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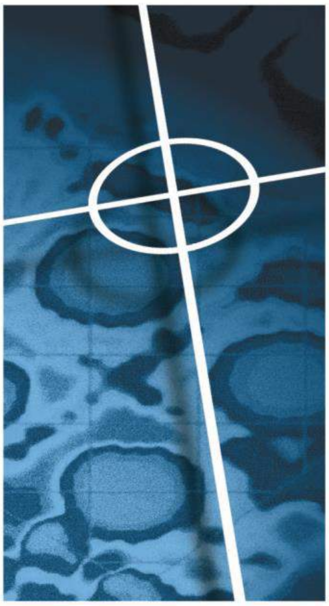

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Project No.	P4808-14
Project Title	SITESAFE UXO DESK STUDY
Project Location	Crogsland Road, London Borough of Camden
Client	EC Harris
Report Ref.	P4808-14-R1-A
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Prepared by	Matt Parsloe
Checked by	Stefan Lang
Authorised by	Mike Sainsbury

SitesafeAlliance

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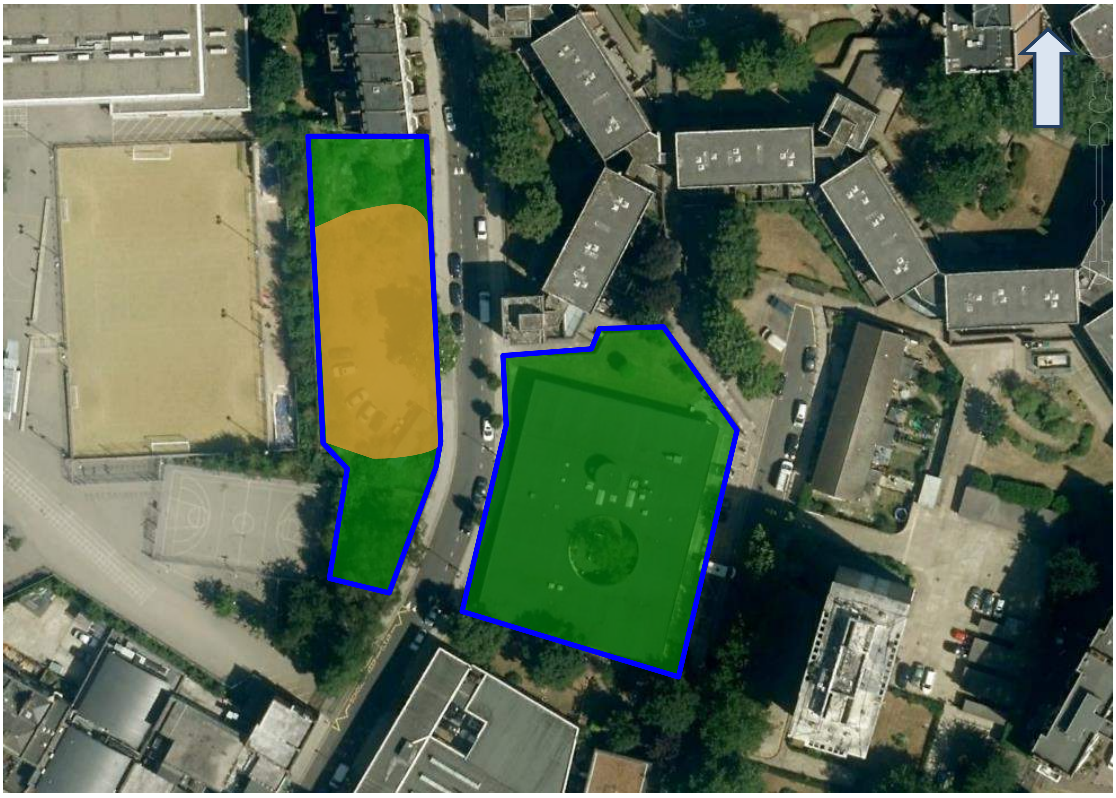
SITESAFE UXO DESK STUDY

Crogsland Road, London Borough of Camden

Executive Summary
Zetica Ltd was commissioned by EC Harris to carry out a SiteSafe Unexploded Ordnance (UXO) Desk Study for 2No. areas totalling approximately 0.4 hectares (ha) on either side of Crogsland Road, in the London Borough of Camden (the 'Site'). The aim of this report is to gain a fair and representative view of the UXO hazard for the Site and its immediate surrounding area in accordance with the Construction Industry Research and Information Association (CIRIA) 'Unexploded Ordnance (UXO), a Guide for the Construction Industry'. There is evidence that 1No. High Explosive (HE) bomb fell on part of the western section of the Site during World War Two (WWII), causing significant damage that may have masked the impact of an Unexploded Bomb (UXB). This area is considered to have a moderate UXO hazard level. There is no evidence of bombing or other significant sources of UXO on the remainder of the Site, which is assigned a low UXO hazard level. It is considered that the UXO hazard level on the Site can be zoned from low to moderate as shown in the accompanying figure, reproduced as Figure 7 in the main report. It is considered prudent to ensure that all staff have an awareness of the UXO hazard through the Site induction process. This will ensure that appropriate action is taken in the event that a suspect item is uncovered. In the area with a moderate UXO hazard level, clearance certification for borehole or pile locations is considered essential. For excavations, non-intrusive geophysical investigation methods, if practical, and Explosive Ordnance Clearance (EOC) Operative supervision is considered prudent. In areas with a low UXO hazard level, clearance certification for borehole or pile locations is considered prudent only if a zero tolerance to risk is adopted. Zero tolerance is commonly adopted for sites that have safety critical infrastructure such as nuclear establishments and oil refineries. Other risk mitigation will depend on the detail and nature of any planned works and the client's risk tolerance. Table 4 in the main report gives recommended actions in relation to the potential UXO hazard level and the anticipated Site activity. Further advice on the mitigation methods can be provided by Zetica on request.

Figure	UXO hazard zone plan of the Site



Source: Google Earth *Not to Scale*

Legend						
	Very Low		Low		Moderate	
	High		Very High		Site boundary	

The main findings of the report are summarised below.

- Available records indicate that no bombs fell on the Site during World War One (WWI).
- During WWII there were strategic targets in the vicinity of the Site. These included major transport infrastructure and public utilities.
- During WWII the Site was in the Metropolitan Borough (MB) of St Pancras, which officially recorded a high regional bombing density of 246.1 bombs per 405ha.
- Records indicate that 1No. HE bomb fell on the western part of the Site during WWII.
- For the geology of the Site, estimated average maximum bomb penetration depths vary between 4.5 metres (m) and 15.0m, depending on the underlying strata and weight of the bomb.

SITESAFE UXO DESK STUDY

Crogsland Road, London Borough of Camden

Note: To aid the reader of this report, Zetica has colour coded each paragraph. Paragraphs with black text on a white background are paragraphs that provide site-specific information or information specifically researched as part of this project.

Paragraphs in a dark blue text with a grey background are paragraphs containing background information or explanations which may appear as standard text in all similar reports.

1 INTRODUCTION

1.1 Project Outline

Zetica Ltd was commissioned by EC Harris to carry out a SiteSafe Unexploded Ordnance (UXO) Desk Study for 2No. areas totalling approximately 0.4 hectares (ha) on either side of Crogsland Road, in the London Borough of Camden (the 'Site').

The aim of this report is to gain a fair and representative view of the UXO hazard for the Site and its immediate surrounding area in accordance with the Construction Industry Research and Information Association (CIRIA) 'Unexploded Ordnance (UXO), a Guide for the Construction Industry'. This hazard assessment includes:

- Likelihood of ordnance being present.
- Type of ordnance (size, filling, fuze mechanisms).
- Quantity of ordnance.
- Potential for live ordnance (UXO).
- Probable location.
- Ordnance condition.

It is essential to note that the effects of military activity will often extend beyond the source of the activity. For example, a base for armed forces may use surrounding areas of open land outside the official or recorded military boundaries for practice and military related activities.

In addition, World War One (WWI) and World War Two (WWII) aerial bombardment was not discrete. 'Pinpoint' targeting did not exist in WWI or WWII. The effects of bombardment would be apparent in areas around the intended target.

It is for these reasons that it is important to address military activity both on the Site and in the relevant surrounding areas.

It should be noted that some military activity providing a source of UXO hazard may not be readily identifiable and therefore there cannot be any guarantee that all UXO hazards on the Site have been identified in this report.

1.2 The Site

The Site is centred on Ordnance Survey National Grid Reference (OSNGR) TQ 282844. It is located in the Chalk Farm district of the London Borough of Camden, approximately 5.6 kilometres (km) northwest of central London.

The Site comprises two areas. The western part of the Site is fenced vacant ground with a small car park on its southern section. The eastern part of the Site comprises the Camden Council Resource Centre. The two areas are split by Crogsland Road.

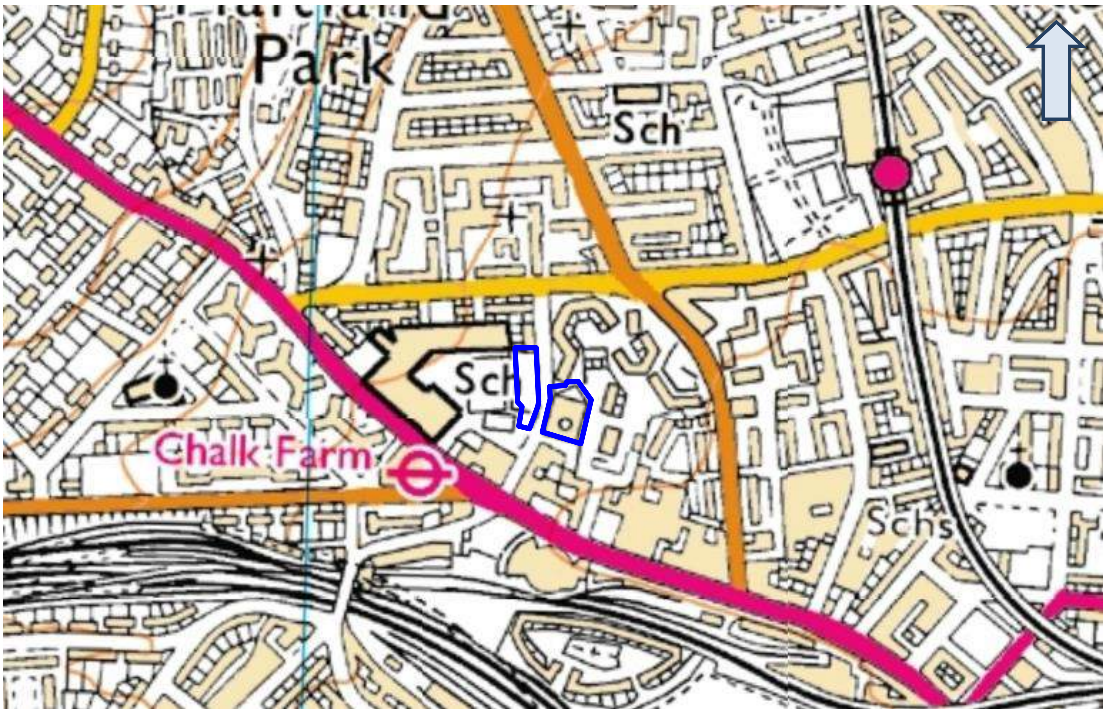
The Site is bounded to the west by a school and to the north, east and south by residential properties. Chalk Farm tube station is approximately 0.1km southwest of the Site.

It is understood that planned works on the Site may include intrusive ground investigations, excavations and piling.

During WWII the Site was within the former Metropolitan Borough (MB) of St Pancras.

Figure 1 is a Site location map and Plate 1 is a recent aerial photograph of the Site.

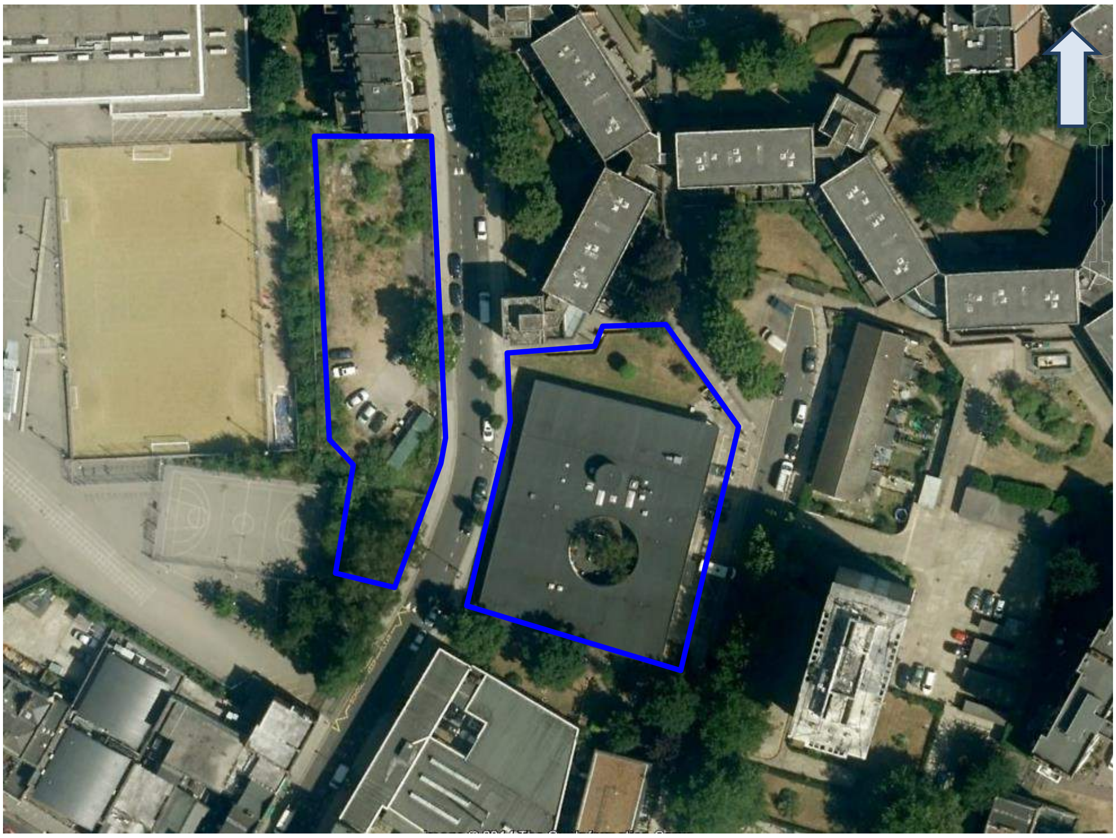
Figure 1 Site location map



Source: © Crown Copyright 2005. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend Site boundary

Plate 1	Recent aerial photograph of the Site



Source: Google Earth *Not to Scale*

Legend	Site boundary

2 SOURCES OF INFORMATION

Zetica Ltd researched the military history of the Site and its surrounding area utilising a range of information sources. The main sources of information are detailed in the following sections and referenced at the end of this report.

2.1 Zetica Ltd Defence Related Site Records

Zetica Ltd's in-house records were consulted, including reference books and archived materials from past work in the region. Relevant documents have been cited within the bibliography of this report.

2.2 Zetica Ltd Bombing Density Records and Maps

Reference has been made to the Zetica Ltd bomb risk maps located on Zetica Ltd's website (http://www.zetica.com/uxb_downloads.htm).

2.3 Ministry of Defence and Government Records

Various government departments and units within the Ministry of Defence (MoD) were approached for information of past and present military activity in the area. These included the Department of Communities and Local Government (DCLG) records of abandoned bombs.

2.4 Other Historical Records, Maps and Drawings

Numerous reference documents including historical maps, aerial photographs and drawings have been consulted from sources such as the National Archives, English Heritage and the Defence of Britain Project.

The British Geological Survey (BGS) was consulted for borehole information.

2.5 Local Authority Records

Information has been sought from Camden Borough Council.

2.6 Local Record Offices and Libraries

Camden Local Studies & Archives Centre provided information.

2.7 Local Historical and Other Groups

Local history groups and archaeological bodies were consulted.

2.8 Historical Information

With most locations, the potential presence of UXO as a result of enemy action, unauthorised disposal or unrecorded military activity can never be totally discounted.

Detailed records of military activity are rarely released into the public domain. Even when military information is made public there may be gaps in the records because files have been lost or destroyed.

Records for periods such as WWII are only as detailed and accurate as the resources and working conditions would allow at the time. Densely populated areas tend to have a greater number of records than rural areas. Such records may be inaccurate due to the confusion surrounding continuous air raids.

Press records can supplement local information, although this source of information must be treated with caution, as inaccuracies do exist, either inadvertently or intentionally in order to confuse enemy intelligence. Classified official records can sometimes be considered inaccurate for the same reason.

Recent research indicates that England alone had 17,434No. recorded defence sites, of which 12,464No. were classified as defensive anti-invasion sites. The precise locations of many of these sites are still to be identified, illustrating the scale of the problem when establishing potential risks from limited historical data.

3 SITE HISTORY

3.1 General History

At the end of the 19th century, the Site was occupied by, and surrounded by, residential properties. This is shown on the historical map of 1895 (Figure 2).

A school was located adjacent in a western direction to the Site. The Malden Factories, which manufactured watercolour and oil paintings, were located approximately 0.1km northeast of the Site.

Figure 2 Historical map, 1897

Source: © Crown Copyright 2005. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend	Site boundary

The historical map of 1916 (Figure 3) shows that the Site remained occupied by residential properties.

The adjacent school had expanded further to the west.

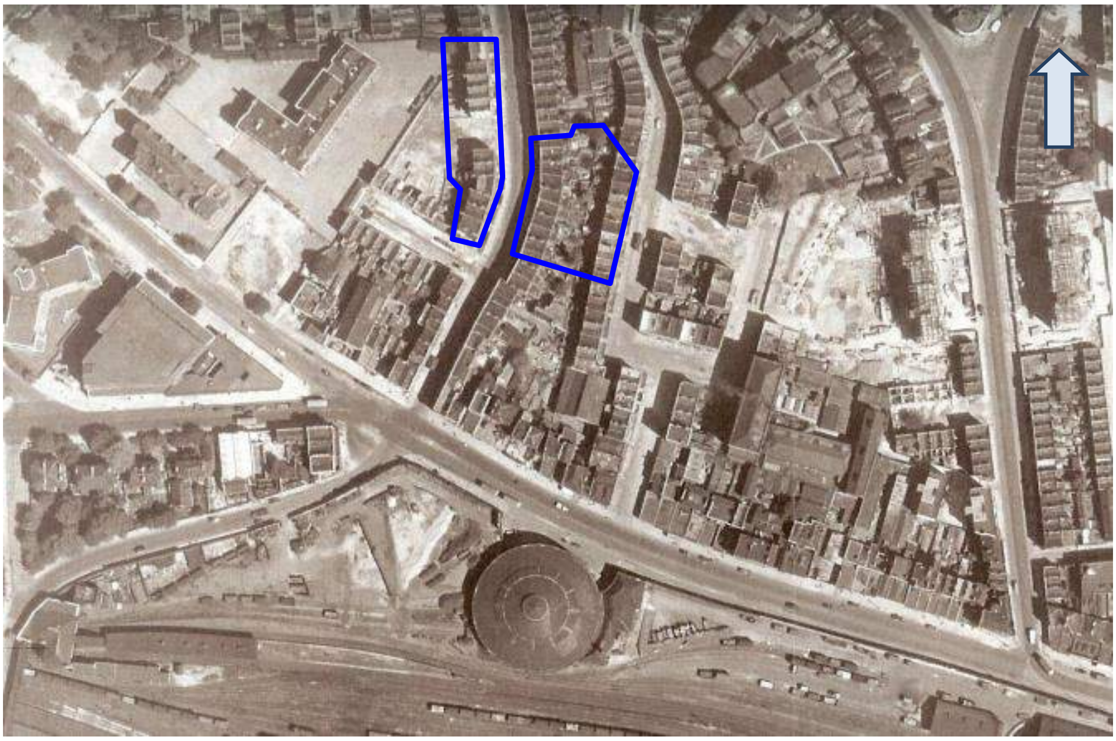
Figure 3	Historical map, 1916

Source: © Crown Copyright 2005. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend	Site boundary

During WWII the western part of the Site was bombed, resulting in the destruction of several houses. This is shown in Plate 2, an aerial photograph dating from 1948.

Plate 2	Aerial photograph, 1948



Source: English Heritage *Not to Scale*

Legend	Site boundary

The historical map of 1954 (Figure 4) shows that the Site and the surrounding areas had undergone significant development. The area in the western part of the Site that had been cleared had remained so to create an area of hardstanding. The eastern part of the Site remained occupied by housing.

To the east of the Site large areas of residential properties had been redeveloped into playgrounds and blocks of flats. The school to the west still occupied the same area.

Figure 4	Historical map, 1954

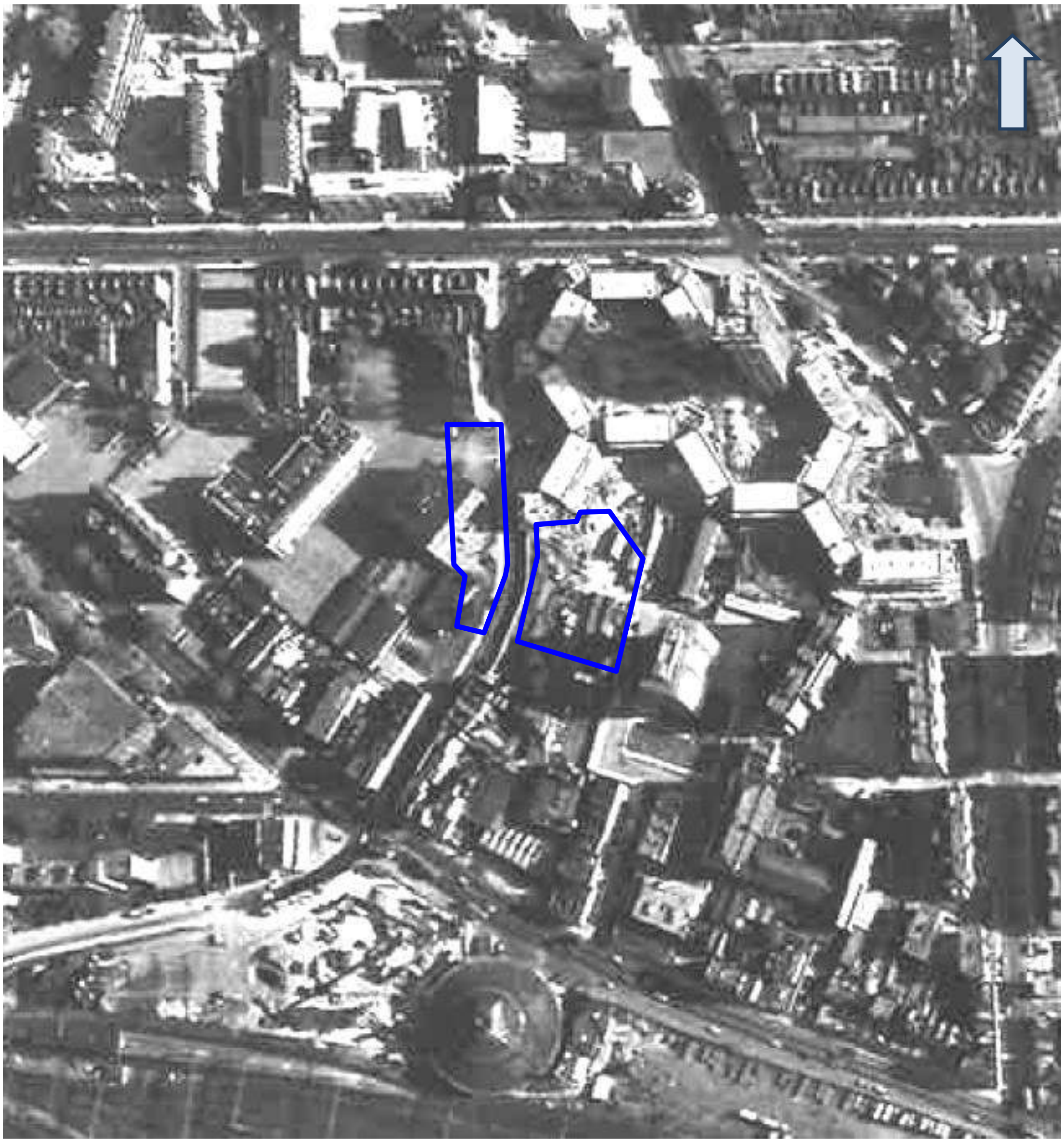
Source: © Crown Copyright 2005. Reproduced by permission of Ordnance Survey *Not to Scale*

Legend	Site boundary

Plate 3, an aerial photograph dated the 21st May 1971, shows that the Site and the surrounding area had undergone further development. The residential property on the eastern part of the Site had been demolished. A new building had been constructed on the western part of the Site.

The residential properties to the northeast of the Site had been changed from terraced housing into blocks of flats set out in a semi-circular fashion with a small open area in front of them. The school still existed to the west of the Site, as did the railways to the south of the Site.

Plate 3	Aerial photograph, 21st May 1971



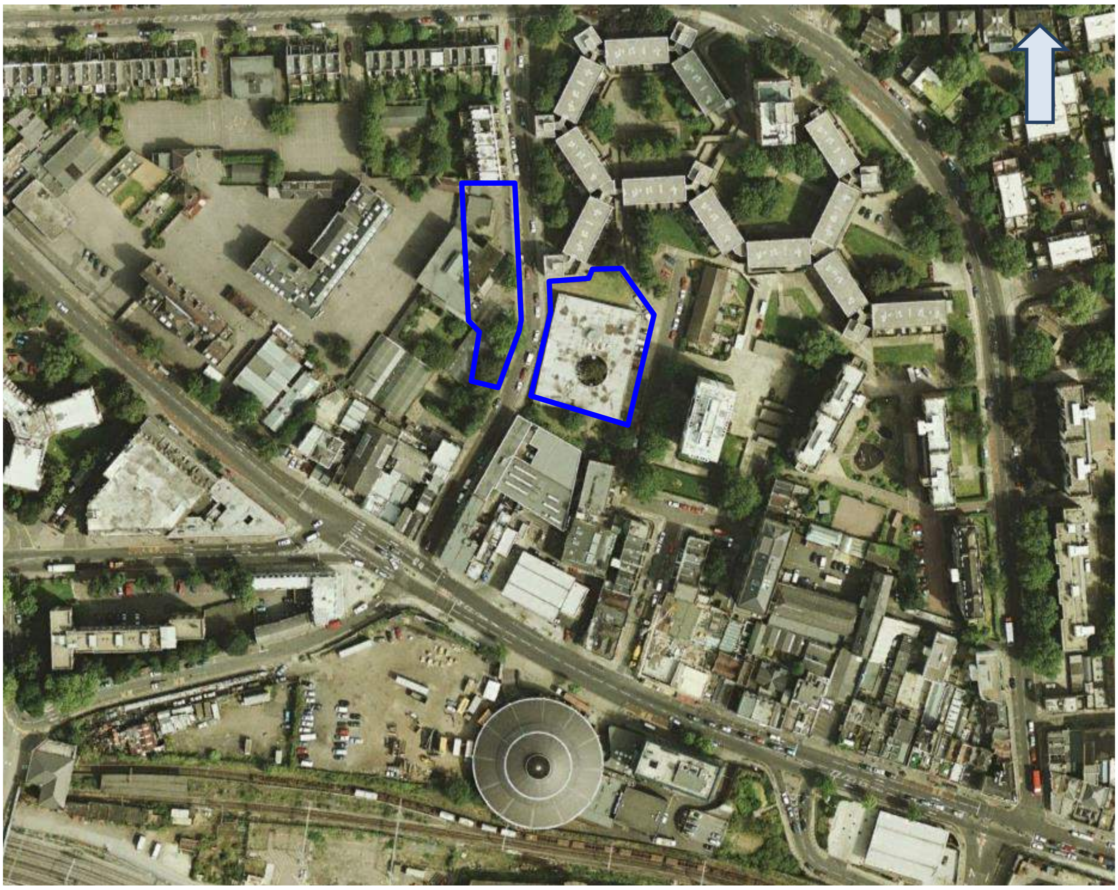
Source: English Heritage *Not to Scale*

Legend	Site boundary

The aerial photograph of 1999 (Plate 4) shows that a building had been constructed on the eastern part of the Site. This is the Camden Council Resource Centre.

The surrounding area remained unchanged.

Plate 4	Aerial photograph, 1999



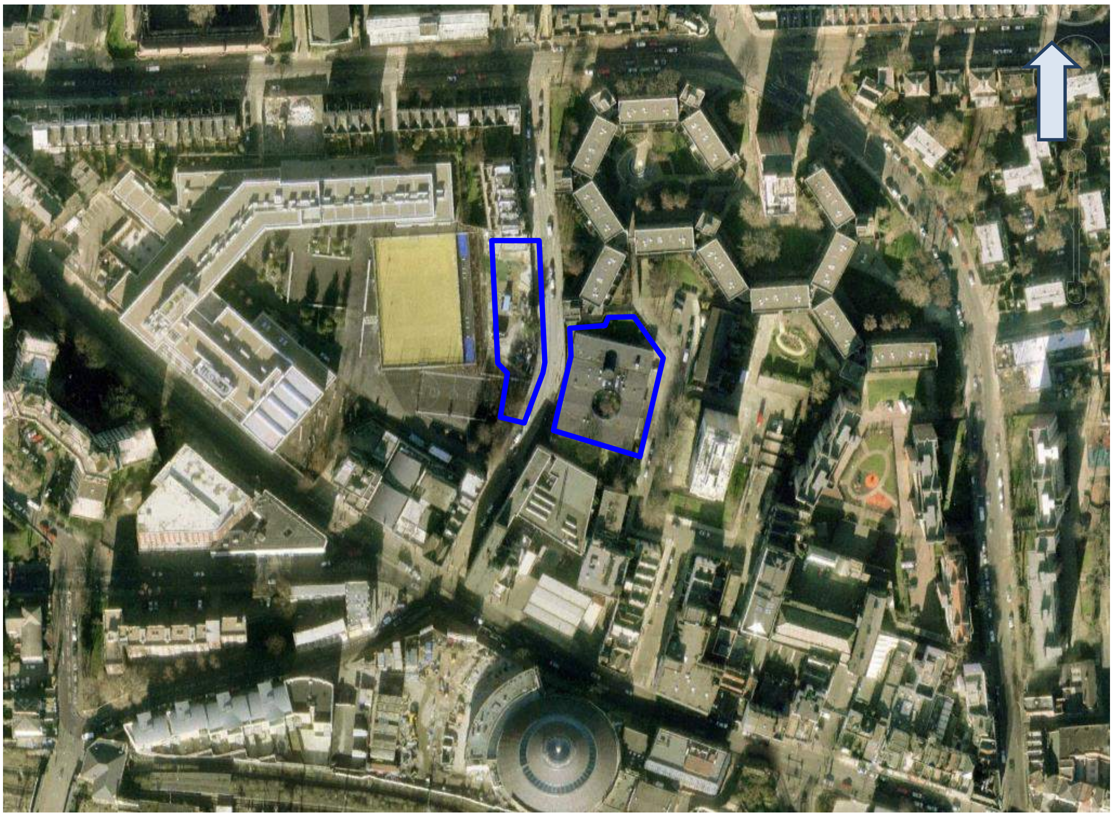
Source: Google Earth *Not to Scale*

Legend	Site boundary

By 2013 the buildings that occupied the western part of the Site had been demolished, as shown in Plate 5. The school to the west of the Site had been redeveloped, and an artificial sports field had been built adjacent to the Site's western boundary.

The eastern part of the Site remained occupied by the Camden Council Resource Centre.

Plate 5	Aerial photograph, 2013



Source: Bing Maps *Not to Scale*

Legend	Site boundary

There has been no further significant development on the Site since 2013.

3.2 Pre-WWI Military History

No significant pre-WWI military activity has been identified on the Site.

3.3 WWI Military History

During WWI the Site was in close proximity to several strategic targets, such as the Camden Goods Depot and the London and Northwest Railway (LNWR) mainline, approximately 0.4km southeast of the Site.

During WWI an estimated 9,000No. German bombs were dropped over Britain. It was the first time that strategic aerial bombing had been used. Nearly 100No. air raids were carried out on London and the southeast of England. Over 40No. of these were by Zeppelin airships.

The nearest recorded air raids to the Site during WWI are described below.

4th September 1917

1No. 12kg High Explosive (HE) bomb fell on Ainger Road, Primrose Hill, approximately 0.6km southwest of the Site. 1No. 50kg UXB was recorded having fallen in the same location.

19th May 1918

2No. HE bombs fell on Kentish Town, approximately 0.6km northeast of the Site.

To counter the German bombing raids, Anti-Aircraft (AA) gun batteries were established throughout London. These were all potential sources of Unexploded AA (UXAA) shells which could land up to 13km from the firing point, although more typically fell within 10km during WWI.

The Site was within the range of at least 50No. defensive AA guns during WWI. The nearest was located at Highgate Ponds, approximately 2.4km north-northeast of the Site. This was armed with 2No. 3-inch (") guns.

WWI military activity is not considered to provide a source of UXO hazard to the Site with the possible, albeit unlikely, exception of undiscovered UXAA shells.

3.4 WWII Military History

The Site was located in an area which was subjected to several heavy air raids during WWII. Details of air raids in the vicinity of the Site are provided in Section 4.

Defensive and offensive military structures were built during WWII. These included lines of defences (Stop Lines), pillboxes and AA guns. Details of those in the vicinity of the Site are provided in Section 5.

Other military establishments in the vicinity of the Site are described in Sections 6 to 9.

3.5 Post-WWII Military History

No significant post-WWII military activity has been identified on or in close proximity to the Site.

4 WWII BOMBING

Bombing raids began in the summer of 1940 and continued until the end of WWII. Bombing densities generally increased towards major cities or strategic targets such as docks, industrial premises, power stations and airfields.

The German bombing campaign saw the extensive use of both High Explosive (HE) bombs and Incendiary Bombs (IBs). The most common HE bombs were the 50kg and 250kg bombs, although 500kg were also used to a lesser extent. More rarely 1,000kg, 1,400kg and 1,800kg bombs were dropped.

The HE bombs tended to contain about half of their weight in explosives and were fitted with one or sometimes two fuzes. Not all HE bombs were intended to explode on impact. Some contained timing mechanisms where detonation could occur more than 70 hours after impact.

Incendiary devices ranged from small 1kg thermite filled, magnesium bodied bombs to a 250kg 'Oil Bomb' (OB) and a 500kg 'C300' IB. In some cases the IBs were fitted with a bursting charge. This exploded after the bomb had been alight for a few minutes causing burning debris to be scattered over a greater area. The C300 bombs were similar in appearance to 500kg HE bombs, although their design was sufficiently different to warrant a specially trained unit of the Royal Engineers to deal with their disposal.

Anti-Personnel (AP) bombs and Parachute Mines (PMs) were also deployed. 2No. types of anti-personnel bombs were in common use, the 2kg and the 12kg bomb. The 2kg bomb could inflict injury across an area up to 150m away from the impact, within 25m of this, death or fatal injury could occur.

PMs (which were up to 4m in length) could be detonated either magnetically or by noise/vibration. Anti-shipping parachute mines were commonly dropped over navigable rivers, dockland areas and coastlines. The Royal Navy was responsible for ensuring that the bombs were made safe. Removal and disposal was still the responsibility of the Bomb Disposal Unit of the Royal Engineers.

WWII bomb targeting was inaccurate, especially in the first year of the war. A typical bomb load of 50kg HE bombs mixed with IBs which was aimed at a specific location might not just miss the intended target but fall some considerable distance away.

It is understood that the local Civil Defence authorities in urban areas had a comprehensive system for reporting bomb incidents and dealing with any UXO. In more rural areas, fewer bombing raids occurred. It is known that Air Raid Precaution (ARP) records under-represent the number and frequency of bombs falling in rural and coastal areas.

Bombs were either released over targets or as part of 'tip and run' raids where bomber crews would drop their bombs to avoid Anti-Aircraft fire or Allied fighter aircraft on the route to and from other strategic targets. Bombs dropped as a result of poor targeting or 'tip and run' raids on rural and coastal areas were often unrecorded or entered as 'fell in open country' or fell 'in the sea'.

4.1 WWII Bombing in London

London was a principal target of Luftwaffe bombing during WWII. The first air raid of the Blitz on London took place on the 7th September 1940 when a large German force bombed the docks and surrounding areas.

From mid-September until the end of that year, London was raided on all but 3No. nights. The raids continued through the early months of 1941 becoming less frequent, although often more intense. Heavier bombs, including PMs and OBs, were now used and major incendiary raids on the 29th December 1940 and 10th May 1941 caused widespread fire damage across the city.

From July 1941 the bombing campaign against London entered a period of relative inactivity. Raids still took place but tended to be relatively minor in severity. Manned bomber raids returned to London in the first few months of 1944 and, after a brief respite, were followed by the start of the Pilotless Aircraft (V1) offensive against the capital in June 1944.

In September 1944 the Long Range Rocket (V2) offensive on London began. Falling from a height of some 50 miles (80km) above the city, these ballistic missiles caused larger craters and greater damage to underground utilities than the V1s, although their surface blast effect was generally less.

4.2 WWII Strategic Targets

The presence of strategic targets significantly increased the likelihood of bombing within the local area. Airfields, docks, industrial facilities, transport infrastructure and anti-invasion defences were all targeted by Luftwaffe bombers. The inherent bombing inaccuracies at the time meant that areas surrounding the targets were often subjected to bombing.

The following Sections describe the main strategic targets in the vicinity of the Site.

4.2.1 Transport Infrastructure

The LNWR mainline ran approximately 0.3km south of the Site. It ran commercial services from Euston Station (approximately 2.1km southeast of the Site) and St Pancras Station (approximately 2.3km southeast of the Site).

A large goods depot (Camden Goods Depot) was located approximately 0.4km southeast of the Site, and used the LNWR mainline to transport materials and goods into London.

Regents Canal, located approximately 0.6km southeast of the Site, was used to transport materials such as iron, steel, chemicals, grain and other commodities as far as Birmingham.

4.2.2 Public Utilities

Public utilities were frequently targeted by the Luftwaffe and target photographs identified gas works, power stations, sewage and water works, pumping stations and filter beds.

The Imperial Gas Works was located approximately 2.2km southeast of the Site and, with its 10No. gas holders, was an easily identifiable target.

4.2.3 The River Thames

The Site was located approximately 4.7km northwest of the River Thames. The London Docks, wharves and warehouses along the River Thames were strategically important targets for the Luftwaffe. The River Thames was also an important navigational aid for Luftwaffe bombers.

Light industrial works along the River Thames, including timber yards, saw mills, small shipyards, electricity sub-stations and coal depots were all secondary Luftwaffe targets.

4.2.4 Political and Government Targets

Many strategically important political and governmental establishments were located in the vicinity of the Site.

The American and other Allied embassies were situated in and around Grosvenor Square, approximately 3.9km south of the Site. Additionally, several hotels in the West End were used to house many exiled foreign leaders, including Charles de Gaulle.

The Allied Forces HQ was in St James's Square, approximately 4.4km south-southeast of the Site, and many of the surrounding buildings were requisitioned for use by the Chiefs of Staff.

4.3 Bombing Density and Incidents

Table 1 gives details of the overall bombing statistics recorded for the Local Authority Districts of the Site and surrounding districts. These were categorised as Rural Districts (RD), Urban Districts (UD), Municipal or Metropolitan Boroughs (MB) and County Boroughs (CB). The Site was in St Pancras MB.

The figures for West Ham CB, generally considered to represent a high bombing density, are included for comparison.

Table 1 Bombing Statistics

Area	Bombs Recorded				
	High Explosive	Parachute Mines	Other	Total	Bombs per 405ha (1,000 acres)
St Pancras MB	**641**	**8**	**14**	**663**	**246.1**
Holborn MB	354	7	8	369	908.9
St. Marylebone MB	398	6	12	416	303.0
Islington MB	568	7	24	599	193.7
Hampstead MB	321	6	31	358	158.1
West Ham CB	1,498	45	47	1,590	334.0

Note that Table 1 excludes the figures for V1s, V2s, AA shells and IBs. Discrepancies between this list and other records, such as bomb clearance records, demonstrate that this data is likely to under-represent actual bombing.

Details of the more significant air raids in the vicinity of the Site are given in the following Section.

14th September 1940

1No. HE bomb on Chalk Farm Station, approximately 0.1km southwest of the Site.

19th September 1940

1No. Delayed Action Bomb (DAB) exploded between Camden Town and Chalk Farm Station, approximately 0.5km southeast of the Site.

21st September 1940

1No. IB fell on Camden Goods Depot, approximately 0.3km south-southeast of the Site.

22nd September 1940

HE bombs fell on Prince of Wales Road, approximately 0.1km northwest of the Site.

26th September 1940

1No. HE bomb fell on Belmont Street, in close proximity to the Site in an eastern direction.

1No. HE bomb fell on Ferdinand Street, approximately 0.2km east of the Site.

1No. HE bomb fell on Marsden Street, approximately 0.3km northeast of the Site.

4No. HE bombs fell on Camden Goods Depot, approximately 0.3km south-southeast of the Site. 1No. was recorded as UXB.

1No. HE bomb fell on Hartland Road, approximately 0.4km east-northeast of the Site.

13th October 1940

1No. HE bomb fell on Queen's Crescent, approximately 0.2km northwest of the Site.

1No. HE bomb fell on Marsden Street, approximately 0.3km northeast of the Site.

17th October 1940

1No. HE bomb fell on Marsden Street, approximately 0.3km northeast of the Site.

1No. HE bomb fell on Dell's Factory, Ryland Road, approximately 0.5km northeast of the Site.

30th January 1941

1No. IB fell on railway property near Camden Goods Depot, approximately 0.2km south of the Site.

16th April 1941

1No. HE bomb fell on Crogsland Road, on the western part of the Site, causing severe damage to several buildings.

1No. HE bomb fell at the junction of Craddock Street and Prince of Wales Road, 0.1km northwest of the Site.

HE bombs fell on Prince of Wales Road, approximately 0.2km northwest of the Site.

1No. PM fell on Queen's Crescent, approximately 0.2km northwest of the Site.

19th April 1941

HE bombs fell on Chalk Farm tube station, approximately 0.1km southwest of the Site.

10th May 1941

1No. HE bomb fell on Haverstock Hill, approximately 0.1km west of the Site.

2No. HE bombs fell on Camden Goods Depot, approximately 0.3km south-southeast of the Site.

1No. HE bomb fell on Queen's Crescent, approximately 0.5km of the Site.

Unknown Dates

3No. HE bombs fell on Chalk Farm Road, in close proximity to the Site in a southern direction.

1No. HE bomb fell on Belmont Street, approximately 0.1km south-southeast of the Site.

1No. HE bomb fell on Eton College Road, approximately 0.2km west-southwest of the Site.

It should be noted that during WWII, many UXB were mapped and subsequently removed as and when conditions and demands on Bomb Disposal teams allowed. Their removal was not always accurately recorded and sometimes records were later destroyed. In practise, most UXB were probably removed and only a much smaller number were actually registered as officially abandoned bombs.

Figure 5 shows the approximate location of bomb impacts in the vicinity of the Site. Only IBs and AA shells recorded as falling on or in close proximity to the Site are shown for clarity. The locations have been compiled from a number of different sources, including bomb census maps and air raid incident reports. It should be noted that air raid incident reports do not always give precise details of the bombs which fell, often only indicating which street or area they fell in.

Figure 5	Compiled bomb impact map for the vicinity of the Site

Source: © Crown Copyright 2005. Reproduced by permission of Ordnance Survey *Not to Scale*

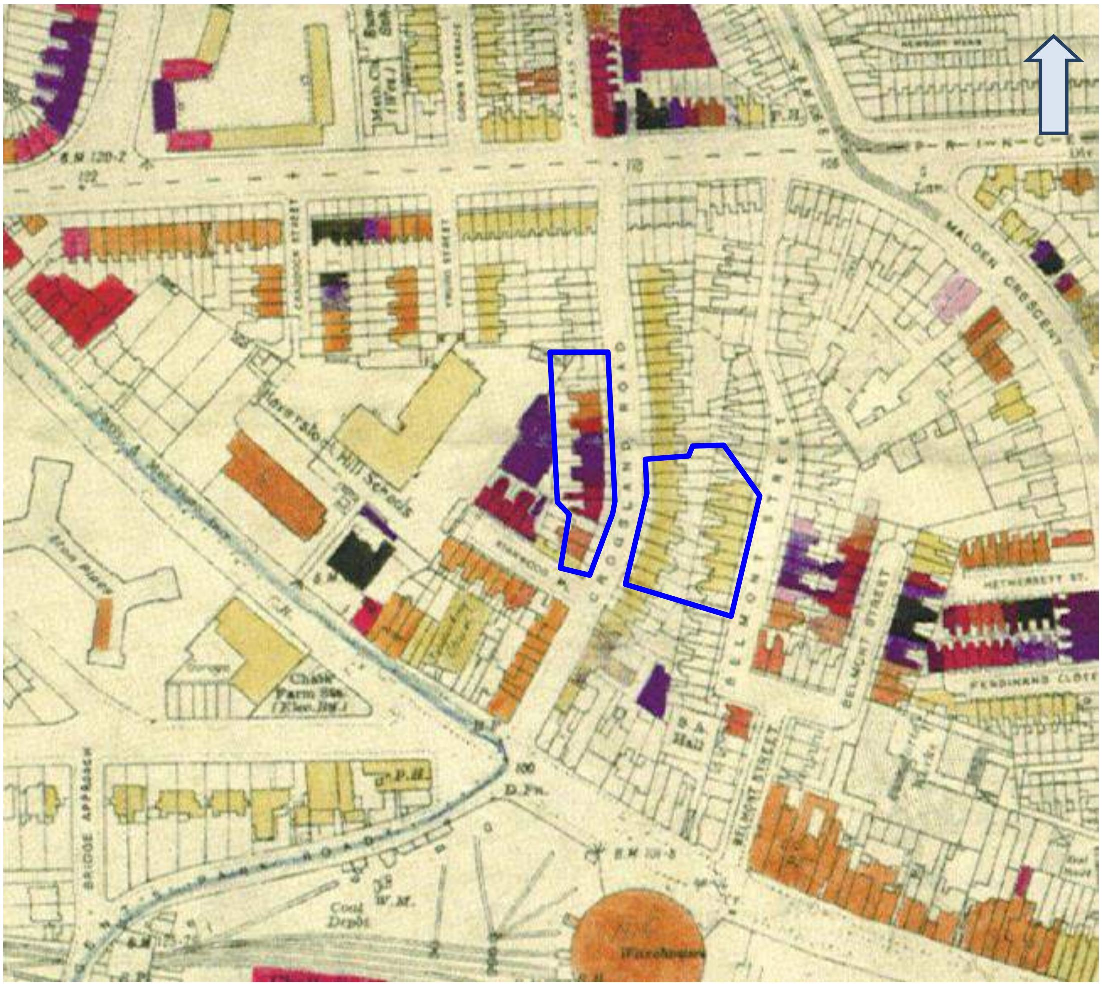
Legend	Site boundary	HE bomb	PM

Figure 6 is an extract from the London Bomb Damage Map. The shadings shown relate to the level of damage to buildings, with darker colours representing a higher degree of damage.

Black represents total destruction, purple is damaged beyond repair, dark red is seriously damaged and probably not repairable, light red is seriously damaged but repairable, orange and yellow show degrees of blast damage which are not structural, and blue and green are cleared areas. Impact sites of V1s (black circles) and V2s (light blue circles) are also shown.

There is evidence of significant structural damage on the western part of the Site and only blast damage on the eastern part of the Site.

Figure 6	Extract from the London Bomb Damage Map

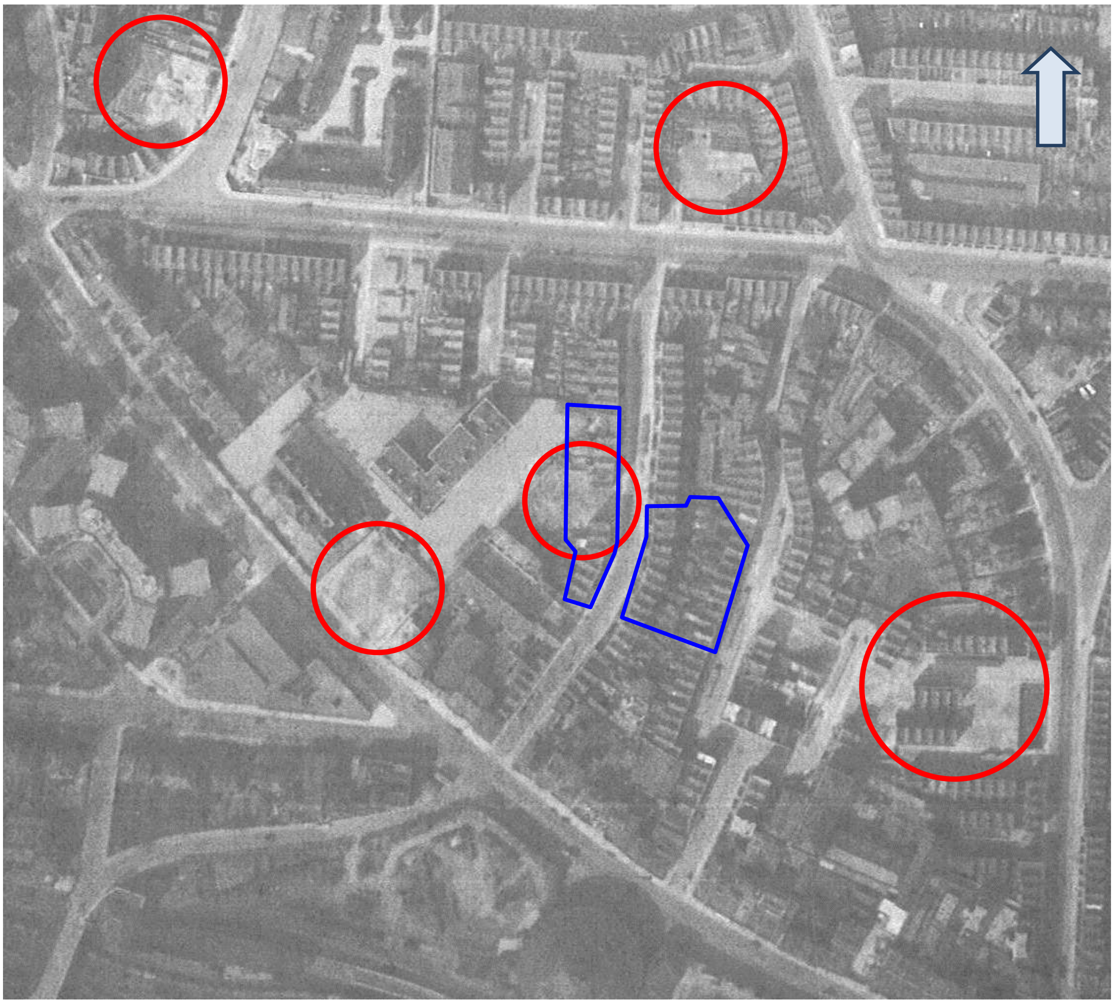


Source: London County Council *Not to Scale*

Legend	Site boundary

Plate 6 is an aerial photograph of the Site, dated the 2nd April 1946. There is evidence of significant bomb damage on the western part of the Site, consistent with the London Bomb Damage map. No evidence of significant damage has been identified on the eastern part of the Site.

Plate 6	Aerial photograph, 2nd April 1946



Source: English Heritage *Not to Scale*

Legend	Site boundary	Possible bomb damage

WWII bombing is considered to provide a possible source of UXO hazard to the western part of the Site.

4.4 Geology and Bomb Penetration Depths

It is important to consider the soil type present at the time that a bomb was dropped in order to establish its maximum penetration depth. The BGS 1:50,000 Sheet 256 North London (Solid & Drift) and BGS borehole records were consulted.

During WWII, the geology of the Site consisted of Made Ground overlying London Clay.

Table 2 provides an estimate of average maximum bomb penetration depths assuming ground conditions during WWII of 1m of Made Ground over 2m of soft clay overlying stiff clay.

Table 2	Estimated average maximum bomb penetration depths	
Estimated average bomb penetration depths for anticipated geology		
Bomb Weight	50kg	4.5m
	500kg	13.0m
	1,000kg	15.0m

The estimated bomb penetration depths given in Table 2 are from the WWII ground level and are based on the following assumptions:

a) High level release of the bomb resulting in an impact velocity of 260m/s (>5,000m altitude).

b) A strike angle of 10 to 15 degrees to the vertical.

c) That the bomb is stable, both in flight and on penetration.

d) That no retarding units are fitted to the bomb.

e) That the soil type is homogenous.

A high altitude release of a bomb will result in ground entry at between 10^{o} and 15^{o} to the vertical with the bomb travelling on this trajectory until momentum is nearly lost. The bomb will then turn abruptly to the horizontal before coming to rest. The distance between the centre of the entry hole and the centre of the bomb at rest is known as the 'offset'. A marked lateral movement from the original line of entry is common.

Low-level attacks may have an impact angle of 45° or more, which will frequently lead to a much greater amount of offset movement during soil penetration.

The average offset is one third of the penetration depth, i.e. an offset of 2m may be expected for a 50kg bomb in dry silts and clays.

If hard standings or Made Ground were present during WWII, bomb penetration depths would have been significantly reduced but offset distances may have been up to four times greater.

5 WWII DEFENCES

5.1 Bombing Decoys

In order to draw enemy aircraft away from towns and other strategically important targets, a series of decoys were developed between 1940 and 1941.

They were estimated to have drawn at least 5% of the total weight of bombs away from their intended targets. Approximately 792No. static decoy sites were built at 593No. locations in England. In addition, numerous temporary and mobile decoys were deployed.

Several different types of decoy were devised:

- Night time dummy airfields (Q sites).
- Daytime dummy airfields (K sites).
- Diversionary fires to simulate successful bombing raids on airfields (QF sites), petroleum depots (P sites) and major towns and cities (Starfish or SF sites).
- Simulated urban lighting (QL sites).
- Dummy Heavy Anti-Aircraft (HAA) batteries, factories and buildings (C series).
- Mobile decoys representing 'hards' for troop embarkation (MQLs), tanks and other vehicles.

Machine gun emplacements and Light Anti-Aircraft (LAA) guns were used to prevent possible enemy landings at decoy airfields.

By their nature, decoy sites provide a potential risk from Unexploded Bombs (UXB), both within the decoy site boundary and in the surrounding areas.

The nearest bombing decoy was located on Hampstead Heath, approximately 2.4km northwest of the Site.

This is not considered to provide a source of UXO hazard to the Site.

5.2 Anti-Aircraft Defences

Anti-Aircraft (AA) gun batteries were targeted by the Luftwaffe. They were also a source of Unexploded AA (UXAA) Shells which could land up to 27km from the firing point during WWII, although more typically fell within 15km. These could be distributed over a wide area.

AA batteries present a potential source of UXO hazard as a result of the storage, use and disposal of ordnance associated with the armaments used. They may have a risk from small caches of ammunition buried locally to them. 3No. types of AA batteries existed:

- Heavy Anti-Aircraft (HAA) batteries of large guns designed to engage high flying bomber aircraft. These tended to be relatively permanent gun emplacements.
- Light Anti-Aircraft (LAA) weaponry, designed to counter low flying aircraft. These were often mobile and were moved periodically to new locations around strategic targets such as airfields.

- Rocket batteries (ZAA) firing 3″ or 3.7″ AA rockets with a maximum altitude of 5,800m and a ground range of 9km were also relatively permanent emplacements.

Many AA batteries were associated with searchlights and consequently 'visible' at night, providing clear targets to the Luftwaffe bombers and a potential for UXB.

The Site was within the range of HAA gun batteries deployed in the London Gun Defended Area (GDA).

Table 3 is a list of recorded HAA and ZAA rocket batteries within 10km of the Site.

Table 3 WWII HAA gun batteries and ZAA rocket batteries within 10km of the Site

Grid Reference	Serial No.	Location	Armament	Approximate Distance and Direction from Site
TQ 275860	ZE14	Primrose Hill	4No. 52.5″ guns	0.9km SW
TQ 278806	ZW5	Hyde Park	4No. 3.7″ guns	3.9km SSE
TQ 257878	ZE22	Hampstead	4No. 3.7″ guns	4.2km NW
TQ 326865	ZE22	Clissold Park	Unknown	4.8km NE
TQ 228857	ZW9	Dollis Hill	2No. 3″ guns	5.5km WNW
TQ 223818	ZW10	Wormwood Scrubs	4No. 5.25″ guns	6.5km WSW
TQ 223818	13Z	Wormwood Scrubs	64No. UP tubes	6.5km WSW
TQ 356819	ZE19	Walthamstow	Unknown	7.9km SE
TQ 211881	ZW14	Brent	Unknown	8.0km NW
TQ 365845	-	Victoria Park	Unknown	8.4km E
TQ 350794	ZE12	Southwark Park	Unknown	8.5km SE
TQ 353789	ZE13	Souhwark Park	Unknown	9.0km SE
TQ 266934	ZW6	Friern Barnet	4No. 3″ guns	9.1km N
TQ 252758	ZW8	Hurlingham	4No. 3″ guns	9.1km SSW
TQ 289751	ZS16	Clapham Common	4No. 4.5″ guns	9.3km S
TQ 374859	ZE21	Hackney Marshes	4No. 5.25″ guns	9.3km E
TQ 375853	ZE21	Hackney Marshes	4No. 5.25″ guns	9.3km E
TQ 267939	ZW7	Glass House	4No. 4.5″ guns	9.5km N

It should be noted that the lack of official records of AA batteries or armaments cannot be taken to imply their absence because many units were mobile and were moved around as operational requirements dictated.

In addition, LAA guns were deployed to protect designated Vulnerable Points (VPs). There were no recorded LAA gun positions in the vicinity of the Site.

UXAA shells from the surrounding gun batteries are considered to provide a possible, albeit unlikely, source of UXO hazard to the Site.

5.3 Barrage Balloons and Anti-Landing Obstacles

Balloon barrages were flown in many British towns and cities to protect against air raids. Their presence deterred low flying aircraft, making it more difficult for bombs to reach their intended targets.

Barrage balloon sites can be a source of UXO as they were targeted by the Luftwaffe. They also often had a small explosive charge fitted with tilt fuzes attached approximately 50m from each end of the balloon cables and designed to detonate if the cables were hit by an aircraft.

Measures were also taken to prevent enemy aircraft landing in the event of invasion. Obstructions were constructed around airfields and on other open sites deemed fit for use as landing grounds. Solid obstructions (such as concrete blocks), posts or stakes, felled trees, haystacks, scaffolding with wire and trenching were the main measures used.

No records of barrage balloons or anti-landing obstacles on or in close proximity to the Site have been found.

5.4 Anti-Invasion Defences

Defence structures are a potential source of UXB as they were especially targeted by low flying enemy aircraft, particularly during 'tip and run' raids which were common in industrialised regions. These defences may also be associated with small caches of UXO in the form of small arms, used by the troops manning the emplacement.

The rapid advance of German Troops into France, Holland and Belgium after the start of WWII prompted the War Office to review the vulnerability of the UK to invasion and a decision was taken to begin work on a national plan of anti-invasion defences. Static defences were built to interrupt and delay the progress of any invading force.

Coastal defences were strengthened (the 'Coastal Crust'). These defences included barbed wire entanglements and minefields, which were often combined to give defence in depth.

Inland, lines of defence structures were constructed along 'Stop Lines' in order to impede enemy progress for long enough to allow mobile defending forces to counter-attack.

Stop Lines included the fortification of key 'centres of resistance', such as river crossings and important road or rail junctions that could seriously hamper the enemy's advance across country. Bridges were mined for demolition and tank traps installed.

Stop Lines were further integrated into a network of fortified nodal points and 'Anti-Tank (AT) Islands'.

No recorded anti-invasion defences on or in close proximity to the Site have been found. The nearest recorded anti-tank block was located approximately 0.8km south of the Site.

5.5 Pillboxes, Mortar and Gun Emplacements

Defences also included gun emplacements, weapons pits and spigot mortar positions, which could be either fixed or mobile.

There are no records of spigot mortar or gun emplacements on or in close proximity to the Site.

Pillboxes provide a potential UXO hazard both from the storage, use and disposal of ordnance associated with them and from UXB because they were targeted by enemy aircraft.

Pillboxes were common along Stop Lines, perimeters of airfields, potential land invasion sites and around important civil sites. Several different designs existed including Seagull Trenches (semi-buried structures), Alan Williams and Tett Turrets (small prefabricated pillboxes). Fortified sites, buildings or loop-holed walls also functioned as pillboxes.

No records of pillboxes on or in close proximity to the Site have been found. The nearest recorded pillbox was located along Camden Road, approximately 0.9km southeast of the Site.

None of the anti-invasion defences identified are considered to provide a source of UXO hazard to the Site.

5.6 Home Guard and Auxiliary Units

Local Defence Volunteers (LDV) units, later known as the Home Guard, were located in all cities, towns and large villages.

Anti-invasion defences were to be defended by the Home Guard and regular Army troops for as long as possible in the event of an invasion. The troops were issued with 'No Withdrawal' orders.

Important elements of the ordnance supply for the use of the Home Guard included substantial supplies of Mills bombs (fragmentation grenades) and Self Igniting Phosphorus (SIP) grenades as well as machine gun and small arms ammunition.

In October 2006 a cache of 76No. SIP grenades was found in a garden at Seend, Wiltshire. In October 2008, a further 26No. SIP grenades were discovered in a garden in Wimborne, Dorset.

Similar caches were discovered in October 2009 in Hove, Sussex and during May 2010 in Halesowen in the West Midlands, and a further cache of 20No. was uncovered on a construction site at Birdlip, Gloucestershire, in July 2010. Also in July 2010, a box of 24No. SIP grenades was found on Cogden Beach, Dorset. In April 2012, more than 8No. SIP grenades were found on a construction site in Banbury and destroyed by members of the Army Royal Logistic Corps (RLC).

In all 7No. cases, the bottles were in good condition and exploded in flames when broken.

Records of Home Guard activities and related sites are rarely preserved. Storage and disposal of munitions by the Home Guard was poorly documented and surplus supplies were either buried or dumped in lakes and ponds. It is considered that all locations occupied or used by the Home Guard provide a moderate UXO hazard. In addition to the regular Home Guard, Auxiliary Units existed which were made up of guerrilla troops trained in sabotage and assassination in case of invasion. Sites used by these Units were Top Secret and many locations are still unknown. It is considered that all locations occupied or used by the Auxiliary Units provide a high UXO hazard.
The Site was in the region patrolled by the 31st Battalion City of London (St Pancras). There are no records of Home Guard activity on or in close proximity to the Site.
5.7 Minefields and Mined Locations
Minefields were laid along the coast, in estuaries and along the banks of major rivers to deter infantry invasion. Strategic points such as bridges and gaps in cliffs were mined to impede enemy advance. Most of the mined locations in the UK have been cleared and the risk of finding UXO in these areas is considered to be low.
No evidence of any mined locations on or in close proximity to the Site has been found.

6 MILITARY AIRFIELDS
Military airfields offer the potential for significant UXO hazards due to the use, storage and disposal of ordnance and as a result of enemy bombing during WWI and WWII. Airfields active during WWII were targeted by the Luftwaffe, providing a potential source of UXB on the airfield. As bombing accuracy was so poor during WWII, it is likely to find UXB in the surrounding areas. Aircraft crashes are also associated with operational airfields.
There were no operational airfields in the vicinity of the Site. The nearest airfield was Royal Air Force (RAF) Hendon, approximately 8.6km northwest of the Site.
6.1 Aircraft Crashes
Aircraft crash sites are a known UXO hazard. The MoD advises that if crashed aircraft are found, the safest policy is to leave them alone where possible. Unless disturbed there is no statutory requirement for the MoD to clear such sites.
No records of aircraft crashes in the vicinity of the Site have been found.

7 EXPLOSIVES AND MUNITIONS ESTABLISHMENTS AND DEPOTS

Explosives and munitions manufacturing or storage sites offer a particularly high risk from both explosive substances and UXO. Standard procedures of explosive/ordnance disposal through burial or burning means that explosive and UXO hazards will be present in some areas of such establishments.

In addition, UXB hazards may be present as a result of enemy bombing during WWI and WWII.

7.1 Explosives and Ordnance Factories

There were no explosives or ordnance factories on or in close proximity to the Site.

The nearest was Phoenix Place National Fuze Rectification Factory (NFRF), approximately 3.6km southwest of the Site. The factory was active during WWI, repairing fuzes damaged in battle and converting imported American Type 100 fuzes to British specifications.

Phoenix Place NFRF is not considered to provide a source of UXO hazard to the Site.

7.2 Munitions Stores

Local ammunition caches would have been present near to defended road blocks, pillboxes, HAA and LAA sites. Most of those associated with the anti-invasion sites are understood to have been cleared.

No records of any munitions stores in the vicinity of the Site have been found.

7.3 Informal Munitions Depots

Informal munitions depots, often made by requisitioning roadside lay-bys or parks. Other informal munitions depots were commonly located in areas of woodland or on train wagons along sidings in marshalling yards.

No records of any informal munitions depots on or in close proximity to the Site have been found.

7.4 Munitions Disposal Areas and Bomb Cemeteries

Munitions disposal areas were often made by requisitioning open areas of land, usually away from habitation. Marshland, beaches or sand dunes were frequently used for this purpose. Disposal of munitions was carried out in many different ways, ranging from destruction to burial. Full records were not necessarily maintained for these locations, and so they can potentially be a source of UXO.

No records of any munitions disposal areas on or in close proximity to the Site have been found.

The nearest bomb cemetery was located at Regents Park, approximately 1.5km south of the Site.

This is not considered to provide a source of UXO hazard to the Site.

8 FIRING RANGES AND MILITARY TRAINING AREAS

By their nature, firing ranges and military training areas represent a potential source of UXO due to associated training activities. The training will involve both practice and live munitions and will offer a significant risk from a very wide range of potential UXO.

8.1 Small Arms Ranges

Small arms ranges (such as rifle ranges) and close combat ranges (such as mortar and grenade ranges) are likely to provide a significant source of UXO. It should be noted that even on small arms ranges, larger munitions such as mortars or grenades cannot be discounted.

No records of any small arms in the vicinity of the Site have been found.

8.2 Artillery Ranges

Artillery ranges will have utilised a wide range of munitions, predominantly shells, although close combat munitions such as mortars, or larger munitions such as bombs, cannot be discounted.

No records of any artillery range within the vicinity of the Site have been found.

8.3 Bombing Ranges

Bombing ranges will have primarily used bombs, although other munitions such as shells and close combat munitions such as mortars cannot be totally discounted.

No records of any bombing range within the vicinity of the Site have been found.

8.4 Training Areas

Training areas will have primarily used blank ammunition or practice shells in 'dry' areas, although live munitions such as shells and close combat munitions such as mortars cannot be discounted in any training area.

No records of any military training area on or in close proximity to the Site have been found.

9 OTHER ESTABLISHMENTS, MILITARY BASES AND BARRACKS

Several military establishments directly linked to the armed forces exist or have existed in the region surrounding the Site. These can provide a source of UXO hazard, although the level of risk from such hazards will depend on the nature of operations carried out.

The following Section describes those establishments in the vicinity of the Site.

9.1 St Johns Wood Barracks

St Johns Wood Barracks were located approximately 1.6km south-southwest of the Site. They were constructed in 1812 by the Board of Ordnance to house artillery brigades.

From 1880 until 2012 the Royal Horse Artillery were stationed in the barracks. The barracks were decommissioned and closed in 2012, and the land is in the process of being sold off for development.

St Johns Wood Barracks are not considered to provide a source of UXO hazard to the Site.

9.2 Albany Street (Regents Park) Barracks

Albany Street Barracks were located approximately 1.7km south-southeast of the Site, adjacent to Regents Park. They were built in the early-nineteenth century and have been mostly associated with cavalry regiments of the British Army, most notably the Royal Horse Guards and current tenants the Queen's Royal Hussars.

As well as the Queen's Royal Hussars, the 20th Transport Squadron and the Artist's Rifles Special Air Service (SAS) regiment are also based here. The barracks are still in active service.

On 24th September 1971 the barracks were bombed in a terrorist attacks by anarchy group The Angry Brigade.

Albany Street Barracks are not considered to provide a source of UXO hazard to the Site.

9.3 Kenwood House Military Camp

Kenwood House is located approximately 3.2km north-northwest of the Site. Formerly a stately home, it was requisitioned in WWII to house servicemen for the duration of the war.

Kenwood House is not considered to provide a source of UXO hazard to the Site.

10 EXPLOSIVE ORDNANCE CLEARANCE ACTIVITIES

Official UK bombing statistics have been compiled from both British and German sources. There were differences in the way the figures were originally reported and collated which has led to discrepancies in the summary data.

Based on data from 1939 to 1945, War Office statistics indicate that 200,195No. HE bombs exploded within Great Britain. Additionally, 25,195No. HE bombs (representing 11%) were recorded as UXBs. However, records from the Royal Engineers who were responsible for bomb disposal at the time indicate that as of 27th February 1946 upwards of 45,000No. UXBs were disposed of.

On average 8.5% UXBs later self-exploded. In some cases the bombs had delayed action fuzes or were never intended to explode, their purpose being to cause inconvenience and fear.

Given the discrepancy in records and the fact that UXBs are still being found unexpectedly, it is clear that the original figures are understated and provide only an approximation of the number of potential UXBs in the UK.

War Office statistics also show that between October 1940 and May 1941 most of the UXBs (93%) were either 50kg or 250kg. It should be noted that details of the recovery and the size of the UXB were not always accurately reported.

The larger WWII UXBs are often difficult to recover due to both penetration depths and the presence of two or more fuzes, combined with more sensitive fillings of explosive mixtures including Amatol and Trialen.

10.1 Abandoned Bombs

Information received from the DCLG confirms that there are no officially registered abandoned bombs on the Site.

10.2 EOC Tasks

Records already held by Zetica indicate the following post-WWII EOC tasks have been carried out in the vicinity of the Site.

5th September 1955

1No. Unexploded IB (UXIB) was recorded at 2 Nassington Road, Hampstead, approximately 1.5km northwest of the Site.

2nd October 1969

1No. 1,200kg Unexploded Parachute Mine (UXPM) was recorded at Burghley Road, St Pancras, approximately 1.3km northeast of the Site.

The MoD has provided no additional information on official EOC tasks on the Site.

11 UXO HAZARD

11.1 Anticipated Ordnance Types

When assessing the risk from UXO including UXB, it is important to be aware of ordnance type and function. The following Section briefly describes the main ordnance types that could potentially affect the Site.

11.1.1 Small Arms Ammunition

Small Arms Ammunition (SAA) is one of the more recognisable categories of ordnance which is primarily designed for anti-personnel use. SAA include items such as bullets, generally up to a calibre (diameter) of 20mm.

Larger calibre small arms munitions can contain fuze mechanisms and high explosives or pyrotechnic fillings and may have been used for anti-aircraft or anti-vehicle purposes.

Generally small arms ordnance has a relatively low risk as UXO, although the larger calibre categories may have the same detonation risk as larger high explosive ordnance. SAA is often associated with discarded ammunition boxes around firing practice ranges. Plate 7 illustrates some common SAA.

Plate 7	Photograph of typical WWII small arms ammunition

Source: Google Images

11.1.2 Hand Grenades

Hand grenades can be filled with explosives or chemicals and have 3No. main parts, a body, a fuze with a pull ring and a safety-clip assembly. Fragmentation grenades are the most common and have a metal or plastic body filled with an explosive. Most use a burning delay fuze that functions for 3 to 5 seconds after the safety lever is released.

Some, such as smoke grenades, are activated instantly when the lever is released. Plate 8 illustrates the typical character and condition of Mills Type 36 hand grenades that have been excavated from a site.

Plate 8	Photographs of a typical and an excavated WWII Mills Type 36 hand grenade

Source: Google Images *Source: Zetica Ltd*

11.1.3 Projected Grenades

Projected grenades are among the most commonly found UXO items, particularly the 40mm type. These contain high explosives and use a variety of fuzes, including some of the most sensitive internal impact-fuzing systems. They are extremely dangerous and can explode if moved or handled.

11.1.4 Mortars

A mortar is a short tube designed to fire a projectile at a steep angle. Mortars can range from approximately 50mm to 280mm in diameter and can be filled with explosives, toxic chemicals, white phosphorous or illumination flares. They generally have a thinner metal casing than projectiles, but use the same types of fuzing and stabilisation.

11.1.5 Shells

Shells are a projectile containing an explosive charge designed to burst the casing that can contain High Explosives, pyrotechnic compounds or other chemicals.

Shells can be found in a range of sizes, from <20mm to several times this size. The most likely shells to be found on the Site are Small Arms Ammunition (SAA) or UXAA shells that have fallen back to the ground unexploded.

Most commonly used anti-aircraft shells were 2" and 3.7" HE shells. If fired and found as UXO, shells can offer a particular hazard from accidental detonation as they can have sensitive fuze mechanisms. A fuze is a device which incorporates mechanical, electrical, chemical or hydrostatic components to initiate a train of fire or detonation.
11.1.6 Incendiary Bombs
Incendiary Bombs (IBs) ranged from small 1kg thermite filled, magnesium bodied bombs to a 250kg 'Oil Bomb' (OB) and a 500kg 'C300' IB. By far the most common air dropped devices across the UK during WWII were small 1kg to 2kg IBs. In some cases the IBs were fitted with a very small High Explosive (HE) bursting charge. This exploded after the bomb had been alight for a few minutes causing burning debris to be scattered over a greater area. The C300 bombs were similar in appearance to 500kg HE bombs. The small amount of HE, if any, and the almost negligible potential for IBs to remain active after more than 65 years in the ground means that these items have very little prospect of causing damage. In the majority of cases if IBs are found in the ground, the incendiary materials have deteriorated to such an extent that they are considered to provide a low UXO hazard level. However, since magnesium and phosphorus were common components in IBs, some localised chemical contamination may occur where the contents have leached out of the IB into the surrounding soil. Plate 9 shows a typical variety of fragmentary remains of IBs and 2No. IBs recovered by the Civil Defence during WWII.

Plate 9 Photographs of typical fragmentary remains of IBs and a UXIB

Source: Swansea Museum

Source: Museum of London

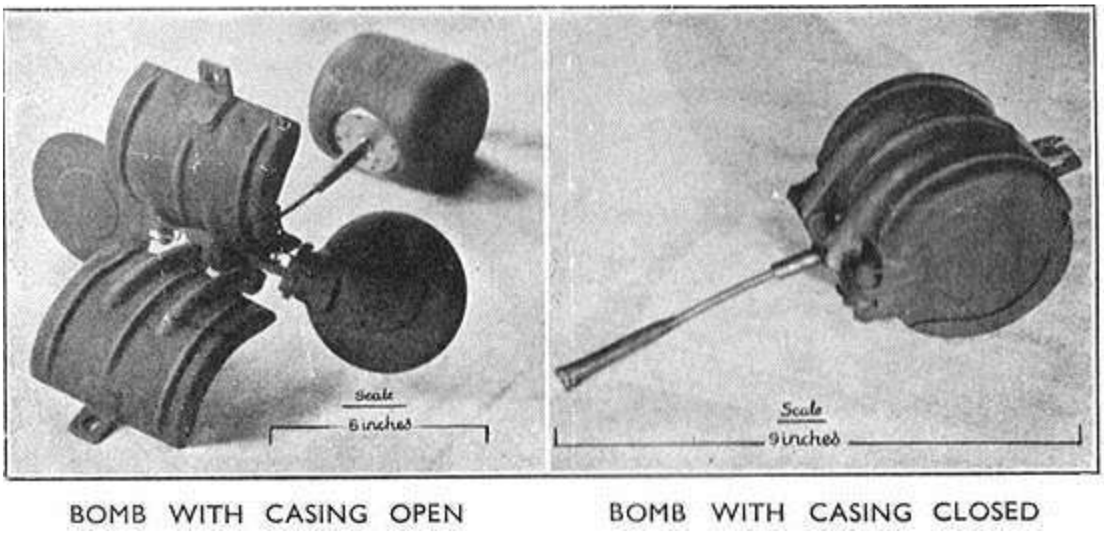
11.1.7 Anti-Personnel Bombs

2No. types of Anti-Personnel (AP) bombs were in common use, the 2kg and the 12kg bomb. The 2kg bomb could inflict injury across an area up to 150m away from the impact, within 25m of this, death or fatal injury could occur.

In the majority of cases WWII AP bombs were so sensitive to disturbance that none have been found since WWII as UXAPB and it is considered very unlikely that such an item would be found buried as an UXAPB

Plate 10 shows typical AP ('Butterfly') bombs recovered by the Civil Defence during WWII.

Plate 10 Photographs of typical AP ('Butterfly') bombs



Source: Smith

11.1.8 Bombs

Probably the most common and certainly most publicised UXOs to be found in the UK are bombs. Air dropped bombs, as a result of WWII enemy action, are found on a relatively frequent basis as UXO. They tend to be highly publicised (at least on a local basis) due to the common disruption where an evacuation of the potentially affected area is put in place.

The amount of High Explosive and the potential for a fuze to still be activated means that these devices have the prospect of causing some of the most widespread damage. WWII bombs were particularly sophisticated for their time, with anti-tamper fuzes.

Many German bombs were designed to not explode on impact and instead to cause disruption as a UXB. Some fuzes were set with a delay time of over 70 hours. During this time, an anti-tamper fuze could also be activated to detonate should it be disturbed.

The most commonly used bombs during WWII were the 50kg and 250kg sized general purpose bombs. Less frequently, the 500kg bomb was also used. Larger bombs were used, but so infrequently that any assessment of hazard is more typically based on bombs ranging up to 500kg only.

It should be noted that the June 2008 find of a 1000kg bomb in London, does demonstrate that larger bombs can be found and any risk mitigation measures should consider this.

Plate 11 shows the variety of UXBs recovered by the Civil Defence during WWII.

Plate 11	Photograph of a variety of UXBs recovered by the Civil Defence during WWII

Source: Imperial War Museum

11.1.9 Magnetic Mines

Magnetic mines are designed to lie at the bottom of relatively shallow water and explode when the earth's magnetic field become distorted by any large metal object such as a ship coming within range.

Luftwaffe aircraft laying mines on tidal rivers are known to have accidentally dropped magnetic mines on to land. It is unlikely that magnetic mines would remain in the ground as unexploded ordnance as they were approximately 2m long, normally dropped by parachute and were unlikely to penetrate the ground because of this. The same is true for other parachute mines.

11.1.10 Land Mines

Wartime activities provide numerous sources of UXO within the land environment. Whilst efforts have been made to clear the known British minefields, it was common for mines to become lost for a variety of reasons and so not recovered. Additionally, such munitions might have been disposed of on an unofficial basis and so no records were kept.

Most of the mined beaches and other land areas in the UK have been cleared by the MoD. Occasionally, wave action or activities such as bombing caused mines to become displaced and these were missed as part of any past clearance activities.

Plate 12 is a photograph of a typical WWII land mine used on the land area, beaches and cliffs around Britain. This example was found at Gatwick Airport formerly RAF Gatwick.

Plate 12	Photographs of original and recently excavated WWII land mines

Source: Google Images

Source: Zetica Ltd

11.1.11 Canadian Pipe Mines

Often crudely made, pipe mines were pipes approximately 100mm in diameter and up to 55m long bored roughly horizontal beneath critical infrastructure such as airfield run ways, or angled between ten and thirty degrees into river banks in places were invasion forces may land. The pipes were filled with explosives and usually a sensitive fuzing mechanism. With nitro-glycerine or Polar Blasting Gelignite (PBG) being the primary component, over time, these devices can become increasingly unstable.

11.1.12 UXO Migration

It is possible for explosive material, UXO or ordnance scrap to migrate to a site during landfill or dredging operations or other ground works which import Made Ground or natural materials already containing UXO. It is important to understand the nature and age of such landfill or dredging operations when assessing the potential UXO hazard level on the site.

11.2 Effects and Consequences

There have been a limited number of recorded incidents in the UK since WWII where bombs have detonated during engineering works, though a significant number of bombs have been discovered. Incidents involving smaller ordnance are, however, relatively common in the UK.

In the UK, there are no recorded incidents since the decade after WWII, of a UXB accidentally detonating. In recent years, bombs have been found that have fuze mechanisms that have started to operate indicating that given the right conditions a UXB may still function.

In June 2008 the UXB uncovered in the Lea Valley caused difficulty to No.33 Regiment (Explosive Ordnance Disposal) Royal Engineers because the fuze mechanism started to operate. The 1,000kg 'Hermann' bomb, the first of this size to be found in over 30 years, took 5 days to deactivate. This demonstrates that larger bombs can be found and any risk mitigation measures should provide the option to deal with this size of device. Since WWII, UXBs have been found on a regular basis in London.

Since WWII, UXBs have been found on a regular basis throughout Britain. Some of the most recent cases are described below.

In May 2009 1No. 50kg WWII bomb was found on a building site in Bexhill-on-Sea, Sussex, and on the 16th August 2009, 1No. 250kg WWII bomb was found near Ebberston, North Yorkshire. Both of these were destroyed in controlled explosions by Bomb Disposal Units.

On the 8th March 2010 1No. 500kg WWII bomb was found at Bowers Marsh in Essex by Zetica EOC operatives following a Zetica desk study concluding a high risk of UXB on the site.

This led to a detailed geophysical survey being carried out by Zetica to detect targets which could be UXB and thus mitigate the risk to future ground works. Plate 13 is a photograph of the bomb as it was discovered in the ground. The bomb was demolished in situ by members of the Army Royal Logistics Corps (RLC).

Plate 13	Photograph of the 500kg WWII UXB at Bowers Marsh, 8th March 2010

Source: Zetica Ltd

On the 23rd February 2011, 1No. WWII UXB was found on a building site in Notte Street in Plymouth City centre. The bomb was removed by EOD personnel and demolished at sea.

On the 22nd July 2012, a landslip in the cliffs at Mappleton in the East Riding of Yorkshire exposed over 1,000No. UXO items, including practice bombs, mortars, rockets, shells and grenades. The cliff was part of a former bombing and artillery range, used during WWII and until the 1970s.

UXO items were removed by Explosive Ordnance Disposal (EOD) officers from Catterick and MoD staff from Leconfield. 15No. controlled explosions were undertaken by the Royal Engineers (RE) to detonate the more volatile items in situ, while other less hazardous UXO devices were left in place to be dealt with at a later date.

Plate 14 is a photograph of some of the UXO exposed by the landslip at Mappleton.

Plate 14	Photograph of exposed UXO at Mappleton, 22nd July 2012

Source: Daily Mail

1No. WWI bomb (Plate 15) was found on the Isle of Sheppey on the 2nd August 2012 during a geophysical survey following desk study research by Zetica Ltd. which had established that a previously unknown WWI bombing range existed on the site.

Plate 15	Photograph of WWI bomb, Isle of Sheppey, 2nd August 2012

Source: Zetica Ltd

There is a long list of incidents during construction work in Germany that in some cases have led to the deaths of workers.

In June 2010, 3No. members of a bomb disposal team were killed, and 6No. others injured, whilst attempting to defuze an unexploded WWII bomb in Goettingen, Central Germany.

The bomb, the second found in Goettingen in the space of a few days, was unearthed at a depth of 7.5m during excavations for a sports stadium.

In September 2008, 17No. people were injured and considerable damage occurred to adjacent buildings when a bomb exploded on a construction site in Hattingen, Germany.

In October 2006 during road works on a motorway near Aschaffenburg in Bavaria, southern Germany, a bomb was struck by a machine and detonated. The plant driver was killed and 5No. others injured, including passing motorists.

In a similar incident in October 2004 in Linz, Austria a bomb exploded injuring 3No. workers and causing considerable damage to plant. In the same month, a WWII bomb under a back garden in Vienna, Austria, was detonated without warning by a minor earth tremor, after remaining undiscovered for over 60 years.

Further details of similar finds can be found at www.zetica.com/uxb_downloads.htm.

The effects of a partial or full detonation of ordnance are usually shock, blast, heat and shrapnel damage. A 50kg buried bomb can damage brick / concrete structures up to a distance of approximately 16m away. Unprotected personnel on the surface up to 70m away from the blast could also be seriously injured. Larger ordnance would obviously be more destructive.

Explosives rarely lose effectiveness with age, although over time mechanisms such as fuzes and gaines can become more sensitive and therefore more prone to detonation, regardless of whether the device has been submersed in water or embedded in silt, clay or similar materials.

The effects of a detonation of explosive ordnance are usually extremely fast, often catastrophic and invariably traumatic to any personnel involved.

12 RISK ASSESSMENT

It is understood that planned works on the Site may include intrusive ground investigations, excavations and piling.

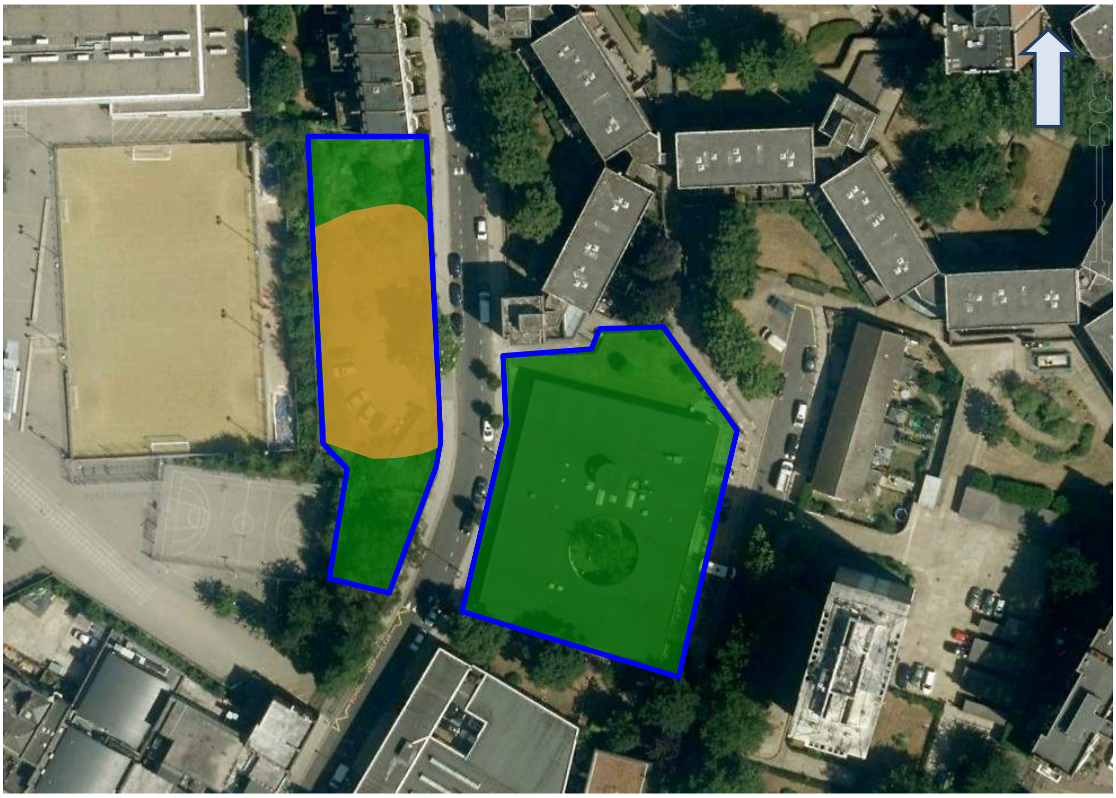
12.1 UXO Hazard Level

There is evidence that 1No. HE bomb fell on part of the western section of the Site during WWII, causing significant damage that may have masked the impact of a UXB. This area is considered to have a moderate UXO hazard level.

There is no evidence of bombing or other significant sources of UXO on the remainder of the Site, which is assigned a low UXO hazard level.

It is considered that the UXO hazard level on the Site can be zoned from low to moderate as shown in Figure 7.

Figure 7 UXO hazard zone plan of the Site



Source: Google Earth *Not to Scale*

Legend			
	Very Low	Low	Moderate
	High	Very High	Site boundary

12.2 Risk Management Recommendations

It is considered prudent to ensure that all staff have an awareness of the UXO hazard through the Site induction process. This will ensure that appropriate action is taken in the event that a suspect item is uncovered.

In the area with a moderate UXO hazard level, clearance certification for borehole or pile locations is considered essential. For excavations, non-intrusive geophysical investigation methods, if practical, and EOC Operative supervision is considered prudent.

In areas with a low UXO hazard level, clearance certification for borehole or pile locations is considered prudent only if a zero tolerance to risk is adopted. Zero tolerance is commonly adopted for sites that have safety critical infrastructure such as nuclear establishments and oil refineries.

Other risk mitigation will depend on the detail and nature of any planned works and the client's risk tolerance. Table 4 gives recommended actions in relation to the potential UXO hazard level and the anticipated Site activity.

Further advice on the mitigation methods can be provided by Zetica on request.

It is recognised that the act of drilling or piling on or very near a UXB increases the risk of detonation. This risk is moderated by the fact that a UXB, if one exists, has lain in the ground for over 65 years and may not function in any event. However, the potentially severe consequences of a UXB exploding, requires appropriate risk mitigation measures to be taken.

Accidental detonation of a UXB during shallow excavation works is considered to be a lower risk than when drilling or piling as any item should be identified by a qualified EOC banksman before repeated disturbance initiates it's functioning. Deeper excavations may need a more considered approach.

The MagCone or MagDrill UXB detection techniques advance a magnetometer by probing or drilling (depending on geology) into the ground in advance of a borehole or pile. The magnetometer is capable of detecting large ferrous metal objects such as UXB. If no objects comparable to a UXB are detected, then the borehole or pile position is considered clear of UXB.

It should be noted that MagCone or MagDrill UXB detection techniques may be ineffectual due to magnetic anomalies in areas containing closely spaced metal driven piles, reinforced cast in-situ piles or ferrous rail tracks. The same is true for use in fill material and Made Ground with a high ferrous metal content.

Table 4	Risk mitigation for assumed Site activities			
Hazard Level	**Typical Future Activity on the Site**			
	None	**Shallow Excavations (<1.0m)**	**Deep Excavations (>1.0m)**	**Boreholes or Pile Construction**
Very low	Ensure suitable records and procedures are in place to highlight the risk should future development be planned.	Ensure site staff, are informed as part of the site safety induction that the potential presence of UXO cannot be discounted. Appropriate action is required to be detailed within site procedures.	Ensure site staff, are informed as part of the site safety induction that the potential presence of UXO cannot be discounted. Appropriate action is required to be detailed within site procedures.	Ensure site staff, are informed as part of the site safety induction that the potential presence of UXO cannot be discounted. Appropriate action is required to be detailed within site procedures.
Low	**As very low.**	**As very low.** **+ It is considered prudent to include some UXO awareness training in site inductions.**	**As very low.** **+ It is considered prudent to include some UXO awareness training in site inductions.**	**As very low.** **+Clearance certification for borehole or pile locations would be considered prudent only if a zero tolerance to risk is adopted.**
Moderate	**As very low.**	**As very low.** **+Non-intrusive investigation methods considered prudent where practical.** **+EOC Operative supervision is considered prudent.**	**As very low.** **+Non-intrusive investigation methods considered prudent where practical.** **+EOC Operative supervision is considered prudent.**	**As low.** **+Clearance certification for borehole or pile locations would be considered essential.**
High	As very low.	As moderate. +Non-intrusive investigation methods considered essential where practical.	As moderate. +Non-intrusive investigation methods considered essential where practical. + EOC operative supervision is considered essential.	As moderate.
Very High	Requires immediate or special attention.	Requires immediate or special attention.	Requires immediate or special attention.	Requires immediate or special attention.
The above table is for guidance only. Hazard levels are defined in Appendix 2.				

Appendices

Appendix 1 Abbreviations

AA	Anti-Aircraft
ACPO	Association of Chief Police Officers
AFU	Advanced Flying Unit
AI	Airborne Interception
ALARP	As Low As Reasonably Practicable
ANS	Air Navigation School
ARP	Air Raid Precaution
ASACS	Air Surveillance and Control System
ASV	Air to Surface
AXO	Abandoned Explosive Ordnance
BD	Bomb Disposal
BDO	Bomb Disposal Officer
BDU	Bomb Disposal Unit
BEF	British Expeditionary Force
CB	County Borough
CBRN	Chemical, Biological, Radiological and Nuclear
CFS	Central Flying School
CMD	Conventional Munitions Disposal
DCLG	Department of Communities and Local Government
DSDA	Defence Storage and Distribution Agency
EFS	Empire Flying School
EFTS	Elementary Flying Training School

EO	Explosive Ordnance
EOC	Explosive Ordnance Clearance
EOR	Explosive Ordnance Reconnaissance
ERW	Explosive Remnants of War
ESA	Explosive Substances and Articles
FFE	Free From Explosives
FIDO	Fog Intensive Dispersal Operation
FITS	Flying Instructors Training School
FTS	Flying Training School
GCHQ	Government Communications Headquarters
GCI	Ground Control Intercept
HAA	Heavy Anti-Aircraft
HCU	Heavy Conversion Unit
HE	High Explosive
HMEF	His/Her Majesty's Explosives Factory
HMFF	His/Her Majesty's Filling Factory
HQ	Head Quarters
HSE	Health and Safety Executive
JSEODOC	Joint Services EOD Operations Centre
IB	Incendiary Bomb
ICBM	Inter-Continental Ballistic Missile
IED	Improvised Explosive Device
IEDD	Improvised Explosive Device Disposal
IRBM	Intermediate Range Ballistic Missile

LAA	Light Anti-Aircraft
LB	London Borough
MAP	Ministry of Aircraft Production
MB	Municipal Borough
MC	Maintenance Command
MCA	Maritime Coastguard Agency
MoD	Ministry of Defence
MMU	Mobile Meteorological Unit
MU	Maintenance Unit
NATO	North Atlantic Treaty Organisation
NSF	National Shell Factory
NTS	Not to Scale
OCU	Operational Conversion Unit
OTU	Operational Training Unit
POW	Prisoner of War
PTC	Personnel and Training Command
PUCA	Pick Up and Carry Away
RAF	Royal Air Force
RASC	Royal Army Service Corps
RD	Rural District
RDX	Research Development Explosive
RE	Royal Engineers
REME	Royal Electrical and Mechanical Engineers
RFC	Royal Flying Corps

RLG	Relief Landing Ground
ROC	Royal Observer Corps
ROF	Royal Ordnance Factory
RRE	Royal Radar Establishment
SAS	Special Air Service
SI	Secret Installation
SIP	Self Igniting Phosphorous
SLG	Satellite Landing Ground
SOE	Special Operations Executive
SOS	Services of Supply
STC	Strike Command
TA	Territorial Army
TEP	Time Expired Pyrotechnics
TFU	Telecommunications Flying Unit
TRE	Telecommunications Research Establishment
UD	Urban District
UKHO	United Kingdom Hydrographic Office
UKWMO	United Kingdom Warning and Monitoring Organisation
USAF	United States Air Force
USAAF	United States Army Air Force
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
WWI	World War One
WWII	World War Two

Appendix 2 Glossary & Definitions	
Abandoned Explosive Ordnance (AXO)	Abandoned Explosive Ordnance is explosive ordnance that has not been used during an armed conflict, that has been left behind or disposed of by a party to an armed conflict, and which is no longer under control of that party. Abandoned explosive ordnance may or may not have been primed, fuzed, armed or otherwise prepared for use.
Camouflet	The type of cavity produced when a charge explodes underground without breaking the surface of the earth to form a crater.
Conflagration	A very large self-sustaining destructive fire.
Dannert Wire	Barbed wire in the form of a coil which could be extended concertina-like to form a barrier to impede the movement of hostile troops.
Deflagration	The fast and violent burning of an energetic material (as opposed to detonation).
Demil	Derived from the term 'Demilitarisation', it refers to the break down and the recycling or disposal of ordnance components.
Detonation	The high-speed chemical breakdown of an energetic material producing heat, pressure, flame and a shock wave.
Device	This term is used for any component, sub-assembly or completed ordnance, which may or may not have an explosive risk. It can apply to detonators, primers, gaines, fuzes, shells or bombs.
Explosive	The term explosive refers to compounds forming energetic materials that under certain conditions chemically react, rapidly producing gas, heat and pressure. Obviously, these are extremely dangerous and should only be handled by qualified professionals.
Explosive Ordnance (EO)	Explosive Ordnance is all munitions containing explosives, nuclear fission or fusion materials and biological and chemical agents. This includes bombs and warheads, guided and ballistic missiles, artillery, mortar, rocket, small arms ammunition, mines, torpedoes, depth charges, pyrotechnics, cluster bombs & dispensers, cartridge & propellant actuated devices, electro-explosive devices, clandestine & improvised explosive devices, and all similar or related items or components explosive in nature.

Explosive Ordnance Clearance (EOC)	Explosive Ordnance Clearance is a term used to describe the operation of ordnance detection, investigation, identification and removal, with EOD being a separate operation.
Explosive Ordnance Disposal (EOD)	Explosive Ordnance Disposal is the detection, identification, on-site evaluation, rendering safe, recovery and final disposal of unexploded explosive ordnance.
Explosive Ordnance Reconnaissance (EOR)	Explosive Ordnance Reconnaissance is the detection, identification and on-site evaluation of unexploded explosive ordnance before Explosive Ordnance Disposal.
Explosive Remnants of War (ERW)	Explosive Remnants of War are Unexploded Ordnance (UXO) and Abandoned Explosive Ordnance (AXO), excluding landmines.
Explosive Substances and Articles (ESA)	Explosive substance are solid or liquid substance (or a mixture of substances), which is either: • capable by chemical reaction in itself of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings. • designed to produce an effect by heat, light, sound, gas or smoke, or a combination of these as a result of a non-detonative, self-sustaining, exothermic reaction. Explosive article is an article containing one or more explosive substances.
Firing Template	The 'template' is the area of a firing range (sea or land) that ordnance is fired into. This is an area usually monitored by the MoD Police and/or Coast Guard to prevent non-authorised persons or vessels straying into the area.
Fuze	A fuze is the part of an explosive device that initiates the main explosive charge to function. In common usage, the word fuze is used indiscriminately, but when being specific (and in particular in a military context), fuze is used to mean a more complicated device, such as a device within military ordnance.
Gaine	Small explosive charge that is sometimes placed between the detonator and the main charge to ensure ignition.

Geophysical survey	A geophysical survey is essentially a range of methods that can be used to detect objects or identify ground conditions without the need for intrusive methods (such as excavation or drilling). This is particularly suited to ordnance as disturbance of ordnance items is to be avoided where ever possible.
Gold line	This is the estimated limit of blast damage from an explosive storage magazine. It usually means that development within this zone is restricted.
High Explosive	Secondary explosives (commonly known as High Explosives (HE)) make up the main charge or filling of an ordnance device. They are usually less sensitive than primary explosives. Examples of secondary explosives are: Nitro glycerine (NG), Trinitrotoluene (TNT), AMATOL (Ammonia nitrate + TNT), Gunpowder (GP), and Cyclotrimethylenetrinitramine (RDX).
Inter-Continental Ballistic Missile	An intercontinental ballistic missile, or ICBM, is a very long-range (greater than 5,500km or 3,500 miles) ballistic missile typically designed for nuclear weapons delivery, that is, delivering one or more nuclear warheads.
Luftflotte	German military air force squadron.
MagCone	MagCone is a method by which ordnance (or other similar metallic items) can be detected at significant depths. This is conducted by the use of a specialised probe. The probe contains a sensitive magnetometer that is pushed into the ground. The magnetometer is able to detect items such as buried ordnance and thus advise on clear routes for drilling, piles, deep excavation or alike.
MagDrill	Similar technique to MagCone, but utilises an augering or drilling (rather than probing) technique to advance the magnetometer into the soil.
Munition	Munition is the complete device charged with explosives, propellants, pyrotechnics, initiating composition, or nuclear, biological or chemical material for use in military operations, including demolitions. This includes those munitions that have been suitably modified for use in training, ceremonial or non-operational purposes. These fall into three distinct categories:- • inert - contain no explosives whatsoever. • live - contain explosives and have not been fired. • blind - have fired but failed to function as intended.

Primary Explosive	Primary explosives are usually extremely sensitive to friction, heat, and pressure. These are used to initiate less sensitive explosives. Examples of primary explosives are: Lead Azide, Lead Styphnate, and Mercury Fulminate. Primary explosive are commonly found in detonators.
Propellants	Propellants provide ordnance with the ability to travel in a controlled manner and deliver the ordnance to a predetermined target. Propellants burn rapidly producing gas, pressure and flame. Although usually in solid form they can be produced in liquid form. Examples of propellants are: Ballistite often found in a flake form and Cordite used in small arm ammunition.
Pyrotechnic	A pyrotechnic is an explosive article or substance designed to produce an effect by heat, light, sound, gas or smoke, or a combination of any of these, as a result of non-detonative, self-sustaining, exothermic chemical reactions.
Unexploded Ordnance (UXO)	UXO is explosive ordnance that has been either primed, fuzed, armed or prepared for use and has been subsequently fired, dropped, launched, projected or placed in such a manner as to present a hazard to operations, persons or objects and remains unexploded either by malfunction or design.
V1 Rocket	The Vergeltungswaffe-1, V-1, also designated Fieseler Fi 103/FZG-76, known colloquially in English as the Flying Bomb, Buzz Bomb or Doodlebug, was the first guided missile used in WWII and the forerunner of today's cruise missile.
V2 Rocket	The Vergeltungswaffe 2 (V-2) ('Reprisal Weapon 2') was the first ballistic missile. It was used by the German Army primarily against Belgian and British targets during the later stages of WWII. The V-2 was the first man-made object launched into space, during test flights that reached an altitude of 189km (117 miles) in 1944.

Definitions of UXO Hazard Level for a Site	
Hazard Level	**Definition**
Very Low	There is positive evidence that UXO is not present, e.g. through physical constraints or removal.
Low	There is no positive evidence that UXO is present, but its occurrence cannot be totally discounted.
Moderate	There is positive evidence that ordnance was present and that other uncharted ordnance may be present as UXO.
High	There is positive evidence that UXO is present.
Very High	As high, but requires immediate or special attention due to the potential hazard.

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zetica sitesafe

Zetica Ltd

Units 15–16
Hanborough Business Park
Long Hanborough
Oxfordshire OX29 8SF
UK

tel: +44(0) 1993 886682
fax: +44(0) 1993 886683
email: info@zetica.com
web: www.zetica.com