

Appendix i - Contextual Information Document

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Glossary

AA	Anti-Aircraft	POW	Prisoner of War
ALARP	As Low As Reasonably Practicable	QF	Quick Firing
AP	Armour Piercing	RAF	Royal Air Force
APBC	Armour Piercing Ballistic Cap	RFC	Royal Flying Corps
APFSDS	Armour Piercing Fin Stabilised Discarding Sabot	RNAS	Royal Naval Air Service
AP	Anti-Personnel	TNT	Trinitrotoluene
ARP	Air Raid Precautions	RNPF	Royal Navy Propellant Factory
AT	Anti-Tank	ROF	Royal Ordnance Factory
BL	Breech Loading	SAA	Small Arms Ammunition
DA	Delayed Action	SIP	Self-Igniting Phosphorous
EOC	Explosive Ordnance Clearance	UC	Unclassified Bomb
EOD	Explosive Ordnance Disposal	UP	Unrotated Projectile
FP	Fire Pot	USAAF	United States Army Air Force
HAA	Heavy Anti-Aircraft	UXAA	Unexploded Anti-Aircraft
HE	High Explosive	UXB	Unexploded Bomb
HEAT	High Explosive Anti-Tank	UXO	Unexploded Ordnance
PB	Phosphorous Bomb	V1	Flying Bomb
POW	Prisoner of War	V2	Long Range Rocket
QF	Quick Firing	WAAF	Women's Auxiliary Air Force
RAF	Royal Air Force	WWI	World War One
RFC	Royal Flying Corps	WWII	World War Two
RNAS	Royal Naval Air Service	TNT	Trinitrotoluene
PB	Phosphorous Bomb		

1 Background Site Information

1.1 OS Mapping

The ability to determine whether a site may have suffered bomb damage necessarily depends on the makeup of the site during WWII. For example, if the site comprised an area of open, undeveloped ground, damage would not be noticeable within this source. However, if the site was composed of a section of terraced structures, a bomb strike which caused significant damage may result in the clearance of structures, resulting in easily identifiable evidence. Alternatively, a significantly damaged structure may be marked as a 'ruin'.

Every effort has been made to analyse as many large-scale maps as possible, providing the best possible details through which to assess the potential UXO risk on site. Of note is military censorship of military training grounds or airfields, where relevant features will not be identified.

1.2 Historical Aerial Photography

This source is often more useful in identifying potential bomb damage. Like OS mapping, this can often be more difficult in areas of open, undeveloped ground. Dense vegetation growth or ploughed soil may conceal evidence of a UXB strike, although craters with lipped edges, caused by exploded bombs or larger UXBs, can be clearly visible. Alternatively, evidence of minor damage to structures, in the form of light-coloured roofing repairs, can be immediately identifiable, with large areas of structural clearance obvious. Where vertical images may obscure internal damage in a structure, oblique photography, if available, will also be consulted to attempt to gain a more complete view of the site.

Of note is that this source can also be very illuminating when assessing potential Allied/British risk. For example, trench systems not recorded on OS mapping can be more easily identifiable in this source, even if recently infilled. Likewise, an impact area from a mortar/artillery range often leaves clear evidence of its presence in the form of impact craters of varying sizes. Other evidence of military activity, such as scrape marks from an anti-tank range, are also observable in imagery. When paired with LiDAR imagery, a wealth of information can be gleaned from these sources.

2 Introduction to German Air Delivered Weapons

2.1 Background to German Bombing Campaigns over Britain

Timeline of Luftwaffe Campaigns over Britain					
1940	1940-1941	1942	1943	1944	1944-1945
Battle of Britain fought to deny the Luftwaffe air supremacy required prior to Operation Sealion.	London, and other major cities, subjected to Blitzes of indiscriminate bombing.	Baedeker Raids target cultural and historic sites throughout Britain. Bath and Exeter badly damaged.	'Tip and Run' raids launched which utilise low-flying high-speed aircraft. Southern coastal towns targeted.	Operation Steinboch targets southern England and London with 31 raids. Last raids on the capital.	V weapon campaign launched against Britain. V1 launch sites overrun following D-Day.

Knowing that they would require air supremacy before launching Operation Sealion (the planned German invasion of Britain), in the summer and autumn of 1940, the Luftwaffe set about targeting RAF airfields (as well as radar stations and other supporting infrastructure). Many of RAF Fighter Command's key airfields, such as RAF Biggin Hill, were raided repeatedly, with the south-east of England suffering the heaviest raids during this period. Once the Luftwaffe realised that they had failed to achieve air supremacy, their attention turned to the indiscriminate 'Blitz' against London.

In the hope of destroying civilian morale and causing the collapse of the government from within, the heaviest raid of this period marked the end of the London Blitz on 12th May 1941. From 7th September 1940, London had been subject to repeated and intense raids, centred on the City of London and eastern boroughs, where the majority of industry in the city was located. This method was mirrored in other large cities across Britain, such as Glasgow, Plymouth and Liverpool. Notably, the Clydebank Blitz of 13th – 15th March 1941 was targeted at the key shipbuilding and ordnance production areas of Glasgow. Bombing of other areas also occurred during this period, likely due to them being identified as targets of opportunity (if aircraft could not locate their target, or did not jettison their entire bombload over it, secondary targets such as transport infrastructure or industrial structures were identified). Furthermore, anti-aircraft fire and the lack of accurate targeting mechanisms in aircraft at the start of WWII led to many bombs missing their intended targets, sometimes by many miles. Landing with live ordnance on board was also dangerous, so aircraft would often jettison any remaining ordnance over Britain before they flew back to mainland Europe. This resulted in rural, and seemingly insignificant areas, being subject to bomb strikes.

In contrast to the raids targeted at military installations during the Battle of Britain, and to an extent those aimed at industrial areas during the Blitzes, the Baedeker Raids of 1942 targeted areas of cultural importance in some of Britain's most historic cities, such as Canterbury and Exeter. These were followed in 1943 by an identification of British weakness to raids carried out by fighter bomber aircraft conducting high-speed low-level raids which would evade radar; the aircraft would pop up when they reached their target, drop their bombs and return home. The raids were therefore named 'Tip and Run'. Notably, by this time, large amounts of American and Canadian troops were stationed in southern Britain. Utilising their LAA guns, as well as repurposing some British ones located around previously heavily bombed cities, an interlocking series of defences were established on the south coast to deter these raiders.

Switching back to targeting London for the first concentrated raids since the London Blitz, Operation Steinboch comprised 31 large-scale raids over southern England in 1944. However, as aforementioned, the massing of anti-aircraft defences in southern England, coupled with significant rates of attrition of pilots in the Luftwaffe meant that these raids were not successful. As a result, the final concentrated Luftwaffe raid over London occurred in May 1944.

Knowing that they could no longer successfully bomb Britain using piloted aircraft, the V1 pilotless aircraft offered an opportunity to inflict casualties in southern England. Equipped with a 850kg HE warhead, the blast wave was lethal. The same was true of the V2 rocket, with an even larger warhead at just over a ton of HE. These weapons were very large and often garnered public attention. Furthermore, a three fuze system in the V1 was designed so that they would never be examined by British forces. As such, the UXO risk that these items pose is typically very low.

2.2 Most Common German Air Delivered Weapons

It is important that the different characteristics and defining features of WWII-era German air delivered weapons (ADWs) are understood. This allows for an accurate assessment of the hazards that each item poses, which feeds into the assessed UXO risk in this report. The table below outlines the most common types of ordnance dropped on Britain. For a visual representation of the types of ordnance described below, please see **APPENDIX iii**.

Type of ADW	Penetrative Ability	Explosive Hazard	Background Information
HE Bomb	High. Their aerodynamics and weight (sometimes up to 2,000kg) greatly aided ground penetration.	General Purpose variant higher at around 50%. For the semi-armour piercing variant, this could drop to around 30% as a cap was added.	The most commonly dropped by weight over Britain. RSK OM's experience proves that large HE UXB entry holes were sometimes assumed to be caused by the detonation of smaller HE bombs. These ADWs pose the greatest risk to sites nowadays.
Mines	Low. The blast power was derived from their air or ground burst ability.	High explosive hazard, with variants possessing approximately 700kg of explosive fill.	Known to have caused significant damage when employed effectively. Due to their slow descent, they do not pose a significant risk to current construction sites.
Incendiary bombs	1/2kg incendiary bombs had very limited penetrative ability. Larger ones could penetrate to shallow depths in soft soil.	Small bursting charge in small IBs. Large variants, such as the Flam 500, had larger bursting charges.	1/2kg IBs were dropped in quantities often too large to accurately record over wide areas. Small items so could go overlooked in vegetated areas. Bursting charges to increases anti-personnel effect could be a hazard during intrusive works.
Anti-personnel bombs	Very low due to their low weight.	Approximate 225g HE charge.	Like small IBs, these were dropped in containers in batches of up to 108. Descent slowed by design, many were encountered during post-raid checks If they did not explode. Still encountered on construction sites today.

2.3 German ADW Failure Rate

During WWII, Bomb Disposal Units (BDUs) accurately recorded all aspects of their work. Based off of this, it is generally accepted that 10% of bombs dropped by the Luftwaffe failed to explode. There are many reasons for this, including:

- Release of bombs at a low altitude, not allowing enough time for the bombs to arm successfully.
- Failure to successfully arm the bombs in the aircraft, likely due to either human or mechanical error.

- Incorrectly functioning fuze, or gaine, mechanism. Evidence suggest that large-scale sabotage in factories staffed by slave labour contributed heavily to this.

2.4 German ADW Failure Rate

Key to assessing the potential risk that German ADWs pose to a site is the maximum depth to which they may have reasonable penetrated. In making this calculation, several factors are considered:

- Weight and type of bomb.
- Height, angle, and velocity of release.
- Geological makeup of the site.

2.5 The 'J-Curve' Effect

As stated in CIRICA C681, as the velocity of a bomb slows down during its passage though underlying soils, it can curve upwards towards the surface again, creating what is known as the 'J-Curve' effect. This affirmed what many BDUs had experienced during WWII when investigating UXBs. This horizontal offset can sometimes be up to 15m, although was more likely to be around one third of the bomb's maximum penetration depth.

2.6 Bomb Penetration Depth

RSK OM have obtained original WWII-era studies (from The National Archives) conducted by the Ministry of Home Security regarding the average and maximum penetration depths of HE bombs in different geologies. This test comprised studies on 1,328 different bombs encountered by BDUs, with measurements produced by analysing the penetration depths of different sized bombs in different geologies. Below is a table presenting their findings:

Bomb Mass (kg)	Geological Conditions and Penetrative Depth (m)									
	Sand		Gravel		Chalk		Clay		Sandstone	
	Average	Max.	Average	Max.	Average	Max.	Average	Max.	Average	Max.
50	2.8	7.8	2.8	7.8	3.5	7.7	4.0	9.1	2.7	6
250	4.8	13.7	4.8	13.7	6	13.1	6.8	15.8	4.6	10.3
500	6	17.3	6	17.3	7.6	16.4	8.7	19.8	5.8	13.1
1,000	7.6	21.9	7.6	21.9	9.6	20.7	10.9	24.9	7.3	16.4

3 Most Common British Ordnance

For a visual representation of the types of ordnance described below, please see **APPENDIX ii**.

3.1 Mortars

Fired from a tube, mortar bombs are fitted with their own propelling charges (supplementary charges can be added around the base as required) and usually have a fuze in the nose. They are fin stabilised and usually comprise either High Explosive or carrier variants; as with other ordnance, this is usually denoted by coloured markings on the item. WWII 2" mortars are identified by their parallel sides, with larger variants, 3" and 4.2", tear drop shaped.

3.2 Grenades

Capable of being thrown by hand, or fired from a specially designed launcher or from the end of a rifle, grenades offer lethality over a short distance, with a typical explosive range of 15-20m. Like mortars, they either comprise HE or carrier versions, capable of producing smoke. Older variants tend to have a 'pineapple' shape.

3.3 SAA

Typically comprising ordnance fired from small arms up to 12.7mm in calibre, this is the most common type of ordnance encountered on land used by the military. SAA refers to the complete round (comprising the solid shot 'bullet' and cartridge) intended to be fired from varying sized hand-held weapons such as rifles, machine guns and pistols. SAA can include the fired bullets, cartridge cases and primers/caps or once complete ordnance.

3.4 AA Shells

Although large anti-aircraft shells may appear similar in appearance to smaller German HE bombs, a copper driving band around the base can be used to correctly identify the item. As these items were not intended to penetrate the ground, they are often found at shallower depths. Due to the large size of unexploded HAA rounds, they possess a higher Net Explosive Quantity than many items of smaller LSA, such as grenades. Likewise, smaller unexploded LAA rounds pose a lower explosive risk.

3.5 Artillery Shells

Artillery has formed the backbone of modern armies, and played a key role in WWI and WWII. The 18 Pounder was the omnipresent field gun of the British Army in World War I, firing an 84mm shell (notably larger than those used by the French and Germans at the time) up to 11,100 yards by the end of its development. A High Explosive shell held 368g of TNT, with shrapnel, shot, and gas variants also available.

Many howitzers, firing larger and heavier shells, were also used by the British Army during WWI. The 9.2" variant was most commonly used in the heavy counter-battery fire or siege roles. Filled with up to 18kg of TNT or Lyddite, these possess far more lethality, although the guns were more cumbersome.

By World War II, tests on the 18 Pounder had ushered into development the 25 Pounder, known to have been equally feared and admired by the Wehrmacht. The gun had an increased range of 13,400 yards, alongside a greater HE fill (820g of TNT). Again, smoke and chemical versions were available, as was the case with the 18 Pounder. However, developments in anti-tank artillery meant that by the end of WWII, the 25 Pounder could fire a solid shot Armour Piercing Ballistic Capped round using charge super for maximum penetration of enemy armour. This was often done with crews firing open sights due to the short range of such engagements, especially in the dense bocage of Normandy following D-Day.

Modern artillery ammunition used by the British Army typically comprises 105mm (L118 light gun) and 155mm (AS90). These guns and ordnance are based on earlier variants, with greater range and lethality.

4 UXO Risk Mitigation

4.1 Clearance of Items of UXO

Land owned by the military, or formerly used by the military, may be subject to Explosive Ordnance Clearance (EOC) tasks in an effort to remove items of UXO. These tasks may be undertaken to allow the land to be used safely by the public. Alternatively, as construction and redevelopment occurs on military land, they may want to make sure that contractors will be as safe as possible; many training areas require clearance operations to take place prior to any ground intrusions taking place, in certain areas. It must be noted that the efficacy of historic EOC tasks intended to achieve complete clearance has been called into question in the last few decades, where subsequent re-investigations has discovered items of UXO that were not identified previously. Naturally, as technology has improved, so has the effectiveness of EOC tasks. Therefore, it cannot be ruled out that items of UXO may remain in an area that has been searched in an EOC task.

4.2 Post-WWII Construction Works

Many stages of post-WWII redevelopment will also have mitigated a degree of risk on a site, if not entirely. Such works can generally be split into three sections:

- Very shallow works.
- Shallow works.
- Deep works.

For example, shell scrapes at very shallow depths may encounter buried SAA just below the surface, while foundations for a residential structure are more likely to encounter a buried HAA shell. Mass soil excavation for a basement level of a multi-storey car park is most likely to encounter a deep buried HE UXB, although these can also be found at shallower depths.

It must be noted that the risk can only be considered to be mitigated in the exact locations and to the exact depths of any post-WWII redevelopment. Any undisturbed ground down to the maximum bomb penetration depth, even if it remains between post-WWII foundations, must be considered unmitigated.

5 UXO Encounter

5.1 Pathways

If UXO is to be encountered on a site, a pathway between the works and the UXO must be present. A pathway almost certainly includes intrusive works, although UXO can sometimes be found on the surface, particularly on sites with a military history. Generally, the greater the volume of soil that will be disturbed, the greater the likelihood of a UXO encounter.

5.2 Encounter Depths

Encountering German ADWs is more likely at shallow and deep depths, such as when constructing a residential estate or piling deep foundations. This is due to the velocity that such items would have impacted the ground, in conjunction with their greater mass.

Items of LSA/SAA are generally encountered within the top 1m of soil. This is as a result of the usual contamination pathways relating to these items; improper disposal (burial), losing them, or burning them. As was noted above, UXO can sometimes be found on the surface. This is most likely to occur when encountering items of LSA/SAA on military training grounds.

6 UXO Initiation

6.1 German UXO Initiation

An item of ordnance that has remained unexploded for a number of years will almost always require an external influence to begin the sequence of detonation. If a fuze has malfunctioned, there are a number of ways that this can restart, or the HE fill can be detonated, such as:

- Percussive/direct impact effect from a high density object, such as a piling rig. Even if the impact occurs away from where the fuze is located on the bomb, direct impact with the HE fill could cause a detonation if hit with enough force.
- Although the Luftwaffe primarily used mechanical fuzes, as outlined in **Section 4.3**, clockwork fuzes were occasionally employed. The prevailing thinking is that if the clockwork fuze malfunctioned at the time of use, it is unlikely to be initiated again. However, this has been known to happen, and the reader should be aware of this possibility.
- Items of unexploded ordnance, like most other buried objects, degrade over time. Part of this degradation process can include sensitive parts of the bomb, such as the fuze pocket, leaking materials. Over time, these materials can crystallise outside of the bomb, coming into contact, and rubbing against, external features. The friction created can sometimes initiate the sequence of detonation.

6.2 British/Allied UXO Initiation

Unlike German ADW UXBs, if not interfered with, it is very unlikely that an item of LSA/SAA would ever initiate. This may be an acceptable risk on a current military training ground that is unlikely to return to public use. However, this would not be the case for military land due to be sold off. Of note is that SAA is even less likely to be initiated, although this can occur if the firing cap is struck, or items are burned.

6.3 Consequences

Consequences of UXO initiation will differ depending on the receptors in the vicinity. The most significant consequence would be the loss of life on site, or in the vicinity, depending on the nature of the UXO find. Of note is that consequences may extend beyond the potential risk of harm; delays in major construction projects, potentially requiring major transport hubs or roadways to be shut down, or leaving plant hire stranded on site, can have large financial ramifications.

7 Risk of Harm

7.1 Introduction

A risk of encountering UXO does not necessarily equate to a subsequent risk of harm. Although there may be deemed to be an elevated likelihood of encountering 3kg practice bombs whose spotting charges have not functioned on a site, the Net Explosive Quantity (NEQ) of these items is far lower than that of a grenade, for example. An unexploded grenade, if it functioned, has the potential to cause fatal injuries, which would indicate a severe risk of harm associated with this item. However, while the 3kg practice bombs would likely not cause fatal injuries if functioning, they are capable of causing serious injuries.

7.2 Assessed Risk Levels

Therefore, the risk of harm can be split into three risk levels:

1. Tolerable – Unlikely to cause any injuries.
2. Medium – Potential to cause slight and serious injuries
3. Severe – Potential to cause fatal injuries.

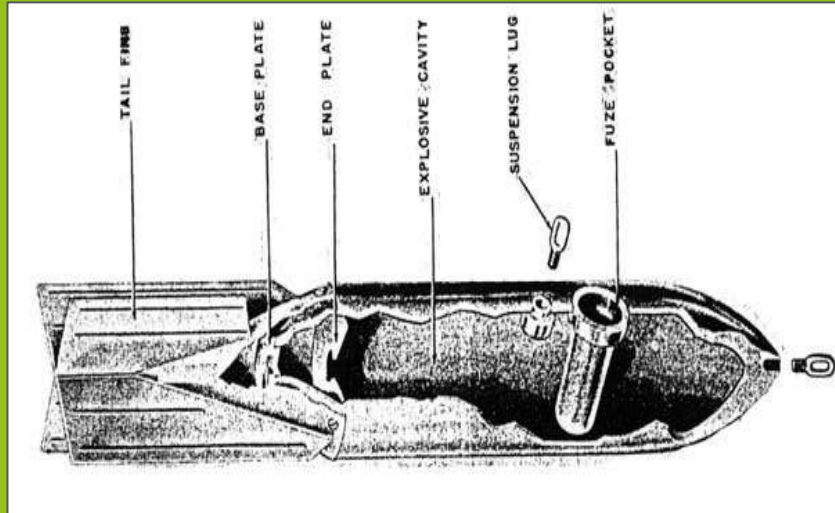
8 Risk Mitigation Methodology

RSK OM have the capability to deliver a wide range of risk mitigation measures. Below is a breakdown of the services we offer. The Executive Summary of this report will detail what specific risk mitigation measures are recommended for your site specific works.

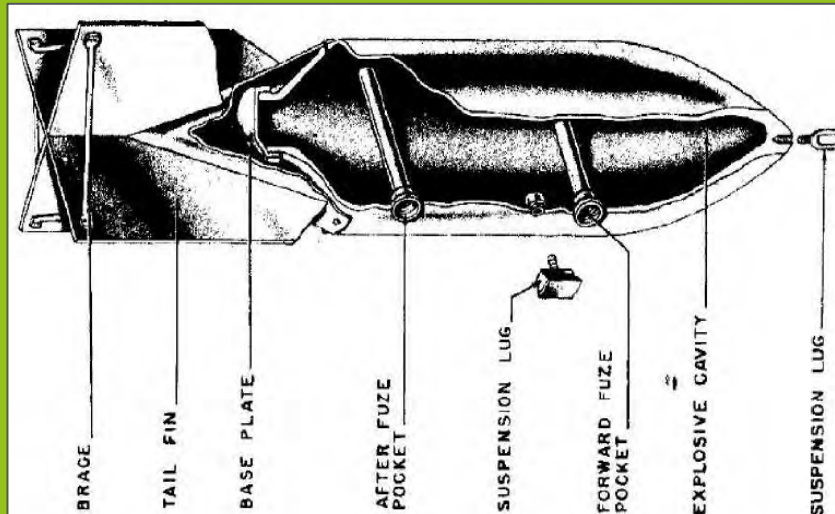
Risk Mitigation Methods	
UXO Safety Awareness Briefings	Recommended for all personnel working on site. The briefings will provide a basic level of knowledge regarding UXO, ensuring workers know what to do when they suspect they may have found an item of UXO. Delivered by a UXO specialist with refresher courses offered at intervals.
UXO Watching Brief	An alternative method to ensure safety on site for when conditions are not appropriate for a non-intrusive survey. A UXO Engineer with a man-portable magnetometer can provide assurances during open excavations to avoid unnecessary timely delays. Allows for borehole clearance and visual identification of potentially items of UXO, avoiding potentially unnecessary evacuations from site.
Non-Intrusive Magnetometer Survey	RSK OM have the capability to deliver non-intrusive surveys via a number of methods; contact our Operations department for specific requirements. A portable magnetometer probe collects data from your site which is then interpreted for evidence of ferrous anomalies. The final stage in this process is a Target Investigation, where any anomalies found can be investigated on site. Note, this survey is only applicable for magnetically clean (i.e. greenfield) ground.
Intrusive Magnetometer Survey	Similarly to non-intrusive magnetometer surveys, RSK OM can deliver an intrusive magnetometer survey in a variety of ways. This survey will successfully clear pile positions to the required bomb penetration depth. Discussion with our Operations team will dictate the best method to deliver this survey once factors such as the site specific geological conditions have been considered.

50kg HE Bomb

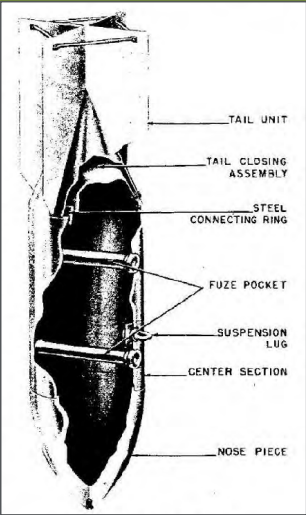
Bomb Weight	54kg
Weight of Explosive Fill	25kg amatol/TNT/trialen
Bomb Dimensions	1090mm x 280mm
Type of Fuze	Impact or electrical time delay
Notes	Most dropped bomb by weight over Britain. Useful against light targets.

**250kg HE Bomb**

Bomb Weight	256kg
Weight of Explosive Fill	130kg amatol/TNT/trialen
Bomb Dimensions	1640mm x 512mm
Type of Fuze	Impact or electrical time delay
Notes	Increased penetrative ability proved useful against sub-terranean targets.



500kg HE Bomb	
Bomb Weight	520kg
Weight of Explosive Fill	220kg amatol/TNT/trialen
Bomb Dimensions	1957mm x 640mm
Type of Fuze	Impact or electrical time delay
Notes	Used against large industrial/military targets, including infrastructure



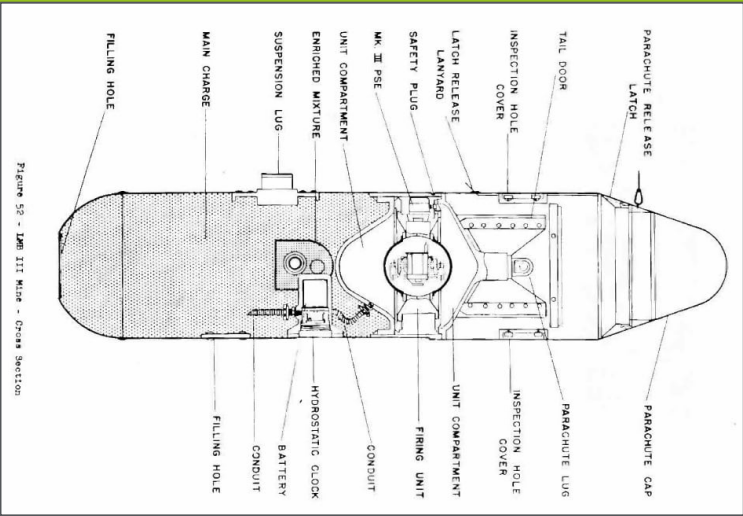
SC 250
MINENBOMBE

Munitions-Lexikon Nr.:
61 100 - 100 - 9

Verwendung: Deutschland, 2. Weltkrieg
Zünder: AZ (25) D, (38), (55), (55)A, L, Z, Z, (17) B und (57)
Gesamtgewicht: 250 + 12 kg
Füllung: 125 kg Fp 60/40 oder Amatol 39 oder Trialen 105
Bemerkung: Wurde später mit Ringleitwerk verwendet

Technical drawing of a 500kg HE Bomb showing dimensions: 1957mm length, 640mm diameter, and 1173mm tail section length. A small label '-27-' is in the top right corner.

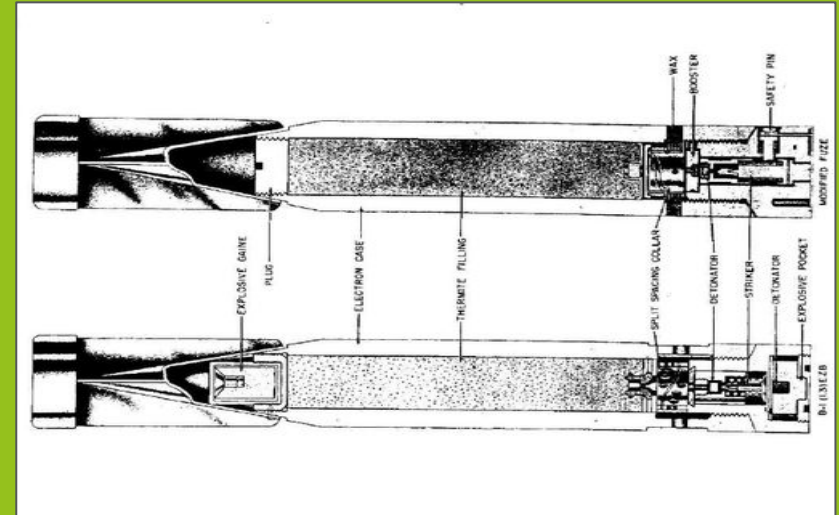
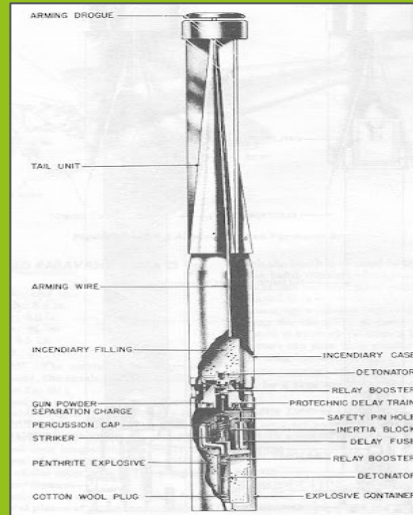
Parachute Mine (Luftmine B)	
Bomb Weight	1000kg
Weight of Explosive Fill	Approximately 700kg amatol/minol
Bomb Length	2640mm
Type of Fuze	Impact or electrical time delay
Notes	Larger than Luftmine A (500kg). Descent retarded by parachute.



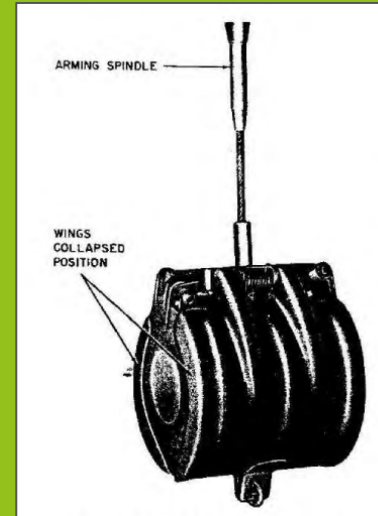
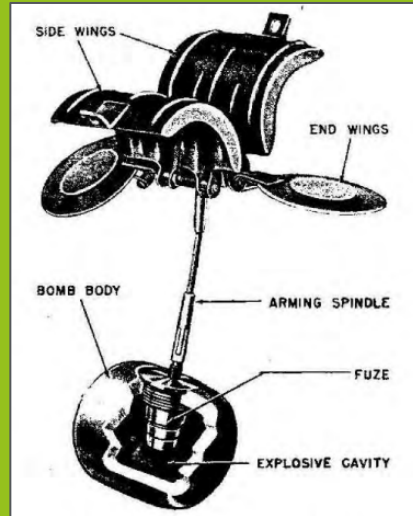
Project Name	Client	Report Reference
Tata Steelworks, Port Talbot	RSK Geosciences	S2RA-1004

2kg Incendiary Bomb

Bomb Weight	2.2kg
Weight of Explosive Fill	100g HE bursting charge
Bomb Dimensions	311mm x 50mm
Type of Fuze	Electrical impact fuze
Notes	Dropped in container in batches of up to 372. Also had 1kg variant.

**SD2 AP Butterfly Bomb**

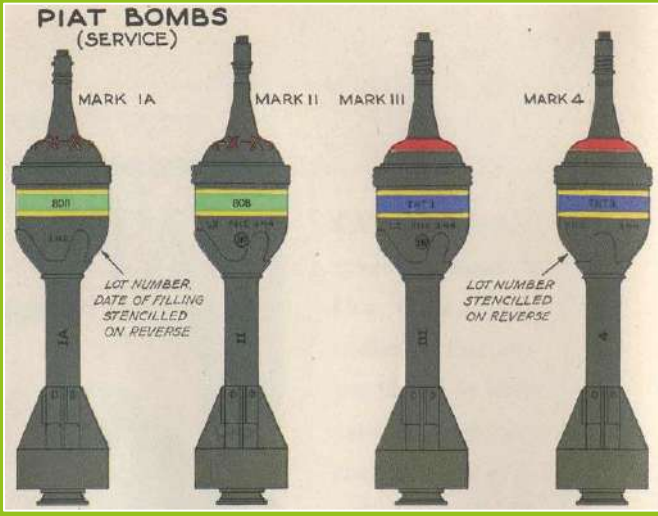
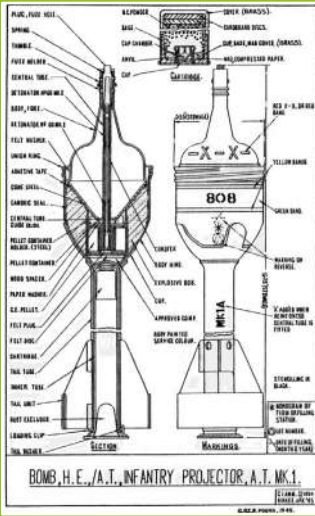
Bomb Weight	2kg
Weight of Explosive Fill	220g amatol
Bomb Diameter	762mm
Type of Fuze	Time delay, anti-handling device
Notes	Fragmentation device. Bomb armed by wings as they spun on descent.



6 Pounder Anti-Tank Gun	
Shell Weight	Approx. 3kg HE shell, 1.42kg APDS
Fill Weight & Fill	HE shell 590g of TNT
Fuze	No.243 percussion
Dimensions	57 x 441mm
Appearance	Later rounds possessed discarding sabot with ballistic cap



PIAT	
Shell Weight	1.1kg
Fill Weight & Fill	570g Nobels 808 PE
Fuze	No.426 Point-Initiating
Dimensions	83 x 407 mm
Appearance	HEAT versions green/brown, practice version white and drill version black



	2" Mortar	3" Mortar	4.2" Mortar
Shell Weight	1.02kg	4.5kg	9.9kg
Fill Weight & Fill	200g TNT	500g amatol	3.6kg TNT
Fuze	No.151 percussion	No.152 direct action	No.152 direct action
Diameter	51mm	81mm	107mm
Appearance	Parallel sides. Red and yellow band on black body often denoted HE.	Tear drop shape. Red or green rings may denote HE.	Tear drop shape. Red or green rings may denote HE.

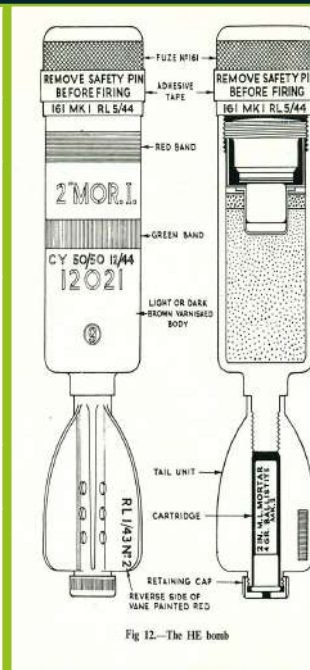
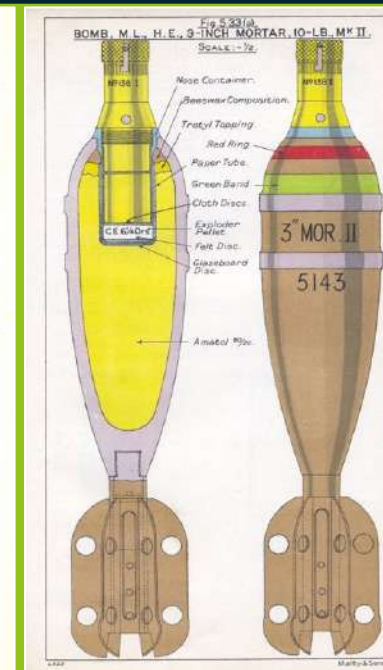
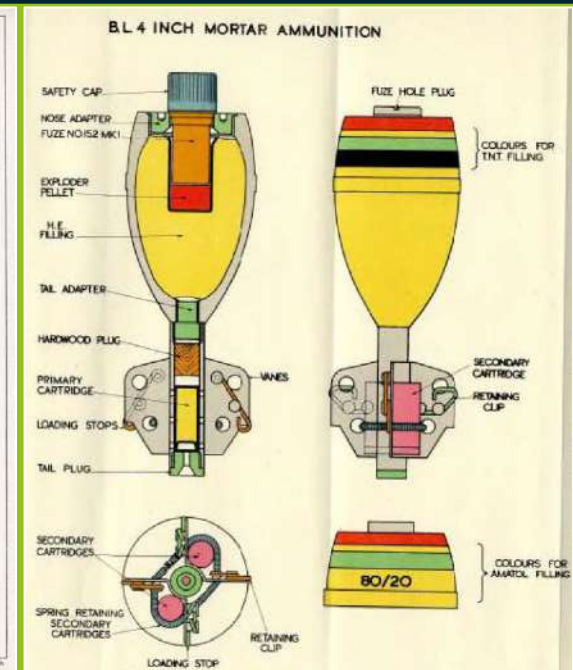


Fig 12.—The HE bomb

HE 2" mortar



HE 3" mortar



HE 4.2" mortar

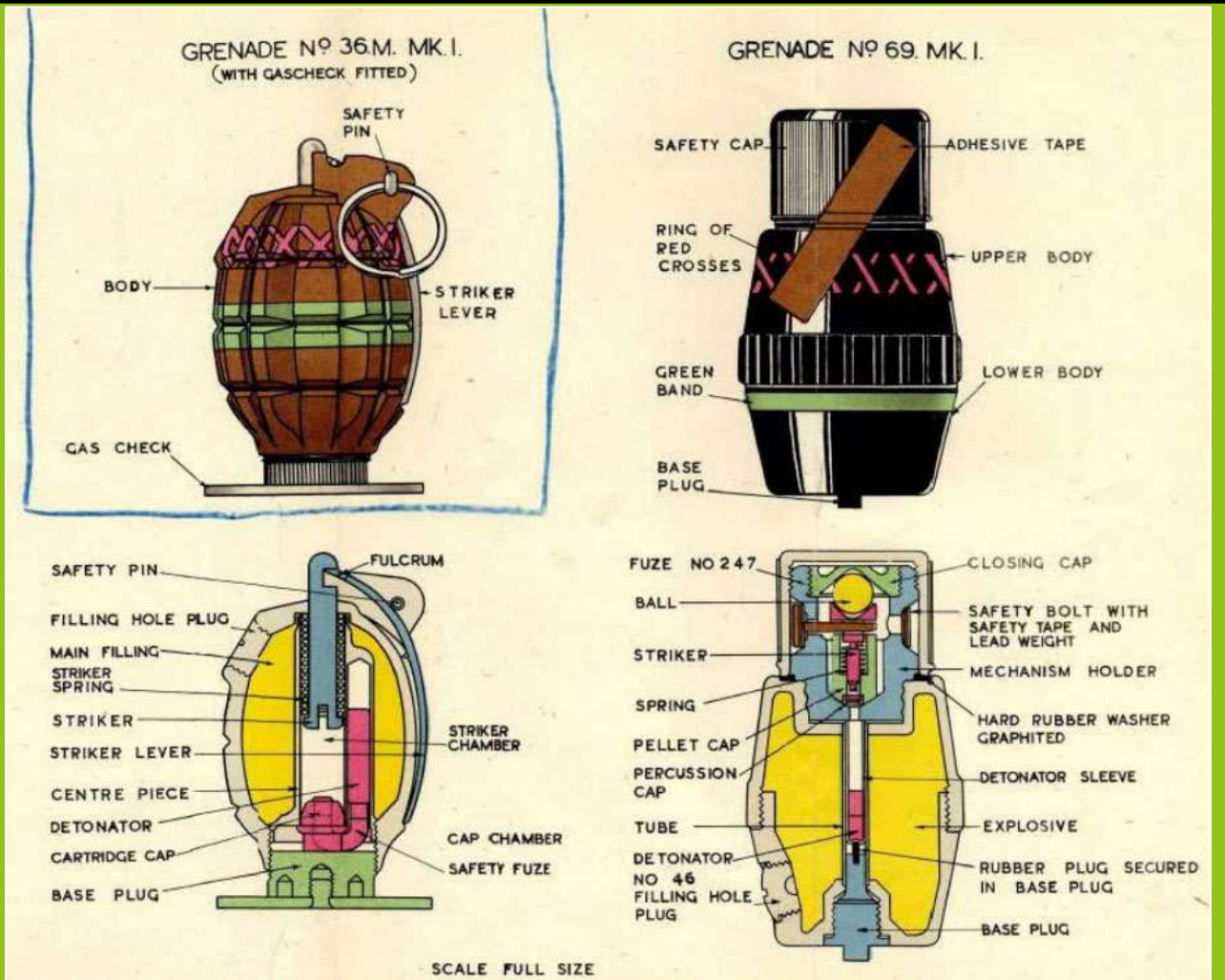
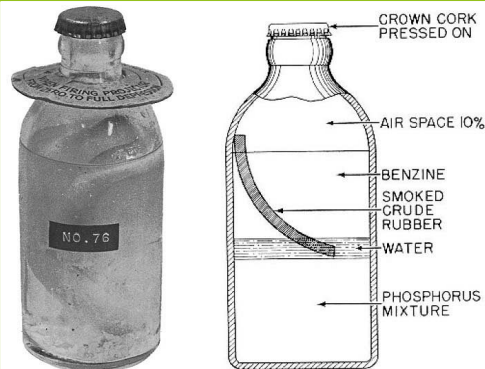


An overview of two 2" mortars, one with tail fin attached, alongside spare nose caps and tail fins. Red and green bands are present on the 2" mortar with the fins.



An unexploded 4.2" mortar found in a garden. Although corroded and dirty, the tail fins, teardrop body shape and No.152 fuse can be identified. Found less commonly than 2" mortars, 4.2" mortars possess a much higher Net Explosive Quantity.

	No.36 Grenade	No.69 Grenade	No.76 Grenade
Weight	765g	383g	530g
Fill Weight & Fill	71g ammonal	93g Lyddite	Benzene and WP
Fuze	Initially seven second fuse, reduced to four	Impact only "all-ways"	n/a
Dimensions	95 x 61mm	15 x 60mm	n/a
Appearance	'Pineapple' ridging, safety pin near top	Largely smooth, filling plug near bottom	Glass bottle with rubber tube in the middle



Left: No.76 grenade Above: No.36 and No.69 grenades

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Project Name	Client	Report Reference
Tata Steelworks, Port Talbot	RSK Geosciences	S2RA-1004



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Technical Note



Ref. ST20879-0001

CLIENT:	TATA Steel UK
PROJECT:	Project EAF
SUBJECT:	Coal Mining Risk Assessment
JOB NO.:	ST20879
DATE:	12 April 2024
PREPARED BY:	Adam Clarke, Engineering Technician
APPROVED BY:	Rebecca Marvell, Technical Director

Introduction

The British Geological Survey (BGS) data indicates that the land beneath the Port Talbot Steel Works site is located on Coal Measures geological formation. A part of the site proposed for redevelopment is described by the Coal Authority (statutory planning consultee for land containing coal) as being a Development High Risk Area. This designation highlights a potential for ground instability, resulting from legacy coal mining operations. A Coal Mining Risk Assessment (CMRA) is a requirement for any planning consultation with such a designation. The CMRA will provide a deeper understanding of the below ground hazards and to allow any proposed redevelopment of the site to be designed in such a way to mitigate against any risk that might be identified.

Coal Measures Summary

The site is underlain by Carboniferous age, Lower and Middle Coal Measures deposits, which range in age from approximately 300 to 360 million years old. These deposits consist primarily of mudstones, siltstones and sandstones, interspersed with bands of coal dipping in a north - east direction. The thickest and most valuable of these coal seams have been given names to help reference and map their mineral value. There are as many as 15 named coal seams which are indicated to subcrop (outcrop beneath soil deposits) within the planning boundary. These named seams are likely to be of mineable thickness, and at least four of these seams are known to have been mined beneath the site. Additional unnamed coal seams are thought to be present but are unlikely to be of sufficient thickness or mineral value to have been mined.

Technical Note

Ref. ST20879-0001

Several geological faults subdivide the stratigraphy at the site. The Kenfig-Tytalwyn Thrust Fault crosses through the site in an approximate east-west direction and offsets (throws) the geological sequence. The offset is such that several named coal seams are thought to subcrop within the site on both sides of the fault. BGS records also describe additional faulting (Giant's Grave fault and Morfa fault) at the site; but without detailed investigation, the conjectured position, and throw of these faults cannot be accurately determined.

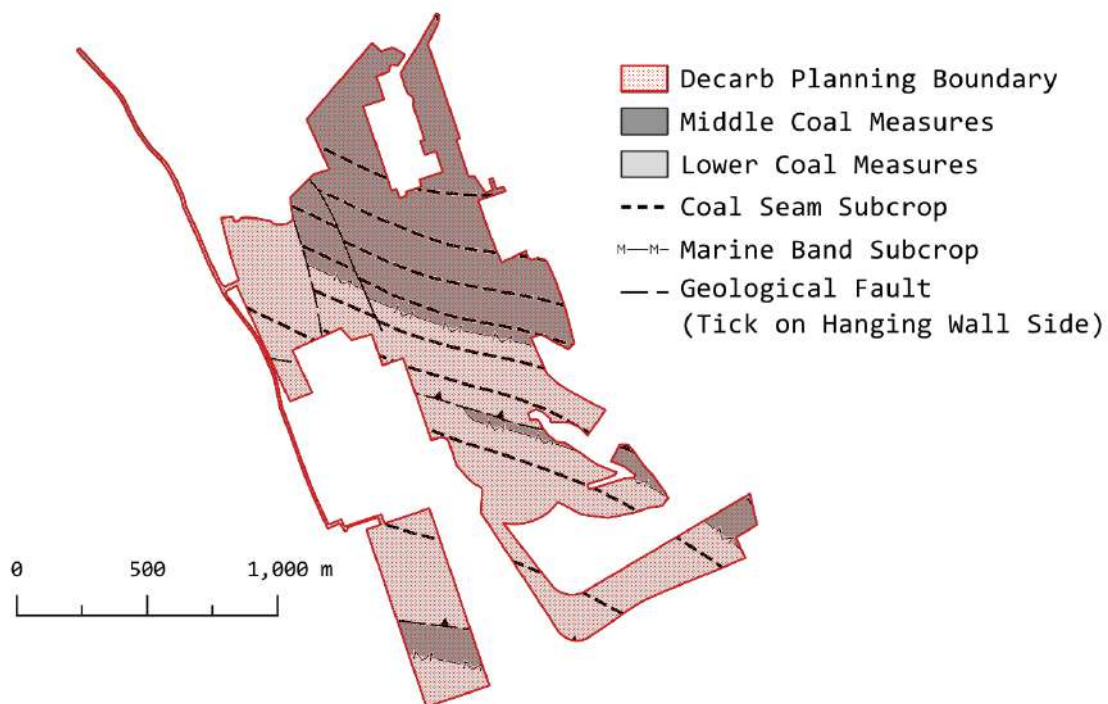


Figure 1 Geological structure within Planning Boundary. Contains British Geological Survey materials © UKRI 2024

Coal mining is known to have historically occurred at the site, most notably associated with the former Morfa Colliery, formerly located at the site. Wardell Armstrong has previously carried out a CMRA on part of the site, identifying only a low to moderate risk to any future development.

Three mine entries are recorded by the Coal Authority within the provided Planning Boundary. Wardell Armstrong has previously carried out physical searches for the three mine entries, physically proving the position of one shaft and providing search records for the other two.

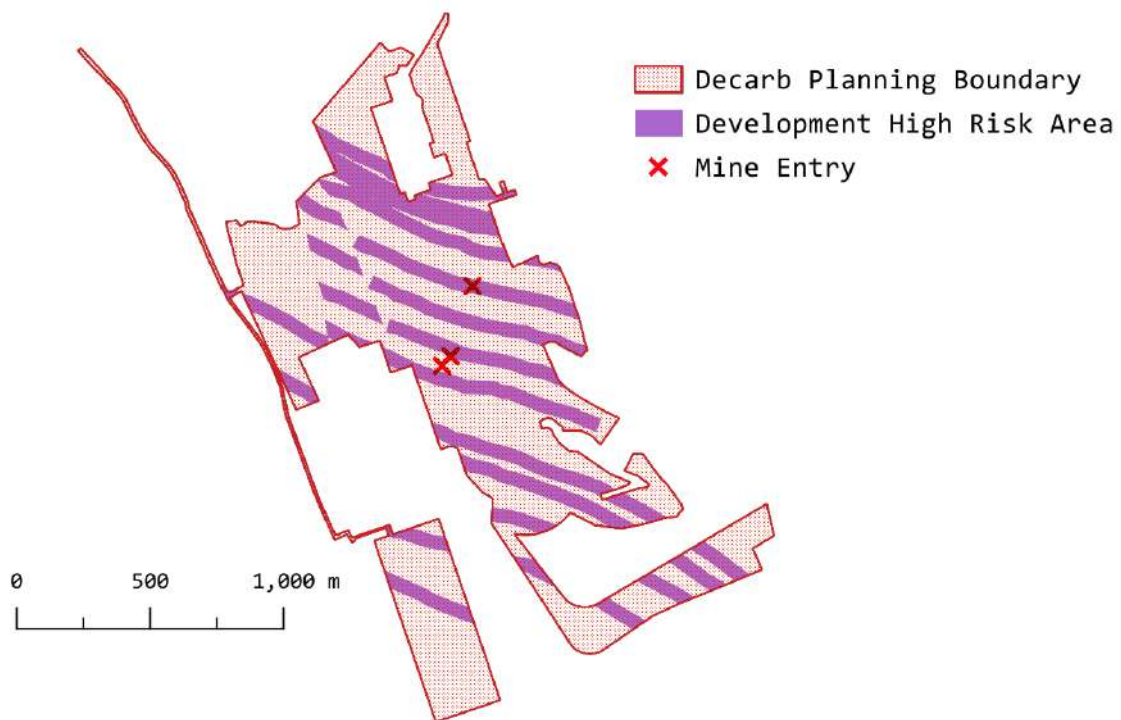


Figure 2 Development High Risk Areas to be revised following CMRA and ground investigation. Coal Authority information © The Coal Authority, 2023

Evidence of possible coal mine workings exists for up to eight of the coal seams beneath the site, and is summarised by each source of the information below:

1. The Coal Authority Consultant Mining Report records workings in the Five Foot, Gellideg, Lower Nine Foot Top Leaf and Garw Vein coal seams.
2. Available Morfa Colliery abandoned mine plans describe workings in the Four Feet (L 4 FT) and Nine Feet (U 9 FT and/or L 9 FT).
3. The North of England Institute of Mining and Mechanical Engineers - Forster Collection, records workings in the Nine Feet (U 9 FT and/or L 9 FT) and Garw Vein.
4. The Northern Mining Research Society website reports the “Morfa colliery worked the North Fawr, South Fawr, Six-Foot, Three-Foot, Nine-Foot, Five-Quarter and Cribbwr seams; and worked the Clay seam between 1854 and 1865”.

Several of the seam names can be corroborated between sources, with evidence for the Nine Feet and Gawr Vein seams reported as worked in three of the above searches. The most recent date of recorded mine workings at the site is 1913, in the Gawr Vein seam, from the

Coal Authority Consultant Mining Report. The likelihood of subsidence or significant ground collapse resulting from recorded mine workings of this age and at the depths is very low. The possibility for historical unrecorded workings at a shallower depth cannot be discounted. Further understanding of the location of any workings, and the depth, age and mineable thickness of each of the coal seam contributions to site risk will be determined by the Coal Mining Risk Assessment.

Coal Mining Risk Assessment

The CMRA as a planning document is divided into sections to reflect each hazard and typically presented in a tabular format with risks, potential consequences and mitigations measures discussed. The specific hazards considered are as follows:

- Past recorded underground mining;
- Past unrecorded underground mining;
- Present and future surface mining;
- Present and future underground mining;
- Mine entries;
- Mine gases; and,
- Geological features – Faults, fissures and breaklines.

Risk Assessment Conclusions

Based on available data, there are coal mining related hazards at the Project EAF development site. A series of coal seams from the Lower and Middle Coal Measures; geological faulting of the Coal Measures; recorded mine workings within several coal seams; and three mine entries are the identified hazards within the site. The current proposed layout for the site redevelopment is understood to have taken into consideration the position of the known mine entries and any sensitive plant and built structures have been kept away from these positions. While scale of the risk has yet to be fully determined, the outline understanding is that the risks to any proposed development are low to moderate. None of the risks identified thus far are considered unsurmountable by design or remediation techniques, in line with the recommendations of the Coal Authority, and industry standard guidance (CIRIA C758 – Abandoned Mine Workings Manual). Pending detailed review of the background information, the CMRA will likely recommend that a phase of ground investigation be carried out to help further quantify the risks.

APPENDIX D

TECHNICAL BACKGROUND

C 1. Desk Study

Aquifer designation and Source protection zones (England and Wales)

Principal aquifer: layers of rock or drift deposit that have high intergranular and/or fracture permeability (usually providing a high level of water storage). They may support water supply and/or river base flow on a strategic scale.

Secondary A aquifer: permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

Secondary B aquifer: predominantly lower permeability layers that may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.

Secondary undifferentiated aquifer: it has not been possible to attribute either a category A or B to a rock type. In most cases this means that it was previously designated as both a minor and non-aquifer in different locations owing to the variable characteristics.

Unproductive' strata: low permeability with negligible significance for water supply or river base flow.

The EA generally adopts a three-fold classification of source protection zones (SPZ) surround abstractions for public water supply. The Site is situated in an area defined as follows:

- Zone 1 or the 'inner protection zone' is located immediately adjacent to the groundwater source and is based on a 50-day travel time from any point below the water table to the source. It is designed to protect against the effects of human activity and biological/chemical contaminants that may have an immediate effect on the source
- Zone 2 or the 'outer protection zone' is defined by a 400-day travel time from a point below the water table to the source. The travel time is designed to provide delay and attenuation of slowly degrading pollutants
- Zone 3 or the 'total catchment' is the area around the source within which all groundwater recharge is presumed to be discharged at the source.

Preliminary risk assessment methodology

LCRM outlines the framework to be followed for risk assessment in the UK. The framework is designed to be consistent with UK legislation and policies including planning. An outline conceptual model should be formed at the preliminary risk assessment stage that collates all the existing information pertaining to a site in text, tabular or diagrammatic form. The outline conceptual model identifies potentially complete (termed possible) contaminant linkages (contaminant–pathway–receptor) and is used as the basis for the design of the site investigation. The outline conceptual model is updated as further information becomes available, for example as a result of the site investigation.

Production of a conceptual model requires an assessment of risk to be made. Risk is a combination of the likelihood of an event occurring and the magnitude of its consequences. Therefore, both the

likelihood and the consequences of an event must be taken into account when assessing risk. RSK has adopted guidance provided in CIRIA C552 for use in the production of conceptual models.

The likelihood of an event can be classified on a four-point system using the following terms and definitions based on CIRIA C552:

- highly likely: the event appears very likely in the short term and almost inevitable over the long term or there is evidence at the receptor of harm or pollution
- likely: it is probable that an event will occur or circumstances are such that the event is not inevitable, but possible in the short term and likely over the long term
- low likelihood: circumstances are possible under which an event could occur, but it is not certain even in the long term that an event would occur and it is less likely in the short term
- unlikely: circumstances are such that it is improbable the event would occur even in the long term.

RSK also adopt a 'very unlikely' probability to account for where there may be increased certainty over whether an event is probable in the long term.

The severity can be classified using a similar system also based on CIRIA C552. The terms and definitions relating to severity are:

- severe: short term (acute) risk to human health likely to result in 'significant harm' as defined by the Environment Protection Act 1990, Part IIA. Short-term risk of pollution of sensitive water resources. Catastrophic damage to buildings or property. Short-term risk to an ecosystem or organism forming part of that ecosystem (note definition of ecosystem in 'Draft Circular on Contaminated Land', DETR 2000)
- medium: chronic damage to human health ('significant harm' as defined in 'Draft Circular on Contaminated Land', DETR 2000), pollution of sensitive water resources, significant change in an ecosystem or organism forming part of that ecosystem
- mild: pollution of non-sensitive water resources. Significant damage to crops, buildings, structures and services ('significant harm' as defined in 'Draft Circular on Contaminated Land', DETR 2000). Damage to sensitive buildings, structures or the environment
- minor: harm, not necessarily significant, but that could result in financial loss or expenditure to resolve. Non-permanent human health effects easily prevented by use of personal protective clothing. Easily repairable damage to buildings, structures and services.

Once the probability of an event occurring and its consequences have been classified, a risk category can be assigned according to the following table.

		Consequences			
		Severe	Medium	Mild	Minor
Probability	Highly likely	Very high	High	Moderate	Moderate/low
	Likely	High	Moderate	Moderate/low	Low
	Low likelihood	Moderate	Moderate/low	Low	Very low

	Unlikely	Moderate/low	Low	Very low	Very low
	Very Unlikely	Low	Very Low	Negligible	Negligible

Definitions of these risk categories are as follows together with an assessment of the further work that may be required:

- very high: there is a high probability that severe harm could occur or there is evidence that severe harm is currently happening. This risk, if realised, could result in substantial liability; urgent investigation and remediation are likely to be required
- high: harm is likely to occur. Realisation of the risk is likely to present a substantial liability. Urgent investigation is required. Remedial works may be necessary in the short term and are likely over the long term
- moderate: it is possible that harm could arise, but it is unlikely that the harm would be severe and it is more likely that the harm would be relatively mild. Investigation is normally required to clarify the risk and determine the liability. Some remedial works may be required in the longer term
- low: it is possible that harm could occur, but it is likely that if realised this harm would at worst normally be mild
- very low: there is a low possibility that harm could occur and if realised the harm is unlikely to be severe.