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The UXO risk management experts

Part of the Optima Group

Detailed UXO Risk Assessment

FIL Reference:

Client:

Project:

Site Location:

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FELLOWS

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Acronyms and Abbreviations

AAA	*Anti-Aircraft Artillery*
AP	*Armour Piercing*
AP	*Anti-Personnel*
ARP	*Air Raid Precaution (Wardens)*
BD	*Bombing Density*
BGL	*Below Ground Level*
BGS	*British Geological Survey (UK)*
BH	*Borehole*
CDM	*Construction (Design and Management) Regulations 2015 (UK)*
CIRIA	*Construction Industry Research and Information Association*
CPT	*Cone Penetrometer Test*
EOC	*Explosive Ordnance Clearance*
EOD	*Explosive Ordnance Disposal*
ERP	*Emergency Response Plan*
ERW	*Explosive Remnants of War*
FFE	*Free From Explosives*
GI	*Ground Investigation*
GPS	*Global Positioning System*
HE	*High Explosive*
HSE	*Health and Safety Executive*
HSWA	*Health and Safety at Work Act 1974*
IB	*Incendiary Bomb*
JSEODOC	*Joint Services Explosive Ordnance Disposal Operations Centre (UK)*
LE	*Low Explosive*
LM	*Luftmine (Germany)*
LSA	*Land Service Ammunition*
MOD	*Ministry of Defence (UK)*
NEQ	*Net Explosive Quantity*
RAF	*Royal Air Force*
RN	*Royal Navy*
ROF	*Royal Ordnance Factory*
SAA	*Small Arms Ammunition*
SAP	*Semi-Armour-Piercing*
SI	*Site Investigation*
SIP	*Self-Igniting Phosphorous*
UXB	*Unexploded Bomb*
UXO	*Unexploded Ordnance*
V1	*Vengeance Weapon 1 - Flying bombs or doodlebugs*
V2	*Vengeance Weapon 2 - Long range rocket*

WW *World War*

1. Executive Summary

Site details

The site is currently agricultural land located XXXXXXXX. The site, covering an area of 8.9 hectares is situated approximately XXXX.

Risk Assessment

Unexploded Ordnance (UXO) risk at the sites is assessed as:

UXO	RISK
German air dropped weapons	*Medium Risk*
British Anti-Air defensive munitions	*Medium Risk*
Other (Land service Ammunition / Historic (Home Guard) / Military Training)	*Low Risk*

Full detail of the UXO risk and the risk assessment process including site zoning is within section 11.

UXO Risk

The primary UXO risk is assessed as medium from British AA munitions and German aerial dropped bombs. For other munitions, the risk has been assessed as low.

Summary of findings

Official records show that 1,477 high explosive (HE) bombs, 36 land mines, 18 Flying bombs (V1), 7 long-range rockets (V2) and numerous Incendiary bombs (IBs) were deployed in the rural area of XXXXX. In comparison to XXXXX, this is considered to be a low bombing density.

There are official records confirming 48 IBs and 20 HE bomb strikes as directly hitting the site and surroundings on the 28th of August 1940.

Prime targets for the Luftwaffe (German Air Force) around the site location during WW2 included military camps and dock yards, ordnance storage areas, power stations and industrial units situated within XXXX of the site boundaries. Many of these were recorded as being hit during the air raids by, HE bombs, Parachute mines and IBs.

UXO Risk management recommendations

The risk of encountering deep buried HE bombs and British AA munitions has been assessed as Medium. For other ammunitions, the risk has been assessed as Low.

For all works within the site area:

A UXO Awareness Brief (UXOAB) be delivered to all site personnel. This can also include a site safety walk-through and provision of a UXO Emergency Response Plan for inclusion into the site HSE documentation.

Excavations and intrusive works within the site area (Moderate Risk area):

Provision of an UXO Engineer to oversee intrusive works will reduce the risk of a UXO incident occurring. The UXO Engineer can be on-site to identify any items uncovered during excavation. This can reduce down-time and improve site efficiency.

Piling (in fresh ground):

Due to the risk from German aerial bombs at the site, an intrusive magnetometer survey is recommended to assure safety of personnel and equipment during the piling works. This can be in the form of or Cone Penetration Testing (CPT) where load bearing or contiguous piling is planned.

For deep piling, CPT probing should take place to a minimum probe depth of 10m bgl.

Fellows International Limited can provide all of the above services and would be pleased to provide a proposal accordingly.

For further information, or to discuss requirements, please get in touch.

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2. 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 13.

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'.

Fellows has been supporting the UK construction industry with UXO Risk Management measures for over 2 decades and offer the complete UXO risk management process from the preliminary and detailed desk study though 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.

3. 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, principle 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 Act

All employers have a responsibility under the Health and Safety at Work 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.

4. Site Description (Current)

Site location

The site is agricultural land located XXXXXX. The site, covering an area of 8.9 hectares is situated approximately XXXXXXX.

Mapping / Satellite Imagery

Figure 1. Showing Satellite Imagery of the approximate site boundaries outlined in red. [Google Earth Pro, 2018]

Figure 2. OS Map showing the site boundaries outlined in red. [From Ordnance Survey UK, 2018]

5. Site History

History

XXXXXXX is situated on XXXXXXX. The word XXXXX refers to a XXXXXX. It is situated within the XXXXXXXXXX. Originally referred to simply as XXXXXXX, the town has a history spanning back to the 8th century when the first church was constructed in the area. There was a workhouse within XXXXXXX until the XXXXXX. Following the Local Government Act 1933, the name of the civil parish was changed from XXXXX to XXXXXXXXX. This was later updated on maps by Ordnance Survey in XXXX. Throughout the 19th and 20th century, there were several military installations within the surrounding area. These were well known to the Luftwaffe and aerial reconnaissance photography was conducted to assist with planning of bombing targets. This can be seen in figure 3 below.

Figure 3. Showing Luftwaffe target areas in the area surrounding the site. The Luftwaffe targets are shown in red and blue.

XXXXXXX

XXXXXXX has a history dating back more than 100 years. XXXXXX had a training ship moored on the river banks since 1933, run by the XXXXXXXX. This was named the XXXXXXX and was a replacement for the previous training ships (XXXXXX and XXXXX) situated on the XXXXXX. In 1933, the ship was moved to XXXXXX to be used as a childrens home and training school. The ship was requisitioned by the Royal Navy throughout WWII and named XXXXXX. Following the end of the war, the ship was returned to XXXXXXX and moored at XXXXX once more before being retired in 1975.

Figure 4. Showing XXXXXXXXXX, 1947 (XXXXXXX).

XXXXXXXX and XXXXXXX Depot

XXXXXX, originally commissioned as an artillery fort in the 1500's, was used throughout WWI as a magazine and ammunition store. In 1810, a new magazine with space for 10,000 barrels of gunpowder was constructed further downstream from the castle. This was coupled with a second magazine store which was constructed in 1856 alongside the first. There were several buildings built alongside designed for storing and maintaining artillery shells.

XXXXXX was originally constructed in two phases, the first starting in 1559 and the second in 1599. The initial construction, designed by XXXXXXX, began with the aim of protecting anchored British Warships which were out of commission within the dockyards at XXXXXXX. The second phase was to provide landward defence improvements to the castle.

One of the most prominent features of the castle is the lowered open gun platform which projects over the river. This housed the majority of the castle's heavy artillery. This is flanked by two square towers linked to the main building by a crenelated wall. These are fronted by turrets and gun embrasures on the first floor. Further gun emplacements are present on the gatehouse, protected by two rectangular towers.

The castle saw action for the first time in 1667 during the 2nd Dutch war. The enemy naval squadron, commanded by XXXXXXXX, broke through the chain boom defence positioned across the river between XXXXXXX and XXXXXX and threatened XXXXX. This resulted in the loss of English shipping before the defence at XXXXXXX repelled the attackers. In 1668, the castle was converted to a naval magazine and storage depot, extending to the XXXXXX. The XXXX and XXXXXX supplied naval munitions until 1827 before it was converted to an ordnance laboratory. This changed hands from the War Office to the Admiralty and the Naval Armament Supply Department began to use it as a proof yard.

The castle became a part of the extended Magazine Establishment during WW2. Two bombs fell into the adjacent XXXXXX, damaging parts of the castle structure. Following the end of WWII in 1945, the castle was opened to the public.

It was soon discovered that the storage for artillery shells was inadequate, and as such there was further construction to the XXXXX to provide more space for shell magazines. The large houses close to the stores were bought to serve as offices for the depot. With a further need for gunpowder storage, more land was purchased in XXXXXXXX and accessed via a narrow-gauge railway. The magazines at XXXXXX were then converted into filled shell stores.

The Admiralty gained control of the Ordnance Yard at XXXXXXX and constructed yet more shell stores in the 1880's, as well as stores for both wet and dry guncotton for use in naval mines and torpedoes. By the 1900's, further expansion of the Ordnance Yard to the XXXX occurred to allow for a much larger filled shell store and a mine store. More buildings were constructed behind the original magazines for the filling of shells with powder, trityl or amatol.

XXXXXXX and XXXXXX Military Camps

It became apparent in 1912 that both the XXXXX Ordnance Depot and the Magazine storage in XXXXXX were vulnerable to air attack. There is a WWI anti-aircraft emplacement on XXXXXX (close to some WWI training trenches) which is thought to be one of the first in the world. There is evidence suggesting that the area to the XXXXX of the site was used for military training purposes. Aerial photography from XXXX shows practice trench systems, pillbox locations and anti-tank positions.

There is further evidence of XXXXX positioned on the other side of the forest. Records indicate that this area was the site was used for barracks and training as well as further storage for munitions. Dense woodland was planted, and embankments were constructed for safety reasons.

Following the end of WWII, this area continued to be used as barracks and training facilities for the XXXXXXXXX. The XXXXXXXXXX moved here in XXXXXX from the original location in XXXXXXXXXX

Figure 5. Showing XXXXXXXX and Ordnance storage in 1940. Individual storage facilities are visible as well as AA emplacements and barracks buildings to the west.

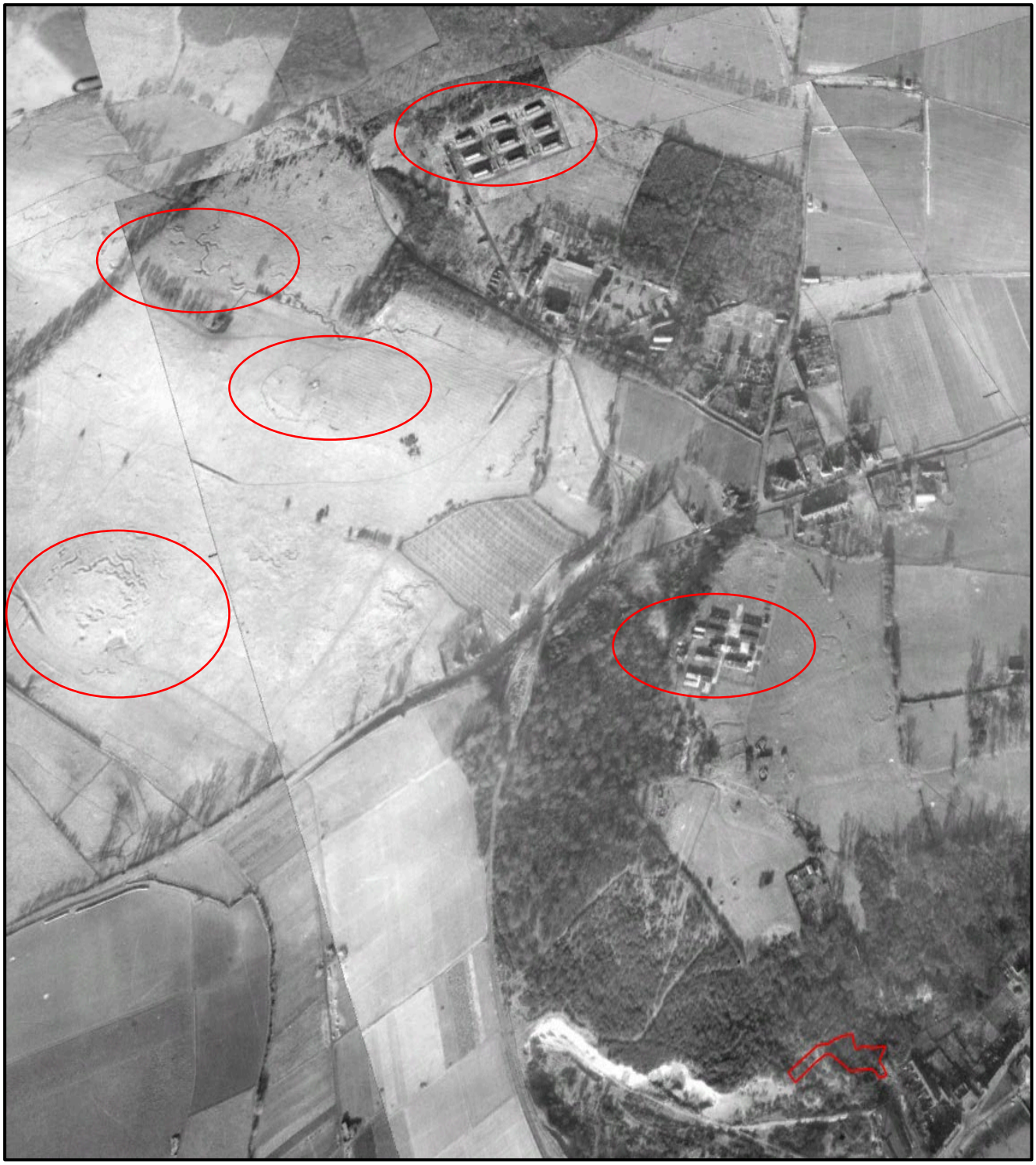


Figure 6. Showing practice trenches and XXXXXX to the XXXXXX of the site.

FELLOWS The UXO risk management experts Part of the Optima Group	Site details: *XXXXXXXX*	Report Ref: *XXXXXX* Type: *Aerial photography* Date: *XXXX*	Key:

Figure 7. Aerial photography from XXXX showing the approximate location of the site outlined in red.

Aerial bombing of XXXXXXX

Almost every possible kind of aerial bomb was dropped on XXXXXXX during the Second World War. Most of the high explosive bombs which fell in the XXXXX area up to May 1941 were relatively light, either 50 or 250 kilogram bombs. Later in the war, the proportion of heavier bombs, up to 2500 kilograms, increased. Within ten days of the start of the Blitz the Luftwaffe also began to drop sea mines by parachute, these were known as land mines. Over 36 mines were dropped in XXXXXX area. Land mines were Naval weapons re-roled into land use as blast bombs due to their thin case and large explosive content. These pose little risk today as burial on impact was negligable and they were observed and dealt with at the time.

The table below summarises recorded German bomb strikes on XXXXXX (Rural) during the WW2. This information has been obtained from ARP archives, Unexploded Bomb registers, and Air Raids Incidents held by 'XXXXXXXXX'.

Area	Date	Description	No. of German Ordnances per period	Sub-totals
XXXXX	*1940*	*HEs*	*628*	
		UX. HEs	*129*	
		Mines	*19*	
		UX. Mines	*4*	*780*
XXXXXX	*1941 to 30th June*	*HEs*	*239*	
		UX. HEs	*34*	
		Mines	*10*	
		UX. Mines	*3*	*286*
XXXXXXX	*To V.E Day 8th May 1945*	*HEs*	*256*	
		UX. HEs	*191*	
		Mines	*/*	
		UX. Mines	*/*	
		Flys (V1)	*18*	
		LRRs (V2)	*7*	*472*
Total of German Ordnance (without considering Incendiaries bombs) deployed in XXXXXXX				*1538*

Table 1. Record of HE bombs, and Parachute mines dropped during WW2 on XXXXXXXX.

Bombing activity near the site

Fellows has reviewed Air Raid Precaution (ARP) records, Bomb Census survey records 1940-1945, Unexploded bombs reports, Aerial photography, historical images of bomb damage held by 'XXXXXXXXX' and Internal Fellows documents related to XXXXXXXXXX.

However, it is worth noting historic records and Air Raid Precaution (ARP) reports cannot establish a full description of air raids that may have occurred during WWII as the accuracy of wartime records are frequently difficult to verify.

The figure below shows recorded Air Raids over XXXXXXXX area within XXXkm from the site boundaries:

Figure 8. Showing German Ordnance dropped in the vicinity of the site boundaries.

The table below summarises in chronological order recorded Air Raids over XXXXXXXX area within XXXkm radius from the site boundaries:

Message number	Map reference	Latitude	Longitude	Date	Parish. Local Authority	Type of bomb	No.	Damage	Action taken	Distance from the site
135	*XXXX*	*XXXX*	*XXXX*	*26.08.40*	*XXXX*	*UX.HE*	*1*		*Cleared*	*XXXX*
171	*XXXX*	*XXXX °*	*XXXX*	*28.08.40*	*XXXX*	*IBs / HE*	*48 and 20*	*Electric mains damages*	*Repaired*	*XXXX*
250	*XXXX*	*XXXX °*	*XXXX*	*2.09.40*	*XXXX*	*UX.AA*	*2*		*Cleared*	*XXXX*
361	*XXXX*	*XXXX*	*XXXX*	*8.09.40*	*XXXX*	*UX.HE*	*1*		*Cleared*	*XXXX*
404	*XXXX*	*XXXX*	*XXXX*	*10.09.40*	*XXXX*	*UX.HE*	*1*		*Cleared*	*XXXX*
633	*XXXX*	*XXXX*	*XXXX*	*18.09.40*	*XXXX*	*Aircraft*	*1*			*XXXX*
1621	*XXXX*	*XXXX °*	*XXXX*	*8.11.40*	*XXXX*	*HE*	*2*	*Slight property damage*	*Repaired*	*XXXX*
	XXXX	*XXXX*	*XXXX*		*XXXX*					*XXXX*
2180	*XXXX*	*XXXX*	*XXXX*	*12.1.41*	*XXXX*	*HE*	*8*	*Electric and telephone services damaged*	*Repaired*	*XXXX*
2193	*XXXX*	*XXXX*	*XXXX*	*12.1.41*	*XXXX*	*HE*	*4*			*XXXX*
2352	*XXXX*	*XXXX*	*XXXX*	*16.2.41*	*XXXX*	*HE*	*1*	*XXXX*		*XXXX*
2354	*XXXX*	*XXXX*	*XXXX*	*16.2.41*	*XXXX*	*HE*	*3*	*Damage to subway*		*XXXX*
2701	*XXXX*	*XXXX*	*XXXX*	*19.4.41*	*XXXX*	*HE and IBs*	*3 and many*			*XXXX*
	XXXX	*XXXX*	*XXXX*		*XXXX*					*XXXX*
	XXXX	*XXXX*	*XXXX*		*XXXX*					*XXXX*
	XXXX	*XXXX*	*XXXX*		*XXXX*					*XXXX*
2979	*XXXX*	*XXXX*	*XXXX*	*5.6.41*	*XXXX*	*HE*	*12*	*XXXX. 30 Sheep killed*		*XXXX*
2988	*XXXX*	*XXXX*	*XXXX*	*5.6.41*	*XXXX*	*UX.HE*	*2*	*XXXX Road closed*	*Cleared - Road open*	*XXXX*
3029	*XXXX*	*XXXX*	*XXXX*	*24.6.41*	*XXXX*	*UX.AA (Shell)*	*1*		*Discredited*	*XXXX*

Message number	Map reference	Latitude	Longitude	Date	Parish. Local Authority	Type of bomb	No.	Damage	Action taken	Distance from the site
3162	*XXXX*	*XXXX*	*XXXX*	*11.8.43*	*XXXX*	*HE*	*3*	*4 homes severely damaged. 2 Slightly damaged*		*XXXX*
	XXXX	*XXXX*	*XXXX*		*XXXX*	*HE*				*XXXX*
	XXXX	*XXXX*	*XXXX*		*XXXX*	*HE*				*XXXX*
3176	*XXXX*	*XXXX*	*XXXX*	*22.10.43*	*XXXX*	*HE (50kg)*	*12*	*Telephone lines down. Slight damage to houses*	*Repaired*	*XXXX*
3186	*XXXX*	*XXXX*	*XXXX*	*25.11.43*	*XXXX*	*HE*	*2*			*XXXX*
	XXXX	*XXXX*	*XXXX*		*XXXX*	*HE*				*XXXX*
3199	*XXXX*	*XXXX*	*XXXX*	*21.1.44*	*XXXX*	*HE*	*2*		*Slight damage to XXXX*	*XXXX*
	XXXX	*XXXX*	*XXXX*		*XXXX*					*XXXX*
3200	*XXXX*	*XXXX*	*XXXX*	*21.1.44*	*XXXX*	*HE*	*4*			*XXXX*
3209	*XXXX*	*XXXX*	*XXXX*	*22.1.44*	*XXXX*	*UX.HE*	*1*		*Cleared*	*XXXX*
3223	*XXXX*	*XXXX*	*XXXX*	*24.1.44*	*XXXX*	*HEs 500kg / HE 50kg*	*3 & 1*			*XXXX*
3224	*XXXX*	*XXXX*	*XXXX*	*24.1.44*	*XXXX*	*HE 50kg*	*1*			*XXXX*
3286	*XXXX*	*XXXX*	*XXXX*	*4.2.44*	*XXXX*	*HE and lbs*	*3 & Several*	*Road blocked XXXX*	*Road open 1.3.44*	*XXXX*
	XXXX	*XXXX*	*XXXX*		*XXXX*					*XXXX*
3324	*XXXX*	*XXXX*	*XXXX*	*10.2.44*	*XXXX*	*UX.AA (Shell)*	*1*		*Disposed*	*XXXX*

Table 2. Record of German Ordnance dropped within a 2.5km radius from the site boundaries.

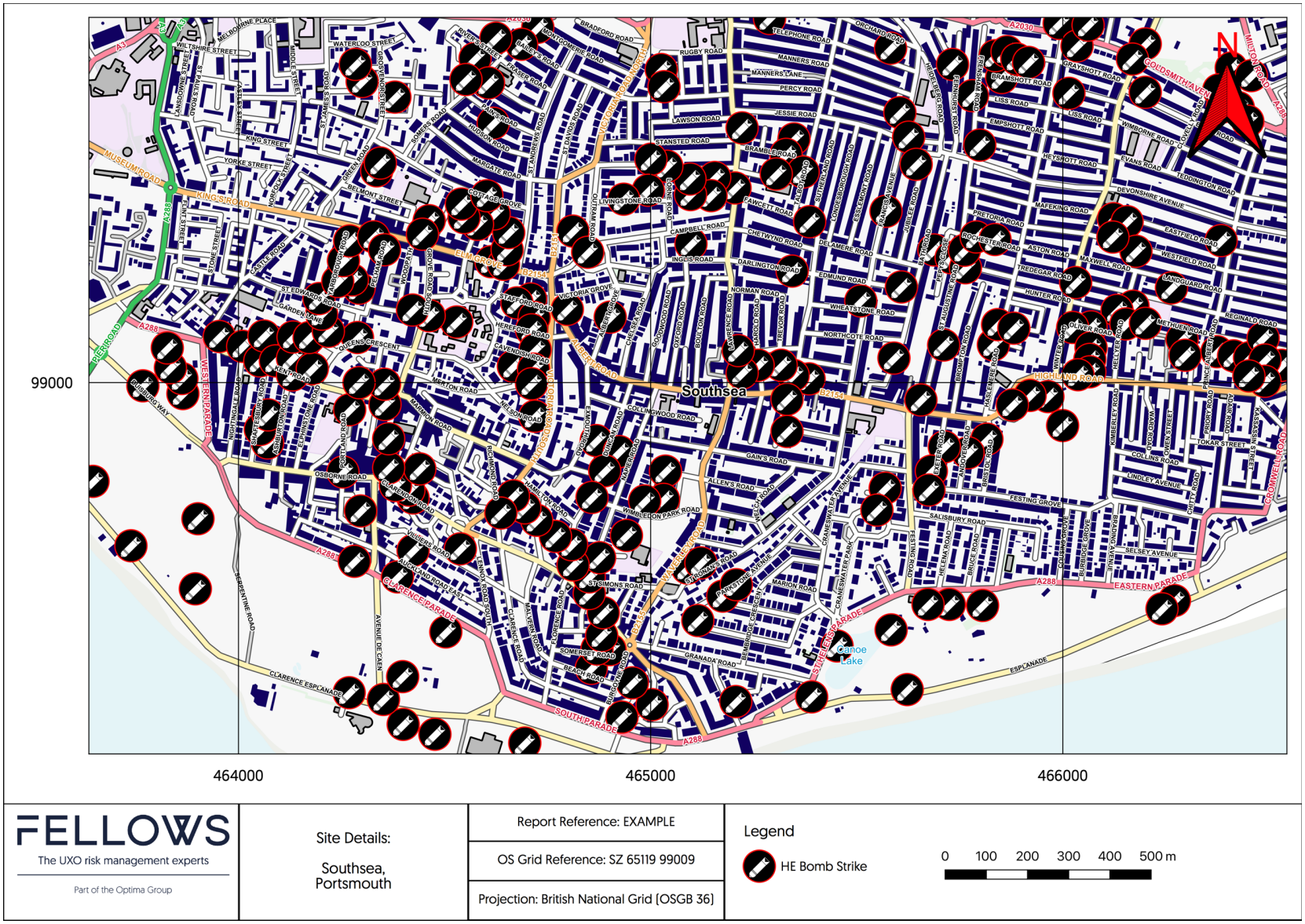


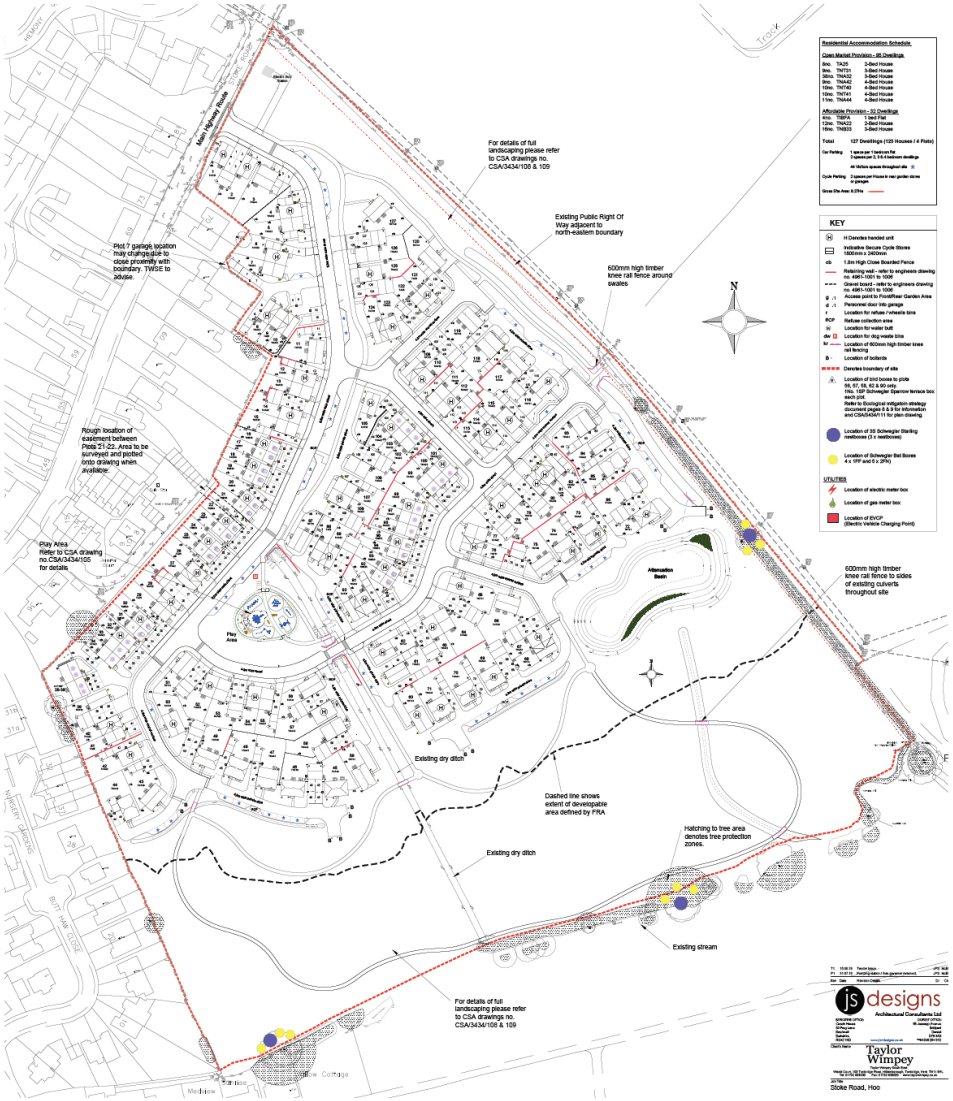
Figure 10. OS map showing German Ordnance dropped in the vicinity of the site.

Historical developments

The table below depicts in chronological order the changes that the site has undergone from XXXX

OS Map	
Showing a section of the 1907 revision of OS map of the area. The western part of the site has been developed prior to WW1 and shows 'Brick Works' on site.	*Showing a section of the 1938 revision of OS map of the area. Brick Works are no longer located on site. The site is still rural land and no major changes are observed.*
Showing a section of the 1960 revision of OS map of the area. No changes are observed.	*Showing a section of the 2018 OS map of the area. The site has not been developed yet.*

Table 3. Summary table showing development works in the site before and after WW2 Ordnance Survey Maps, 1907 – 2018.



FELLOWS The UXO risk management experts Part of the Optima Group	Site details: *XXXXX*	Title: *Proposed development of the site* Report Ref.: *XXXX*	*Site boundary*

		Date: *2018*	

Figure 11. Showing proposed development of the site (on the left) and current satellite imagery of the site (on the right).

6. Site Environment

Proposed scope of works

The proposed scope of work for this site consists of the development of residential properties with access to roads and landscaping.

It is understood that planned intrusive works on the site will involve shallow foundations and may involve CFA piled foundations in some areas.

Ground conditions

According to the British Geological Survey (BGS) and Geo-environmental site assessment (Ref. No.: XXXXX) the ground condition is comprised of superficial deposits of silt and clay underlined by XXXXXX.

Site geological conditions

The British Geological Survey (BGS) assess the site geological conditions expected to be encountered at this site to include varies from silt to clay, usually yellow-brown and massive. Made Ground is expected to be encountered on the XXXXX part of the site.

Local Borehole and Window sample information

Local borehole data has been collected from Historical borehole log held by the British Geological Survey and Geo-environmental site assessment, XXXXX. A summary of the expected ground conditions at the Site are presented in the table below:

Borehole reference	Date	Location	Hole Depth	Strata (Thickness)
TQ77SE207	*2005*	*700m N*	*20m*	*(0.40m) TOPSOIL* *(1.60m) Very stiff brown CLAY, with rare fine gravel and rootlets.* *(9.60m) Stiff brown and occasionally blue grey mottled indistinctly fissured CLAY.* *(8.40m) Very stiff dark fissured CLAY, with rare selenite crystals.*
WS6	*09.02.17*	*On site*	*3.45m*	*(0.45m) TOPSOIL: Very soft to soft dark brown slightly gravelly slightly sandy silty CLAY. Sand is fine to medium. Gravel is angular to rounded fine to coarse flints. With occasional rootlets and chaff.* *(0.75m) Firm to stiff dark grey and reddish brown with occasional black speckling sandy silty CLAY. Sand is fine. (SUPERFICIAL DEPOSITS)* *(0.50m) Stiff dark grey and reddish brown with occasional black speckling slightly sandy gravelly silty CLAY. Sand is fine to coarse. Gravel is angular to rounded fine to coarse flints. (SUPERFICIAL DEPOSITS)* *(0.30m) Stiff dark orangish brown and grey with occasional black speckling slightly sandy very gravelly CLAY. Sand is fine to coarse. Gravel is angular to rounded fine to coarse flints. (SUPERFICIAL DEPOSITS)* *(1.45m) Stiff becoming very stiff orange mottled grey slightly sandy slightly gravelly CLAY. Sand is fine. Gravel is angular to rounded fine to coarse flint. (SUPERFICIAL DEPOSITS)*

Borehole reference	Date	Location	Hole Depth	Strata (Thickness)
TP10	*07.02.17*	*On site*	*3m*	*(0.40m) TOPSOIL: Dark brown slightly gravelly slightly sandy silty CLAY. Sand is fine to medium. Gravel is angular to rounded fine to coarse Flints with rare brick pottery and wood. With occasional roots and rootlets and chaff.* *(0.40m) POSSIBLE MADE GROUND: Soft to firm orangish brown slightly sandy gravelly silty CLAY. Sand is fine to medium. Gravel is angular to rounded fine to coarse flints. Single rounded sandstone fragment.* *(2.20m) Stiff to very stiff orange slightly sandy slightly gravelly silty CLAY. Sand is fine. Gravel is angular to rounded fine to coarse flint. (SUPERFICIAL DEPOSITS)*

Table 4. Showing borehole logs for the site. (From the British Geological Survey and Geo-technical report, 2017, XXXX)

7. 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 WW1 or 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.

8. Aerial Bombing

General

During WWI and WWII, 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', but bombing also affected many other towns and cities including Portsmouth and Southampton.

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.

The main focus of research for this report concerns German air-delivered ordnance dropped during WWII, although other forms of explosive contamination will also be considered.

The most common type 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 WWII 'Vengeance' weapons (V1 and V2 rockets), small Incendiary Bombs (IBs), and Anti-personnel (AP) bomblets.

World War One aerial bombing

WWI bombs were generally smaller than those used in WWII and were dropped from a lower altitude, resulting in limited UXB penetration depths. Aerial bombing was often such a novelty at the time that it attracted public interest and even spectators to watch the raids in progress.

Only limited information is available of WWI attacks and targeting and although some evidence exists of limited WW1 bombing, it is assessed that the risk of encountering WW1 bombs is low due to their limited ability to penetrate buildings and made ground.

World War Two aerial bombing

Targeting

Although the Luftwaffe had designated primary bombing targets across the UK, their high-altitude night 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 sometimes struck.

When Luftwaffe aircraft wished to scape due to interception by fighter aircraft or anti-aircraft fire they would jettison their bomb-load 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.

Decoy sites

RAF and Royal Navy decoy sites were constructed in the vicinity of legitimate targets to deceive and decoy enemy bombers. For obvious reasons, such sites were often built in remote and uninhabited areas. Some were more successful than others and received relatively high bombing rates.

There were three decoy sites within XXXXX from the site boundaries.

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.

WWII German aerial Ordnance

Type		*Description*
High Explosive (HE) Bombs	 *German SC250 (recovered casing)*  *German SC50 (London 2015)*	*The SC series of HE Bombs were a thin cased general-purpose bomb used as general demolition bombs.* *Most bombs were 50kg, 250kg or 500kg, although larger bombs of up to 1,800kg were also used. About half the weight of these HE bombs comprised of explosive fill.* *The SC50 had a one-piece drawn steel body and its total weight was 48 to 55 kg.[1] It was dropped on targets across the UK.* *The SD series of bombs were thicker cased, with a lower charge weight used against hardened targets.*

Type		*Description*
Incendiary bombs	 *1Kg Incendiary Bomb*	*The 1 kg B1E incendiary bomb consisted of a cylinder of magnesium alloy, with an incendiary filling of thermite. Rivetted 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 head was incorporated into the IB.*

Type		*Description*
Anti-Personnel (AP) bombs	 *SD2 'Butterfly' Bomb (Armed status)*	*A Butterfly Bomb (or Sprengbombe Dickwandig 2 kg 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.*

UXB Initiation

Unexploded ordnance does not 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. 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 WWII bombs employed clockwork fuzes. It is probable that clockwork or mechanical fuze mechanisms would have corroded since WWII 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 WWII 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 assessed 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.

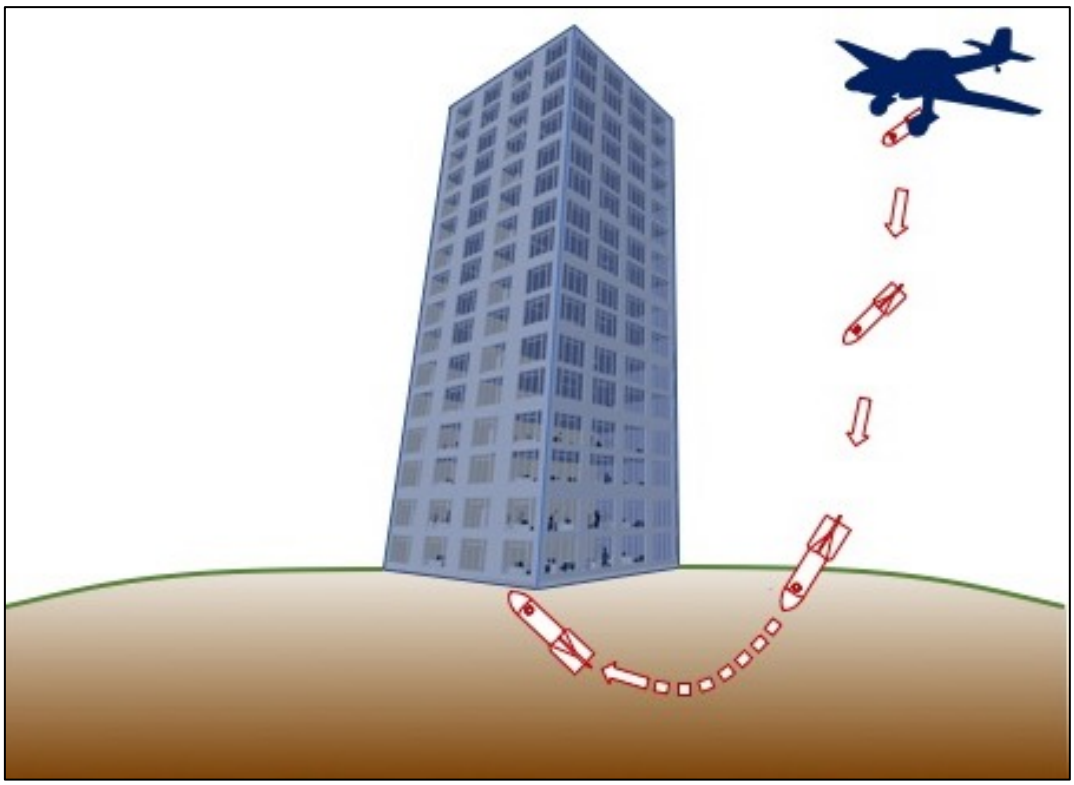


Figure 12. Demonstrating the J-Curve

Abandoned bombs

Research did not indicate the presence of any abandoned bombs within the site boundary.

Bombing density at Site

Official records show that 1477 high explosive (HE) bombs, 36 land mines, 18 Flying bombs (V1), 7 long-range rockets (V2) and numerous Incendiary bombs (IBs) were deployed in the rural area of XXXXXX. In comparison to XXXXXXX, this is considered to be a low bombing density.

There are official records confirming 48 IBs and 20 HE bomb strikes as directly hitting the site and surroundings on the XXXXXXX.

9. UXB Risk at the Site

Local geology

The local geology consists of superficial deposits comprising of SILT and CLAY. Beneath this is the London Clay formation, made up of mainly clays, silts and sand. This is consistent across the entire site.

Post war / previous works

The site is an agriculture land and has not undergone any major changes since WWII.

Bomb penetration

Taking into account the local geology, it is estimated that the maximum bomb penetration depth for one of the most common German air dropped bombs, the SC250 (250kg) HE bomb, is 10m bgl.

10. Other 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:

- *Former mine-fields; often on beaches on the South and East coasts of England*
- *Home Guard weapons and munitions*
- *Anti-Aircraft sites*
- *Training & firing ranges*
- *Military bases*
- *Munitions manufacture and storage sites*

During the early years of WWII huge preparations were underway to defend the UK against German attack. This often included the hiding or caching of defensive ordnance at or near to strategically or tactically important locations.

Items may include small arms ammunition, mortar bombs and hand grenades or even crudely manufactured defensive weapons designed for Home Guard use such as the No.76 SIP (Self Igniting Phosphorus) grenades. These items, resembling a milk bottle are frequently found in original crates during shallow excavations or building demolition and although small in size can inflict life-changing injuries if not dealt with correctly.

The potential risk of encountering allied ordnance on construction sites is particularly elevated in areas previously associated with military activity. This includes munitions deposited by military training exercises, dumped as a result of poor working practices, or deliberately placed to prevent adversary occupation.

Anti-Aircraft Artillery

Urban areas can be at risk from buried unexploded Anti-Aircraft projectiles fired during WWII.

At the onset of WWII two types of Anti-Aircraft Artillery (AAA) guns were deployed:

- *Heavy Anti-Aircraft Artillery (HAA), using large calibre weapons, such as the 3.7" QF (Quick Firing) gun. Normally fixed batteries.*
- *Light Anti-Aircraft Artillery (LAA) using smaller calibre weapons, such as 40mm Bofors gun. Often mobile, vehicle mounted batteries.*

Type		*Description*
Anti-Aircraft Shells	 40mm AA Shells found at W Sussex site	*Fixed (Heavy) Anti-Aircraft batteries were set up all around the country to defend potential targets from aerial attack. Size of guns and shells ranged from small, quick-firing 40mm Bofors guns to larger 3.7 or 4.5inch guns.* 3.7 Inch = 12.7kg 94mm x 438mm 40mm = 0.9kg 40mm x 311mm 4.5 Inch = 24.7kg 114mm x 578mm

LAA batteries were intended to engage fast, low flying aircraft and were typically deployed around military bases, RAF airfields or important installations. These batteries were mobile and could be moved to new positions with relative ease when required. The most numerous of these were the 40mm Bofors gun, which could fire up to 120 x 40mm HE shells per minute to over 1,800m.

HAA projectiles were high explosive shells, usually fitted with a time delay or a barometric pressure fuze to make them explode at a pre-determined height. If they failed to explode or strike an aircraft, they would eventually descend back to earth.

Although the larger unexploded fall-to-earth projectiles could enter beneath the ground surface, they did not have a great penetration ability and are therefore likely to be found close to WWII ground level. If encountered, the high explosive fill and fragmentation hazard of these items of UXO would present a significant risk.

The smaller 40mm projectiles are similar in appearance and effect to SAA and, although still dangerous, present a lower hazard due to its decreased explosive content.

Numerous unexploded AAA shells were recovered during and following WWII and are still occasionally encountered on sites today.

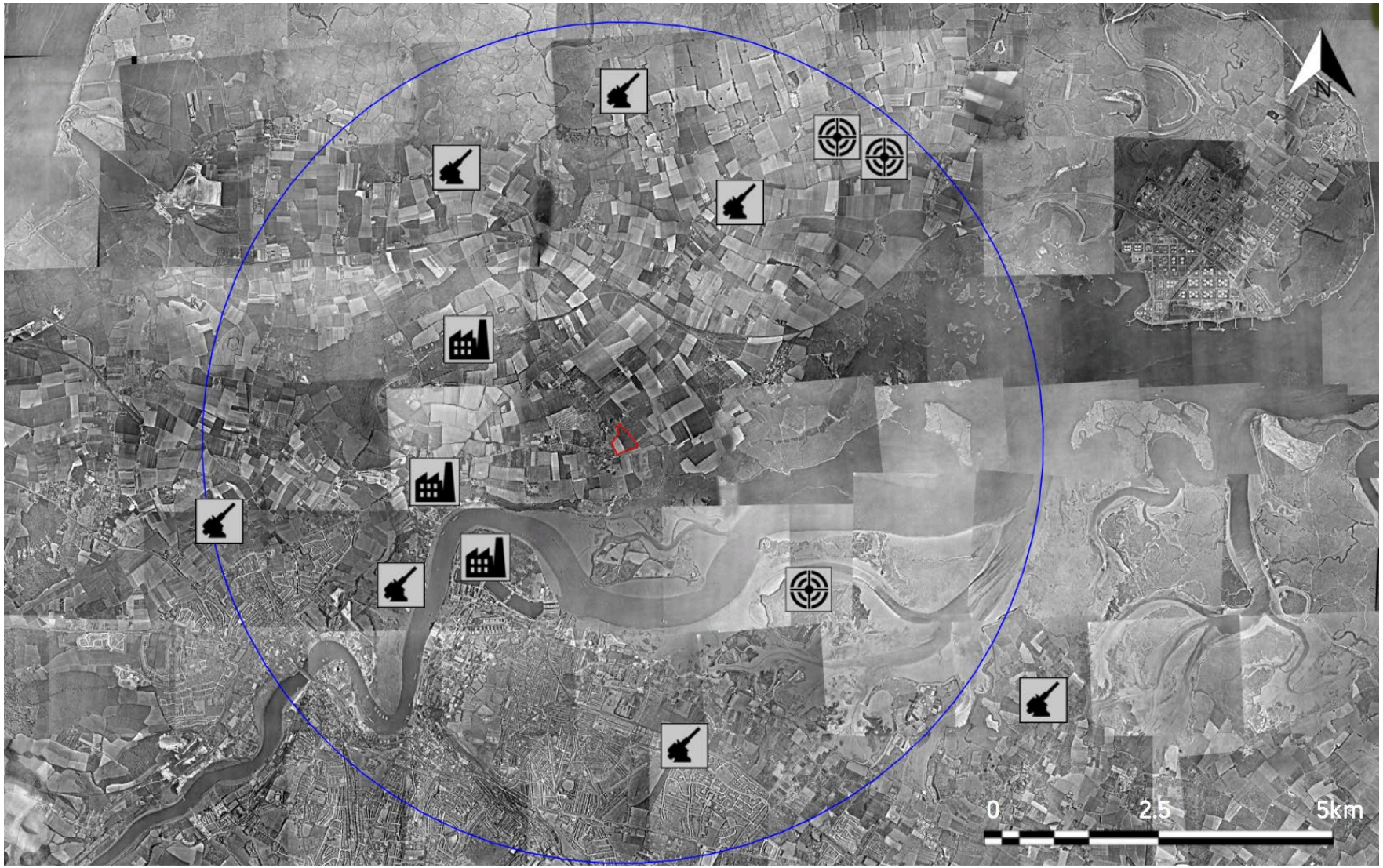
AAA Emplacements

There were 6 British Anti-Aircraft Artillery emplacements within 6km of the site ***(Fig. 13)***. These are tabulated below:

Location	Distance from Site
XXXX	*XXX*
XXXX	*XXX*
XXXX	*XXX*
XXXX	*XXX*
XXXX	*XXX*
XXXX	*XXX*

Table 5. Showing British anti-aircraft emplacements within XXX of the site.

Due to the proximity of the AAA sites, there is a risk from unexploded fall-to-earth AA projectiles.



FELLOWS The UXO risk management experts Part of the Optima Group	Site details: *XXXX*	Report Ref: *XXXXX* Type: *Aerial Photography* Map date: *1960*	Key: *6km radius* *AA gun sites* *Decoy site* *German targets*

Figure 13. Showing Aerial photography of the site in relation to AA Gun Sites, Decoy Sites, German Aerial targets, within 6km radius from the site.

Other defensive munitions

As the threat of invasion lingered over Britain during WWII, 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.

Type		*Description*
No.76 SIP Grenade		*No.76 SIP (Self Igniting Phosphorus) grenades. These items, resembling a milk bottle are frequently found during shallow excavations or building demolition and although small in size can inflict life-changing injuries if not dealt with correctly.* *Found in wooden crates of 24 items.*

Type		*Description*
Hand Grenades	 *British No36 'Mills' grenade*	*Contains a small amount of High Explosive and a rudimentary time delay fuze.* *The absence of a pin and fly-off handle indicate the item is potentially live.* *The distinctive segmented (Pineapple) casing gives the*

		fragmentation effect on detonation.

Small Arms Ammunition

The most common type of ordnance encountered on land formerly used by the military are items of Small Arms Ammunition (SAA). SAA refers to the complete round or cartridge designed to be used with hand-held infantry weapons such as rifles, machine guns and pistols. SAA can include bullets, cartridge cases and primers/caps. Items of SAA can be accidentally initiated by striking the casing or coming into contact with fire. SAA presents only minimal risk although it must be disposed of correctly if found on-site.

Type		*Description*
Small Arms Ammunition		*Small arms of various sizes from 4 or 5mm calibre (diameter) up to 12 to 13mm.* *Generally, the head is inert and made of lead or similar dense material.* *Brass cases without the head pose no risk.*

11. Overall UXO Risk Assessment

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

- *The amount and nature of WWI and WWII 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*

Risk Assessment

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 fuzing and explosive train) 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

Aerial bombs

Due to official records showing bomb strikes on site, German bombing targets in the vicinity and the number of bomb strikes within 1km radius of the site, there is a medium risk of encountering buried ordnance.

AAA Emplacements

There were 6 anti-aircraft emplacements within XXXX of the site, all of which were used throughout raids in the area. There are records indicating fall to earth munitions from British anti-air defences. Therefore, there is considered to be a medium risk of "fall to earth" AA munitions that may have failed to explode and been shallow buried at the time.

Other (Land service Ammunition etc.)

There is no history of military use of the site, therefore the chance of encountering buried or discarded defensive munitions is considered to be low.

Overall Risk Assessment

ACTIVITY	THREAT ITEM	CHANCE OF ENCOUNTER	CONSEQUENCE	RISK	REASONS
Shallow Excavation (<2m) i.e. Trial Pits, shallow Window Sampling / shallow Bore-holes	HE Bombs	3	5	15	• Bombing targets in the vicinity of the site • ARP records shows bomb strikes within the site boundaries. • Records show numerous bomb strikes within 1km radius from the site. • The site was an opened land before, during and after the WW2 and no post war works have taken place on site. • No defensive structures present on site
	AAA Shells / IBs	3	4	12	
	Other munitions	1	3	3	
	HE Bombs	3	5	15	
	AAA Shells / IBs	3	4	12	
	Other munitions	1	3	3	

ACTIVITY	THREAT ITEM	CHANCE OF ENCOUNTER	CONSEQUENCE	RISK	REASONS
Deeper excavations (>2m) i.e. Basement excavations	HE Bombs	3	5	15	• AAA projectiles would not typically be found deeper than 2m bgl. • Records show numerous bomb strikes within 1km radius of the site boundaries. • ARP Records show HE bomb strikes as directly hitting the site.
	AAA Shells / IBs	1	4	4	
	Other munitions	1	3	3	

ACTIVITY	THREAT ITEM	CHANCE OF ENCOUNTER	CONSEQUENCE	RISK	REASONS
Piling/deep boreholes	HE Bombs	3	5	15	• Increased risk of encountering previously undiscovered UXB at depth. • Bomb penetration to a maximum depth of 10m.
	AAA Shells / IBs	1	3	3	
	Other munitions	1	2	2	

Site zoning

The risk assessment covers the whole site.

12. Recommendations to Reduce UXO Risk to ALARP

The risk of encountering deep buried HE bombs and British AA munitions has been assessed as Medium. For other ammunitions, the risk has been assessed as Low.

For all works within the site area:

A UXO Awareness Brief (UXOAB) be delivered to all site personnel. This can also include a site safety walk-through and provision of a UXO Emergency Response Plan for inclusion into the site HSE documentation.

Excavations and intrusive works within the site area (Moderate Risk area):

Provision of an UXO Engineer to oversee intrusive works will reduce the risk of a UXO incident occurring. The UXO Engineer can be on-site to identify any items uncovered during excavation. This can reduce down-time and improve site efficiency.

Piling (in fresh ground):

Due to the risk from German aerial bombs at the site, an intrusive magnetometer survey is recommended to assure safety of personnel and equipment during the piling works. This can be in the form of or Cone Penetration Testing (CPT) where load bearing or contiguous piling is planned.

For deep piling, CPT probing should take place to a minimum probe depth of 10m bgl.

Fellows International Limited can provide all of the above services and would be pleased to provide a proposal accordingly.

For further information, or to discuss requirements, please get in touch.

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13. References

The following sources of information were consulted in putting together this report:

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