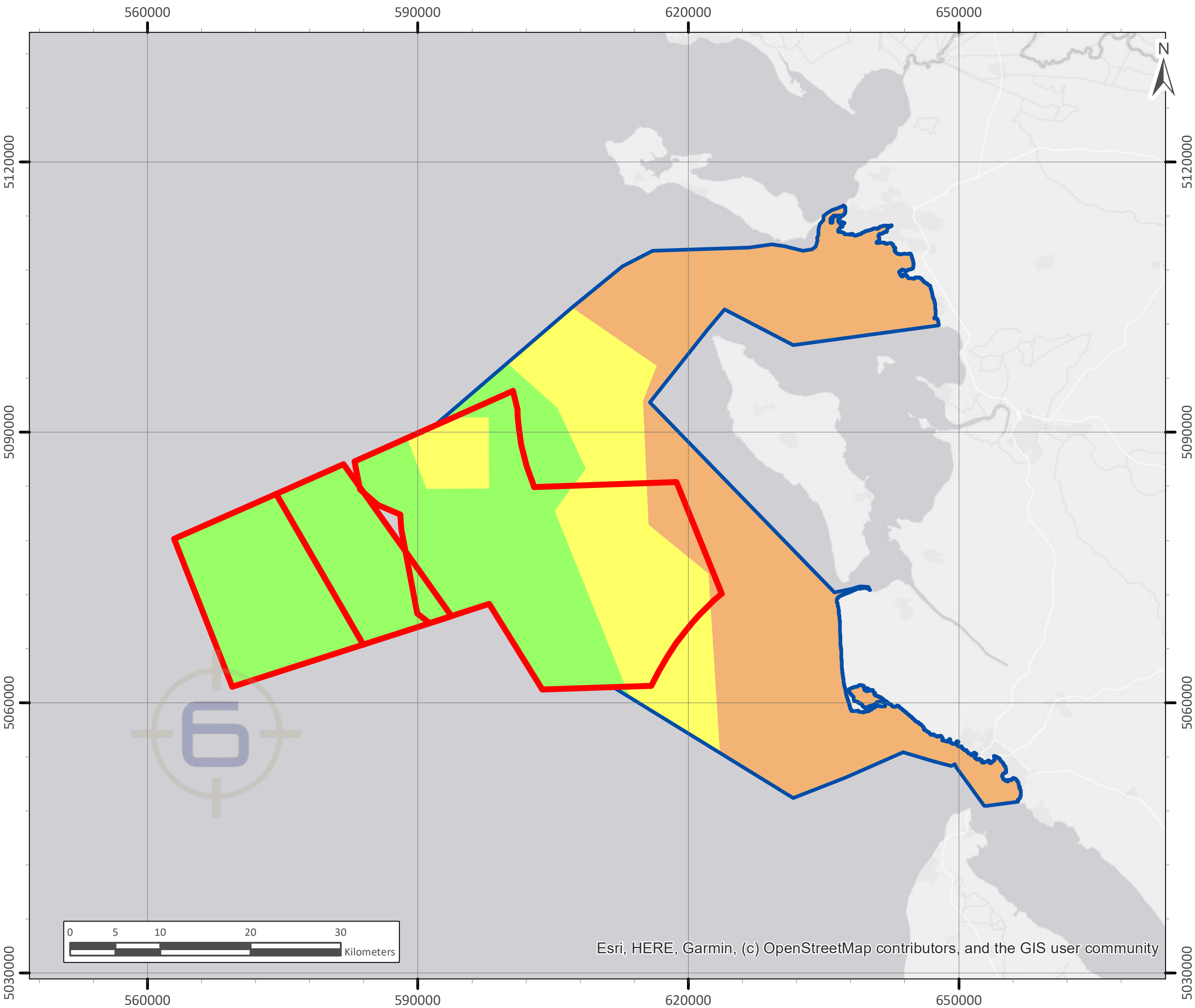

LEGEND

GENERAL

- OWF_Boundaries
- Export_Cable_Corridor

Risk_Rating

- HIGH
- MEDIUM
- LOW

PROJECT	PROJECT TITLE
9407	AO7 OLERON OWF

DRAWING TITLE

UXO Risk Zones - Enabling Operations

DRAWING NUMBER

AO7 Oleron OWF\017C\V2.0

PURPOSE

FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
WGS 1984 UTM Zone 30N	1:600,000	A4	LH	27/02/2023	LG

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Annexes

Annex A

Legislation and UXO Risk Management

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1 Legislation and UXO Risk Management

1.1 Introduction

The law requires that the client fulfils both their statutory and legal duties to protect those that may be exposed to harm. In the event of an UXO incident that causes harm, failure to adequately manage the UXO risk may lead to the prosecution and imprisonment of those deemed responsible for breaching their duty of care. The following sections outline national legislation, industry good practice, the ALARP principle, the assumptions made of the client's risk tolerance, as well as the expected behavioural responses of the project stakeholders when confronted with the UXO risk.

1.2 European Union Directives and National Legislation

The primary regulation, and minimum standard requirement for all European Union (EU) countries and businesses, residing in and/or working within the EU, is the Council Directive 89/391/EEC – OSH "Framework Directive" of 12th June 1989, on the introduction of measures to encourage improvements in the safety and health of workers at work. This framework directive contains basic obligations for employers and workers, with emphasis on the employer's obligation to ensure the safety and health of workers in every aspect related to work, without imposing financial costs on the worker to achieve this aim. From this legally binding EU directive, the minimum standards and fundamental principles (such as risk assessment) were passed into national law and enforced by the EU member states.

By contracting a UXO risk management consultant, the client has drawn upon help from a competent person to perform a risk assessment and to assess and advise upon the UXO risk posed to the client's employees and contractors. In doing so, the client has acted in compliance with the legal duties required as dictated in the above legislation. 6 Alpha Associates has acted based on the guidance of industry good practice, professional risk management, explosive ordnance disposal (EOD) experience, and its interpretation of the law.

In the end, it is for both national and EU courts to decide whether the client has acted in compliance with the law, and to determine if sufficient risk management and mitigation measures were undertaken and effectively applied.

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 risk in the marine environment (CIRIA C754, published 2016, London). CIRIA is a neutral, non-government, non-profit body linking organisations with common interests, that collaborate with the aim of improving and setting an agreed level of minimum industry standards.

The CIRIA C754 guide therefore represents an industry agreed standard for the assessment and management of UXO risk, which has been judged and recognised by the Health and Safety Executive (HSE) of the UK as a minimum standard or source of good practice, that satisfies the law when applied in an appropriate manner.

For UXO assessment and risk management, 6 Alpha Associates assesses itself against the CIRIA C754 guide to ensure compliance with the minimum legal requirements of industry good practice to manage UXO risks to as low as reasonably practicable (ALARP).

1.4 Reducing Risks to ALARP

Reducing risks to ALARP is the concept of weighing a risk against the resources (effort, time, and money) required 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 to the project, whilst also fulfilling their legal obligations.

Industry good practice in the form of CIRIA C754 guide, offers the direction as to assessing both ALARP and the risk tolerance, so that an agreement amongst the stakeholders can be reached as to what the ALARP level is, and what resources are required to achieve it. ALARP therefore describes the level to which risks are controlled, as determined by good practice.

Confirming that the UXO risks have been reduced to ALARP involves weighing the residual risk against the resources to further reduce it. 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 is presented at Figure 1.

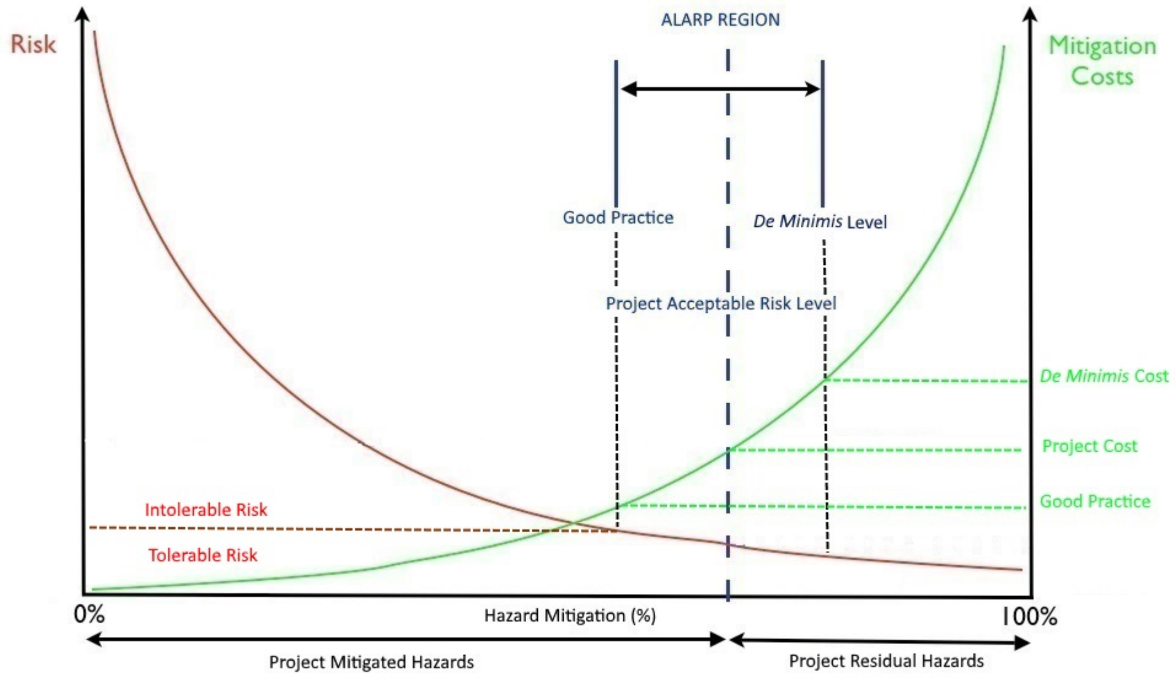

Figure 1: The ALARP principle of managing risk.

1.5 UXO Risk Tolerance

6 Alpha Associates have made certain assumptions about the client's tolerance of UXO risk. Our assumptions include that the following interrelated elements are to be considered when determining the projects UXO risk tolerances:

- **Corporate Governance** – is the system of rules, practices, and processes by which companies are managed and controlled. It is assumed that the client will wish to adhere to the highest international standards of corporate governance. Discharge of corporate responsibility is expected to be on risk based criteria and it is expected that the client will have in place a framework for managing risk for good governance. It is anticipated that safety and risk management are integrated in the client's business culture and be actively applied throughout the project.
- **Risk Management** – the client will expect the highest standard of risk and safety management to be applied to this project and will have a risk management system in place for responding to business, programme, and project risks. The client will rely upon help from a competent person to identify UXO risks, but also to design appropriate UXO risk management solutions in accordance with industry good practice. Any risks posed by UXO must be assessed based upon probability and consequence criteria. Potential UXO targets must be avoided or otherwise

mitigated not only in accordance with the law, but also with CIRIA C754 industry guidelines. A competent person will oversee the UXO geophysical survey and the UXO risk mitigation contractors who are responsible for the subsequent execution of those works, ensuring they are performed to appropriate quality and meet good practice standards.

- **Safety** – personnel safety will assume the highest priority for the 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.

1.6 UXO Risk Behaviour

UXO incidents that result in harm to construction personnel, are generally termed an extreme, or a low probability-high consequence (LP-HC) event. Given the ambiguity and uncertainty surrounding such events, project stakeholders may respond to the risk in an extreme manner, and demand a disproportionate level of risk mitigation. The client should be aware of the following common responses and attitudes to LP-HC risks, to manage stakeholder expectations of the UXO risk throughout the project's life cycle. There are three general behavioural patterns for dealing with LP-HC events (Kunreuther, 1995):

1) Individuals do not think probabilistically and demand zero risk when costs do not need to be absorbed. Alternatively, when individuals do need to absorb the cost themselves, they are more likely to tolerate very high probability risks.

2) Risk is a multidimensional problem which cannot be simply measured quantitively, such as the number of fatalities per year. Risk tends to be influenced by people's 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 accordingly.

3) Given the lack of knowledge over the probability of these event, people are more likely to use simple decision making measures, such as threshold values. The general perception is, that the probability of LP-HC risks is too low to possibly occur, and as a result not take adequate steps to protect themselves.

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

- A desire for zero risk;
- A concern for future generations;

- Denial that the event can ever happen to them;
- A perception that the situation is under their control and therefore can never happen;
- That the hazard is perceived to be benign after a certain amount of time;
- Short sighted behaviour and an aversion to spend today to reap the potential benefits later.

1.7 References

1) Kunreuther, H., 1995, Protection against low probability high consequence events.

Annex B

Semi-Quantitative Risk Assessment Methodology

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1 Semi-Quantitative Risk Assessment

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 x 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.

Likelihood – Probability of Encounter and Initiation	Consequences – Consequence of 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: *6 Alpha Associates*' UXO Risk Matrix

The numerical values assigned to the UXO risk are compared to Table 2, 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.

Risk Rating (P x C)	Grading	Risk Tolerance	Action Required to Achieve UXO Risks ALARP
1	Very Low Risk	Tolerable	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.
2-5	Low Risk		
6-10	Medium Risk	Potentially Tolerable	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.
12-20	High Risk	Intolerable	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.
25	Very High Risk		

Table 2: *6 Alpha Associates*' Project Risk Tolerability

1.3 Calculating the Project's Probability of Encounter and Initation

At the strategic level, and for risk assessment purposes, *6 Alpha Associates* 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 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 ordnance 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 an ordnance 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 an ordnance 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 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 Projects 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 5, 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 5: Consequence Rating of an unplanned UXO 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

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1 Classification of Unexploded Ordnance

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

Unexploded ordnance 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 Charge

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 Torpedo

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

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1 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 World War One and Two (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

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 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 *Bay of Biscay* was a significant a naval theatre of war in both WWI and WWII, given its proximity to *France* and its position along *Atlantic* shipping routes. 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 coastlines of *Charente-Maritime* and *Gironde* were 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 in the *Bay of Biscay* 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 the *Bay of Biscay* to this day, as demonstrated by the following publicly accessible news article summarising encounters with historic munitions.

World War II bomb injures French beachgoer

Bomb on the beach. A 40-year-old holiday maker was lightly burned after a World War II-era phosphor bomb detonated on August 27th. Archive photo: Theo Heimann/AFP

A holiday-maker in south-western France got an unexpected 'blast from the past' this week, after a bomb dating from World War II detonated and left him with burns to his body.

The 40-year-old man was on the 'Grande conche' beach at Royan, in the Charentes-Maritime region on Tuesday afternoon, when his children reported seeing something strange close to the water.

On investigating, the curious holiday-maker found what looked like a rusty tube covered in barnacles, but was in fact an undetonated phosphorous bomb from World War II.

He began handling the device, and to his shock it burst into flames, leaving him with light burns to his legs and lower abdomen.

At around 3.30 pm, beach security called in the emergency services and the bomb disposal squad from nearby La Rochelle, which neutralised the device.

A 50-metre safety perimeter was put in place, but lifted some three hours later.

"The victim was hospitalised and should be kept under observation until Thursday, in order to do some tests," a representative from the local fire brigade told French TV TF1.

"Phosphorous can cause blood poisoning," he added.

During World War II, Royan was at one time home to small pockets of German fighters, whose efforts attracted heavy bombing from Allied Forces.

This isn't the first time in recent memory that a World War II relic has caused panic in France.

In January 2012, authorities in the southern city of Marseille had to evacuate thousands of residents while disposing of an unexploded 250 kg US aircraft bomb dating from World War II.

Dan MacGuill, *World War II bomb injures French beachgoer*, 28th August 2013.
https://www.thelocal.fr/20130828/curious-french-beachgoer-burned-by-world-war-ii-bomb/

La Rochelle: Une mine de la Seconde Guerre mondiale neutralisée à 45 mètres de profondeur

Publié le 26 mars 2017 par 20Minutes

SECURITE C'est le navire chasseur de mines « Pégase » de la marine nationale qui a localisé l'engin jeudi matin, dans le chenal d'accès au port de la Rochelle...

Le pégase est un chasseur de mines de la Marine Nationale, qui a permis de localiser la mine sous-marine, dans le chenal d'accès au port de la Rochelle. - SIRPA / AFP

L'opération délicate s'est bien passée. Une mine anglaise de la Seconde Guerre mondiale a été neutralisée avec succès dans le chenal d'accès au port de La Rochelle, à plus de 45 mètres de profondeur, a annoncé vendredi la préfecture maritime de l'Atlantique.

Une mine de 408 kilos

La neutralisation a été effectuée jeudi en fin d'après-midi par le chasseur de mines tripartites « Pégase » dans le Pertuis d'Antioche, chenal d'accès au port de La Rochelle. Ce chasseur avait découvert jeudi matin cette « mine historique anglaise de type AMK1». Elle était immergée à 45 mètres de profondeur, pour un poids de 408 kg équivalent TNT.

Un avis aux navigateurs a été immédiatement diffusé auprès des usagers de la mer et un périmètre de sécurité mis en place autour de la zone d'opération de déminage.

« En raison de l'immersion importante, l'explosion de la mine n'a provoqué qu'un léger frémissement à la surface », a précisé la préfecture maritime.

Mémoires de Guerre, *La Rochelle: Une mine de la Seconde Guerre mondiale neutralisée à 45 mètres de profondeur*, 26th March 2017.
https://www.memoiresdeguerre.com/2017/04/la-rochelle-une-mine-de-la-seconde-guerre-mondiale-neutralisee-a-45-metres-de-profondeur.html

MAIB
MARINE ACCIDENT INVESTIGATION BRANCH

PRELIMINARY ASSESSMENT

SERIOUS MARINE CASUALTY

December 2020

Preliminary assessment of the explosion resulting in damage and abandonment of the potting fishing vessel *Galwad-Y-Mor* (BRD116) 22 nautical miles north of Cromer, Norfolk on 15 December 2020

The information contained in this preliminary assessment is based on investigations to date. Readers are cautioned that new evidence may become available that might alter the circumstances as depicted in this statement, and the MAIB's final report of this accident.

NARRATIVE

On 15 December 2020, *Galwad-Y-Mor* was operating in potting fishing grounds east of the Wash **(Figure 1)**. At about 1120, the crew was in the process of hauling in a string of crab pots; the skipper was in the wheelhouse with other crew members below decks working the pots. The hauler was being used to heave in the back rope, and the crew had let the skipper know that there was a lot of tension on the line, when there was an unexpected explosion.

Galwad-Y-Mor was thrown up from the sea surface, then landed heavily back down; all propulsion and electrical power was immediately lost. The skipper was injured and dazed, but conscious, and saw that the wheelhouse had been completely wrecked. As he became aware that other crew members had been badly injured and that the engine room was flooding, the skipper ordered the crew to abandon ship. He also raised the alarm by texting the skipper of a sister vessel and activating the electronic position indicating radio beacon.

Image courtesy of Macduff Ship Designs

Galwad-Y-Mor

Extract from The United Kingdom Merchant Shipping (Accident Reporting and Investigation) Regulations 2012 – Regulation 5:

"The sole objective of a safety investigation into an accident under these Regulations shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of such an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

NOTE

This report is not written with litigation in mind and, pursuant to Regulation 14(14) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

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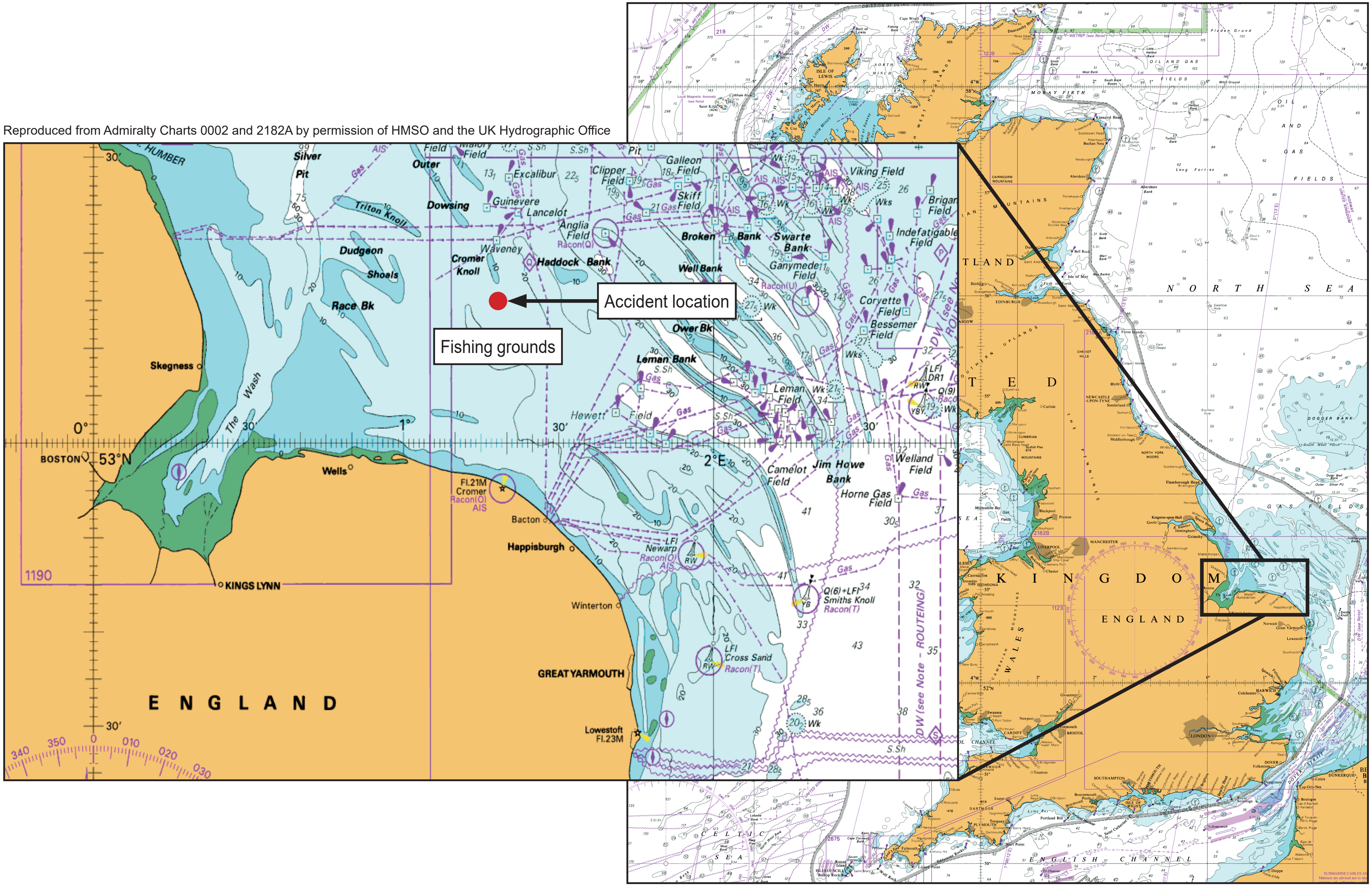


Figure 1: Charts showing the fishing grounds and accident location

Although the liferaft had been manually activated, all crew members were initially rescued by the offshore support vessel, *Esvagt Njord*, then transferred ashore to hospital by helicopter and lifeboat. The abandoned *Galwad-Y-Mor*, which had settled low in the water **(Figure 2)**, was towed to Grimsby by the tug, *GPS Avenger*, then lifted out of the water.

Figure 2: *Galwad-Y-Mor*, low in the water, after the abandonment

VESSEL AND CREW

Galwad-Y-Mor was a 12.9m registered length, potting fishing vessel built in 2007. It was powered by a 268kW main engine driving a single, fixed-pitch propeller; deck machinery included a crane and hauler for handling pots.

There were seven crew on board, two UK nationals and five Latvians. All crew members suffered injuries, some life-changing, during the explosion.

INVESTIGATION

MAIB inspectors attended *Galwad-Y-Mor* once it had been lifted ashore in Grimsby. A summary of the key areas of damage was:

- Extensive shell plating indentation between frames **(Figure 3)**
- Shell plating ruptures and shearing of a seawater suction
- Main engine displaced from bedplate
- Widespread and significant levels of destruction of the wheelhouse **(Figure 4)** and other internal compartments
- Buckling of internal bulkheads and warping of decks
- Widespread damage to upper deck fittings.

There was no evidence of an internal explosion.

Figure 3: Detail of shell plating damage showing coating loss and indentation between internal frames

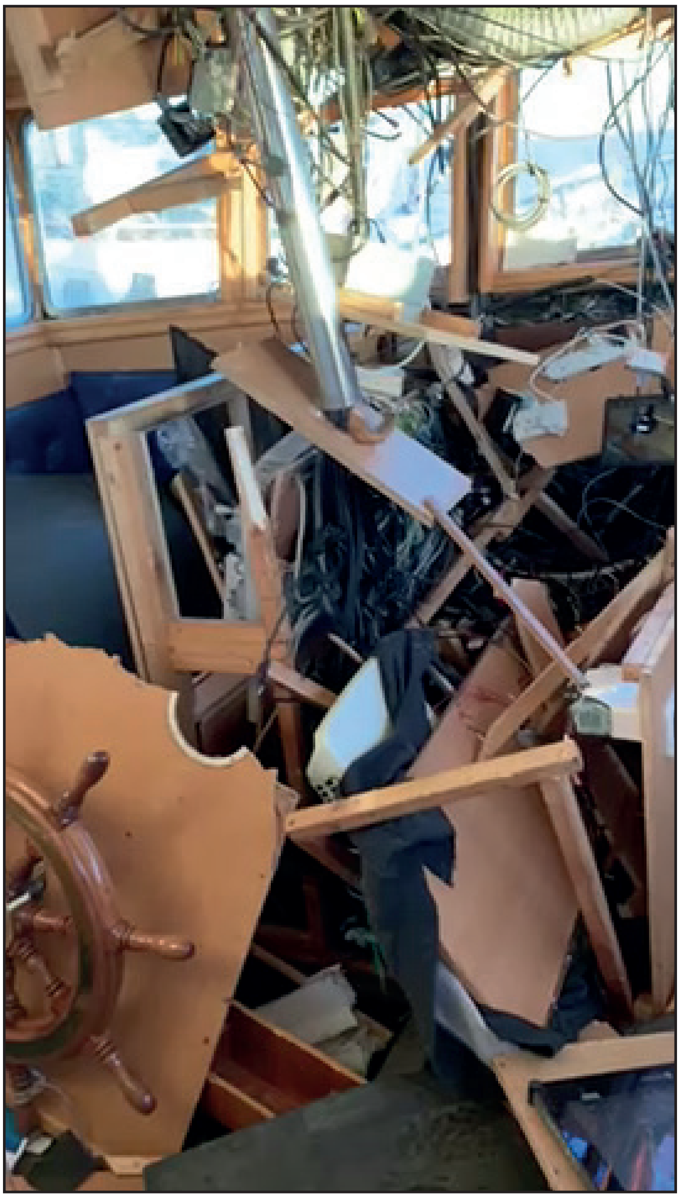


Figure 4: Wheelhouse destruction by shock damage

PRELIMINARY ASSESSMENT

While recovering crab pots using its hauler, *Galwad-Y-Mor* was extensively damaged and serious injuries were inflicted on the crew by an explosion. The explosion was in the water and external to the vessel. There was nothing that the crew could have done to prevent the accident. The source of the explosion has not been determined, but it was possible that old munitions on the seabed were disturbed as the vessel hauled its pots. Although extensively damaged and flooded, it is almost certain that *Galwad-Y-Mor* stayed afloat because the bulkheads either side of the engine room maintained their watertight integrity, containing the flood.

ONGOING ACTION

The MAIB has notified other relevant agencies including: the Maritime and Coastguard Agency, the Receiver of Wreck and the Ministry of Defence. The MAIB investigation is ongoing and a report of the accident will be published in due course.

SHIP PARTICULARS	
Vessel's name	*Galwad-Y-Mor*
Flag	United Kingdom
Fishing numbers	BRD116
Type	Potting fishing vessel
Registered owner	Galwad-Y-Mor Shellfish Limited
Construction	2007
Year of build	Steel
Length overall	14.95m
Registered length	12.90m
Authorised cargo	Shellfish

VOYAGE PARTICULARS	
Port of departure	Grimsby
Port of arrival	Grimsby
Type of voyage	Commercial
Cargo information	Shellfish
Manning	7

MARINE CASUALTY INFORMATION	
Date and time	15 December 2020, 1120 UTC
Type of marine casualty or incident	External explosion (Serious Marine Casualty)
Location of incident	53°18.53'N 001°13.25'E
Place on board	Hull and all compartments
Injuries/fatalities	Significant, including life-changing injures – full details not being disclosed with this report
Damage/environmental impact	Extensive damage to hull, including shell plating breaches, engine room flooded and severe shock damage in all internal compartments
Ship operation	Fishing, recovering crab pots
Voyage segment	In operation
External and internal environment	Wind, south-westerly force 3-4; sea state, slight/moderate; visibility good.
Persons on board	7

Annex F

Ordnance Burial, Scour and Migration

1 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 ALARP sign-off certificate, as well as the expansion size of the avoidance radii.

1.2 Physical Environment

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

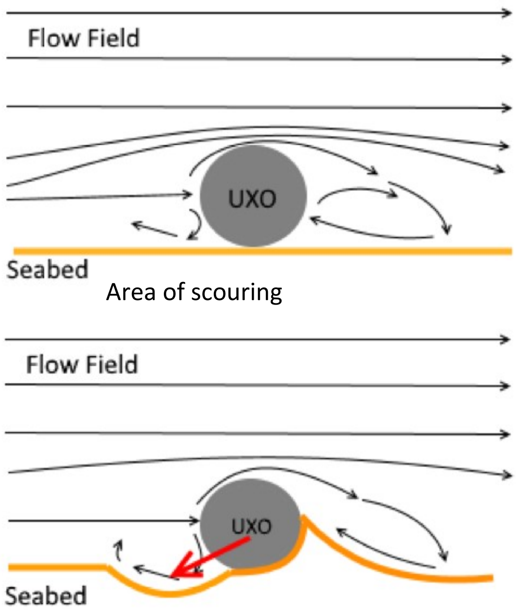
The nature of the sediments on any site is important for understanding the prospective movement of UXO. The ability of sediments to allow for either full or partial burial of such objects, is key to understanding the potential for scour, burial and the future mobility of the UXO item.

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.

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: 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.

Annex G

UXO Detection Methods

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1 UXO Detection Methods

1.1 Overview

There are several systems and underwater tools available on the commercial market for detecting unexploded ordnance (UXO). Generally, UXO detection methods rely on either one or more of the following ordnance properties: the known physical dimensions of the threat items likely to be encountered upon the site, whether the ordnance casing is metallic, and/or whether the ordnance casing comprises a ferrous metal for most ordnance types. The other property that an item of UXO has which classifies it from benign debris, is the explosive content. However, marine explosive detectors are still at the experimental stage and currently not widely utilised.

UXO detection is accomplished by utilising one or more of the following methods:

- Visual detection methods;
- Magnetic methods;
- Electromagnetic methods;
- Acoustic methods.

1.2 Visual Detection

A visual inspection typically employs a remotely operated vehicle (ROX) or diver, to inspect the seabed at the site of the intrusive investigation, installation or construction operation and detect any UXO present. The classification of any potential UXO targets found is performed simultaneously during the visual inspection. An ROV or diver is typically equipped with a pulse induction metal detector, to detect any shallow buried potential UXO targets, or to search for and relocate any marked potential UXO targets. The costs of performing a visual inspection across an extensive area of the seabed makes visual detection of UXO a more appropriate method for small specific locations.

1.3 Magnetic Methods

Magnetic methods for UXO detection, relies on the ferrous metal content of the UXO item producing a local magnetic distortion/anomaly of the Earth's magnetic field. This magnetic distortion will occur even when the ferrous source is buried under the seabed. Magnetometer sensors are typically employed to provide a scalar or vector measurement of the Earth's magnetic field. A suitably qualified interpreter may then record the positions of these anomalies for further target classification.

Magnetometers for UXO detection are generally regarded as the main detection methods for UXO and allow flexibility in the towing arrangement for rapid geophysical acquisition of extensive survey areas. Diurnal fluctuations of the Earth's magnetic field may be eliminated by towing two or more magnetometers in a gradiometer arrangement. As a gradiometer, the magnetometers measure the rate of change of the magnetic field distortion in one or more axial planes and have the benefit over a conventional single magnetometer of an improved signal to noise ratio, permitting the detection of smaller ferrous sources. Geology with a high susceptibility to magnetisation, will act as a source of magnetic noise potentially masking potential UXO targets from detection. Ordnance casing made from non-ferrous metals, such as aluminium, are undetectable by magnetometers as are any other non-ferrous debris occurring upon the site.

1.4 Electromagnetic Methods

UXO detection using electromagnetic methods classifies UXO targets by their electrical conductivity and will detect both ferrous and non-ferrous metallic targets. Pulse induction is an electromagnetic method, commonly employed for the detection of UXO, although the system is generally mounted upon an ROV during relocation of potential UXO targets.

Pulse induction works by generating a pulse of electrical current, within a few microseconds through a coil of wire. Each pulse produces a brief magnetic field which collapses with the stoppage of the current resulting in a large voltage spike across the coil and a second current or reflected pulse flowing through the coil. If there is a conductor present, the pulsing magnetic field induces eddy currents. These eddy currents produce a second magnetic field which propagates back to the detector inducing a small voltage within the coil. The eddy currents generated by a conductor are scaled with the item's inherent conductivity, which is dependent on the item's material, thickness, and length.

If a target is purely magnetic and non-conductive (e.g. a boulder), no eddy current would be generated and nothing would be detected on the sensor. One of the advantages of electromagnetic methods over magnetic methods is that geology is not detected, removing a potential source of false positive potential UXO targets to be investigated.

However, the range of detection is inferior to that of magnetic methods with EM methods possessing a faster signal falloff rate proportional to $1/r^6$ compared to a total magnetic field falloff rate of $1/r^3$ (r being the separation distance between the detector and the target). Boat towed metal detectors are commercially available; however, they are required to be flown very close to the seabed which may prove difficult. For increased control, pulse induction detectors are generally mounted on an ROV, making this method suitable for potential UXO target relocation, and to limited survey areas where there is a threat of non-ferrous UXO.

1.5 Acoustic Methods

Acoustic methods for UXO detection rely on the distinguishable contrasts in reflected acoustic energy between a UXO item and the surrounding seabed.

Sound navigation and ranging (sonar) is a method of using acoustic energy to determine distance and direction. Single and multi-beam echo sounders (MBES) use this method to determine distance to the seabed. Side scan sonars (SSS) are used to insonify and produce an image of the seafloor. SSS is generally used during geophysical surveys for the locating of boulders and debris, as well as mapping the boundaries of sediment types and bedforms. Classification of potential UXO targets from non-UXO targets is typically based on matching the SSS contacts' dimensions to the physical dimensions of possible UXO threat items.

Although SSS is used to detect potential UXO (pUXO) items on the seabed, sonar methods are unable to detect fully buried targets. Instead, seismic reflection methods are used, specifically 3D chirp and other high-resolution seismic systems, which rely on variations of density and therefore acoustic impedance, to detect buried contacts.

Acoustic methods of UXO detection are susceptible to error during the classification of contacts, particularly when using SSS and/or MBES. Partial burial of the UXO within the seabed may reduce the dimensions of targets (length and width), resulting in pUXO targets being incorrectly graded as benign debris. Further errors may also be introduced via human error during the measuring process of the contacts' dimensions, leading to false classifications of targets.

For UXO detection, acoustic methods are ideally combined with either magnetic or electromagnetic methods to provide a further method of target classification. Without a second method to classify between targets, the client may be overwhelmed by the sheer number of SSS contacts that have dimensions like that of UXO, which are subsequently graded by the UXO consultant as pUXO targets and would require either avoiding or further target investigation.