

RWE Renewables UK Dogger Bank South (West) Limited

RWE Renewables UK Dogger Bank South (East) Limited

Dogger Bank South Offshore Wind Farms

**Unexploded Ordnance (UXO) Risk Management – Potential
UXO Predictive Numbers**

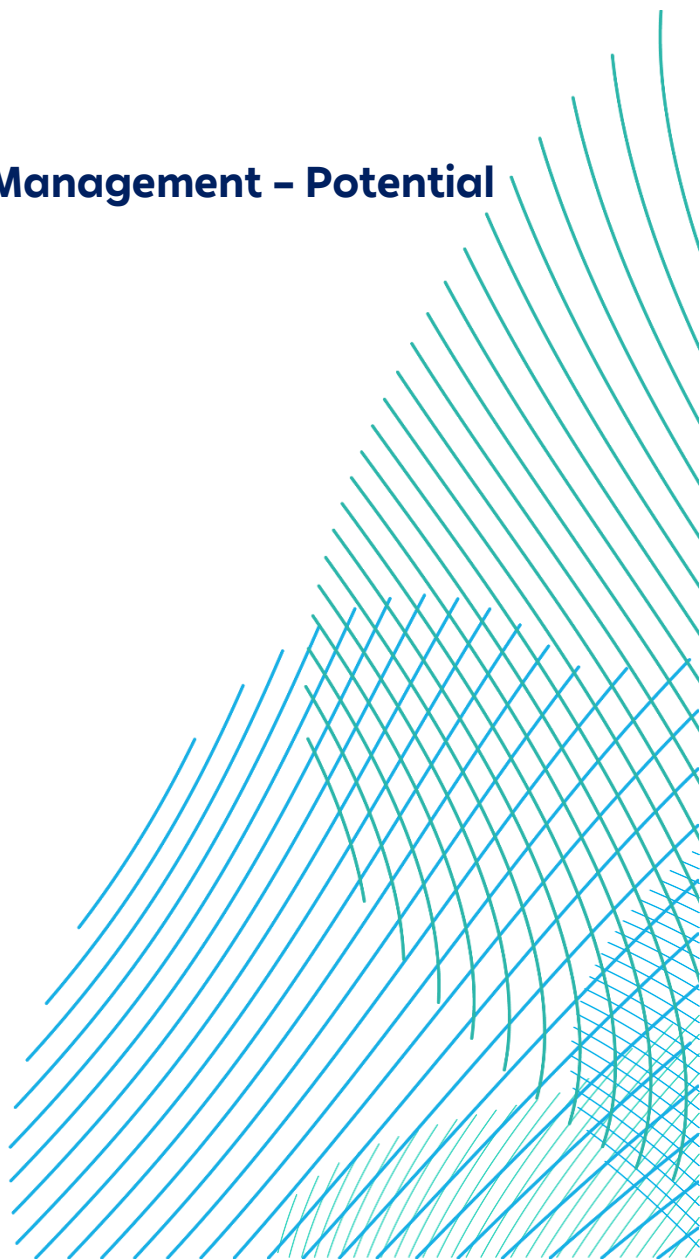
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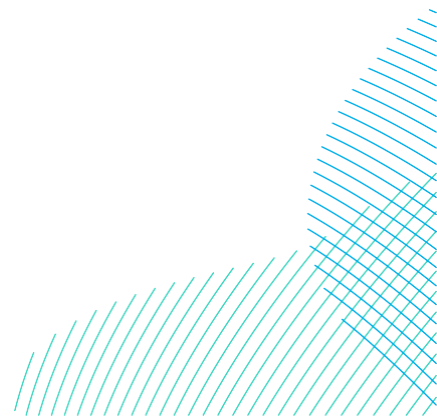
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Prepared for:

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Report Title:

**Unexploded Ordnance
(UXO) Risk Management –
Potential UXO Predictive
Numbers Assessment**

Project:

**Dogger Bank South (DBS) Offshore Wind
Farm**

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INDEPENDENT UNEXPLODED ORDNANCE
(UXO) RISK MANAGEMENT

ORDTEK

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British Assessment Bureau, ISO 45001:2018, Certificate Number 225413

Document Revisions and Amends

Project Number	Status	Version	Date	Written	Technical Review	Quality Review	Released
JM7027	Final	V4.0	10/11/2023				
				Graduate Project Engineer	Senior UXO Consultant	UXO Consultant	Managing Director
Version	Page	Section	Amends				
V1.0	-	-	Issued to Client as final.				
V2.0	Throughout		Document revised following update to figures and comments within comment sheet "Comment-Sheet_004545088-01" and review of captured geophysical datasets.				
V3.0	Throughout		Amended as per Client comments.				
V4.0	17		Statement added to outlining: "The predictive numbers assessment is made under the assumption that geophysical data quality objectives have been adhered to and consequently the relevant smallest hazard item will be detectable to the expected burial depth."				

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Abbreviations and Acronyms

AA	Anti-Aircraft	M	Metres
AEZ	Archaeological Exclusion Zone	MBES	Multibeam Echo Sounder
ALARP	As Low As Reasonably Practicable	MBD	Maximum Burial Depth
AOI	Area of Interest	MCM	Mine Countermeasures
BL	Breech Loading	MDD	Maximum Detection Depth
BOEM	Bureau of Ocean Energy Management	UX	Munitions and Explosives of Concern
CDM	Construction Design and Management (UK legislation)	ML	Muzzle Loading
CIRIA	Construction Industry Research and Information Association	mm	Millimetres
CW	Chemical Weapon	MoD	Ministry of Defence
EMA	German moored contact mine Type A	MTB	Motor Torpedo Boat
EMC	German moored contact mine Type C	MW	Megawatt
EMG	German moored contact mine Type G	NEQ	Net Explosive Quantity
EO	Explosive Ordnance	NM	Nautical Mile
EOD	Explosive Ordnance Disposal	OSPAR	Convention for the Protection of the Marine Environment of the North East Atlantic
ERW	Explosive Remnants of War	PLGR	Pre-Lay Grapnel Run
EU	European Union	RAF	Royal Air Force
GC	Allied designation for German type LMB mine	RMF	Risk Management Framework
GD	Allied designation for German type LMA mine	RML	Rifled Muzzle Loading
GG	Allied designation for German type BM1000 mine	RN	Royal Navy
GY	Allied designation for German type EMC/EMG mine	ROV	Remotely Operated Vehicle
GZ	Allied designation for German type UMA mine	QA/QC	Quality Assurance/Quality Control
GIS	Geographical Information System	SAA	Small Arms Ammunition
H&S	Health and Safety	SBP	Sub Bottom Profiler
HAA	Heavy Anti-Aircraft Artillery	SF	Shock Factor
HE	High Explosive	SOP	Standard Operating Procedure
HSE	Health and Safety Executive	SQRA	Semi Quantitative Risk Assessment
HSF	Hull Shock Factor	SSS	Side Scan Sonar
Kg	Kilogram	TNT	Trinitrotoluene
KHz	Kilohertz	UK	United Kingdom
Km	Kilometre	UKHO	United Kingdom Hydrographic Office
KSF	Keel Shock Factor	UMA	German anti-submarine mine Type A
kV	Kilovolt	UXB	Unexploded Bomb
LMA	Luftmine A (German air dropped ground mine Type A)	UXO	Unexploded Ordnance
LMB	Luftmine B (German air dropped ground mine Type B)	WWI	World War One
LSA	Land Service Ammunition	WWII	World War Two

Definitions

Several industry specific terms are used in this document. However, *Ordtek* considers the following worthy of special note.

- **As Low As Reasonably Practicable (ALARP)** – The health and safety principle is that *any residual risk shall be as low as reasonably practicable*. For a risk to be ALARP it must be possible to demonstrate that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained. The ALARP principle arises from the fact that infinite time, effort and money could be spent on the attempt of reducing a risk to zero.
- **Confirmed UXO** – An object that has been positively identified as UXO.
- **De minimis** – A residual risk that is deemed to be too trivial or minor to merit consideration, especially in law. It is the failure to reach the threshold level required to be actionable.
- **Exclusion Zone** – An avoidance zone placed around a potential UXO item, designed to avoid disturbance of that item.
- **Explosive Ordnance (EO)** – A military munition that is designed to detonate or explode. It may contain either High or Low Explosive or both (it may also contain nuclear fissile material, but this is not relevant within this document). In the context of this Desk Study with Risk Assessment, the term includes Chemical Weapons (CW).
- **Potential UXO (in terms of UXO survey)** – A geophysical anomaly modelling as UXO but not yet inspected. Within this context, the term is also understood to include primarily inert practice munitions that may or may not have a low explosive element.
- **Safety Zone** – An avoidance zone implemented around confirmed UXO to protect both Project and third-party personnel, vessels and equipment should the item detonate.
- **Suspect UXO** – An object inspected (usually by diver or ROV) but awaiting further confirmatory inspection or analysis.
- **Unexploded Ordnance (UXO)** – UXO is defined as military munitions, including CW, that have been primed, fused, armed or otherwise prepared for action; have been fired, dropped, launched, projected or placed in such a manner as to constitute a hazard to operations, installations, personnel or material; and remain unexploded whether by malfunction, design or any other cause. In the context of this study it also includes EO that has been dumped or is contained within wrecks or crashed aircraft.
- **Use of Language Giving Direction** – in this document and in accordance with the latest edition of the ISO/IEC Directives the following verbal forms are used:
 - ‘Shall’ and ‘shall not’ are used to indicate requirements strictly to be followed in order to comply with the document and from which no deviation is permitted.
 - ‘Should’ and ‘should not’ are used to indicate that among several possibilities, one is recommended as particularly suitable without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.
 - ‘May’ and ‘need not’ are used to indicate a course of action permissible within the limits of the document.
 - ‘Can’ and ‘cannot’ are used for statements of possibility and capability whether material, physical or casual.

1 Introduction

Table 1 - Project Details and Scope	
Commissioning Client	RWE ('the Client')
Project	Dogger Bank South Offshore Wind Farm ('the Project')
General Location	The proposed Dogger Bank South Offshore Wind Farm is located within the North Sea, off the northeast coast of the UK, making landfall south of the town of Bridlington, East Riding of Yorkshire.
Ordtek's Document Scope	Ahead of rerouting and target inspection campaigns, <i>Ordtek</i> has been asked to provide an estimate for the number of contacts modelling as UXO that could be identified in the geophysical datasets and numbers of likely confirmed UXO resulting from the inspection of these potential UXO (pUXO) contacts. This is in order to aid project planning both operationally and commercially.

1.1 References

To support *Ordtek's* study, the Client has provided a number of pertinent Project related documents. These documents, in addition to information from many other sources, were used to inform *Ordtek's* study. In addition, key industry material has been referenced.

Table 2 - References			
Reference	Author	Title	Date
Industry Guidance			
A.	CIRIA	Assessment and Management of Unexploded Ordnance (UXO) Risk in the Marine Environment (C754)	2015
B.	Carbon Trust	Guidance for geophysical surveying for UXO and boulders supporting cable installation	2020
C.	CBI Explosives Industry Group	Guide to management of disposal of explosives	2020
Project Specific			
D.	Ordtek	Unexploded Ordnance (UXO) Hazard Assessment – Main Array: <ul style="list-style-type: none"> JM7027_UXO_DTS_HA_V3.0 	2022
E.	Ordtek	Unexploded Ordnance (UXO) Hazard Assessment –Export Cable <ul style="list-style-type: none"> JM7027_DBS ECR_UXO_Phase 1_HA_V2.0 	2022
F.	Ordtek	Unexploded Ordnance (UXO) Risk Assessment with Risk Mitigation Strategy – Main Array: <ul style="list-style-type: none"> JM7027_UXO_RARMS_V3.0 	2022

Table 2 - References			
Reference	Author	Title	Date
G.	Ordtek	Unexploded Ordnance (UXO) Risk Assessment with Risk Mitigation Strategy – Export Cable: <ul style="list-style-type: none"> JM7027_DBS ECR_UXO_Phase 2-3_RARMS_V2.0 	2022
H.	Fugro	Geophysical Data – Main Array: <ul style="list-style-type: none"> Magnetometer Side scan sonar Multibeam echosounder 	2023
I.	Fugro	Geophysical Data – Export Cable: <ul style="list-style-type: none"> Magnetometer Side scan sonar Multibeam echosounder 	2023

2 Factors Considered in Generating an Estimation

A number of factors must be considered, and assumptions made in undertaking this task, including Ordtek’s regional experience, the engineering footprint and working areas for the Project, the scope of any geophysical survey undertaken to date (References H and I) and the previously undertaken works.

2.1 UXO Contamination of the Project

Ordtek has previously undertaken a UXO Hazard and Risk assessment (References D, E, F and G) for the Project works in order to identify the types of UXO likely to be present within the Project area and the risk these present to the proposed Project operations. The level of UXO contamination in the Project area, and the smallest item requiring detection for ALARP sign-off (Table 3) will drive the survey parameters and therefore the number of targets modelling as potential UXO (pUXO). Please refer to UXO Hazard and Risk assessments for further information.

Table 3 - Smallest hazard item				
Site Zone	Smallest hazard Item	Length/ Diameter (m)	Net Explosive Quantity (kg)	Ferrous Mass Quantity (kg)
Nearshore Cable Route (<10m LAT)	German SC-50kg bomb	0.67/0.2	25kg	25kg
Offshore Cable Route (>10m LAT)	500lb British MC Bomb	0.94/0.33	102.5kg	110.80kg
Main Array	500lb British MC Bomb	0.94/0.33	102.5kg	110.80kg

2.2 Scope of Geophysical Survey

As stated, the number of pUXO identified during geophysical survey is affected by the survey parameters used, therefore this must be taken into consideration during estimation. The estimate was calculated with the survey scope for all working areas.

2.2.1 Main Array

Table 4 – Main Array Survey Scopes		
Scope	Main Array Scope 1	Main Array Scope 2
Sensors	<ul style="list-style-type: none"> Side Scan Sonar (SSS) Multi-beam Echosounder (MBES) Magnetometer (single line) 	<ul style="list-style-type: none"> Side Scan Sonar (SSS) Multi-beam Echosounder (MBES) Magnetometer (multi-line across the required areas)
Purpose	In areas to address lower risk activities and areas where UXO burial is unlikely.	Standard UXO Survey for where there is the potential for UXO burial.

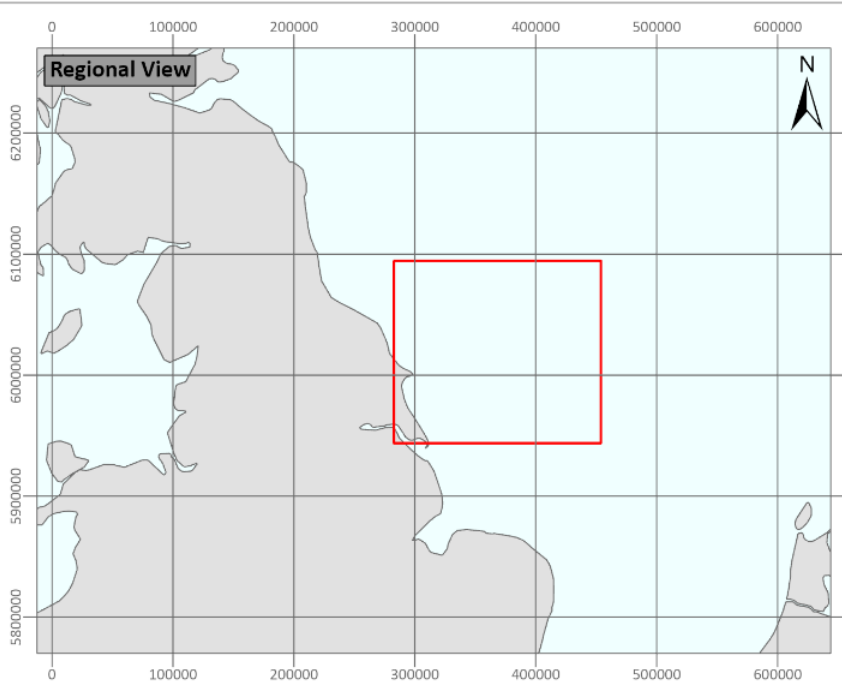
2.2.2 Export Cable

Table 5 – Export Cable Survey Scopes		
Scope	Export Cable Scope 1	Export Cable Scope 2
Sensors	<ul style="list-style-type: none"> Side Scan Sonar (SSS) Multi-beam Echosounder (MBES) Magnetometer (single line) 	<ul style="list-style-type: none"> Side Scan Sonar (SSS) Multi-beam Echosounder (MBES) Magnetometer (multi-sensor array)
Purpose	Pre-geotechnical UXO survey, and lower risk activities, i.e., anchoring, environmental monitoring.	Pre-construction UXO survey for seabed intrusive and high energy activities, i.e., site preparation, cable installation.

2.2.3 Engineering Layout

At time of assessment the full geophysical survey results are not available. Ordtek’s experience with neighbouring projects in the area and review of the pre-consents survey datasets have been used to quantify and guide predictions. Results from the pre-consents survey have been utilised to refine and quantify likely geophysical contact numbers for higher resolution data and resultant conversion to pUXO from these.

Table 6 - Project working areas considered within the report		
Asset	Quantity/Length	Indicative Survey Area
Wind turbine generator (WTG)	200 no.	250m
Offshore substation (OSS)	10 no. within array area (8 substations, 1 switching station, 1 accommodation platform)	750m
Inter array cable (IAC)	650km	75m
Inter Platform Cabling (IPC)	342km	225m
Shared Export cable (ECR)	86km	500m
DBS West Export Cable (ECR)	59km	350m
DBS East Export Cable (ECR)	94km	200m



Legend for Study Area

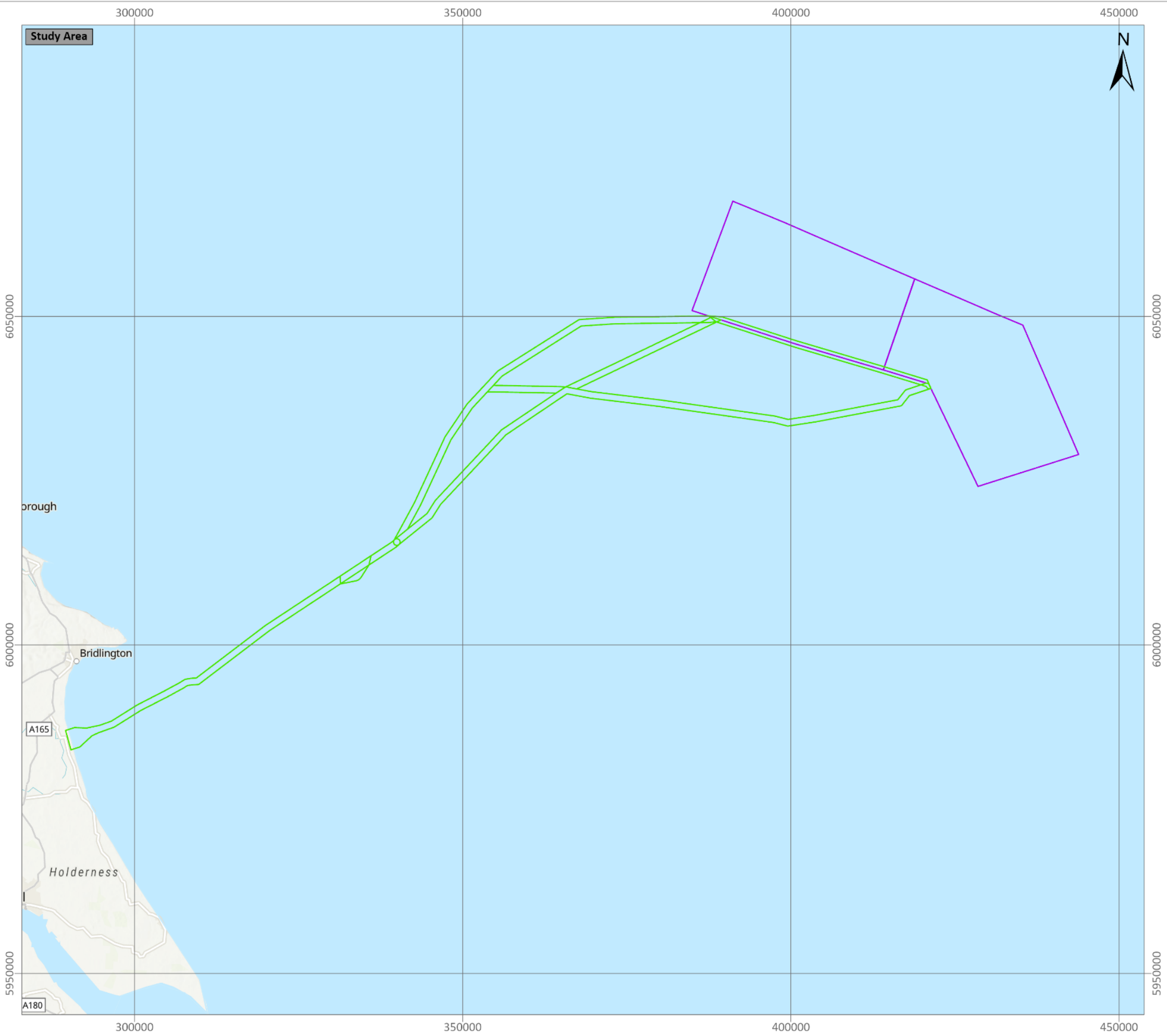
Infrastructure

- Main Array
- Export Cable Corridor

Study Area Scale 1:600,000 @ A3

0 12.5 25 50 Kilometres

0 5 10 20 Nautical Miles



3 Likelihood of UXO Finds

3.1 Overview

To devise the risk assessment for this Project, a ‘Likelihood of Encounter’ value was generated for different areas of the Project. This was compared with Project Activities to generate the risk assessment results. This likelihood of encounter score is based on the criteria in Table 6. The results can be found in Table 7.

Level	‘Likelihood’ Term	Meaning
1	Very Unlikely	Very unlikely to encounter this type of EO within an area but it cannot be discounted completely.
2	Unlikely	Some evidence of this type of EO in the wider region but it would be unusual for it to be encountered.
3	Possible	Evidence suggests that this type of EO could be encountered within the area.
4	Likely	Strong evidence that this type of EO will be encountered within the area.
5	Very Likely	Indisputable evidence that this type of EO will be encountered within the area.

UXO Type	Likelihood Level – Zones			
	Nearshore Cable Route (<10m LAT)	Offshore Cable Route (>10m LAT)	DBS Eastern Array	DBS Western Array
WWI British Mines	1	3	1	1
WWII British Mines	1	2	2	2
WWI German Mines	1	3	1	1
WWII German Ferrous Mines	2	2	2	2
WWII German Low Ferrous Mines	3	2	1	1
Large Bombs (500lb or larger)	4	3	2	2
Small Bombs (250lb or smaller)	4	3	2	2
Large Projectiles (6-inch – 16-inch)	2	3	3	3
Small Projectiles and Rockets (smaller than 6-inch)	2	3	3	3
Chemical Munitions	1	1	1	1
Depth Charges and Torpedoes	1	3	3	3
Land Service Ammunition	2	2	2	2

Table 8 - Likelihood of UXO Encounter in the Project				
UXO Type	Likelihood Level – Zones			
	Nearshore Cable Route (<10m LAT)	Offshore Cable Route (>10m LAT)	DBS Eastern Array	DBS Western Array
Small Arms Ammunition	2	3	3	2

3.2 Potential UXO Items within the Study Area

The below table summarises the potential UXO items which may be found within the Study Area based upon the likelihood of encounter tables found within the Hazard Assessments (Reference D and E), including their approximate NEQ and their source of origin. This table is a summary of the most likely items and should not be considered an exhaustive list of all the potential items of UXO that may be encountered.

Table 9 – Potential UXO Items within the Study Area					
UXO Type	Approximate NEQ (kg)	Total Length/ Diameter (m)	Approximate Ferrous Mass Quantity (kg)	Total Weight (kg)	Likely Source
German SC-50 Bomb	~25.00	0.67 / 0.20	25.00	~50.00	Attacks on shipping, jettisoning
British 250lb MC Bomb	~55.00	1.21 / 0.25	59.00	113.40	Jettisoning
WWI German IV Mine	82.00	0.86 / 0.86	~200.00	281.00	WWI mining
British 500lb MC Bomb	~116.00	1.50 / 0.36	102.50	226.80	Jettisoning
WWI U-Boat Torpedo (Multiple Variants)	118.00 (Max.)	5.10 / 0.27	537.00	550.00	U-Boat attacks
German SC-250 Bomb	130.00	1.19 / 0.37	119.00	249.00	Attacks on shipping, jettisoning
WWI German V Mine	163.00	0.89 / 0.89	118.00	281.00	WWI mining
German SC-500 Bomb	220.00	1.41 / 0.46	280.00	500.00	Attacks on shipping, jettisoning
British 1000lb MC Bomb	~239.00	1.84 / 0.45	213.00	453.60	Jettisoning
WWII U-Boat Torpedo (Multiple Variants)	280.00 (Max.)	7.20 / 0.50	1243.00	1528.00	U-Boat attacks
British 2000lb MC Bomb	~483.00	2.78 / 0.76	446.00	907.20	Jettisoning
German LMB Mine	554.00	1.98 (2.83 with	10.00 (nominally)	987.00	Air dropped or vessel laid

Table 9 – Potential UXO Items within the Study Area

UXO Type	Approximate NEQ (kg)	Total Length/ Diameter (m)	Approximate Ferrous Mass Quantity (kg)	Total Weight (kg)	Likely Source
		parachute) / 0.53			
German TMB Mine	554.00	1.98 (2.26 with parachute) / 0.53	10.00 (nominally)	703.00	Air dropped or vessel laid
German SC-1000 Bomb	620.00	1.91 / 0.06	468.00	1088.00	Attacks on shipping, jettisoning
German TMC Mine	907.00	1.98 (3.40 with parachute) / 0.53	10.00 (nominally)	1043.00	Air dropped or vessel laid

4 Prediction Methods and Results

To undertake the quantity and distribution predictions Ordtek considered the following points:

- Past pUXO quantities seen on similar projects
- Geophysical data available for the project (Reference H and I)
- Historic use of project area
- Landfall location and surrounding ports/harbours
- Water depth/nearshore extent
- UXO hazard assessment and likely UXO contamination levels

It should be noted that Ordtek do not consider this a ‘worst case’ assessment, however, have applied the above to predict a realistic level of pUXO constraints to operation, i.e. pUXO which require avoidance or inspection. Ordtek assume a level of route optimisation and rerouting will be possible for cabling to avoid pUXO, and to a lesser extent avoidance of pUXO from jack-up positional change and anchoring avoidance.

Table 10 – Potential UXO, inspection and confirmed UXO estimates

	WTG	OSS/RCS	IAC/IPC	Shared ECR	DBSW ECR	DBSE ECR
Number of asset (no./km)	200	10	992	94	59	94
Assessment area (max)	250m radius	750m radius	75m to 225m	500m	350m	200m
Average pUXO per area	1	3.5	1.25	2	1.75	1.75
Total pUXO as constraints	200	35	1240	188	103.25	164.5
Percentage requiring inspection	50%	50%	25%	25%	25%	25%
pUXO requireing inspection	100	18	310	47	26	41
Potential UXO as constraints to operations	1931					
Potential UXO requiring inspection	542					
Total confirmed UXO (above threat item)	41					

4.1 Justification of Results and Further Comments

The following should be considered in terms of the target numbers generated during estimation:

- Some adjustments have been made to account for rounding and approximations in calculation.
- Averages have been used based on the proposed number of assets and survey area sizes stated within this document. Should these increase or decrease as the project develops the number of pUXO will also change, however not necessarily in a linear fashion.
- Unknown mass debris areas, or bomb dumps where not identified within the historic research have not been accounted for within calculations.
- Where UXO burial is limited within the site, the increased pUXO interrogation capabilities provided with correlation from surface features may reduce the total number of pUXO identified within these areas, and therefore reduce the number requiring to be inspected.
- Only disposal of confirmed high NEQ UXO has been considered, i.e. above smallest threat item size (Table 3). Small items of UXO or inert items have not be included as to predict these would be impracticable and any finds can be pragmatically managed without the need for high order or indeed recovery.
- The predictive numbers assessment is made under the assumption that geophysical data quality objectives (Reference F and G) have been adhered to and consequently the relevant smallest hazard item will be detectable to the expected burial depth.

5 Risk Management for Subsea Explosive Ordnance Disposal (EOD)

5.1 Predictive Numbers UXO Types Found

Table 11 – Predictive Numbers Potentially to Be Found Above Threshold					
UXO Type	Nearshore Cable Route (<10m LAT)	Offshore Cable Route (>10m LAT)	DBS Eastern Array	DBS Western Array	Subtotal
German SC-50 Bomb	1	2	0	0	3
British 250lb MC Bomb	1	1	0	0	2
WWI German Mine	0	3	2	2	7
WWI British Mine	0	2	1	1	4
British 500lb MC Bomb	3	3	1	1	8
WWI U-Boat Torpedo (Multiple Variants)	0	1	0	0	1
German SC-250 Bomb	0	1	1	1	3
WWII British buoyant mine	0	2	1	1	4
German SC-500 Bomb	0	1	1	1	3
British 1000lb MC Bomb	0	1	1	1	3
WWII U-Boat Torpedo (Multiple Variants)	0	1	0	0	1
British 2000lb MC Bomb	0	0	0	0	0
German LMB Mine	0	1	0	0	1
German TMB Mine	0	0	0	0	0
German SC-1000 Bomb	0	1	0	0	1
German TMC Mine	0	0	0	0	0
Totals	5	20	8	8	41

5.2 Disposal Options

For subsea ammunition disposal operations and underwater blasting, each UXO must be considered separately, and the table presented below only aims to provide a base case option.

Generally valid hazard limits cannot be set because of the often-changing environmental factors and countless different ammunition/fuzing types. This table is only intended as a rough guideline for overview purposes and does not constitute binding statements on a particular procedure to be followed.

Table 12 – UXO risk management options for subsea disposal

UXO Risk Management Options
A. Likely to be safe to move with ROV/Crane
B. Detonation in situ.
C. Likely to be safe to move with controlled lift and shift operation then detonation at new location.
D. Unsafe to detonate or move, or not possible to move due to nature of object, therefore rerouting advised.

Table 13 – UXO risk management table for subsea disposal

Total Mass Classification	Munition Type	Asset within 50m of UXO		Asset between 50m and 100m of UXO		Asset between 100m and 200m of UXO		Asset between 200m and 300m of UXO		Asset between 300m and 400m of UXO		Asset between 400m and 500m of UXO	
		Power or FO Cable	Gas Pipeline	Power or FO Cable	Gas Pipeline	Power or FO Cable	Gas Pipeline	Power or FO Cable	Gas Pipeline	Power or FO Cable	Gas Pipeline	Power or FO Cable	Gas Pipeline
Small Munitions up to 20kg	Rockets	A	A	A	A	A	A	A	A	A	A	A	A
	Solid shot or unfuzed projectiles	A	A	A	A	A	A	A	A	A	A	A	A
	Land Service Ammunition	A	A	A	A	A	A	A	A	A	A	A	A
	Projectiles	A	A	A	A	A	A	A	A	A	A	A	A
Air dropped bombs	100lbs	C	C	C	C	B	C	B	B	B	B	B	B
	250lbs	C	C	C	C	C	C	C	C	B	C	B	C
	500lbs	C	C	C	C	C	C	C	C	C	C	B	C
	1000lbs	C	C	C	C	C	C	C	C	C	C	C	C
	2000lbs	D	D	D	D	D	D	D	D	D	D	D	D
	4000lbs	D	D	D	D	D	D	D	D	D	D	D	D
Mines, depth charges	Buoyant Mines	D	D	D	D	D	D	D	D	D	D	D	D
	Depth Charges	C, D	C, D	C, D	C, D	C, D	C, D	C, D	C, D	C, D	C, D	C, D	C, D
Large Munitions over 200kg	Ground Mines	C, D	C, D	C, D	C, D	C, D	C, D	C, D	C, D	C, D	C, D	C, D	C, D
	Torpedoes	D	D	D	D	D	D	D	D	D	D	D	D
	Buoyant Mines	D	D	D	D	D	D	D	D	D	D	D	D
Inert UXO Scrap or Practice Munitions		A	A	A	A	A	A	A	A	A	A	A	A

**RWE Renewables UK Dogger
Bank South (West) Limited**

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