Appendix 3.4: Explosive Ordnance Threat Assessment

EXPLOSIVE ORDNANCE (EO) THREAT ASSESSMENT (EOTA)

Dunside Wind Farm , East of Longformarcus, Berwickshire, TD11 3PE

in the management of UXO risks in the construction industry, for which PLANIT was an instrumental driver for improved UXO risk management and transparency.

HIGHEST EXPLOSIVE ORDNANCE THREAT LEVEL: **HIGH**

Client:	Land Use Consultants Limited 250 Waterloo Road London SE1 8RD	EDF Renewables UK 144 Morrison St Edinburgh EH3 8EX
C/O:	Unexploded Scotland Ltd [redacted]	
[redacted]	[redacted]	
POC:	Garrie Bain	
Email:	[redacted]	

OUR CONTACT DETAILS

Company:	**PLANIT UXB Limited**
Address:	PO BOX 285 Nunburnholme York YO42 9AU
Tel:	[redacted]
Email:	[redacted]

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Author Review:	Daniel WHELAN	[redacted]
Peer Review:	Andrew HAMILTON	

GLOSSARY OF TERMS

AAA	Anti-Aircraft Ammunition
AP	Anti-Personnel/Armour Piercing (weapon)
ARP	Air-Raid Precautions
BD	Bomb Disposal
BDO	Bomb Disposal Officer
BD Section	Bomb Disposal Section
EO	Explosive Ordnance
EOC	Explosive Ordnance Clearance
EOD	Explosive Ordnance Disposal
EOTA	Explosive Ordnance Threat Assessment
HE	High Explosive
IB	Incendiary Bomb
LSA	Land Service Ammunition
Luftwaffe	German Air Force
MoD	Ministry of Defence
RA	Royal Arsenal
SAA	Small Arms Ammunition
SI	Site Investigation
UXAAA	Unexploded Anti-Aircraft Artillery [projectile]
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V-1	'Doodlebug' – self-propelled, ground to ground missile deployed against Britain from July 1944. V – "Vergeltungswaffe" (Vengeance)
V-2	Long Range Rocket (first ballistic missile used against London from Sep 1944)
WWI	First World War 1914 – 1918 (The Great War)
WWII	Second World War 1939 - 1945

EXECUTIVE SUMMARY

SITE DESCRIPTION	The Site lies in the Lammermuir Hills and comprises undulating moorland dominated by heather. The Site takes the form of a shallow bowl, with the highest area around the edges of the Site which form the tops of Hunt Law, Wedder Lairs, Willies Law and Meikle Says Law between 486m and 535m above Ordnance Datum (m AOD). The Site dimensions are approximately 5 km from north to south and 13 km from east to west with the proposed Dunside Wind Farm occupying the approx centre of the boundary, the existing Fallago wind farm to the extreme East and Longformarcus to the West. (annex 2A for site boundary)
POTENTIAL THREAT SOURCE	*If a UXO-related threat exists*, the following items of EO may be anticipated to be potentially present on the site of concern together with the estimated bomb penetration depth (BPD) and potential offset (i.e., lateral movement underground post-impact):

The following UXO encounter depths and offsets from WW2 ground levels are estimated:

Type of Ordnance	Av. Penetration Depth (m bgl)	Geology Multiplication Factor	Barrier Geology	Adjusted Av. Penetration Depth (m bgl) to 1sf	Offset (m)
British LSA projectiles	2.0	1	na	**2.0**	**0.6**
Air-dropped Bombs: 50kg	4.0	1	na	**4.0**	**1.2**
Air-dropped Bombs: 250kg	6.0	1	na	**6.0**	**2.0**
Air-dropped Bombs: 500kg	9.0	1	na	**9.0**	**3.0**
Air-dropped Bombs: 1000kg	11.0	1	na	**11.0**	**3.6**

The average bomb penetration depth (BPD) of a British projectile returning to earth unexploded is estimated at **2.0m bgl** with a maximum offset of **0.6m**.

THREAT PATHWAY	For the purposes of this assessment, it has been assumed that site investigation and development works would include energetic intrusive engineering into WW2 ground volumes. It is anticipated that personnel or key equipment may complete the risk pathway during excavation and/or piling operations that may bring them into physical contact with potential threat items.

KEY FINDINGS	• The Site itself is not known to have been affected by large, air-dropped bombs. • The site area is likely have been used for military training so *ad hoc* EO contamination from this source cannot be reasonably ruled out. • The possibility that Anti-Aircraft Ammunition remains under the Site as potential threat items may be reasonably ignored. • The following Explosive Ordnance-related items are considered to potentially remain under the Site as potential threat items today within WW2 ground volumes: o Land Service Ammunition (LSA) and Small Arms Ammunition (SAA) of British Army origin.
THREAT LEVEL	The Ordnance Threat Levels for the Site from the Threat Assessment Matrices as they apply to various energetic activities are assessed as:

The Ordnance Threat Levels for the Site as they relate to various energetic activities are assessed as:

Ordnance Type	Engineering Activity				
	No Excavations, no energetic engineering, Controlled Public Access	Shallow Excavations by hand/ Uncontrolled Public Access	Shallow Excavations by machine/ Controlled Public Access	Deep Excavations > 1mbgl, Energetic compaction/ rolling	Boreholes/ Piling
	Ordnance Threat Level				
British LSA	LOW	MEDIUM	MEDIUM	HIGH	HIGH

THREAT MITIGATION	An Explosive Ordnance Threat Management Strategy **IS REQUIRED** prior to intrusive engineering works at the Site.
THREAT REVIEW	A review of these recommendations must be undertaken considering any additional, relevant information being provided. Such a review may, if the EO Threat Level is deemed to have altered, make alternative recommendations from those made above to implement work safely.
AIM & METHODOLOGY	The aim of this assessment is to identify any threats that may be posed by EO during the proposed engineering works at the site of concern and, where a threat is identified, to recommend a threat mitigation strategy that will reduce this threat to acceptable levels i.e., ALARP. The following key considerations are assessed when evaluating EO Threat levels: • The likelihood that the site of concern was contaminated by EO, considering: o Historical use of the site in relation to ordnance manufacturing, storage, and disposal.

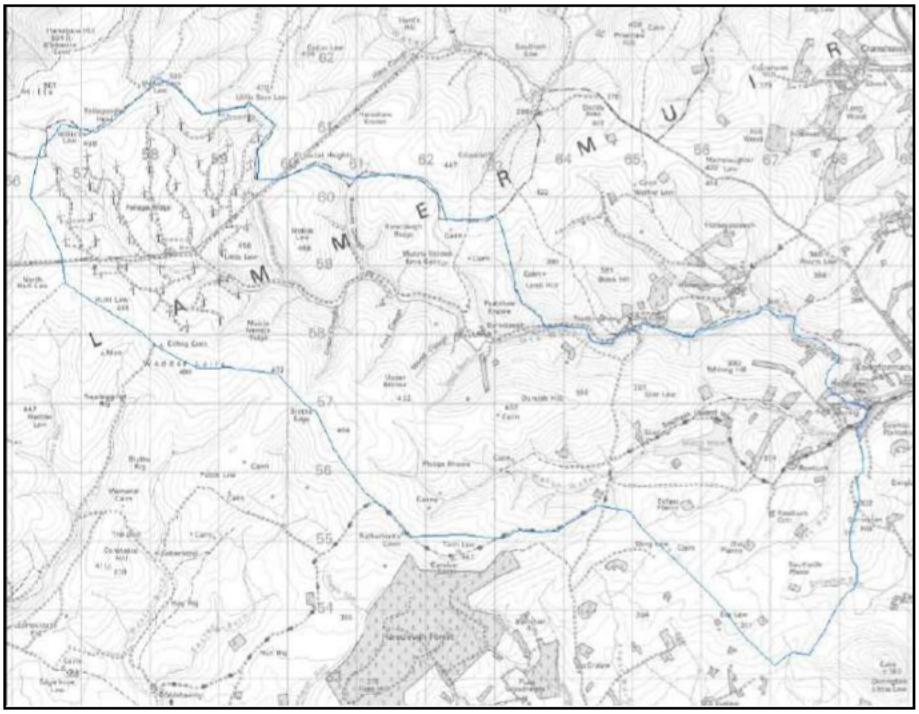
	○ Historical use of the site in relation to Military training and related activities. ○ Evidence of offensive aerial and/ or naval bombardment during armed conflict. • The likelihood that EO may be encountered during proposed engineering works. ○ Evidence of Unexploded Bombs (UXBs). ○ Previous EO incidents and/or EO survey/clearance activities. ○ Extent of post-war redevelopment. ○ Extent and effectiveness of post-War UXO Survey/ Clearance operations. • The likelihood and consequences of encountering and/or initiating EO during the proposed engineering works. PLANIT UXB Limited's approach to EO threat assessment has been fundamental in driving change throughout the UK Commercial Explosive Ordnance Disposal (EOD) Industry and was instrumental in the drafting of CIRIA 681. If the likelihood of encountering EO is significant, information about the nature of that EO and the expected level of contamination is considered within the source-pathway-receptor context of contamination. Our approach provides transparency to our EO threat assessment process allowing the Client to make valid decisions on what is a specialist activity; empowering them to maintain control over this vital aspect of their project. Should a confirmed pathway exist, the information is processed through our proprietary Threat Assessment Model to arrive at a valid and transparent Threat Level, which allows relevant conclusions to be made about the EO Threat at the site of concern and aid the development of an appropriate Threat Mitigation Strategy if required.
RELIABILITY OF HISTORICAL RECORDS	This assessment is drawn from detailed research into the available historical evidence. Every effort is made to gather all the relevant material; however, PLANIT cannot be held responsible for any changes to the assessed level of risk or proposed risk mitigation strategies due to subsequent information that may come to light later. The accuracy and detail of wartime historical records is difficult to verify, not least of which is due to the conditions under which much of this information was gathered and recorded. Additionally, recording of information was less formalised in the early days of the German air campaign against the UK mainland (Pre-Bomb Census Record) and much information recorded early on was lost during subsequent air raids. Records for rural, sparsely populated areas are not always reliable, being based on second-hand information in many cases; records of attacks on military installations were often recorded independently from general records and many such archives have been lost or remain undisclosed to the public. Consequently, the exact location, quantity, and nature of the EO threat cannot be definitive but rather remains subjective and is based on the careful analysis by experts of the available information. PLANIT cannot accept liability for any gaps in the historical record.

CONTENTS

REFERENCES:

1. 3723 Fallago Rig Wind Farm - Bactec Report pt 1.
2. Dunside Boundary Plan-Blue.

SITE LOCATION & DESCRIPTION

SITE OF CONCERN	 The Site lies in the Lammermuir Hills and comprises undulating moorland dominated by heather. The Site takes the form of a shallow bowl, with the highest area around the edges of the Site which form the tops of Hunt Law, Wedder Lairs, Willies Law and Meikle Says Law between 486m and 535m above Ordnance Datum (m AOD). The Site dimensions are approximately 5 km from north to south and 13 km from east to west with the proposed Dunside Wind Farm occupying the approx centre of the boundary map. The Dye Water flows from northwest to southeast through the central part of the Site. Three hydrological catchments noted as Black Burn, Wester Black Burn and Middle Black Burn run from north to south and feed into Dye Water in the eastern part of the Site. Several smaller streams feed into Dye Water, generally flowing towards the central part of the Site.
SCOPE OF PROPOSED WORKS	Dunside Wind Farm is currently anticipated to comprise up to 20 turbines and their supporting infrastructure which includes access tracks, crane hard standings, an extension to the existing electricity sub-station, borrow pits search areas and two temporary construction compounds. It is supposed that both site investigation and development works will involve energetic intrusion into WW2 ground volumes.
GEOLOGICAL ENVIRONMENT	Soil Survey of Scotland mapping reveals that most of the Site is underlain by blanket peat with the remainder underlain by peaty podzols with some humus-iron podzols.

	Where superficial deposits are recorded, these generally comprise Alluvium deposits of clay, silt, sand, and gravel within the valley bottoms and along the course of the largest watercourses draining the area. BGS mapping reveals that the Site is underlain by rocks of the Gala Group comprising greywacke, sandstone, siltstone, and mudstone of Silurian age. Several minor Devonian and Carboniferous to Early Permian minor felsic and basic intrusions are shown trending southwest to northeast within the Dye Water valley.

REVIEW OF RELEVANT DATASETS	
SOURCES OF INFORMATION	PLANIT ensures that Explosive Ordnance Threat Assessments (EOTAs) are as comprehensive as possible and detailed research is undertaken to collate all the available EO-related information that relates to the site of concern. Information sources may include, but are not restricted to: • National Historic Archives. • Local Authority & Council Archives. • English Heritage National Monuments Record. • Ministry of Defence Archives • PLANITs extensive archives drawn from many years of detailed research and operational experience of UXO Risk Management activities in the UK and abroad. • Joint Service EOD Centre (JSEOD). • Historic Mapping and Aerial Photography. • Specific UXO-related documents such as military bombing and casualty records. • Local libraries and history groups. • Open sources such as published books and internet searches. • Anecdotal evidence from eyewitnesses. *NB: The MoD information office that deals with requests for information relevant to EO clearance operations completed by the MoD is currently facing significant delays. Although a request has been submitted, any information that may be relevant has not yet been forwarded for timely inclusion in this assessment. However, if any relevant information comes to light from this source that affects the threat assessment, this will be notified to the client as a matter of urgency.*
SITE HISTORY	The Site has remained essentially *undeveloped* since the end of WW2 with the only significant development within the boundary the area being the installation of the Fallago wind farm to the west which involved the installation of (48) wind turbines and associated infrastructure. The mainl and uses within the Site are for renewable energy production (i.e., the existing wind farm), sheep grazing and grouse shooting. Land management activities including drainage ditching and moor burning currently take place on the Site.
ORDNANCE MANUFACTURE & STORAGE	There is no evidence that the Site was ever used for the storage or manufacture of explosive-related articles.
MILITARY HISTORY	Reference 1 comprises UXO Clearance certificates relating to UXO Survey and clearance work undertaken in support of Fallago wind farm. Several articles of UXO including 25lb High Explosive and Carrier projectiles and 6lb Shot projectiles were recovered during this work which provides incontrovertible evidence that the Fallago site was used for military purposes, including the live firing of explosive ordnance. It is reasonable to assume that Dunside Wind Farm site may have been affected in the same way. There is local, anecdotal historical evidence that in WW2, military training was conducted within the Lammermuir Hills, within which the Site is located - An area that provided the vast space needed for tank manoeuvres and training in the techniques of mobile armoured warfare. It is not known whether armoured vehicles used live ammunition. Further local anecdotal evidence suggests that the area in and around *Hope Water* (Some 4km NW of the NW corner of the site) was used both by the RAF for practicing bombing runs and the Polish Artillery for live firing into the hills.

CIVIL DEFENCE	**Anti-Aircraft Artillery (AAA) Batteries**. The Luftwaffe targeted AAA batteries. They were also a source of unexploded AA shells which could land a great distance from the firing point during WWII, although typically fell within 15km and could be distributed over a wide area. AAA batteries present a potential source of UXO hazard because of the storage, use and disposal of ordnance associated with the armaments used. They may have a risk from small caches of ammunition buried locally to them. Three types of AAA batteries existed: • Heavy Anti-Aircraft (HAA) batteries of large guns designed to engage high flying bomber aircraft. These tended to be relatively permanent gun emplacements. • Light Anti-Aircraft (LAA) weaponry, designed to counter low flying aircraft. These were often mobile and were moved periodically to new locations around strategic targets such as airfields. • Rocket batteries (ZAA) firing 3" or 3.7" AA rockets with a maximum altitude of 5,800m and a ground range of 9km were also relatively permanent emplacements. Many AAA batteries were associated with searchlights and consequently 'visible' at night, providing clear targets to the Luftwaffe bombers and a potential for UXB. Berwickshire possessed Heavy Anti-Aircraft Batteries during WW2, including 4.5, 3.7 and 3- inch Anti-Aircraft (AA) guns. None were sited on or near to the site of concern to have created a direct source of potential ordnance contamination. **Decoy Sites**. To draw enemy aircraft away from towns and other strategically important targets, a series of decoys were developed between 1940 and 1941. They were estimated to have drawn at least 5% of the total weight of bombs away from their intended targets. Almost 800 static decoy sites were built at around 600 locations in England and numerous temporary and mobile decoys were also deployed. Several different types of decoy were devised: • Night-time dummy airfields (Q sites). • Daytime dummy airfields (K sites). • Diversionary fires to simulate successful bombing raids on airfields (QF sites), petroleum depots (P sites) and major towns and cities (Starfish or SF sites). • Simulated urban lighting (QL sites). • Dummy Heavy Anti-Aircraft (HAA) batteries, factories, and buildings (C series). • Mobile decoys representing 'hards' for troop embarkation (MQLs), tanks and other vehicles. As would be expected Berwickshire had several Civil Defence ('Starfish)' sites designed to protect the region from aerial attack. None of these sites would indicate the possibility that erroneous Luftwaffe bombing would have produced a consequent UXO risk on the site of concern.
WW1	Scotland suffered several 'Zeppelin' aerial bombardment during WW1 but did not deliver ordnance on to or nearby any of the sites of concern.
WW2 – GERMAN AERIAL BOMBING CAMPAIGN	At the outbreak of WWII, the site sat close to the flight path of several viable Luftwaffe targets such as docks, railways and shipyards, all infrastructure targets for the Luftwaffe. The high-altitude area bombing during this period was notoriously inaccurate with areas surrounding specific targets suffering during attacks on the targets themselves. Berwickshire was in District 11 for Civil Defence purposes and the bombs recorded as falling in the district throughout the War are well known:

Ordnance Type	Number of Bombs/ Year					
	1940	1941	1942	1943	1944	1945
High Explosive						
50Kg HE	-	-	-	14 (1)	-	-
250Kg HE	-	-	30 (2)	24 (2)	-	-
500Kg HE	-	-	24 (6)	86 (7)	-	-
1000Kg HE	-	-	2	-	-	-
1200Kg HE	-	-	-	-	-	-
1700Kg HE	-	-	-	-	-	-
1800Kg HE	-	-	-	-	-	
Parachute Mine	18	261	-	4	-	-
G-Mine	-	-	1 (1)	-	-	-
V1 'Doodlebug' (PAC)	-	-	-	-	-	-
V2 Long Range Rocket Bomb (LRRB)	-	-	-	-	-	-
Incendiary Bombs						
Small Incendiary Bombs	-	-	-	310	-	-
45Kg Phosphorus Bomb	-	-	-	27 (4)	-	-
250Kg Phosphorus Bomb				9 (2)	-	-
Fire Pots	-	-	-	126 (11)	-	-
Oil Bomb	16	25	-	-	-	-
Unclassified Ordnance	2192	3822	10	1	-	-
*Figures in brackets indicate UXBs						

UNEXPLODED BOMBS (UXBs) & other UNEXPLODED ORDNANCE (UXO)

Between 1940 and 1945, Bomb Disposal (BD) Teams cleared over 50,000 items of German air-dropped ordnance of 50Kg or larger, 7 000 anti-aircraft (AA) projectiles and more than 30 000 beach mines – This work claimed the lives of 394 Officer's and men. The War Office at the time stated that over 200 000 HE bombs exploded in Britain during WW2 with some 25, 195 remaining a threat as UXBs i.e., 11%. Some 93% of all UXBs were 50Kg HE and 250Kg HE aerial bombs.

No UXBs are recorded on the Site.

ABANDONED BOMBS

A post-air raid search of damaged buildings and facilities would have included a specific search for bomb entry holes. If such evidence was discovered, then BD Teams would have been tasked (in order of strict priority from Category A, the highest priority, to category D, the lowest) to assess the potential UXB and to recommend a course of action. UXBs that were deemed to be a high enough priority, were tackled by the BD Teams who made strenuous efforts to recover and dispose of these items. However, it was not always possible to recover such bombs either through physical constraints, a lack of resources or a change in priority. Such UXBs were noted as 'Abandoned'.

Due to the low priority of abandoned bombs, records that detail them are sketchy and sometimes contradictory. Others were subsequently recovered after the War when time and resources permitted, and others remain 'abandoned'. It is worth remembering that 'abandoned' bombs may also include suspected UXBs that were reported but not confirmed, but simply efforts to locate the 'bomb' were exhausted.

No Abandoned Bombs are recorded on the Site.

BOMB CENSUS MAPS

There are no records to indicate that the Site was affected by aerial bombing in WW2.

HISTORICAL MAPS	Historic maps of the period are a useful indicator of whether an area may have suffered bomb damage. The street layout prior to WW2 is the start state and major changes to street layouts or building boundaries may indicate that the change was due to bomb damage. In this instance, the map record shows no significant changes across the Site and its immediate surrounding area which could reasonably be attributed to potential bomb damage. However, this is unsurprising given that the Site was essentially open moorland at that time.
HISTORICAL AERIAL PHOTOGRAPHY	The same rational applies with historic aerial photography as it does when we examine historical street plans – changes between pre-war and post-war images may indicate the possibility of damage caused by bombs falling on the site. Sometimes, detail is such that it allows bomb damage to be seen directly on sites of concern. Post-War historic aerial imagery is unfortunately not available, in this instance.

THREAT ANALYSIS	
IS THERE EVIDENCE THAT THE SITE WAS POTENTIALLY AFFECTED BY LARGE, AIR-DROPPED HIGH EXPLOSIVE BOMBS?	**No.** The historical record is acknowledged as being incomplete from a National perspective but, although there is no direct evidence to show that the Site was directly affected by large air-dropped high explosive and/or incendiary bombs during WW2. Anecdotal evidence of the RAF using nearby Hope Water for practising bombing runs exists, but there is no evidence that *live* bombs were dropped, whether practice or HE bombs and no evidence that the valley attending the Site was used in a similar way.
WAS THE SITE POTENTIALLY AFFECTED BY OTHER EXPLOSIVE ORDNANCE CONTAMINATION EVENTS?	**Yes.** The potential for British anti-aircraft artillery falling back to earth as UXOs and remaining on the Site undiscovered can rarely be entirely ruled out, although it is very unlikely in any event. The potential for *ad hoc* military activity to have generated explosive ordnance contamination at any site is generally unquantifiable but cannot be reasonably discounted in this instance due to the UXO discovered on the Fallago site, likely because of military training in WW2, in proximity to the Site. No other EO/ UXO contamination events are known to potentially impact on the site.
IF AN EO-RELATED THREAT EXISTS, WHAT ORDNANCE TYPES ARE ANTICIPATED?	The large bombs that were recorded as falling in District 11 shows an atypical distribution of bomb types which is not routinely experienced nationally where 50kg bombs predominate. It is more likely that 250/500kg HE bombs present the largest Ordnance Category. However, there is no evidence that the Site was affected by EO of this nature. We must consider the possibility that Anti-Aircraft Artillery (AAA) projectiles could remain as a potential threat to any site with significant AA defences in proximity during WW2, which had cause to engage the enemy. Given the discovery of several items of UXO during the Fallago project, we cannot discount the potential for *ad hoc* military activity over the years, generating potential threat items that may remain under the site today. The following items of Explosive Ordnance (EO) related articles may be anticipated to be potentially present on the Site: • British AAA projectiles returning to earth unexploded. • Land Service Ammunition (LSA) and Small Arms Ammunition (SAA) of British Army origin.
WHAT IS THE EXPLOSIVE ORDNANCE (EO) ENCOUNTER DEPTH?	**Ministry of Homeland Defence Security Bomb Penetration Studies**. A major study was completed by the Ministry of Homeland Security during WW2, during which the penetration depths of 1 328 air-dropped bombs (as reported by the BD Sections of the day and mostly in the Birmingham area) were recorded. It was concluded, not surprisingly, that the penetration depths of different sized bombs varied according to the geology into which they fell.

The average Bomb Penetration Depth (BPD) of 430 x 50Kg HE bombs in London Clay was found to be 4.6m and that for a 250Kg bomb 6.1m. Also, they concluded that a 500Kg bomb, the largest common bomb dropped during the War, had a likely penetration depth of 6m in sand and 8.7m in clay – the maximum observed for a 500Kg was 10.2m and for a 1000Kg bomb was 12.7m. It should be remembered that these depths were achieved unencumbered by obstacles to penetration such as buildings, concrete, and brickwork.

The 'J' Curve. The 'J-curve' describes the path of a bomb (dropped from a normal altitude of about 5 000m) into homogenous ground will continue its line of flight (unless deflected by a substantial obstacle) but then turn upwards towards the surface before it stops. The horizontal distance (the 'offset') between the point of entry and final resting position was typically 1/3 of the ultimate penetration depth for a bomb. Therefore, if a bomb fell close to the exterior of a building or site and did not explode, the path that the bomb subsequently travelled beneath the ground, the "J-Curve", may have delivered it beneath the building or site footprint. The J-curve is often misunderstood and used to describe the path taken by a bomb dropped from low flying aircraft to which it should not be applied.

The final penetration depth of an air-dropped depends upon several factors; the velocity (as a function of the mass and speed) of the bomb, – PLANIT uses a standard velocity of 267m/s for assessment purposes – the angle of penetration of the bomb, the physical features through which the bomb travelled prior to impact with the ground, and the geology of the ground into which it entered - Generally, the softer the ground, the deeper the expected penetration depth of the bomb. Peat, alluvium, and soft clays are easier to penetrate than gravels and/or sand and water content also plays a part. In addition, it must be remembered that 'barrier geology' such as very dense gravels or bedrock i.e., geology dense enough to stop the progress of a bomb underground, is an important factor in determining the median BPD.

The following UXO encounter depths and offsets from WW2 ground levels are estimated:

Type of Ordnance	Av. Penetration Depth (m bgl)	Geology Multiplication Factor	Barrier Geology	Adjusted Av. Penetration Depth (m bgl) to 1sf	Offset (m)
British LSA projectiles	2.0	1	na	2.0	0.6
Air-dropped Bombs: 50kg	4.0	1	na	4.0	1.2
Air-dropped Bombs: 250kg	6.0	1	na	6.0	2.0
Air-dropped Bombs: 500kg	9.0	1	na	9.0	3.0
Air-dropped Bombs: 1000kg	11.0	1	na	11.0	3.6

The average bomb penetration depth (BPD) of a British projectile returning to earth unexploded is estimated at 2.0m bgl with a maximum offset of 0.6m.

HOW COULD AN UNCONTROLLED DETONATION BE BROUGHT ABOUT?	Unexploded Bombs rarely spontaneously explode. High Explosive (HE) requires a great deal of energy to create the necessary conditions for detonation to occur. In the case of WWII German bombs being disturbed during intrusive ground works, there are a few scenarios to be considered: • **Direct impact onto the main body of the bomb**. Although this is a possibility, there is little chance of generating enough energy to detonate the explosive fill unless the fuse itself is directly struck. • **Re-starting the mechanical clock-timer in a bomb fuse**. This is a possibility. It is probable that environmental conditions have corroded the fuse sufficiently to prevent clockwork mechanisms from functioning. However, under some conditions, fuse elements will be in a good condition and additional movement of a bomb fuse may be sufficient to restart a previously 'jammed' mechanical clockwork mechanism. • **Induction of a static charge, creating a sufficient current to initiate an electric fuse**. This is an unlikely event. Environmental conditions are likely to have corroded the fuse, degrading its components sufficiently to prevent them from functioning. Any elements of the fuse capable of holding a charge would have dissipated in the time since the bomb failed to function. • **Friction impact initiating fuse elements causing bombs to detonate**. Although remote, this is the most likely scenario that may result in a bomb detonating. Weathering within the fuse pocket can cause the explosives within the fuse to breakdown, crystallize and exude from the fuse itself. Violent physical disturbance of this exuded material carries the remote possibility of initiating the fuse mechanism which in turn will initiate the bomb.
WHAT WOULD THE EFFECTS OF SUCH A DETONATION BE TO THE SITE?	The effects of WWII German bombs detonating have been the subject of a few well recorded studies. The general effect of an explosive detonation will depend upon: • The size of the bomb and its Net Explosive Quantity (NEQ) (i.e., how much explosive material it contains). • The type of fill in the bomb (i.e., high explosive, incendiary, photoflash). • The physical location of the bomb. Whether it is: o On the surface. o Partially buried. o Buried (A bomb is considered 'buried' when it is more than 2½ times its own length below ground level and covered). • The locations of the bomb in relation to other structures. • The strength and design of structures near to the seat of an explosion. • The nature of the ground (i.e., sand, gravel, clay, marsh etc.). • The location of the bomb in relation to human and animal populations. There would be the potential for ground shock to damage important underground structures including sewers, communication cables, and foundations. The potential Damage Radii to various underground structures has been assessed by extrapolating from the Joint Service Publication 364 which is the MOD Manual for assessing bomb damage. Potential damage radii for underground structures are assessed as:

<table>
<tr><td></td><td>
<table>
<tr><th>Underground Structure</th><th>Damage Radius (m)</th></tr>
<tr><td>Brick Walls</td><td>30</td></tr>
<tr><td>Foundations</td><td>60</td></tr>
<tr><td>Cast Iron/ Concrete Pipes</td><td>15</td></tr>
<tr><td>Earthenware/ brisk Sewers</td><td>25</td></tr>
<tr><td>Electric Cables/ Steel Pipes</td><td>12</td></tr>
</table>
</td></tr>
<tr><td>WOULD THE SITE CONDITIONS AFFECT THE BOMB FAILURE RATE?</td><td>Yes.

Given the soft superficial geology across the Site, it is reasonable to suggest that bomb failure rates at the Site would have been higher than that routinely experienced, i.e., 10-15% of all bombs dropped. Failure rates of 20-30% in peat from impact-fused EO would not be considered excessive.</td></tr>
<tr><td>WOULD UXBs HAVE BEEN DISCOVERED DURING WW2?</td><td>Density of Bombing. The Site received a very low density of bombing in WW2. Combined with the rural nature of the Site, this would have made data gathering at the time more difficult and the likelihood of overlooking UXBs higher.

Frequency of Access. The site was open moorland at the time of the raids and so could not have been subject to post-air raid survey and clearance as part of the wider emergency recovery effort. This would have made the likelihood of identifying UXBs virtually impossible.

Ground Cover. The physical characteristics of the site would not act to retard the progress of UXBs underground by reducing their overall velocity prior to and immediately after impact.

Peripheral Bomb Damage. This consideration in rendered moot when considering open, rural landscapes that have not likely been affected by large detonations.</td></tr>
</table>

DOES THE SITE'S DEVELOPMENT HISTORY AFFECT THE POTENTIAL FOR UXO ENCOUNTER?	No. No significant intrusive engineering has } µ Œ Œ across the Site since the end of the War. Therefore, the opportunities for dealing with potential threat items such as UXO have been scarce to non-existent.
IF A UXB-RELATED THREAT EXISTS, DOES IT VARY ACROSS THE SITE?	No.

THREAT ASSESSMENT	
POTENTIAL EXPLOSIVE ORDNANCE THREAT ITEMS	There is no evidence that the Site was affected by large, air-dropped bombs and this possibility may be reasonably discounted. The possibility that Anti-Aircraft Ammunition (AAA) fell back to earth within the Site can never be known with certainty, although it is very unlikely in any case. However, such facilities were not in proximity, there is a threat from similar EO (i.e., LSA and SAA) and therefore this possibility may be reasonably discounted. The potential for *ad hoc* military activity to have generated explosive ordnance contamination at any site is generally unquantifiable but cannot be discounted in this instance due to the UXO discovered on the Fallago site in proximity to the Site. The UXO discovered consisted of 25 HE projectiles, carriers and 6lb projectiles. This is likely a result of military training in WW2 and the possibility that the Site was used in a similar way cannot be discounted. The following Explosive Ordnance-related items are reasonably considered to potentially remain under the Site as potential threat items today: • Land Service Ammunition (LSA) and Small Arms Ammunition (SAA) of British Army origin.
ENGINEERING WORKS	Dunside Wind Farm is currently anticipated to comprise up to 20 turbines and their supporting infrastructure which includes access tracks, crane hard standings, an extension to the existing electricity sub-station, two borrow pit search areas and two temporary construction compounds.
RISK PATHWAY	For the purposes of this assessment, it has been assumed that engineering works would likely include energetic intrusion into *at risk* ground volumes. It is anticipated that personnel or key equipment may complete the risk pathway during excavation and/or piling operations that may bring them into physical contact with potential threat items.

CURRENT EXPLOSIVE ORDNANCE THREAT LEVELS

The Ordnance Threat Levels for the Site as they relate to various energetic activities are assessed as:

Ordnance Type	Engineering Activity				
	No Excavations, no energetic engineering, Controlled Public Access	Shallow Excavations by hand/ Uncontrolled Public Access	Shallow Excavations by machine/ Controlled Public Access	Deep Excavations > 1mbgl, Energetic compaction/ rolling	Boreholes/ Piling
	Ordnance Threat Level				
British LSA	LOW	MEDIUM	MEDIUM	HIGH	HIGH

WHAT ARE THE CONSEQUENCES OF AN UNCONTROLLED DETONATION?

The consequences of the uncontrolled detonation of any of the items of ordnance listed above are:

Asset	Consequence
People	Lost time injury >7 days
Plant	Unit Level Damage
Property	Major Wider Damage
Environmental	Major Effect

THREAT MATRICES

ORDNANCE DANGER RATING (ODR)

The 'Ordnance Danger Rating' (ODR) is assessed for the different types of ordnance in terms of the potential harm that may result were the ordnance to detonate as designed and is a function of the calibre of the ordnance and whether it is encountered on the 'surface' or 'buried'[1].

Potential Threat Item	Ordnance Category Description	Danger Radii (m)	Ordnance Danger Rating (ODR)
	No Explosive Ordnance (EO) suspected to be present.	NA	1
British LSA	Landmines, Anti-Personnel, HE; HE in Bulk <5Kg; Pyrotechnics, Small Arms Ammunition (SAA): Projectiles, HE <75mm calibre; Projectiles, Mortar, HE 50mm to < 75mm calibre; Grenades, Hand, HE; Grenades, Rifle, HE. British AAA Projectiles, HE < 125mm calibre; Rockets, HE, Anti-Tank (HEAT); Bombs PIAT, HE	100+	2
50-500kg HE Bombs	Aerial Bombs, HE, 50Kg (Surface/ buried); Aerial Bombs, Blast, HE & Sea Mines 20-250Kg; Aerial Bomb, HE, 250-500Kg (Buried) Bombs, Mortar, HE <105mm calibre; Bombs, Mortar, Spigot, HE; Landmines, Anti-Tank	300+	3
	Projectile, HE > 125mm calibre; Aerial Bombs, HE, 1000kg (buried), HE, 1500-2500Kg (Surface); Aerial Bomb, Blast, HE & Sea Mines 500-1500Kg (Surface)	500+	4
	Aerial Bombs, HE, 2000-10000Kg (Buried); Aerial Bombs, Blast, HE & Sea Mines 1500-4000Kg (Surface)	800+	5

[1] An item of Explosive Ordnance (EO) is 'buried' when it is 2 ½ times its own length underground.

ENCOUNTER RISK (ER)

The Encounter Risk (ER) is a function of the Ordnance Danger Rating (ODR) and the Likelihood Factor (LF) (i.e., how likely is it that certain items are present underground) – The higher the Ordnance Danger Rating (DR) and the higher the Likelihood Factor (LF), the higher the Encounter Risk (ER).

Likelihood of Encounter	Likelihood Factor (LF)	EXPLOSIVE ORDNANCE DANGER RATING (ODR)				
		1	2	3	4	5
		ENCOUNTER RISK (ER) = LF x ODR				
Extremely Unlikely	0	0				
Very Unlikely	1	1	2	3	4	5
Unlikely	2	2	4	6	8	10
Likely	3	3	6	9	12	15
Very Likely	4	4	8 British LSA	12	16	20
Extremely Likely	5	5	10	15	20	25

ORDNANCE THREAT LEVEL

The 'Ordnance Threat Level' is a function of the Encounter Risk (ER) and the Site Activity Factor (SAF) i.e., what type of activity is being undertaken at the site.

Encounter Risk (ER)	Explosive Ordnance (EO) Type	Site Activity Factor (SAF)				
		No Excavations, no energetic engineering, Controlled Public Access	Shallow Excavations by hand/ Uncontrolled Public Access	Shallow Excavations by machine/ Controlled Public Access	Deep Excavations > 1mbgl, Energetic compaction/ rolling	Boreholes/ Piling
		1	2	3	4	5
		Explosive Ordnance (EO) Threat Level = ER x SAF				
0		0				
1 (1 – 2)		1	2	3	4	5
2 (3- 5)		2	4	6	8	10
3 (6 – 9)	British LSA	3	6	9	12	15
4 (10 – 15)		4	8	12	16	20
5 (16+)		5	10	15	20	25

Explosive Ordnance Threat Level	ASSETS AFFECTED				EXPLOSIVE ORDNANCE (EO) THREAT MITIGATION REQUIREMENTS
	PEOPLE	PLANT	PROPERTY	ENVIRONMENT	
NEGLIGIBLE	NOT APPLICABLE				
LOW	First aid injury	Slight damage	Slight damage	Slight Effect	Monitor & manage potential risks
MEDIUM	Medical Injury to Lost time <7 days	Slight Damage to Item write off	Minor to Major damage	Minor to Local Effect	Review & emplace strict control measures if necessary
HIGH	Lost time injury >7 days to Fatality	Unit level to Multiple damage	Major wider damage to Catastrophe	Major to Massive Effect	Intolerable Risk Level. Immediate control measures required to mitigate risks to acceptable levels prior to any further works

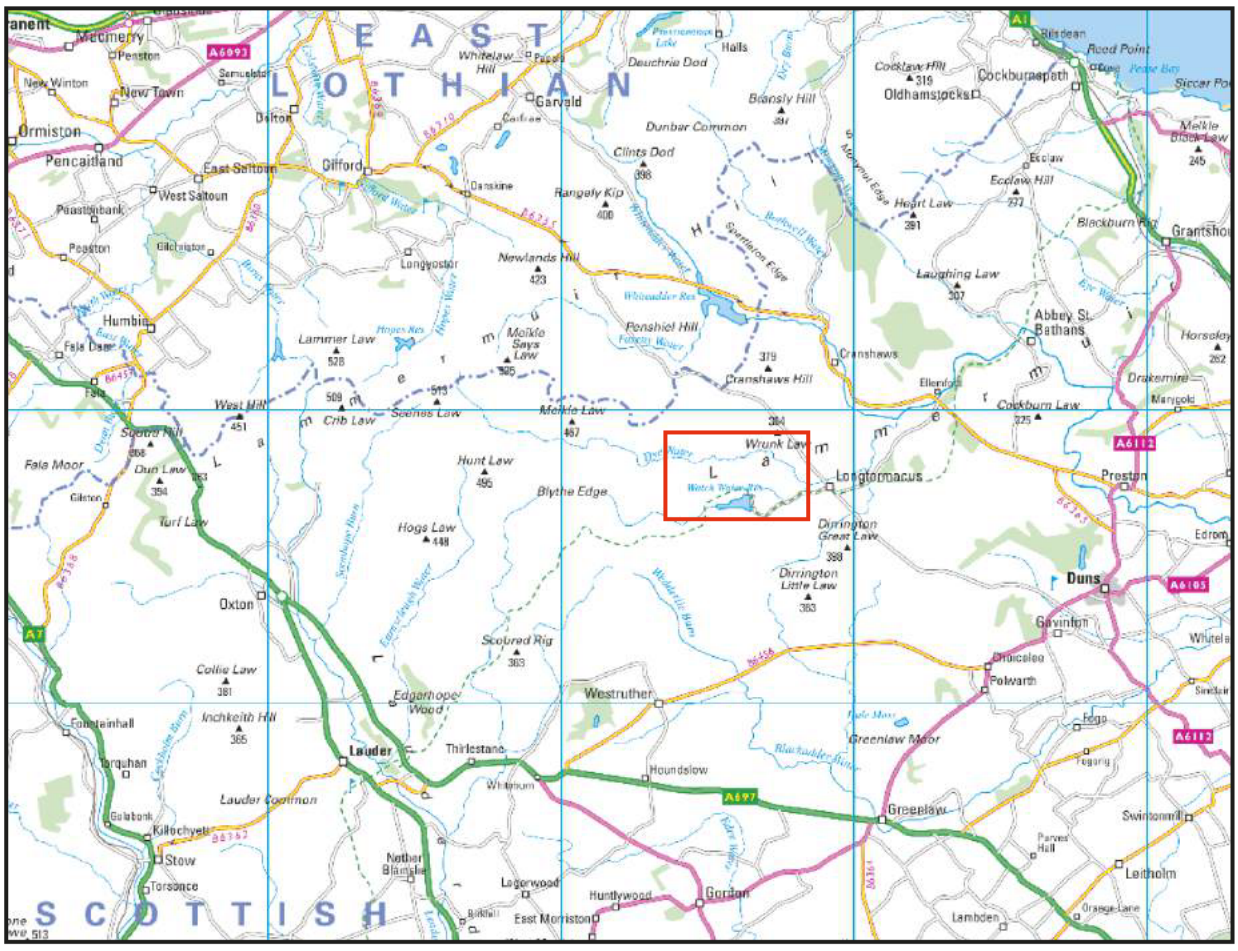
THREAT MITIGATION OPTIONS		
ACTIVITY	THREAT MITIGATION OPTIONS	FINAL THREAT LEVEL
GENERAL	If planned intrusive engineering works are breaking into ground volumes where the potential for UXB encounter is created, *i.e., Within previously undisturbed ground volumes*, then a UXO Threat Management Strategy **IS REQUIRED** prior to intrusive engineering works at the site of concern. **Explosive Ordnance Safety Awareness Briefings.** An explosive ordnance Safety Briefing should be included as part of routine site health and safety training and form a key element of the Site Health & Safety Plan. This should be conducted by a trained specialist and would assist conformance with the CDM Regulations 2015. The briefing will instruct all personnel on the identification of EO hazards, actions to take in the event of an EO incident to protect personnel, key equipment, property, and the public. **Explosive Ordnance Site Safety Instructions.** Explosive Ordnance Site Safety Instructions should be drafted for inclusion in the site-specific health and safety manual and would include information on dealing with an EO incident safely and appropriately. These instructions would form part of the permanent site documentation and will be an aide memoire for identifying potential EO hazards, making a preliminary threat assessment as well as specific guidelines on what to do in the event of a confirmed incident.	AS LOW AS REASONABLY PRACTICABLE (ALARP)
SITE INVESTIGATION WORKS	Site investigation works should be supported by UXO survey as appropriate. Consideration should be given to whether the works are shallow or deep from the perspective of UXO Survey. 'Shallow' Survey is survey of the ground from 0.0m bgl to 6.5m bgl and 'Deep' UXO Survey is that beyond 6.5mbgl. • **Boreholes.** PLANIT can conduct a non-intrusive survey of a 5m x 5m box which will accurately allow your borehole to proceed into a volume of ground under which there are no ferrous obstructions. Several locations may be provided within a survey box, allowing maximum flexibility for positioning, and preventing any boreholes being terminated because of encountering a potential threat item at depth. • **Trial Pits.** Using shallow non-intrusive survey, the area for your trial pit can quickly be surveyed and confirmed as free from ferrous anomalies/UXO. Data is interpreted on-site and therefore locations can be changed very efficiently in the event of a potential obstacle. **Window Sampling.** Using shallow non-intrusive survey, the area for your window sample can quickly be surveyed and confirmed as free from	AS LOW AS REASONABLY PRACTICABLE (ALARP)

	ferrous anomalies/UXO. Data is interpreted on-site and therefore locations can be changed very efficiently in the event of a potential obstacle.	
SHALLOW INTRUSIVE ENGINEERING WORKS	Where 'shallow' engineering may complete the risk-receptor pathway, there are two options available to effectively deal with the EO Threat when conducting shallow intrusive ground works. **On-Site UXO Support.** On-site UXO Support for shallow ground works would involve the presence of an appropriately trained and experienced UXO Technician during this phase of construction. The role of the UXO Technician is to: • Conduct EO Safety Awareness Briefings as required. • Monitor all intrusive ground works using visual and instrument aided means to locate any EO that may be uncovered during site works. • Provide an immediate and expert assessment of any EO that may be discovered. • Assist in implementing an appropriate and safe response to an EO incident. • Design and emplace protective works as an immediate response to protect personnel, key equipment, property, and the public as may be required. • Advise on best safe working practice considering the perceived EO Threat. • Act as the liaison with the Authorities on behalf of the Client in the event of an EO incident. **Shallow Non-Intrusive UXO Survey**. PLANIT can deploy industry leading technology that will survey your site of concern non-intrusively (if ground conditions permit) to identify potential EO Threat Items. Any anomalies identified following the non-intrusive survey that may be EO should then be subject to Controlled Excavation to confirm them as EO and remove the threat or discount them. Once the non-intrusive survey and controlled excavation are complete, there is no further requirement for UXO Support at the site of concern since all EO Threats would have been identified and dealt with.	AS LOW AS REASONABLY PRACTICABLE (ALARP)
DEEP INTRUSIVE ENGINEERING	There are a few options available to effectively deal with potential EO Threats when conducting deep intrusive ground works. Which approach is applicable will depend upon the ground conditions of the site of concern: **Deep Non-Intrusive UXO Survey.** PLANIT can deploy industry leading technology that will survey your site of concern non-intrusively (if ground conditions permit) to identify potential EO Threat Items at depth – UXO Survey should proceed to the expected UXB penetration depth or maximum depth of intrusive ground works, whichever is shallower. As a benchmark, PLANITs Deep Non-Intrusive Survey can identify a bomb 500Kg HE to some 8.0m bgl in average ground and larger bombs deeper. This approach is ideal for covering large areas quickly and can be employed to survey piling runs and borehole locations.	AS LOW AS REASONABLY PRACTICABLE (ALARP)

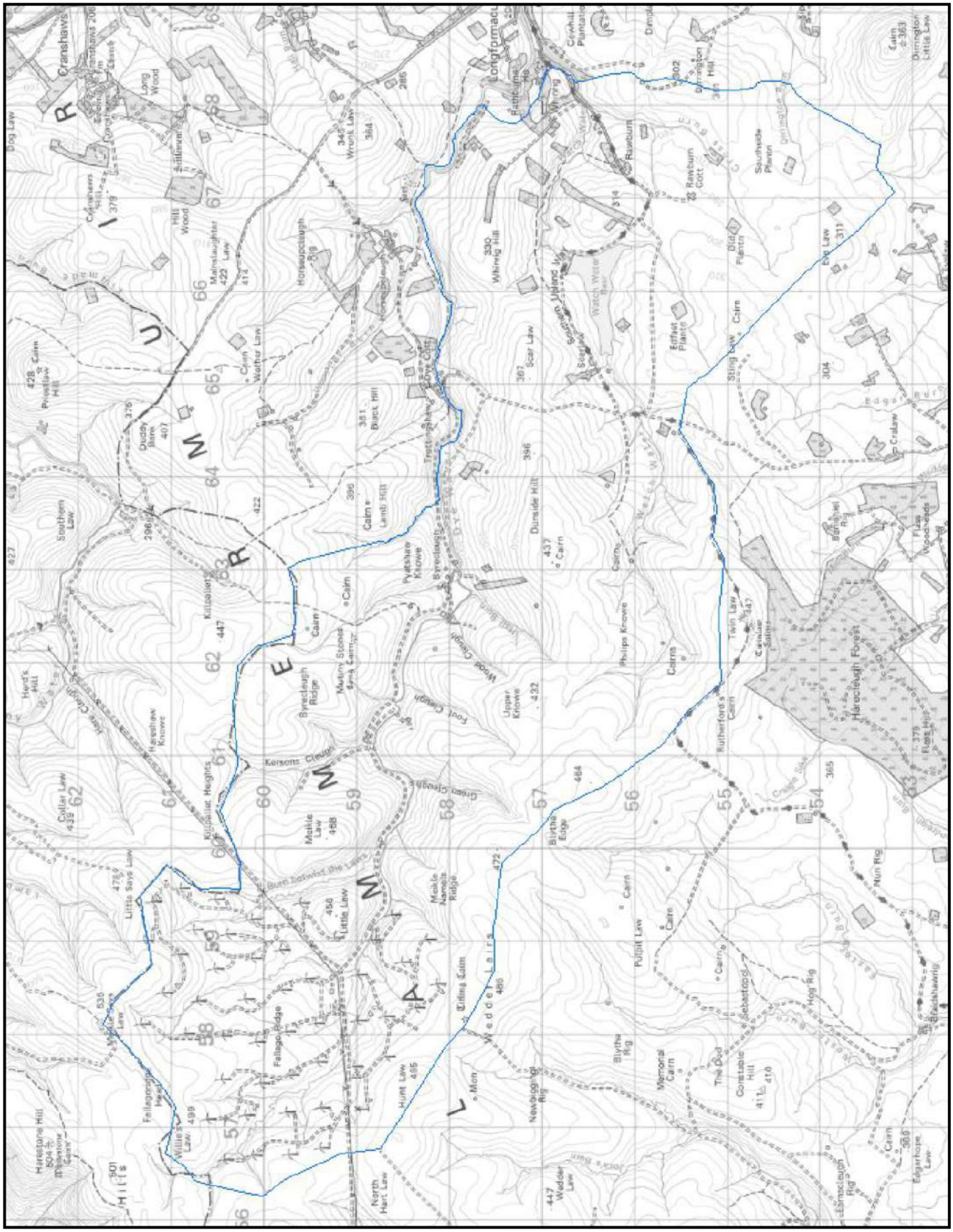
	Any anomalies identified following the non-intrusive survey that may be EO should then be subject to Controlled Excavation to confirm them as EO and remove the threat or discount them. Once the non-intrusive survey and controlled excavation are complete, there is no further requirement for UXO Support at the site of concern since all EO Threats would have been identified and dealt with. **Magcone UXB Survey.** PLANIT can deploy world class Magcone Survey Systems to survey either pile locations or small areas ahead of intrusive engineering including piling and drilling. The Magcone system is very versatile and can survey to great depths if required. **Down-Hole Magnetometer UXO Survey**. PLANIT can deploy down-borehole UXO Survey equipment that will clear ahead of a piling or borehole rig as it descends underground. The main drawbacks of this approach are that it is time consuming, 'blind' (insofar as the borehole may proceed for some depth before a potential threat item is identified, at which stage the borehole will have to be terminated and relocated, wasting time and money), equipment heavy and expensive. Any anomalies identified during this survey that may be EO should either be subject to Controlled Excavation to confirm them as EO and remove the threat or discount them or relocate the borehole or adjust the piling plan. ***UXO Survey should proceed to the expected UXB penetration depth or maximum depth of intrusive ground works, whichever is shallower.***	

ANNEXES

A. Site Location & Layout.



Doc Ref:	EOTA Dunside Wind Farm, 21 Jan 2022	Key:	PLANIT RESTORING BALANCE
Project Ref:	Dunside Wind Farm, TD11 3PE	Site Boundary	
Client:	EDF Renewables & Land Use Consultants Limited		A - 1



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