



Detailed Unexploded Ordnance (UXO) Risk Assessment

Project Name: Billingshurst

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Contents

Annexes.....	3
Acronyms & Abbreviations	4
UK UXO Risk Mitigation Process	4
1. Executive Summary	5
1.1 Site Overview	5
1.2 Proposed Works	5
1.3 Summary of Available Information	5
1.4 Risk Assessment Summary	6
Risk Level	6
1.5 Project Specific Recommendations.....	6
2. Project Context.....	7
2.1 Project Rational & Scope.....	7
3. Methodology	12
3.1 Methods	12
4. Site Profile	13
4.1 Location	13
4.2 Historical Context & Previous Studies.....	14
4.3 Proposed Work & Risk Pathways	15
4.4 Potential Hazards	15
4.5 Site Geology & Bomb Penetration Depth	19
4.6 Lateral Off-set or 'J-Curve'	20
4.7 Allied UXO Burial Depth	Error! Bookmark not defined.
5. Risk Analysis	21
5.1 Analysis.....	21
5.2 Risk Levels and Interpretation.....	21
6. Risk Mitigation & Recommendations.....	24
6.1 Recommended Risk Mitigation Measures	24
Bibliography	26

Annexes

- A-1: SITE LOCATION
- A-2: SITE LOCATION
- A-3: AERIAL PHOTOGRAPHY
- B-1: EXAMPLES OF ANTI-AIRCRAFT PROJECTILES
- B-2: EXAMPLES OF ANTI-AIRCRAFT PROJECTILES
- B-3: LAND SERVICE AMMUNITION - ROCKETS
- C-1: HIGH EXPLOSIVE BOMBS
- C-2: HIGH EXPLOSIVE BOMBS
- C-3: INCENDIARY BOMBS

Acronyms & Abbreviations

AA	Anti-Aircraft	GI	Ground Investigation	OS	Ordnance Survey
AAA	Anti-Aircraft Ammunition	GIS	Geographic Information Systems	PM	Parachute Mine
ALARP	As Low As Reasonably Practicable	GL	Ground Level	PoW	Prisoner of War
AOD	Above Ordnance Datum	GP	General Purpose	RADAR	Radio Detection And Ranging
ARP	Air Raid Precaution	GPS	Global Positioning Systems	RAF	Royal Air Force
AXO	Abandoned Explosive Ordnance	HAA	Heavy Anti-Aircraft	RN	Royal Navy
BD	Bomb Disposal	HE	High Explosive	RNAS	Royal Naval Air Service
BDO	Bomb Disposal Officer	HO	Home Office	ROF	Royal Ordnance Factory
bgl	Below Ground Level	HSE	Health and Safety Executive	SAA	Small Arms Ammunition
BGS	British Geological Survey	IB	Incendiary Bomb	TA	Territorial Army
BH	Borehole	kg	Kilograms	TNT	Trinitrotoluene
BPD	Bomb Penetration Depth	km	Kilometres	UK	United Kingdom
CDP	Cast Driven Piles	LAA	Light Anti-Aircraft	UN	United Nations
CFA	Continuous Flight Auger	LCC	London County Council	USAAF	United States Army Air Force
CIRIA	Construction Industry Research and Information Association	LE	Low Explosive	UXB	Unexploded Bomb
CPT	Cone Penetration Testing	LSA	Land Service Ammunition	UXO	Unexploded Ordnance
CS	County Series	m	Metres	V	Weapons Vergeltungswaffe–Vengeance Weapons
EO	Explosive Ordnance	MoD	Ministry of Defence	WD	War Department
EOC	Explosive Ordnance Clearance	mm	Millimetres	WWI	World War One
EOD	Explosive Ordnance Disposal	NEQ	Net Explosive Quantity	WWII	World War Two
		NFF	National Filling Factory	ZAA	'Z' Anti-Air Rocket Battery
		NGR	National Grid Reference		
		OD	Ordnance Datum		

UK UXO Risk Mitigation Process

CIRIA 681 Phases

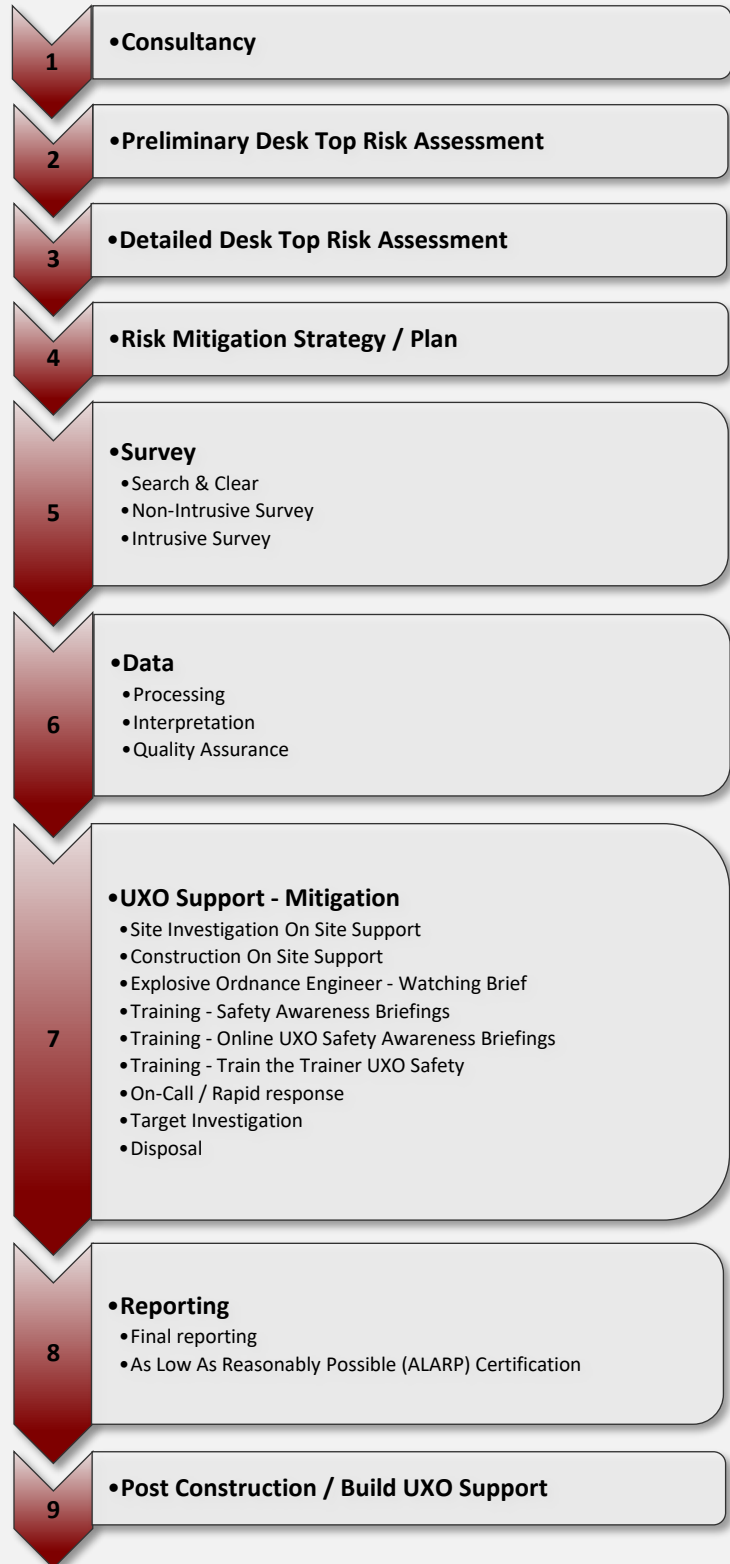
RMS UXO Detailed Phases

1. Preliminary Risk Assessment

2. Detailed Risk Assessment

3. Risk Mitigation

4. Implementation



1. Executive Summary

1.1 Site Overview

The client has specified the site location as Billingham and is approximately centred on the National Grid Reference: TQ 07597 26042.

RMS UXO Limited, (RMS UXO) was commissioned by Ground Condition Consultants Ltd to conduct an Unexploded Ordnance (UXO) Desk Study Risk Assessment for Billingham. The primary objective of this document is to evaluate the UXO risks present at the specified site and its surrounding areas, in compliance with the Construction Industry Research and Information Association (CIRIA) C681 guide on 'Unexploded Ordnance (UXO), a Guide for the Construction Industry'.

1.2 Proposed Works

The proposed works outlined by the client include window sampling and trial pits.

1.3 Summary of Available Information

- During WWII, the Rural District of Horsham sustained a low-density bombing campaign according to The National Archives statistics, with an average of 6.5 items of ordnance recorded per 1,000 acres.
- There are 8 HE bomb strikes recorded to have occurred within an approximate 1km radius of the site; however, there are no records or evidence to suggest any HE bombs struck within the site boundary. There is a possibility that additional HE bombs, UXBs and IB clusters may have struck certain areas of the site unrecorded due to open ground across the site masking any evidence of such strikes. Incendiary bomb showers were not recorded within these records and therefore may also pose a risk to the site. The open areas on site being the main risk pathway.
- Bomb Damage mapping was unavailable for the area of Billingham.
- High-resolution aerial photographs around the Billingham area in 1959 corroborate with pre-war OS mapping and reveal the site consisted open, undeveloped ground. A high-resolution aerial photograph around the Billingham area in 1999 shows the site in its modern-day composition, this corroborates with the post-war OS mapping.
- The site is anticipated to have received low levels of access and observation due to its undeveloped nature. However, during any bombing raids the anticipated level of access would have dropped significantly, and the chance of observing a bomb strike to the open ground on site in the east and south and west is low
- RMS UXO's geo-referenced database has identified allied defensive features within an approximate 1km radius, however the risk from LSA and SAA is negligible.
- There are HAA batteries within proximity to the site where unexploded HAA may have landed unnoticed.
- No evidence has been located to suggest that the site formerly had any military occupation or usage that could have led to contamination with items of British / Allied ordnance.

1.4 Risk Assessment Summary

Risk Level					
Low					
Table 1.1 - Risk Assessment					
Type of work	Potential Hazard	Likelihood (L)	Severity	Risk Rating	Risk Zone
Future developments	HE Bombs	1	5	5	Low
Future developments	IBs	1	4	4	Low

1.5 Project Specific Recommendations

The table below provides the recommended methods of UXO risk mitigation required to adequately mitigate the risk of UXO for the project in line with the scope of works detailed within the report and is in accordance with the CIRIA 681 Guidelines.

	Table 1.2 MITIGATION METHOD – Low Risk Areas	YES	TBC*
	Safety Awareness Briefings Explosive Ordnance Safety and Awareness Training is provided to site personnel to make them aware of the potential threat from UXO on the work site, what UXO might look like and what to do if suspected UXO is encountered.	✓	
	Site Specific Safety Instructions – Emergency Response Plan Provides site management teams the training, information and guidance to respond to a UXO related incident. Delivered by experienced EOD qualified personnel and often employed alongside an on-call offsite EOD responder.	✓	
	On-call EOD Engineer – Off-site Responder A retained service whereby a qualified EOD engineer will respond to a suspicious find on-site.		✓
	UXO Removal & Disposal The removal from site of safe to move or inert items of UXO for disposal off-site.		✓
	UXO Disposal The disposal of UXO onsite. This may be through explosive means, burning or mechanical dismantling methods.		✓

*Note: These are mitigation options that may be required.

For the complete list of UXO risk mitigation measures available please refer to section 6 within the report.

2. Project Context

2.1 Project Rational & Scope

Objective

The objective of this assessment is to evaluate the potential for encountering unexploded ordnance (UXO) at Billingham during the proposed site investigations. This assessment adheres to the UXO risk management process and follows CIRIA Guidelines.

Aims

The primary aim of this report is to examine the likelihood of encountering explosive ordnance during the planned works at Billingham. Based on the findings, risk mitigation measures will be recommended to either eliminate or minimize the threat from UXO.

Issues Addressed

The report will focus on the following key issues:

- The risk of UXO contamination at the site.
- The possibility of remaining UXO on site.
- The potential for encountering UXO during intrusive works.
- The risk of ordnance initiation.
- The consequences of initiating or encountering ordnance.
- Appropriate risk mitigation measures will be recommended, contingent on the assessed level of risk and specific site conditions.

Tasks:

- **Preliminary Site Assessment:** Conduct an initial review of historical data and previous studies related to the site.
- **Data Collection:** Gather relevant data through field surveys etc.
- **Data Analysis and Risk Assessment:** Analyse the collected data to identify UXO threats and assess risks.
- **Mitigation Planning:** Develop a set of tailored risk mitigation measures.

Responsibilities:

- RMS UXO will be responsible for all data collection, analysis, and reporting.
- The client is responsible for providing access to the site and any existing data or reports.

Limitations and Assumptions:

- The assessment is based on the data available at the time of the study.
- Any changes in project scope or site conditions must be communicated to RMS UXO for re-assessment.

3. Methodology

3.1 Methods

Risk Assessment Process

Our risk evaluation employs a systematic methodology, focusing on several crucial aspects:

- Assessing historical UXO contamination at the location.
- Assessing the likelihood – pathways for UXO to have contaminated the site.
- Assessing the likelihood of UXO being still present
- Estimating the likelihood of encountering UXO during upcoming activities.
- Assessing the chances of UXO functioning as designed.
- Understanding the implications of either encountering or UXO detonating.

To comprehensively cover these aspects, we've considered:

- Past records of bombings and military engagements.
- Conditions and historical context of the site during times of conflict.
- Post-conflict developments and any documented UXO removal efforts.
- The characteristics and scale of the planned activities.
- The variety of munitions that could have affected the area.

Sources of Information

To ensure a thorough and comprehensive report, material from the following sources has been consulted:

- The National Archives.
- Local Historical Archives.
- Relevant Government Departments.
- Information provided by client.
- RMS UXO's comprehensive historical archives and UXO geo-database.
- Open sources such as published books and internet resources.

Reliability and Limitations

As of the date this document was issued, all contained information is verified to be both current and accurate. Our databases undergo systematic updates to include the most recent data, and RMS UXO has employed rigorous precision and specialised expertise in the creation of this document.

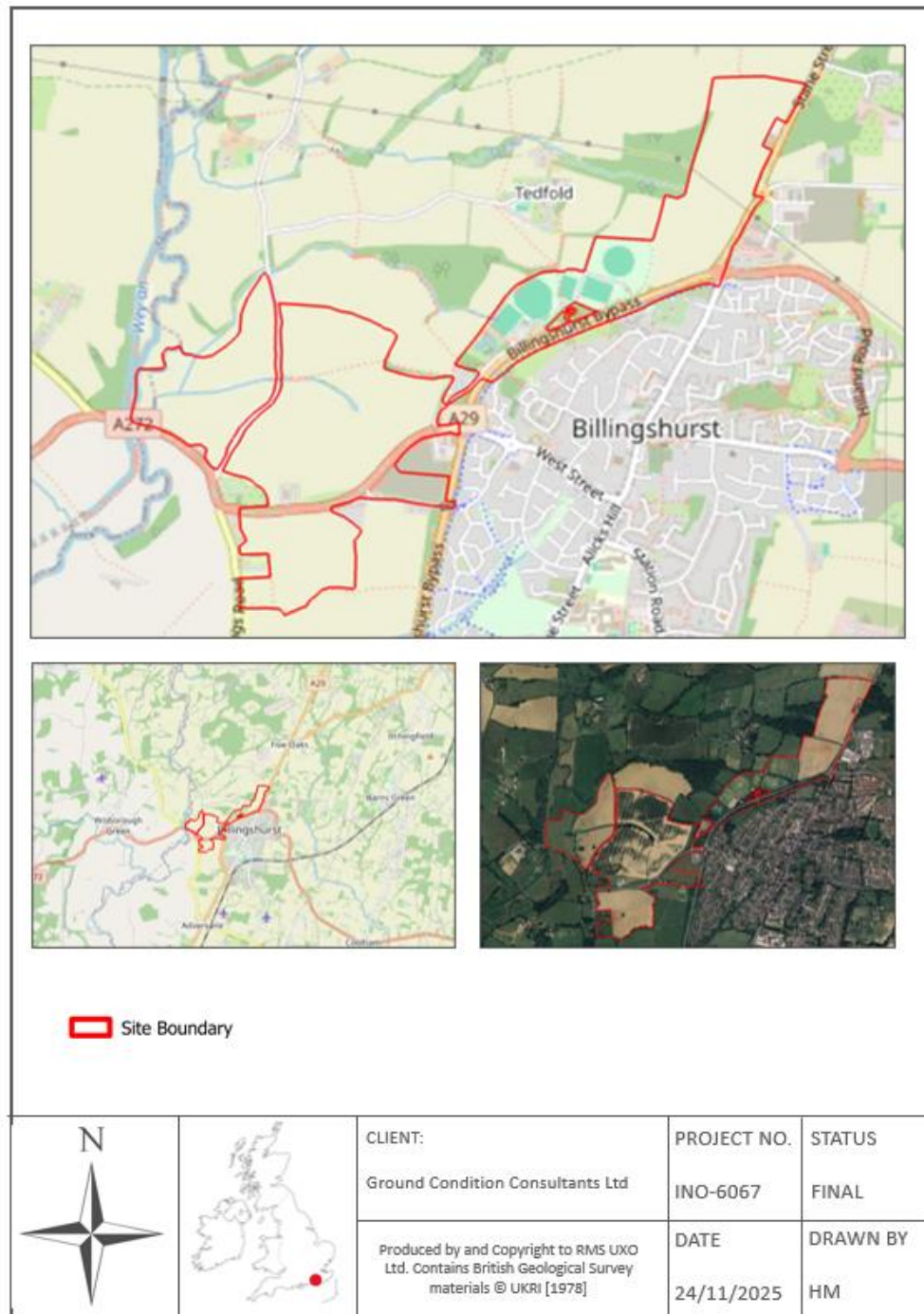
Our risk evaluations are grounded in thorough investigation and supported by data from multiple, verified external sources. While every measure has been taken to ensure the reliability of this data, it is understood that historical records may contain inherent limitations. Consequently, RMS UXO disclaims liability for any inaccuracies present in external data sets beyond our purview.

4. Site Profile

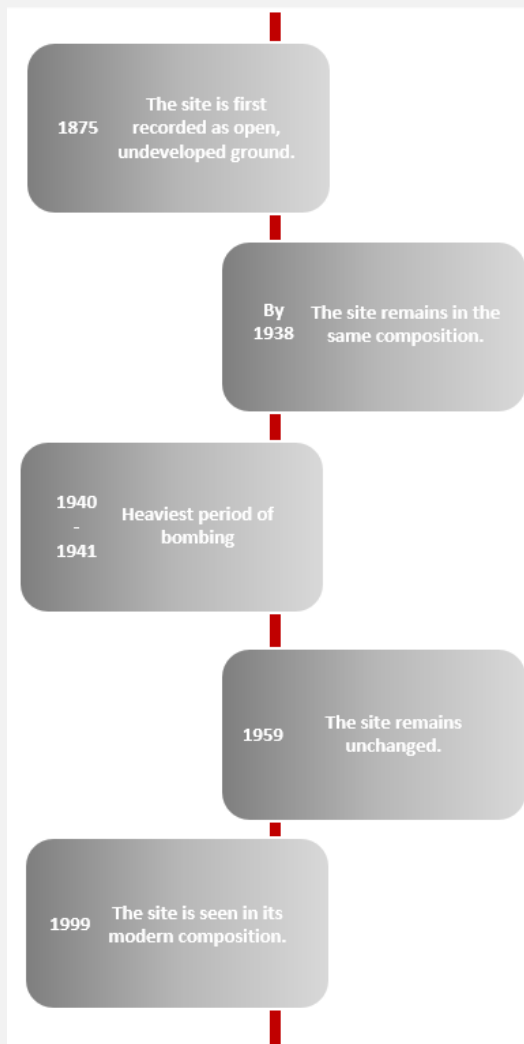
4.1 Location

The Client has defined the site as Billingshurst and is approximately centred on the National Grid Reference: TQ 07597 26042.

The site is situated in the Rural District of Horsham, approximately 1km from Billingshurst Station.



4.2 Historical Context & Previous Studies



Military Activity & WWII Site Utilisation: The site has not been identified as an area of military activity during the war.

Bombing Decoys: Records indicate no bombing decoys in the immediate area.

Air Delivered Ordnance: Archival records confirm the deployment of HE and Incendiary bombs via aerial delivery in the vicinity of Meadowhall between 1940 and 1945. 8 HE bomb strikes are recorded to have occurred within an approximate 1km radius of the site; however, there are no records or evidence to suggest any HE bombs struck within the site boundary. Incendiary bomb showers were not recorded within these records and therefore may also pose a risk to the site, the entire site being the main risk pathway.

Anti-Aircraft Defences: There are no Heavy-Anti-Aircraft (HAA) gun batteries located within an approximate 15 kilometres radius from the site. These pose a risk of UXO contamination primarily due to storage of ammunition and partially due to searchlights rendering them clear targets for bombing at night. The main risk associated with this site is that unexploded HAA shells can land up to an average of 15km from the firing point. However, as

there are none within a 15km radius, the risk of HAA can be discounted.

Aerial Photography: High-resolution aerial photographs around the Meadowhall area in 1959 corroborate with OS mapping and reveal the site consisted of open, undeveloped ground. It should be noted that the entirety of the site is not visible in either consulted images.

Access to the Site: The site is anticipated to have received low levels of access and observation due to its undeveloped nature. However, during any bombing raids the anticipated level of access would have dropped significantly, and the chance of observing a bomb strike to the open ground on site is low.

Bomb Damage Maps: Research indicates that bomb damage maps are not available for Billingham and therefore are unavailable for this report.

Pre-WWII Maps: Historical maps dated 1938, have been consulted and show the site consisted of open, undeveloped ground.

Post-War Maps & Historical Records: A thorough review of post-WWII maps and historical records show post-war the site retained its pre-war composition until at least 1961 as this is the last set of available mapping.

Modern Development: Further development has comprised the construction of 2 smaller structures to the centre and east of the site, the rest of the site has seen no developments.

Intentional or Unintentional Disposal: Records indicate no instances of disposal of UXO, within the confines of site.

4.3 Proposed Work & Risk Pathways

The planned activities at Billingshurst encompass various intrusive engineering tasks, such as Trial pitting and Window Sampling. These tasks inherently create risk pathways for potential encounters with Unexploded Ordnance. The probability of encountering UXO is contingent upon the type and depth of the intrusive work being conducted. Consequences of UXO initiation could range from critical injuries to personnel to substantial damage to equipment and project delays. To mitigate these risks, a comprehensive approach will be employed, considering historical data, site-specific conditions, and previous UXO clearance operations. Tailored risk mitigation strategies will be developed to address the unique risk pathways associated with the proposed work. Considering the range of UXO that could exist within the site, trial pits and window sampling could introduce a high-risk scenario. While not every UXO encountered in this manner is guaranteed to activate upon contact, the discovery of one could have severe repercussions. These could range from endangering personnel and damaging equipment to causing substantial delays in project timelines.

4.4 Potential Hazards

German Air Delivered Ordnance

To gain a comprehensive understanding of the impact of air raids on Sussex during wartime, a comprehensive examination of record sets was conducted at the National Archives and within online sources.

World War I

Billingshurst was not bombed during WWI and therefore the risk of encountering unexploded WWI bombs today is very low.

World War II

Primary strategic targets in Britain included airfields, depots, docks, warehouses, wharves, railways, factories, and power stations. Later in the war the Luftwaffe bombing started to include civilian areas and sites of cultural and historical significance.

WWII Home Office Bombing Statistics

The table below shows the quantity of German aerial delivered bombs (excluding 1kg incendiaries and anti-personnel bombs) dropped on the area of Horsham from 1940 to 1945.

Table 4.1 - Record of German Ordnance Dropped on Horsham	
Area (Acres)	75835
High Explosive Bombs	410
Parachute Mines	-
Oil Bombs	29
Phosphorus Bombs	27
Fire Pots	-
V1	24
V2	-
Total	490
Bombs per 1000 Acres	6.5

During WWII, the Rural District of Horsham sustained a very high-density bombing campaign according to The National Archives statistics, with an average of 6.5 items of ordnance recorded per 1,000 acres.

Records of the 1kg incendiary and anti-personnel bombs were not routine as they were too numerous to record. Although risk from IB's is less than that of HE bombs they were still designed to harm. Anti-personnel bombs are rare to find today but are potentially more dangerous. Although statistics for these bombs were not often recorded, it is important to carefully consider when evaluating risk to personnel and equipment.

Primarily HE bombs are most commonly associated with historical military activities in the area of Billingshurst. These UXO items are typically found in undisturbed soil, up to a standard depth of 9m.

4.2	Type of UXO	Characteristics
HE	High Explosive Bombs	The most commonly deployed German High Explosive (HE) bombs during WWII were the SC50, with 97% of all bombs dropped being in the 50kg, 250kg, and 500kg range. These bombs, which comprised 40-50% explosive fill, were capable of creating entry holes as small as 20cm in diameter and could easily penetrate the ground if they failed to detonate on impact. HE bombs were the primary ordnance used by the Luftwaffe in terms of weight. Post-air raid assessments often struggled to identify unexploded ordnance (UXO) due to the extensive damage caused by detonated bombs, which sometimes rendered the small entry holes of UXO undetectable, especially in certain ground conditions. This is further complicated as Air Raid Precautions (ARP) documents highlight the risk of misidentifying large UXO damage as resulting from an exploded 50kg bomb. As a result, UXO pose a significant risk to current intrusive works.
LIB	Large Incendiary Bombs	Large Incendiary Bombs (IBs) were less common than the 1kg variants but were used more frequently than Parachute Mines and Anti-Personnel bomblets. In instances where these large IBs penetrated the ground, complete combustion did not always take place. As a result, they could remain a hazard for any intrusive works, maintaining a risk due to their potential unburnt components.
IB	1kg Incendiary Bombs	In terms of the number of weapons dropped, small IBs were the most numerous. Millions of these were dropped throughout WWII. Large IB's were not as common as the 1kg IBs, although they were more frequently deployed than PMs and AP bomblets.
PM	Parachute Mine or G Mine	These were deployed less frequently than HE and IBs due to size, cost, and the difficulty of deployment
AP	SD-2 Anti-Personnel Bomblets	Anti-Personnel (AP) bomblets, though not widely used, are generally regarded as posing a low risk to most operations in the UK. The SD2 bomblets, typically packed in containers with 6 to 108 submunitions, had limited ability to penetrate the ground. They would have likely been identified during post-raid surveys, barring instances where they landed in water, dense vegetation, or amidst bomb rubble, where their detection might have been more challenging
V-1	Vergeltungswaffe-1, Flying Bomb, Buzz Bomb, or Doodlebug	The V-1 was a pivotal advancement in military weaponry during WWII. It holds the distinction of being the first guided missile utilized in the conflict, serving as a precursor to modern cruise missiles. This innovative design was propelled by a pulsejet, marking a significant technological breakthrough at the time

4.2	Type of UXO	Characteristics
V-2	Vergeltungswaffe 2 (Reprisal Weapon 2)	The V-2 was the first ballistic missile in military history. It was predominantly employed by the German Army against Belgian and British targets during the latter stages of World War II. Notably, the V-2 holds the distinction of being the first man-made object to reach space, achieving an altitude of 189 km (117 miles) during test flights in 1944.

German Air-delivered Ordnance Failure Rate

It has been estimated that approximately 10% of the HE bombs dropped during WWII failed to explode as designed. This estimate is probably based on the statistics of wartime recovered UXBs and therefore will not have taken account of the unknown numbers of UXBs that were not recorded at the time and is probably an underestimate.

The reasons for failures include:

- Fuse or gain malfunction due to manufacturing fault, sabotage (by forced labour) or faulty installation.
- Clockwork mechanism failure in delayed action bombs.
- Failure of the bomber aircraft to arm the bombs (e.g. charge the electrical condensers which supplied the energy to initiate the detonation sequence) due to human error or equipment defect.
- Jettison of the bomb before it was armed or from a very low altitude.

Allied Explosive Ordnance

The potential risk of encountering Allied ordnance on construction sites is particularly high in areas with a history of military activity, including munitions from military exercises, poor disposal practices, or defensive placements against enemy occupation. Such areas may contain remnants like Land Service Ammunition (LSA) and Small Arms Ammunition (SAA).

While there's no evidence of military use at the specific site in question that could lead to contamination with Allied ordnance, urban areas like this one are still at risk from unexploded Anti-Aircraft projectiles from WWII. This is particularly relevant considering the Ministry of Defence's WWII defence tactics against the Luftwaffe, which involved heavy and light anti-aircraft artillery and 'Z' batteries to protect major towns, cities, and strategic locations. The table below offers further details on these defence systems and the associated risks.

4.3	Type of UXO	Characteristics
LSA	Land Service Ammunition	LSA resulting from historic military activity is commonly encountered across the UK by the public and construction industry alike. Such finds are much more common in rural areas than in urban environments and can often be anticipated in areas such as former RAF stations or ranges. However, many such items are encountered entirely by surprise where the landowner or developer has no knowledge of any previous military use of the land.
	Mortars	A mortar is typically a simple, lightweight, man-portable, muzzle-loaded cannon, consisting of a smooth-bore metal tube fixed to a base plate (to spread out the recoil) with a lightweight bipod mount and a sight. Mortars are typically used as indirect fire weapons for close fire support with a variety of ammunition. Mortars launch high explosive or carrier shells in high-arching ballistic trajectories.

4.3	Type of UXO	Characteristics
	Grenades	A grenade is a small explosive weapon typically thrown by hand (also called hand grenade) but can also refer to a shell (explosive projectile) shot from the muzzle of a rifle (as a rifle grenade) or a grenade launcher.
	Mines	A landmine is an explosive weapon often concealed under or camouflaged on the ground and designed to destroy or disable enemy targets as they pass over or near it. Land mines are divided into two types: anti-tank mines, which are designed to disable tanks or other vehicles; and anti-personnel mines, which are designed to injure or kill people
	Rockets	During World War II, a variety of rockets were mounted on planes, including air-to-air rockets, air-to-surface rockets, and guided bombs
SAA	Small Arms Ammunition	The most common type of ordnance encountered on land used by the military are items of Small Arms Ammunition (SAA). SAA refers to the complete round or cartridge designed to be discharged from varying sized hand-held weapons such as rifles, machine guns and pistols. SAA can include bullets, cartridge cases and primers/caps
	.303	It was the standard British and Commonwealth military cartridge for rifles and machine guns (Bren Gun) from 1889 until it was replaced by the 7.62×51mm NATO in the 1950s.
	7.92mm BESA	The British military's Besa machine gun was chambered for the 7.92×57mm Mauser and was used in armoured vehicles during World War II.
	9x19mm	These rounds were issued for use with Sten guns, the Lanchester sub machine gun and the Browning Hi Power pistol and were produced in huge quantities.
	20mm Hispano	Used in the Hispano 20mm Cannon, which was installed in various fighter planes including the spitfire and the hurricane.
	20mm Oerlikon	A semi-rimmed round that was used in the 20mm Oerlikon gun, which was a key weapon in defending ships and aircraft. During WWII, twin and quadruple Oerlikon mounts were developed, both for army and for navy use

4.4	Type of UXO	Characteristics
AAA	Anti-Aircraft Artillery	At the start of WWII, two types of AAA guns were deployed: Heavy Anti-Aircraft Artillery (HAA), firing large shells (3.7" plus calibre) and Light Anti-Aircraft Artillery (LAA) employing smaller calibre weapons, firing .303", 20mm and 40mm shells.
LAA	Light Anti-Aircraft	The Light Anti-Aircraft (LAA) artillery, notably the 40mm Bofors and 20mm Oerlikon guns, played a significant role in WWII, primarily targeting fast, low-flying aircraft. These mobile units were strategically repositioned along town perimeters and near key industrial sites, enhancing their operational flexibility. However, this mobility results in limited historical records regarding their exact locations. The 40mm Bofors gun, widely utilized due to its capacity to fire up to 120 projectiles per minute over a range of 1,800 meters, was a common fixture. The RAF Regiment initially employed the 20mm Oerlikon gun, capable of discharging up to 330 rounds per minute up to 4,000 meters, before gradually integrating the Bofors gun from 1943 onwards, often maintaining a mix of both types until the end of the war. All Allied military airfields were fortified with these LAA batteries, strategically placed in isolated positions to optimize defence during aerial attacks. The primary function of these batteries was to intercept fast, low-flying German fighter bombers. The ammunition used in LAA batteries consisted of small projectiles equipped with contact fuses and either a high-explosive or

4.4	Type of UXO	Characteristics
		incendiary charge, designed to detonate upon impact. In instances where these projectiles failed to hit their intended targets, they would fall back to the ground with their charges intact. Despite their reduced risk compared to larger ordnance, the 40mm projectiles, resembling large-calibre small arms ammunition, still pose a considerable safety concern.
HAA	Heavy Anti-Aircraft	Heavy Anti-Aircraft (HAA) batteries, equipped with large guns like the 3.7" Quick Firing (QF), were strategically positioned for engaging high-flying bomber aircraft. These installations, often permanent gun emplacements, were a key component of the UK's aerial defence during WWII. In addition to firing large High Explosive (HE) projectiles, triggered by various fuses including impact, area and time delay mechanisms, local ammunition caches were commonly situated near strategic location like defended roadblocks or pillboxes.
ZAA	Z (Rocket) Batteries:	A Z-Battery comprised a grid formation of 64 rocket projectors which fired 2" and later 3" Unrotated Projectile (UP) rockets to a maximum altitude of 5,800m; a ground range of some 9,000m. They were deployed in cities all around the UK from 1941 and proved to be an effective addition to the existing AA guns. The rockets measured 0.9m (2") and 1.8m (3") in length with four stabilising fins at the base and were fitted with 3.5kg or 8.2kg HE warheads. The larger warhead had an effective airborne blast radius of up to 20m. Some variants deployed a form of aerial mine described as a "small yellow bomb" which was designed to detach from the rocket at height and descend on a parachute with the objective of becoming snagged on target aircraft and then detonating.

4.5 Site Geology & Bomb Penetration Depth

Assessing ground conditions is a key factor in determining both the maximum penetration depths of unexploded ordnance (UXO) and the likelihood of hidden munitions.

Should there be any changes in site investigation protocols, construction methods, or focus areas within the project site, immediate communication with RMS UXO is advised. This action allows for a timely reassessment of existing UXO risks and the adjustment of risk mitigation plans. Certain soil and rock conditions, such as iron-rich or mineralised soils, can impact the effectiveness of UXO risk reduction methods like magnetometer surveys. Identifying the source of altered soil types is essential for accurately assessing the ground state at the time of potential UXO contamination. This information aids in fine-tuning the calculations for average and maximum bomb penetration depths, thereby enabling more targeted risk reduction strategies in line with ALARP guidelines.

Table 4.5 - GROUND TYPE	DEPTH
Topsoil	0.0 – 0.15m
Firm grey, brown mottled silty clay	0.15 – 0.85m
Firm dark grey silty clay	0.85 – 2.3m

Table 4.5 - GROUND TYPE	DEPTH
Soft blue grey very silty clay	2.3 – 5.6m
Firm grey black silty clay	5.6 – 8.7m
Firm blue grey mottled silty clay	8.7m – 9.9m (borehole continues)

Following a review of the BGS borehole log “TQ02NE6 – BILLINGSHURST NEWBRIDGE 5” (located 30m west of the site), RMS UXO have been able to provide an estimate of the likely maximum bomb penetration depth:

The estimated average bomb penetration depths accounting for ground composition are:

500kg	<8m
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The estimated bomb penetration depth for 50kg and 250kg bombs would be expected to be at shallower depths.

The calculation of bomb penetration depths involves several key factors.

These factors include the bomb being dropped from a significant height, leading to an impact speed of 260 m/s from heights above 5,000m. The angle of impact with the ground varies between 10 and 15 degrees from the vertical, and the bomb remains stable during its descent and upon ground penetration. Additionally, no slowing mechanisms are attached to the bomb, and the soil composition is consistent. When released from a high altitude, the bomb generally enters the ground at an angle of 10 to 15 degrees to the vertical. It maintains this angle until its momentum is nearly depleted, at which point it shifts suddenly to a horizontal position before coming to rest. The term 'offset' refers to the gap between the centre of the entry hole and the bomb's final position. Significant sideways movement from the initial entry path is not uncommon. For attacks from lower altitudes, the angle of impact can be 45 degrees or more, often resulting in increased lateral movement during penetration.

Determining the average impact velocity of World War II bombs like the 50kg, 250kg, and 500kg high-explosive (HE) bombs is not straightforward due to several factors, including the altitude from which they were dropped, their design/shape, and the mediums they passed through.

4.6 Lateral Off-set or 'J-Curve'

The lateral off-set, or 'J-curve' effect, is an important aspect of bomb trajectory, primarily influenced by the bomb's interaction with the ground upon impact. Bombs would typically fall nose-first and result in a varied deceleration between the nose and tail upon contact with the ground with the nose slowing down before the tail. This differential in speeds leads to a notable shift in trajectory and often results in the bomb either achieving a horizontal orientation or, in certain scenarios, curving upward in a J-shaped trajectory.

The horizontal distance between the bomb's entry hole and its final resting position is known as the offset and is typically a distance of about one third of the bombs penetration depth for bombs dropped from high altitudes.

5. Risk Analysis

5.1 Analysis

For each type of investigative method that might be used, RMS UXO has carried out unique calculations to rate the risks. The risks associated with encountering and activating UXO can vary widely. These variations depend on several factors, including the amount of high-explosive material in the UXO and the intensity with which it is encountered. Ground investigation specific to this research location have been prepared to help analyse these risks, as the likelihood of encountering UXO can differ based on the nature of the intrusive activities being conducted.

5.2 Risk Levels and Interpretation

Risk Rating

RMS UXO's Risk Assessment gauges and categorises the dangers presented by the most likely hazardous items during various operations on the site. The Hazard Assessment Score is calculated by evaluating the likelihood of coming across UXO and the potential outcomes of triggering it.

Firstly, the probability of encountering UXO (PE) has been considered and rated for the different construction techniques, as detailed below. The probability of detonating a UXO (PD) has been considered and rated for the different construction techniques, as detailed below.

Table 5.1.1 - Probability of Encounter (PE)	Rating	Table 5.1.2 - Probability of Detonation (PD)	Rating
Highly likely and frequent.	5	Highly likely and frequent.	5
Probable and likely to happen.	4	Probable and likely to happen.	4
Occasional, increased chance or probability.	3	Occasional, increased chance or probability.	3
Remote, unlikely to happen but could	2	Remote, unlikely to happen but could.	2
Improbable, highly unlikely	1	Improbable, highly unlikely.	1
Impossible	0	Impossible	0

Next, the probability of encountering and detonating the UXO (PE x PD) has been used to generate an overall likelihood rating (L).

Each potential risk has been assessed separately to generate the overall likelihood of encountering and detonation a UXO:

For the purpose of this risk assessment, the following values have been applied;

- German HE Bombs - PE= 2 and PD= 2. Therefore, the overall likelihood (L) = 4.
- IBs - PE= 2 and PD= 2. Therefore, the overall likelihood (L) = 4.

Table 5.2 L = PE x PD	Likelihood of Encounter and Detonation	Rating
21 to 25	Frequent, highly likely, almost certain.	5
16 to 20	Probable, more likely to happen than not.	4
10 to 15	Occasional, increased chance or probability.	3
6 to 9	Remote, unlikely to happen but could.	2
1 to 5	Improbable, highly unlikely.	1
0	Impossible	0

L ranges from 25, a certainty of UXO being encountered and detonated on the site by engineering activity, to 0, a certainty that UXO does not occur on the site and will not be detonated by engineering activity.

The likelihood of encountering and detonating UXO during site works is multiplied by the severity of such an event occurring (L x S), in order to provide a risk level using the following matrix.

Table 5.3 - Severity (S)	Rating
Multiple fatalities	5
Major injury, long term health issues, single fatality	4
Minor injury, short term health issues, no fatalities.	3
First aid case but no lost time or ill health.	2
Minor injuries, no first aid.	1
No injuries.	0

This risk matrix is underpinned by historical data, site-specific conditions, and expert analysis. The likelihood and severity ratings assigned are not just theoretical estimates but are grounded in a detailed understanding of the site's past and present characteristics. These factors combine to form a risk profile that guides our UXO mitigation strategy and ensures all necessary precautions are tailored to the site's unique context.

The final risk assessment for the site is given in Table 5.5.

Table 5.4	Severity (s)					
Likelihood (L)		1	2	3	4	5
	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5

Table 5.5 - Risk Assessment Table					
Type of work	Potential Hazard	Likelihood (L)	Severity	Risk Rating	Risk Zone
Future developments	HE Bombs	1	5	5	Low
Future developments	IBs	1	4	4	Low

6. Risk Mitigation & Recommendations

6.1 Recommended Risk Mitigation Measures

The recommendation table below is provided as an overview of the methods required to adequately mitigate the risk of UXO and is in accordance with the CIRIA 681 Guidelines. All of the methods listed are acceptable methods of mitigating explosive risk but do have limitations and should be employed only if viable, interpretable data can be collected.

This is particularly true of intrusive surveys, carried out on sites which are not suitable for this type of method, be it as a result of the underlying strata not allowing sufficient depth penetration or the magnetic environment being too high for the sensors to adequately detect a bomb at the distances from the probe as specified. There is also a reluctance by UXO contractors to raise these constraints once identified on site as it is in their interest to have their survey rigs fully employed.

As this is a direct conflict of interest, RMS UXO has made the decision to not own survey rigs and offer this service, when appropriate, in partnership with UK market leading geotechnical providers – combining our UXO knowledge and our partners ground engineering expertise.

	Table 6.1 - MITIGATION METHOD – Low Risk Areas	YES	NO	TBC*
1	Project Specific Risk Mitigation Strategy A project specific overarching strategy to manage UXO project risk on more complex sites. Developed in line with the clients construction plan and methods of construction to be used.		✓	
2	Safety Awareness Briefings Explosive Ordnance Safety and Awareness Training is provided to site personnel to make them aware of the potential threat from UXO on the work site, what UXO might look like and what to do if suspected UXO is encountered.	✓		
3	Site Specific Safety Instructions – Emergency Response Plan Provides site management teams the training, information and guidance to respond to a UXO related incident. Delivered by experienced EOD qualified personnel and often employed alongside an on-call offsite EOD responder.	✓		
4	On-call EOD Engineer – Off-site Responder A retained service whereby a qualified EOD engineer will respond to a suspicious find on-site.			✓
5	Onsite EOD Engineer – Support to Site Investigation Providing Realtime on-site EOD support to site investigation activities. Delivering safety briefings & employing handheld survey instruments ahead of trial pit excavations, drilling activities etc.		✓	
6	Onsite EOD Engineer- Watching Brief Providing a reactive on-site support where pro-active UXO risk mitigation measures, are not practical. Supervising all open/bulk excavations, responding to suspicious finds & managing UXO related incidents.		✓	
7	Non-Intrusive Survey The collection of survey data which is then processed & interpreted offsite. The purpose of the survey is to locate sub-surface anomalies/targets which may be UXO related. Usually employed on greenfield sites or sites which have not previously been developed.		✓	

	Table 6.1 - MITIGATION METHOD – Low Risk Areas	YES	NO	TBC*
8	Intrusive Survey For sites where a non-intrusive UXO survey cannot reach the maximum depth of UXO risk, or the site is not suitable for a non-intrusive survey such as a brownfield site the intrusive UXO survey provides a suitable alternative. Designed to survey point specific locations where deep engineering works are being undertaken such as piling, pile clusters and sheet piled walls.		✓	
9	Search & Clearance For areas where a non-intrusive survey is not viable or cost effective two-man UXO Specialist teams can be deployed to conduct a manual Search & Clear operation of the site location with handheld UXO detection equipment.		✓	
10	Data Management Data processing, Interpretation or QA (of third-party survey data) The processing and interpretation of third-party survey data for the purpose of UXO clearance.		✓	
11	Target Investigation The investigation of anomalies/targets identified by previously undertaken surveys. Conducted by a two-man EOD team using handheld locators/detectors.		✓	
12	UXO Removal & Disposal The removal from site of safe to move or inert items of UXO for disposal off-site.			✓
13	UXO Disposal The disposal of UXO onsite. This may be through explosive means, burning or mechanical dismantling methods.			✓

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RMS UXO has consulted its internal databases, as well as reference books and archived information, to gather relevant data. Additionally, historic mapping and aerial photography were sourced from the National Archives and other relevant government offices. Information has also been obtained from local county councils and record offices.

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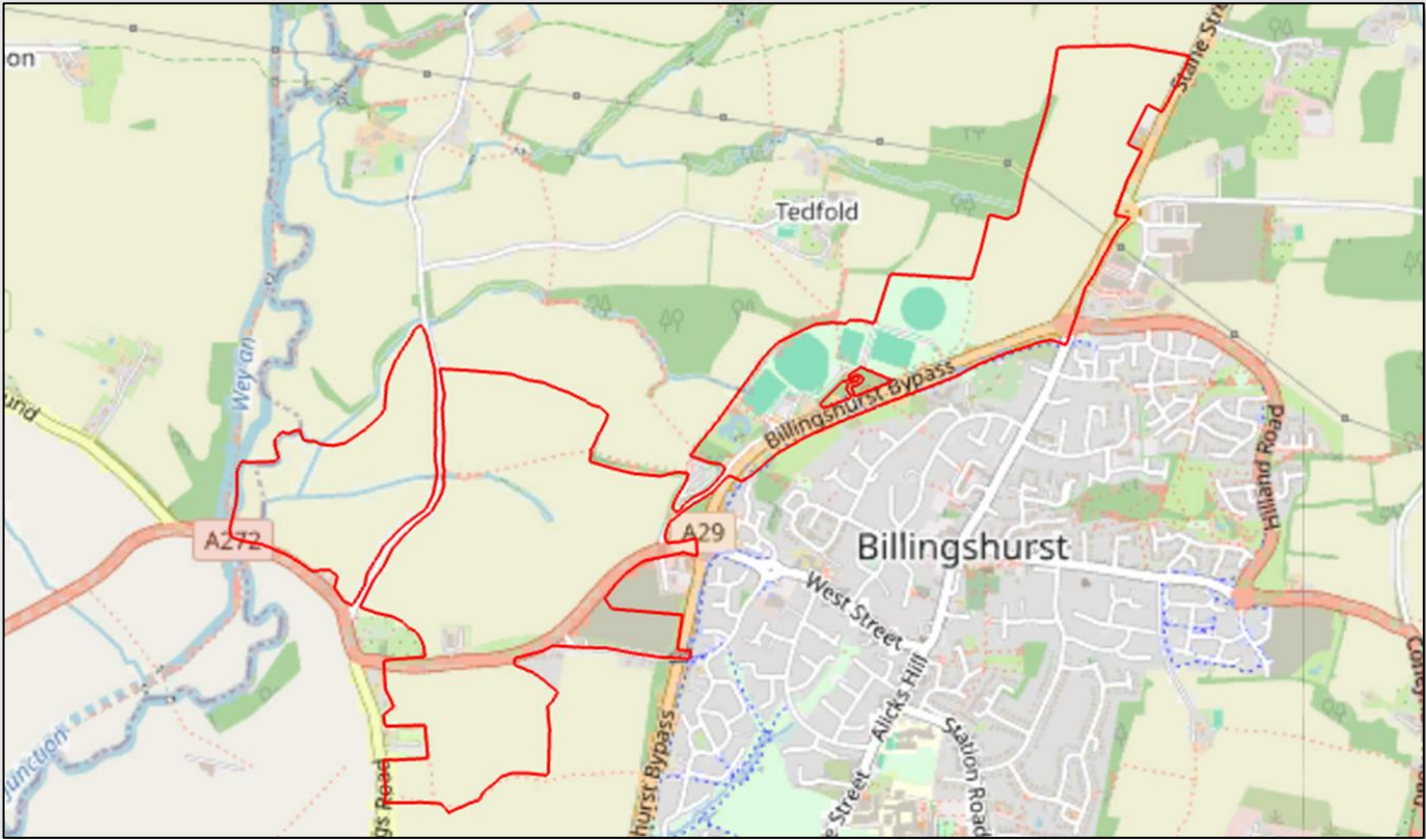
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This report has been constructed with professional thought and care by RMS UXO. Historical data has been meticulously collected and reviewed from third party sources. The validity of this information has been checked to the best of our ability, but RMS UXO holds no accountability for errors resulting from missing or incomplete information. Moreover, despite best efforts to compile a comprehensive historical dataset RMS UXO disclaims responsibility for any subsequent modifications to risk evaluations or mitigation proposals that may be necessitated by the discovery of additional information post factum.



Approx. Site Boundary



Produced by and Copyright to
RMS UXO Limited

CLIENT:
Ground Condition Consultants
Ltd

SOURCE:
Google Earth, OpenStreetMap

PROJECT:
Billingshurst

REPORT REFERENCE:
INO6067

DATE:
26/11/2025





Approx. Site Boundary



Billingshurst - 1959

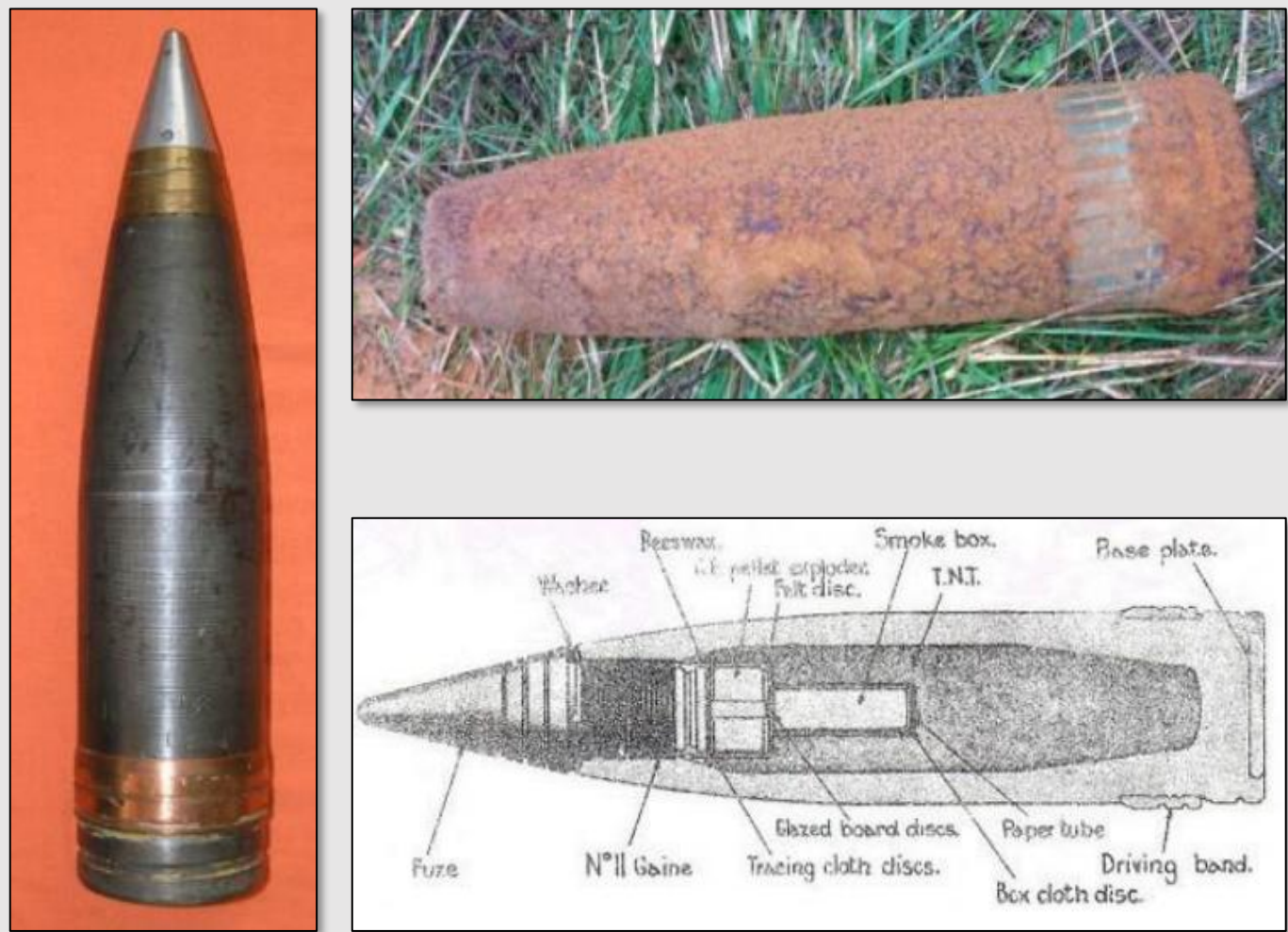


Billingshurst - 1959

Approx. Site Boundary

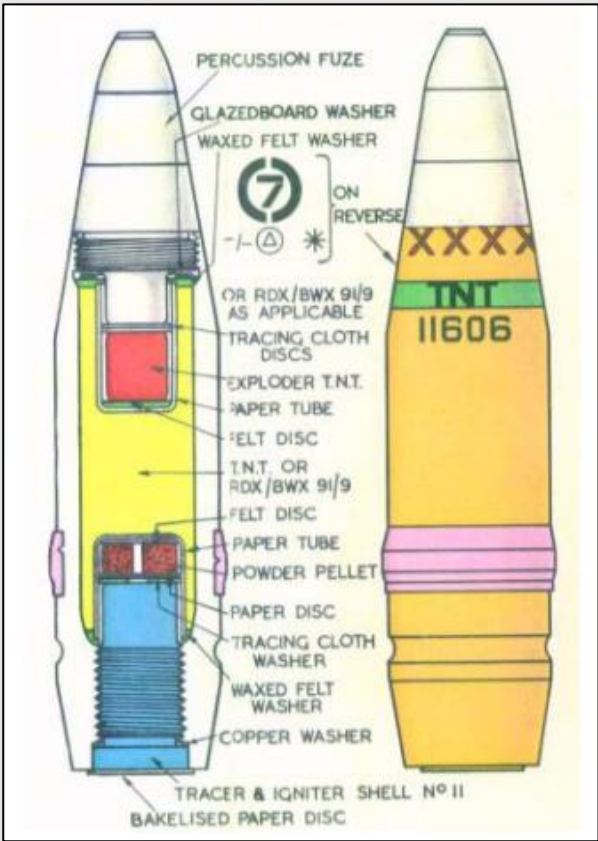
RMSUXO Produced by and Copyright to RMS UXO Limited	CLIENT: Ground Condition Consultants Ltd	PROJECT: Billingshurst	DATE: 26/11/2025
	SOURCE: Historic England	REPORT REFERENCE: INO6067	

3.7 Inch QF Anti-Aircraft Projectile



Total Weight	Projectile Weight 28lb (12.6 kg) Explosive Weight 2.52lbs
Dimensions	3.7in x 14.7in (94mm x 360mm) Rate of Fire 10 to 20 rounds per minute
Fuse Type	Mechanical Time Fuze
Use	The 3.7in AA Mk 1-3 were the standard Heavy Anti-Aircraft guns of the British Army. Ceiling 30,000ft to 59,000ft

40mm Bofors Projectile



Total Weight	Projectile Weight 1.96lb (0.86kg) Explosive Weight 300g (0.6lb)
Dimensions	Dimensions 40 x 180mm
Fuse Type	Impact Fuze
Ceiling	23,000ft (7000m)
Remarks	Light quick fire high explosive antiaircraft projectile. Each projectile fitted with small tracer element. If no target hit, shell would explode when tracer burnt out. Designed to engage aircraft flying below 2,000ft

3in Unrotated Projectile (UP) Anti-Aircraft Rocket ("Z" Battery)

This antiaircraft artillery, designed specifically for the Royal Navy, saw significant deployment in the initial stages of the Second World War. Known as the UP, it was not only utilised at sea but also found applications on land through single and 128-round launchers, commonly referred to as Z Batteries. The ammunition for this system features a cylindrical steel casing that tapers towards the bottom, equipped with external threading for secure attachment to the rocket motor's shell ring



SC 50

Bomb Weight: 40-54kg (110-119lb)

Explosive Weight: c25kg (55lb)

Fuze Type: Impact fuze/electro-mechanical time delay fuze

Bomb Dimensions: 1,090 x 280mm (42.9 x 11.0in)

Body Diameter: 200mm (7.87in)

Use: Against lightly damageable materials, hangars, railway rolling stock, ammunition depots, light bridges and buildings up to three stories.

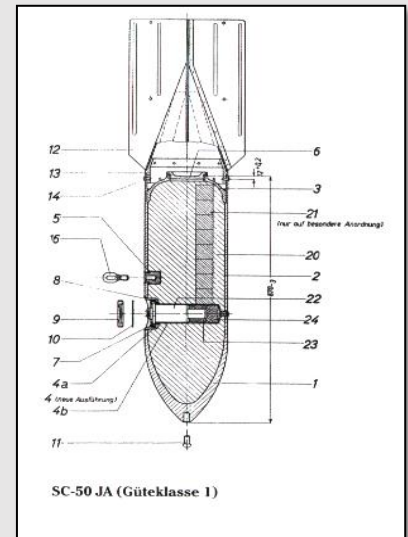
Remarks: The smallest and most common conventional German bomb. Nearly 70% of bombs dropped on the UK were 50kg.



50kg bomb, London Docklands



Minus tail section



SC-50 JA (Güteklasse I)

SC 250

Bomb weight: 245-256kg (540-564lb)

Explosive weight: 125-130kg (276-287lb)

Fuze type: Electrical impact/mechanical time delay fuze.

Post-1943 – Type 50 (Y) electric anti-disturbance fuze

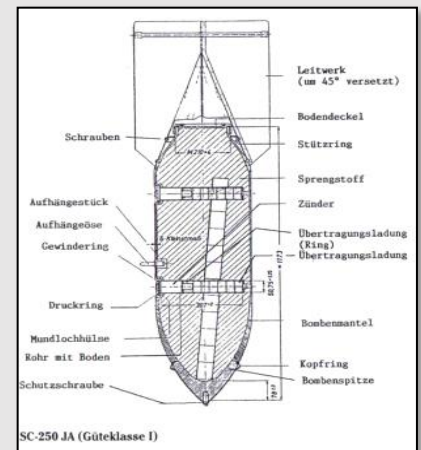
Bomb dimensions: 1640 x 512mm (64.57 x 20.16in)

Body diameter: 368mm (14.5in)

Use: Against railway installations, embankments, flyovers, underpasses, large buildings and below-ground installations.



250kg bomb, Hawkinge



SC 250 JA (Güteklasse I)

SC 500

Bomb weight: 480-520kg (1,058-1,146lb)

Explosive weight: 250-260kg (551-573lb)

Fuze type: Electrical impact/mechanical time delay fuze.

Post-1943 – Type 50 (Y) electric anti-disturbance fuze

Bomb dimensions: 1957 x 640mm (77 x 25.2in)

Body Diameter: 470mm (18.5in)

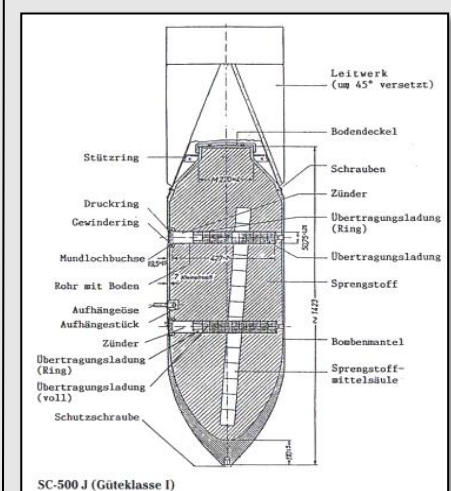
Use: Against fixed airfield installations, hangars, assembly halls, flyovers, underpasses, high-rise buildings and below-ground installations.



50kg bomb included for size comparison (see above)



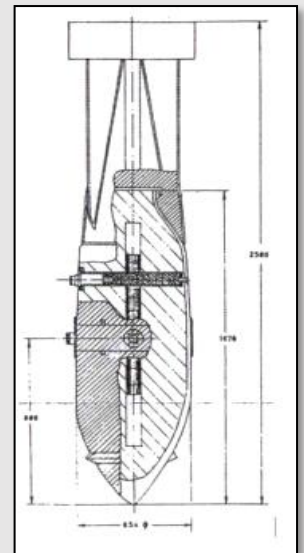
500kg bomb, Felixstowe beach, April 2008



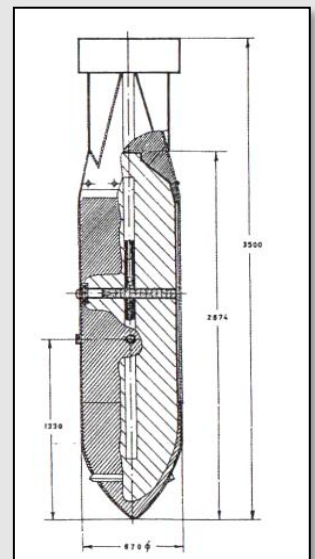
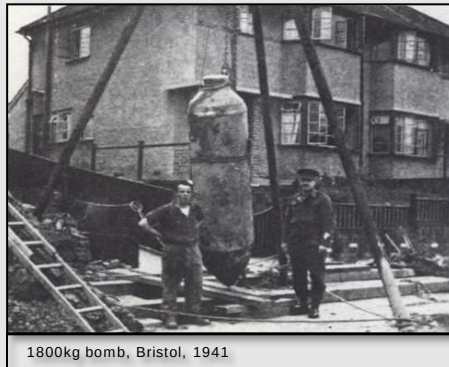
SC-500 J (Güteklasse I)

SC 1000

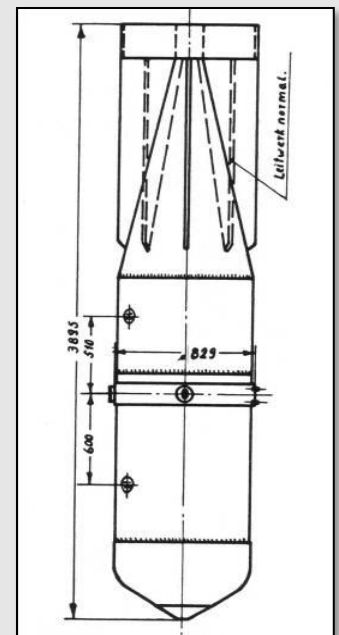
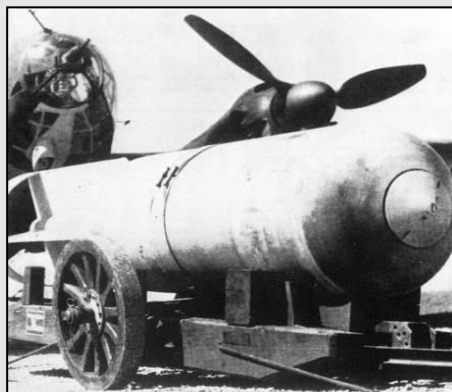
Bomb weight: 993-1,027kg (2189-2,264lb)
 Explosive weight: 530-590kg (1,168-1,300lb)
 Fuze type: Electrical impact fuze.
 Bomb dimensions: 2,580 x 654mm (101.6 x 2.5in)
 Body diameter: 654mm (25.75in)
 Use: Against unarmoured sea and land targets
 Remarks: Known as the 'Hermann'

**SC 1800**

Bomb weight: 1,767-1,879kg (3,896-4,142lb)
 Explosive weight: 1,000kg (2,205lb)
 Fuze Type: Electrical impact fuze
 Bomb Dimensions: 3500 x 670mm (137 x 26in)
 Use: Against building complexes and large merchant vessels
 Remarks: Known as the 'Satan'

**SC 2500**

Bomb Weight: Bomb weights have been quoted as 1,950kg (4,300lb) and 2,500kg (5,512lb)
 Explosive Weight: 1,700kg (3,748lb)
 Fuze Type: Electrical impact fuze
 Bomb Dimensions: 3,895 x 829mm (153.3 x 32.6in)
 Body Diameter: 829mm (32.6in)
 Use: Against building complexes and merchant vessels.
 Remarks: The SC 2500 has an aluminium body with a welded head and tailpiece. Known as the 'Max'. Only a limited number were deployed.



1kg Incendiary Bomb

Bomb weight: 1.0 and 1.3kg (2.2 and 2.87lb)

Filling: 680gm (1.3lb) Thermit

Fuze type: Impact fuze

Bomb dimensions: 350 x 50mm (13.8 x 1.97in)

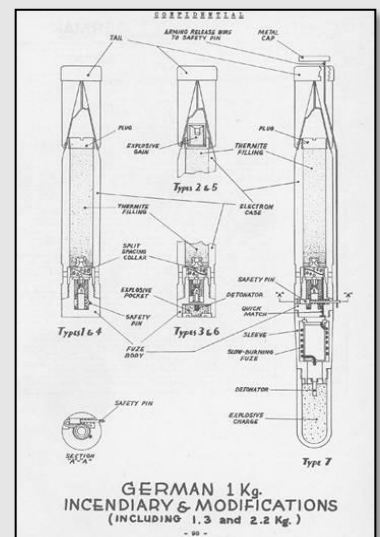
Body diameter: 50mm (1.97in)

Use: As incendiary – dropped in clusters against towns and industrial complexes

Remarks: Jettisoned from air-dropped containers.
Magnesium alloy case. Sometimes fitted with high explosive charge



1. Scaffold pipe
2. Incendiary 1kg bomb
3. Incendiary bomb recently found on site in UK



C-50 A Phosphorous Bomb

Bomb weight: 41kg (90.4lb)

Explosive weight: 0.03kg (0.066lb)

Incendiary filling: 12kg (25.5lb) liquid filling with phosphor igniters in glass phials

Fuze type: Electrical impact fuze

Bomb dimensions: 1,100 x 2800mm (43.3 x 11in)

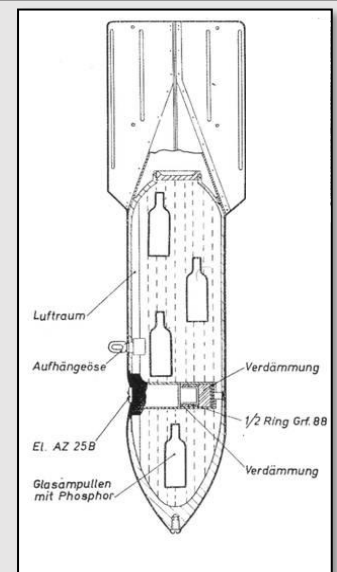
Body diameter: 200mm (2.87in)

Use: Against all targets where an incendiary effect is to be expected

Remarks: Early fill was a phosphorous/carbon disulphide incendiary mixture



Phosphorous Bomb, M25/A2, Kent



Flam C-250 'Oil Bomb'

Bomb weight: 125kg (276lb)

Explosive weight: 1kg (2.2lb)

Flammable weight: 74kg (163lb)

Filling: Mixture of 30% petrol and 70% crude oil

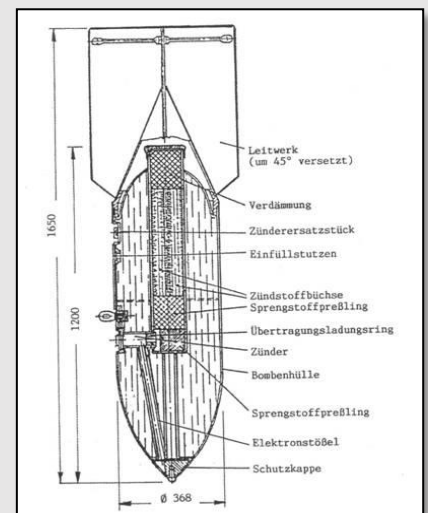
Fuze type: Super-fast electrical impact fuze

Bomb dimensions: 1,650 x 512.2mm (65 x 20.2in)

Body diameter: 368mm (14.5in)

Use: Often used for surprise attacks on living targets, against troop barracks and industrial installations

Remarks: Thin casing – not designed for ground penetration





EXPERTISE, INTEGRITY, PROFESSIONALISM

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