

Other Munitions (Marine or Land Service Munitions)

It is assessed that there is a **Low** risk of encountering other types of munitions.

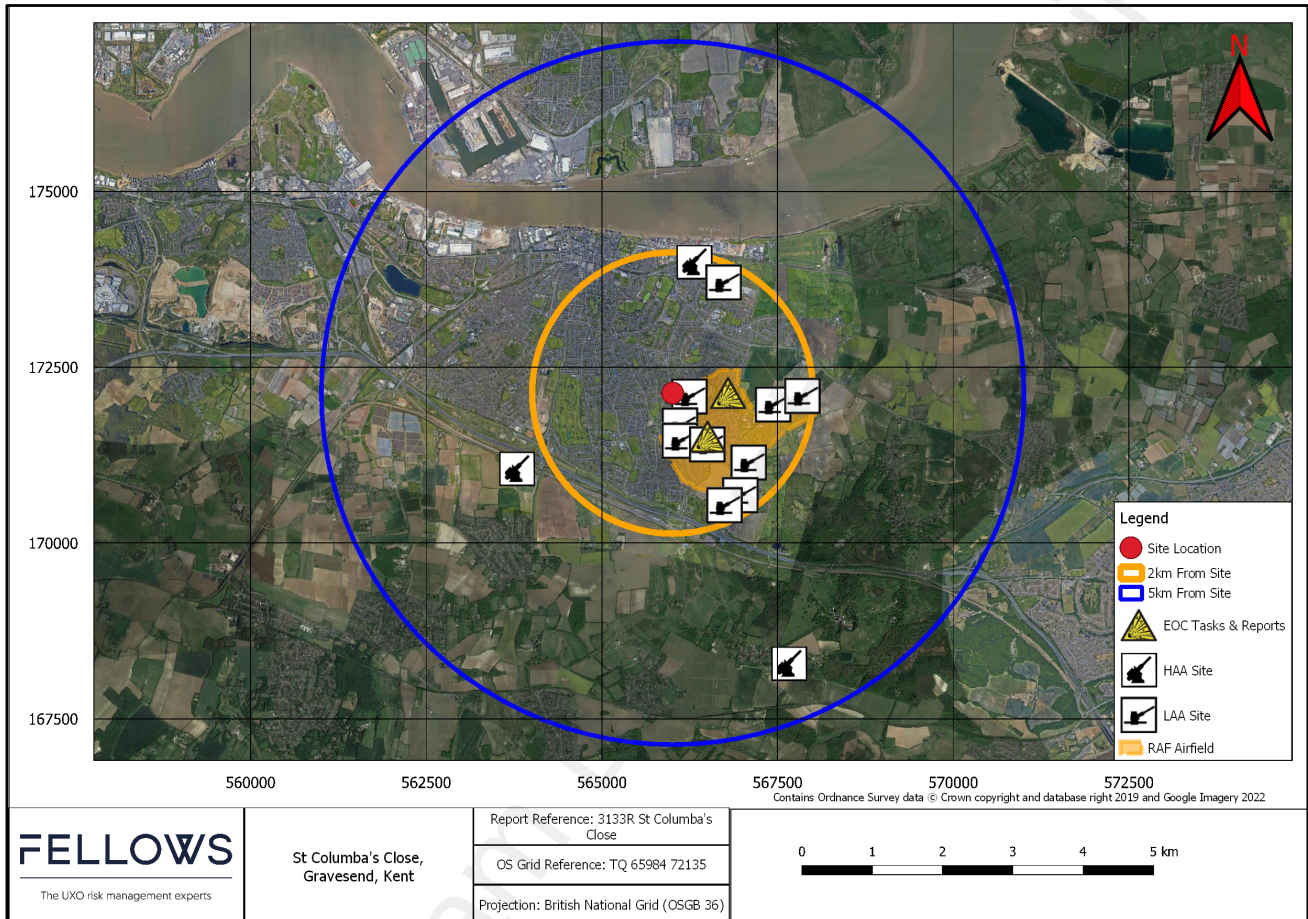


Figure 3. Showing potential UXO influences within 5km of the site

Risk Assessment

In establishing the UXO risk at this site, Fellows take the following factors into account:

- The amount and nature of WW1 and WW2 German aerial bombing
- The nature and conditions of the site during at the time
- Other military use of the site i.e., AA Gun sites, storage, training
- The extent of post-war development and UXO clearance operations on site
- The scope and nature of the proposed works and assessed bomb penetration depth
- The nature of non-aerial ordnance that may have contaminated the site area

The risk assessment matrix below is based upon the chance of encountering items of ordnance and the consequence of interaction with them. This can range from the detonation by design (via fuze and explosive training) of a large aerial bomb to the accidental breakage of old Home Guard glass bottle grenades.

In accordance with standard UK risk assessment methodologies, the overall risk is gained by multiplying the likelihood (chance of encounter) with the consequence (consequence of interaction) and is graded from negligible to Very High risk.

Descriptors

Chance of encounter

1	2	3	4	5
Not at all likely	Unlikely	Possible	Likely	Almost certain

Consequence of interaction with munition

1	2	3	4	5
First aid incident	Minor injuries	Severe injuries	Fatalities	Multiple fatalities

Overall risk calculation (Chance of Encounter X Consequence of interaction)

1-5	6-10	11-15	16-20	21-25
Negligible	Low Risk	Medium Risk	High Risk	Very High Risk

Risk Assessment

Activity	Threat Item	Chance of encounter	Consequence of interaction	Risk
Shallow excavation (<2m)	HE Bombs	2	5	10
	AAA Shells/IBs	2	4	8
	Other Munitions	2	3	6
Window Sampling / Shallow Boreholes	HE Bombs	2	5	10
	AAA Shells/IBs	2	4	8
	Other Munitions	2	3	6
Deeper excavations (>2m)	HE Bombs	3	5	15
	AAA Shells/IBs	2	4	8
	Other Munitions	2	3	6
Piling / deep boreholes	HE Bombs	3	5	15
	AAA Shells/IBs	2	4	8
	Other Munitions	2	3	6

6. Report Methodology

The aim of this report is to conduct a comprehensive assessment of the potential risk from UXO at the site as described by the client.

Every reasonable effort has been made to ensure that all available historical information has been accessed and checked. Where possible, evidence has been included in the report to enable the client to understand the basis of the risk assessment. Fellows cannot be held responsible for any changes to the assessed level of risk or risk mitigation measures based on documentation or other information that may come to light at a later date. The accuracy of wartime records is frequently difficult to verify. As a result, conclusions as to the exact location, quantity and nature of the ordnance threat can never be definitive but must be based on the accumulation and careful analysis of all accessible evidence. Fellows cannot be held responsible for inaccuracies or gaps in the available historical information. All sources are referenced at Section 12.

The report recommends appropriate site and work-specific risk mitigation measures to reduce the risk from explosive ordnance during the envisaged works to a level that is as low as reasonably practicable [ALARP].

This report follows the guidelines outlined in CIRIA Report C681, 'Unexploded Ordnance [UXO] A Guide for the Construction Industry' and CIRIA C785, 'Unexploded Ordnance [UXO] Risk Management'.

Fellows has been supporting the UK construction industry with UXO Risk Management measures for over two decades and offer the complete UXO risk management process from the preliminary and detailed desk study through to the physical site survey and finally, the identification and removal or disposal of an item, either in house or in liaison with military disposal assets. Our desk top studies enable our clients to accurately assess the UXO risk and take proportionate, cost-effective action to manage the risk posed by unexploded aerial bombs and other munitions.

As one of the first companies to offer this service in the UK, Fellows have unrivalled experience delivering the UXO Risk Management process and are proud of our reputation for quality and cost-effective delivery, gained from our years of experience. Fellows can support you through the whole risk management process from project start to final delivery. While Fellows is mainly active in the UK, we also have a long history of operating overseas on projects all over the globe. We are proud to support both the construction and offshore industries with the right experience, people, qualifications and equipment to best identify, quantify and mitigate the UXO risk wherever it may be.

7. Requirement for UXO Risk Assessment

Background

There is no formal obligation requiring a UXO risk assessment to be undertaken for construction or development projects in the UK, nor is there any specific legislation stipulating the management or mitigation of UXO risk. However, the legislation outlined below makes very clear that those responsible for intrusive works (archaeology, site investigation, drilling, piling, excavation etc.) should undertake a comprehensive and robust assessment of the potential risks to employees and that mitigation measures are implemented to address any identified hazards.

CDM Regulations 2015

The Construction (Design and Management) Regulations 2015 (CDM 2015) defines the responsibilities of parties involved in the construction of temporary or permanent structures. CDM 2015 establishes a duty of care extending from clients, principal co-ordinators, designers, and contractors to those working on, or affected by, a project. Those responsible for construction projects may therefore be accountable for the personal or proprietary loss of third parties if correct health and safety procedure has not been applied.

Although CDM 2015 does not specifically reference UXO, the risk presented by such items is both within the scope and purpose of the legislation. It is therefore implied that there is an obligation on parties to:

- Provide or obtain an appropriate assessment of potential UXO risks at the site
- Emplace appropriate risk mitigation measures if necessary
- Supply all parties with relevant risk information
- Prepare a suitably robust emergency response plan.

Other legislation

The 1974 Health and Safety at Work etc. Act

All employers have a responsibility under the Health and Safety at Work etc Act 1974 and the Management of Health and Safety at Work Regulations 1999, to ensure the health and safety of their employees and third parties, so far as is reasonably practicable.

8. Sources of Potential Unexploded Ordnance

UXO found at construction and development sites in the UK originates from three principal sources:

➤ Munitions deposited as part of military training or exercises.

In the UK, this can be historical from both World Wars and before but also more recent, especially as land reserved for military use is released for development.

➤ Dumping

Munitions abandoned or dumped, either deliberately post war, accidentally lost in transit or due to ineffective working practices during manufacture, storage and transportation.

➤ Wartime activity (including aerial bombing)

This includes ordnance resulting from wartime activities including enemy bombing, long range shelling, area or site denial weapons (mine fields or airfield pipe mines) and munitions from defensive activity such as anti-aircraft batteries or pre-invasion measures.

Other factors which may increase UXO risk

Transportation of aggregates containing munitions to an area that was previously free of UXO has led to small munitions contaminating a previously low risk site. This is usually related to construction activities employing material dredged from a contaminated offshore borrow site although the use of explosive contaminated soil or fill from higher risk areas should also be considered.

9. Aerial Bombing

General

During WW1 and WW2, many towns and cities across the UK were subjected to bombing which often resulted in extensive damage to city centres, docks, rail infrastructure and industrial areas. In addition to raids which concentrated on specific targets, indiscriminate bombing of large areas also took place, notably the London 'Blitz'. Bombing also affected many other towns and cities including Birmingham, Portsmouth and Bristol.

Approximately 10% of the bombs dropped on the UK did not detonate as designed. Although extensive efforts were made to locate and deal with these UXBs at the time, many still remain buried and can present a potential risk to construction projects.

Although the main focus of historical UXO research generally concerns German air-delivered ordnance dropped during WW2, all other forms of explosive contamination will also be considered.

One of the most common types of UXO discovered today is the aircraft delivered high explosive (HE) bomb. These are comparatively thick-skinned and dropped from enemy aircraft. If the bomb did not detonate when it was dropped, the force of impact enabled the bomb to penetrate the ground, often leaving behind it an entry hole. These entry holes were not always apparent, and some went unreported, leaving the bomb buried and unrecorded. The bomb then became an Unexploded Bomb or UXB.

Additional forms of German aerial UXO will be considered including WW2 'Vengeance' weapons (V1 and V2 rockets), small Incendiary Bombs (IBs), and Anti-personnel (AP) bomblets.

World War Two aerial bombing

Targeting

Although the Luftwaffe had designated primary bombing targets across the UK, their high-altitude night-time bombing was not accurate. As a result, thousands of buildings were damaged and civilian fatalities were common. Bombs were also jettisoned over opportunistic targets and residential areas were often struck.

When Luftwaffe aircraft wished to escape due to interception by fighter aircraft or anti-aircraft fire, they would jettison their bombload to increase speed and manoeuvrability. This is commonly referred to as tip and run and it has resulted in bombs being found in unexpected locations.

UXB Initiation

Unexploded ordnance does not normally spontaneously explode. Military high explosive is generally reasonably stable and requires significant energy, normally via a fuze and initiation system for detonation to occur. In the case of unexploded German bombs discovered within the construction site environment, there are a number of other potential initiation mechanisms.

Direct impact

Unless the fuze or fuze pocket is struck, there needs to be a significant impact e.g., from piling machinery or large and violent mechanical excavation, onto the main body of the weapon to initiate a buried iron bomb. Although it is unlikely, such violent action could cause a bomb to detonate.

Fuzes

Most German bomb and mine fuzes were electric and were highly engineered compared to their British equivalents. A small proportion of German WW2 bombs employed clockwork fuzes. It is probable that clockwork or mechanical fuze mechanisms would have corroded since the Second World War, and this will generally prevent them from functioning.

Friction impact

Impact from construction machinery or processes could initiate the shock-sensitive fuze explosive. The effects of chemical breakdown of explosive fill and general degradation over time can cause explosive compounds to crystallise and extrude out from the main body of the bomb. It may only require a limited amount of energy to initiate the extruded explosive around the fuze pocket which could detonate the main charge.

Consequence of interaction

When considering the potential consequences of a detonation, it is necessary to identify who may be affected. These will vary depending on the site-specific conditions but can be summarised as:

- People – site workers, local residents and general public.
- Plant and equipment – construction plant on site.
- Services – subsurface gas, electricity, telecommunications.
- Structures – not only visible damage to above ground buildings, but potentially damage to foundations and the weakening of support structures.
- Environment – introduction of potentially contaminating materials.

Failure Rate of German air-delivered ordnance

It has been estimated that 10% of the German HE bombs dropped during WW2 failed to explode as designed. There are a number of reasons why an air-delivered weapon might fail to function as designed:

- Malfunction of the fuze or initiation mechanism (either electric or clockwork)
- Failure of the bomber aircraft to arm bombs correctly
- Jettisoning of the bomb before it was armed or from a very low altitude. Likely if the bomber was under attack or attempting a forced landing due to damage.

Unexploded ordnance is still regularly encountered across the UK and is dealt with on a routine basis by military and commercial Bomb Disposal teams.

Bomb penetration

An important consideration when assessing the risk from a UXB is the likely maximum depth of penetration. There are several factors which determine the depth that an unexploded bomb will penetrate to:

- Size and shape of bomb
- Height of release
- Velocity and angle of bomb
- Nature of the ground cover
- Underlying geology

Geology is perhaps the most important variable. If the ground is soft, there is a greater potential of deeper penetration. For example, peat and alluvial deposits are easier to penetrate than gravel and sand. Layers of hard strata will significantly retard and may stop the trajectory of a UXB.

Impact angle and velocity

It is assumed that bombs struck at an angle 80-85° from vertical and at c. 270 metres per second. These are standard figures used for bomb release from an aircraft at normal altitude. Other factors such as low speed or altitude of the bombing aircraft may alter these figures, but no records are available to suggest any low-level raids or incidents.

Buried bombs

When bombs strike but do not detonate, they can easily remain undetected. Note that the entry hole of an SC50 (the most commonly deployed German HE bomb) could have been as small as 20cm in diameter and therefore easily obscured within dense crops, or unmaintained vegetation, rough soil or rubble from previous damage.

The J-Curve Effect

J-curve is the term used to describe the characteristic curve commonly followed by an air-delivered bomb dropped from height after it penetrates the ground. Typically, as the bomb is slowed by its passage through underlying soils, its trajectory curves towards the surface.

Many UXBs are found with their nose cone pointing upwards as a result of this effect. More importantly however is the resulting horizontal offset from the point of entry. This is typically a distance of about one third of the bomb's penetration depth but can be up to 15m leading to bombs settling underneath undamaged buildings.

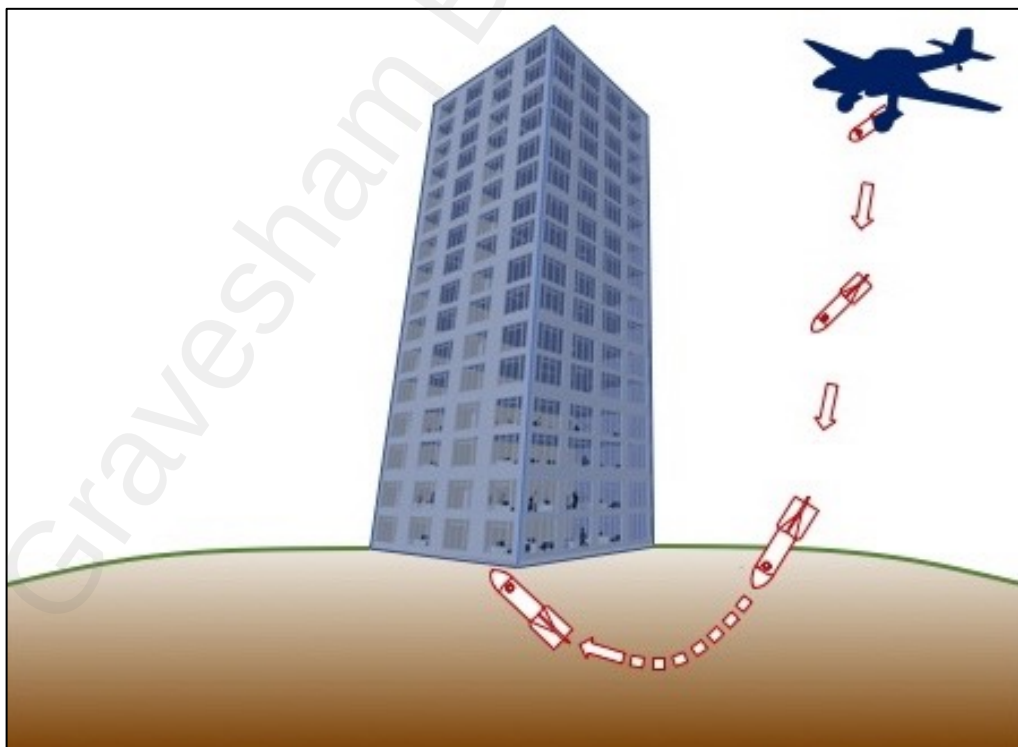


Figure 4. Demonstrating the J-Curve.

10. Military Ordnance

In addition to aerial bombs, there may also be a risk from other items including discarded or forgotten land munitions from both wartime and peacetime military use. Typical military activities may include:

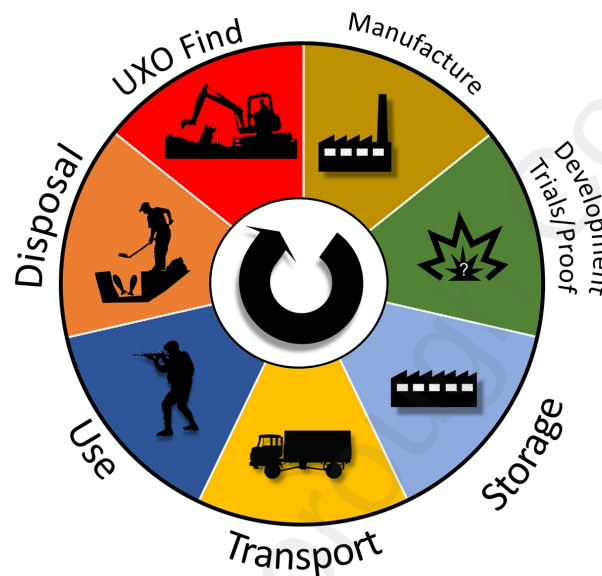


Figure 5. Showing the ordnance lifecycle

- Former minefields; often on beaches on the South and East coasts of England
- Home Guard weapons and munitions
- Anti-Aircraft sites
- Training & firing ranges
- Military bases
- Munition's manufacture and storage sites

The potential risk of encountering ordnance on sites is particularly elevated in areas previously associated with military activity.

As the threat of invasion lingered over Britain during WW2, large areas of land were requisitioned for military training and exercises. Thousands of tonnes of munitions including HE bombs, artillery projectiles, Naval shells, bulk explosives, and infantry weapons such as grenades and small arms ammunition were used in weapon testing and military training. It has been estimated that at least 20 per cent of the UK's land has been used for military training at some point.

11. Air Service Ordnance

FELLOWS

The UXO risk management experts

Part of the Optima Group

AIR SERVICE ORDNANCE



'Butterfly' Bomb



Incendiary Bomb



Pyrotechnic Smoke Float Bomb



German 50kg Bomb



Approximate Scale

Bombs



Allied bombs



German 50kg Bomb

Anti-personnel and Incendiary Bombs



German 'Butterfly' Bomb



German Incendiary Bomb

Smoke Floats



British Pyrotechnic Smoke Float

Aerial bombs

The most commonly dropped German aerial weapon was the SC50 (50kg). The next largest weapon is the SC250 (250kg) HE bomb. These were dropped primarily against soft targets such as gas and electricity installations, factories, housing and transport infrastructure.

Although the Luftwaffe deployed larger bombs in the area, their deployment was infrequent, the majority of bombs dropped were SC50 (50kg) and SC250 (250kg) HE bombs.

UXB risk of encounter has been assessed by using the SC50 and SC250 as the primary risk weapon.

Allied bombs can also be encountered. Air activity over Great Britain sometimes resulted air service ordnance being accidentally dropped or deliberately jettisoned if aircraft were in difficulties.

Incendiary bombs

The German 1 kg B1E incendiary bomb consisted of a cylinder of magnesium alloy, with an incendiary filling of thermite. Attached to the body was a steel tail with three fins. These bombs did not explode but were ignited by a small percussion charge, fired upon impact. They were dropped in a variety of containers. Later an explosive anti-handling version was introduced.

Anti-personel bombs

A Butterfly Bomb (or *Sprengbombe Dickwandig* 2kg or SD2) was a German 2-kilogram anti-personnel sub munition used by the Luftwaffe during the Second World War. It was so named because the thin cylindrical metal outer shell which hinged open when the bomblet deployed gave it the superficial appearance of a large butterfly. The design was very distinctive and easy to recognise. SD2 bomblets were not dropped individually but were packed into containers holding between 6 and 108 sub munitions. These broke open in air and scattered the sub-munitions.

Smoke floats and Pyrotechnics

Pyrotechnics are used in a variety of roles ranging from marking targets to search and rescue. Some pyrotechnics contain a flash element, and some are designed to burn.